TRANS+PED
TRANSFORMING CITIES THROUGH POSITIVE ENERGY DISTRICTS

CATALOGUE OF **PED ASSESSMENT PARAMETERS**

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INTRODUCTION

Monitoring and evaluation are central to the development and success of Positive Energy Districts (PEDs). PEDs are embedded in complex urban development processes. Normative goals, which are of great importance in this respect, need to be measured and evaluated. In the TRANS-PED project, we distinguish between first-order and second-order learning in this context. Evaluation and monitoring represent a form of first-order learning. The focus here is essentially on monitoring the goals that have been set in advance.

There is a wide variety of PED approaches, and the goals pursued in PEDs are correspondingly diverse. Energy-related targets in most cases represent just one of several areas. The variety of indicators and measurement methods already used in practice is correspondingly large. This report provides a comprehensive overview of Key Performance Indicators (KPI) already in use to systematize them and facilitate access to existing indicators and methodologies for current and future PED projects. Moreover, this compilation identifies potential gaps and limitations in existing practices by analysing the distribution and availability of KPIs across a range of investigation perspectives relevant to most PED projects. Thus, this report is intended to support the utilisation of existing know-how in this field and at the same time to provide a basis for further development of monitoring and evaluation concepts for PEDs.

It can be used by stakeholders involved in developing and monitoring districts and PEDs in particular to quickly identify available and established KPIs to assess various key aspects in a comprehensive manner. The catalogue provides a quick overview of available KPIs in six main assessment categories and a number of key characteristics such as the suitable assessment moment during the district development, whether it is a qualitative or quantitative assessment and if it is generally applicable to multiple districts or if it is only relevant to a specific project.

HOW TO USE THE CATALOGUE

The PED KPI catalogue is publicly available for use, review and comment as an online Google sheet. It can be used to find, filter and compare KPIs and find supporting information.

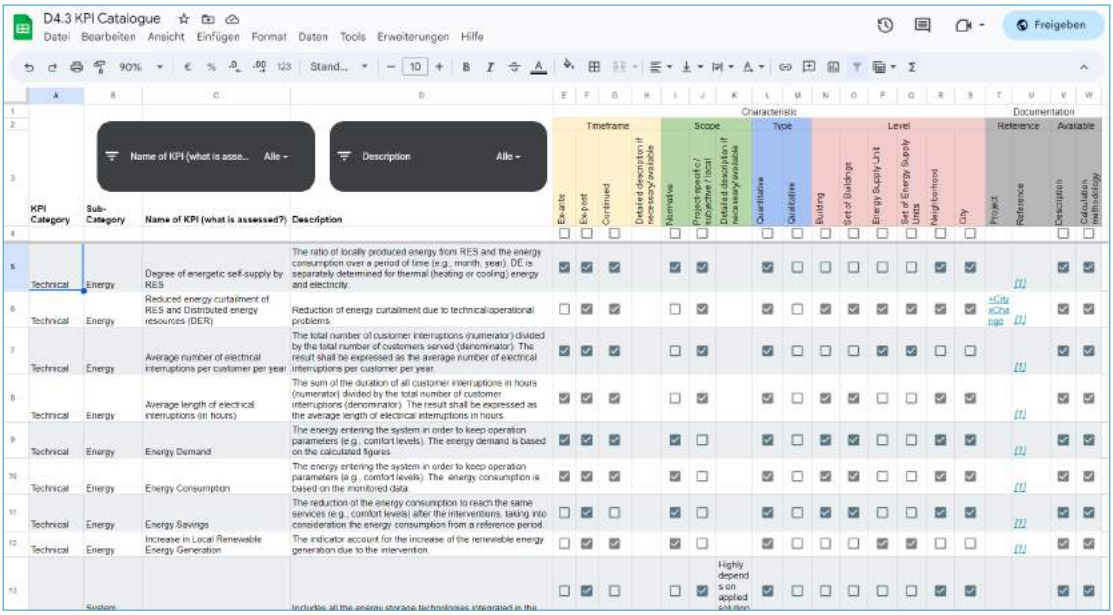

Figure 1: Online Catalogue of PED KPIs (online Google sheet)

The catalogue provides the following functionality:

FIND THE RELEVANT KPIS

The list of KPIs can be quickly and easily filtered by category and characteristic.
Click on the three vertical bars under each column name and select the desired attribute:

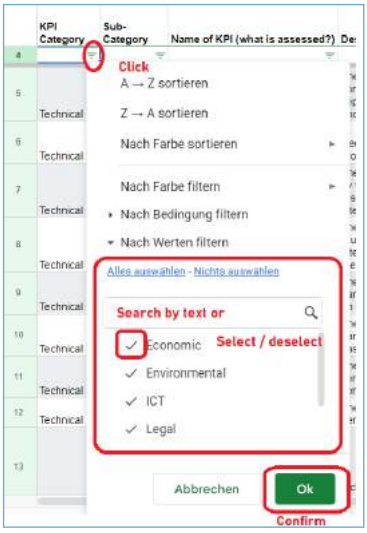

Figure 2: Filtering of KPIs by category (left) and characteristic (right)

The filters can be stacked. For example, Figure 3 shows how it is possible to identify all quantitative KPIs in the social category.

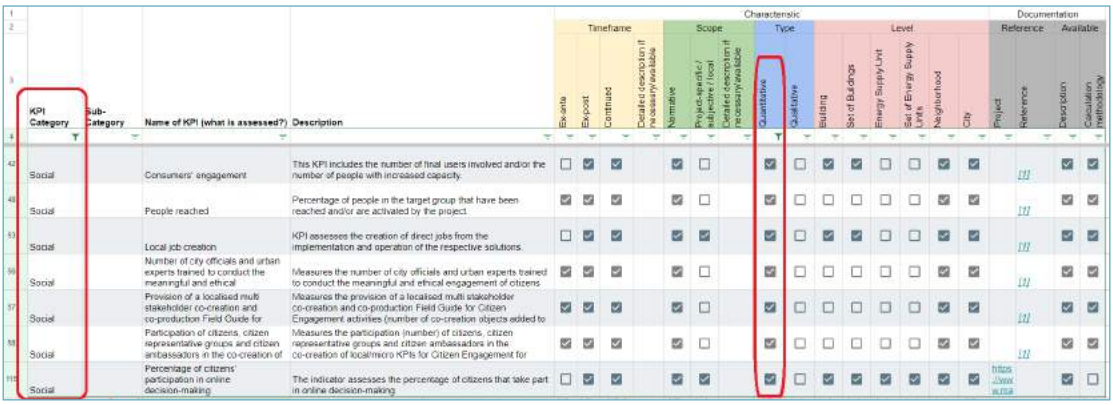

Figure 3: KPIs filtered by category = Social and Assessment type = Quantitative

Alternatively, you can search for keywords in the KPI name or description by pressing Ctrl+F and inserting a search term. All appropriate cells will be highlighted in green in the table and you can jump to the next search result by pressing <ENTER>.

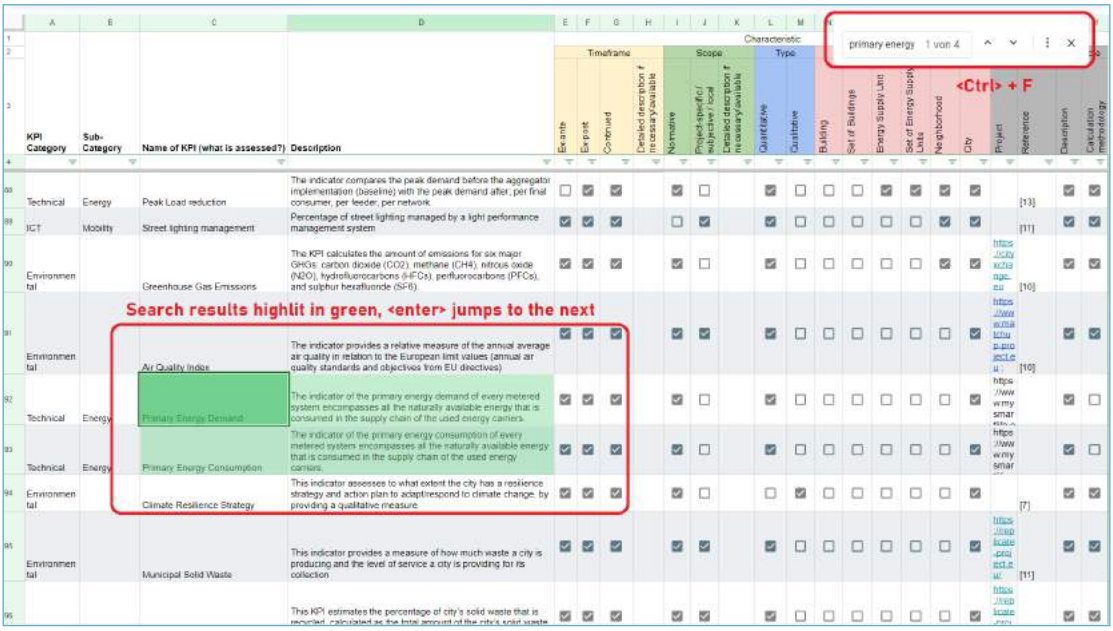

Figure 4: Searching for keywords in KPI name or description

ACCESS DOCUMENTATION AND FURTHER INFORMATION

Finally, the catalogue provides quick and easy access to the description, and, if available, the calculation methodology of the KPI. Hover over the links in the grey reference columns on the right, and follow the link:

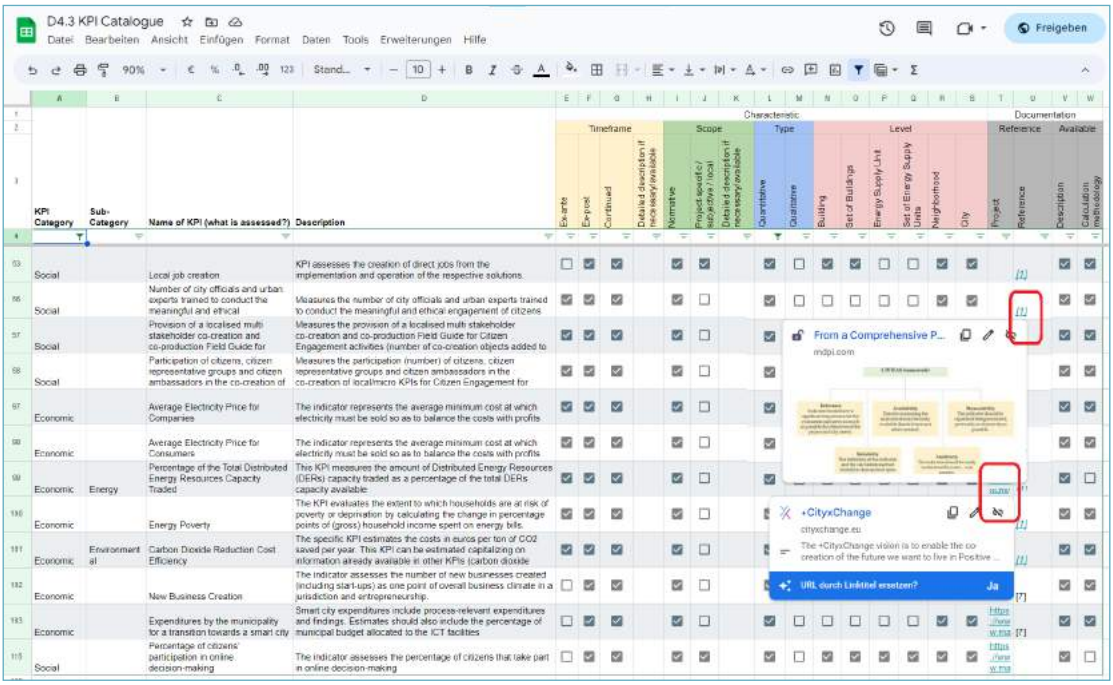

Figure 5: Accessing the available KPI documentation

METHODOLOGY

The catalogue was created by the following the four steps as illustrated in Figure 6.

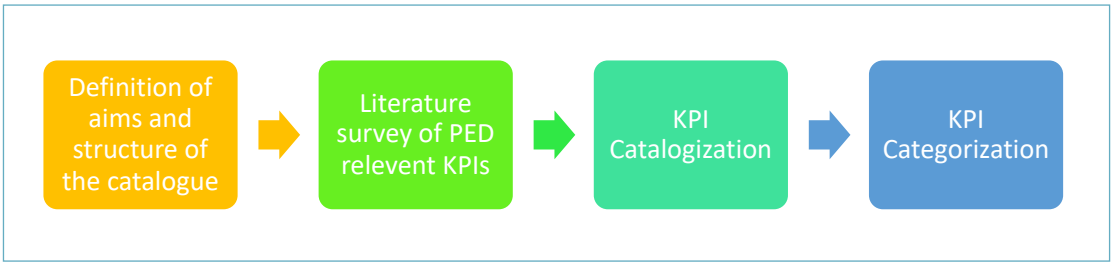

Figure 6: General method of PED KPI Catalogue assembly

The aims of the catalogue were defined during a series of workshops and meetings with the PED lab practitioners and researchers, and this yielded two insights. First, all TRANS-PED practitioners (Graz Reininghaus, Sonnendorf, Abattoir, Brunnshög, and Hammarby Sjöstad) had already established a small number of KPIs to assess specific aspects of their district performance, but their scope and application differed widely. There was no point in designing new KPIs to replace tried and tested versions in the field. The first problem to be addressed in this catalogue was therefore to map out what was already in use and make it easily accessible, and to gauge whether the KPI in question could also be useful in another PED. Second, there is a clear need for assessment in all districts, but rather than a uniform, well-defined task, the requirements differed from district to district. This corresponds to the PED framework itself being open to districts of varying configurations, challenges and sizes. What was unclear was the distribution and focus of the KPIs in use today. What areas of assessment do they cover? Are they strictly quantitative and is their operationalization well-defined and replicable? What size of district are they used for? Are they used for project monitoring or can they also be used to assess (or support) PED planning? To answer these questions, a skeleton structure of characteristics was proposed to classify each identified KPI. These characteristics included the timeframe of assessment, the scope (general or specific), the spatial level of assessment and whether it is quantitative or qualitative. These characteristics are presented in detail in the following sections.

Further, the catalogue was enriched with additional categorization data that became apparent through a literature search that produced 134 KPIs for PED assessment (see Annex A for the complete list). In this stage, an additional topical KPI categorization with sub-categories was introduced, which is also discussed in the following sections.

CATALOGUE STRUCTURE AND ANALYSIS

The KPI Catalogue is presented in a table with six categories: KPI Category, Sub-category, Name of KPI (What is assessed?), Description, Characteristic, and Documentation. Each category is described in the following subsections. These categories allow for a clear and practice-oriented description of the indicators. This aims to support a quick assessment of the goal and possible use of indicators.

KPI CATEGORY

This category defines six general type of KPIs: technical, environmental, economic, social, information and communication technologies (ICT), and legal. Technical KPIs address the technical aspects of PEDs (such as energy supply and demand, characteristics of installed equipment, and so on). Environmental KPIs focus on environmental parameters, such as carbon dioxide emissions and noise pollution. Economic KPIs address everything related to costs and their assessment. Social KPIs include public opinions, reactions to energy transformation, and so on. ICT KPIs address the use of digital technologies in PEDs, for example to control or monitor technical infrastructures. And finally, legal KPIs involve regulatory and institutional issues such as laws, norms and formal and informal rules. The distribution of KPIs in each category is illustrated in Figure 7 and reveals a relatively balanced set of categories. There are a larger number of technical and ICT KPIs but the sample as a whole covers a wide range of topics and objectives.

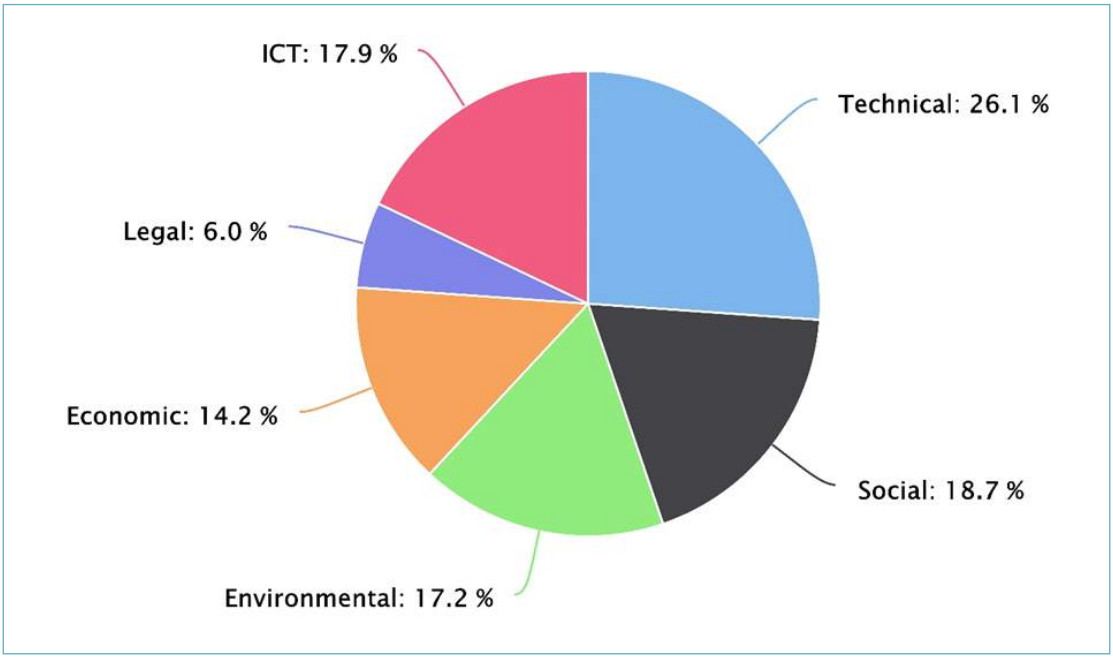

Figure 7: KPI representation by category

SUB-CATEGORY

While the KPI Category delineates the main focus of each KPI, some KPIs have secondary feature(s) and can be further characterized with sub-categories. Sub-categories allow further specification of a KPI and provide more insights on how they can be used. For example, a brief a KPI that describes the legal framework of the usage of electric vehicles can be classified under the legal category (because the essence of this KPI refers to regulatory issues) and then the sub-category of mobility (to address the specific focus on the regulation of mobility in a PED).

We identified 5 sub-categories: energy, system functionality (everything related to functional aspects of a PED), mobility, environmental and social. Figure 8 shows which of the subcategories apply to the 6 categories in the sample. The ICT and legal categories include 4 sub-categories, the technical and economic categories include 3 sub-categories, and the social category includes 2 sub-categories. The environmental category includes no sub-categories.

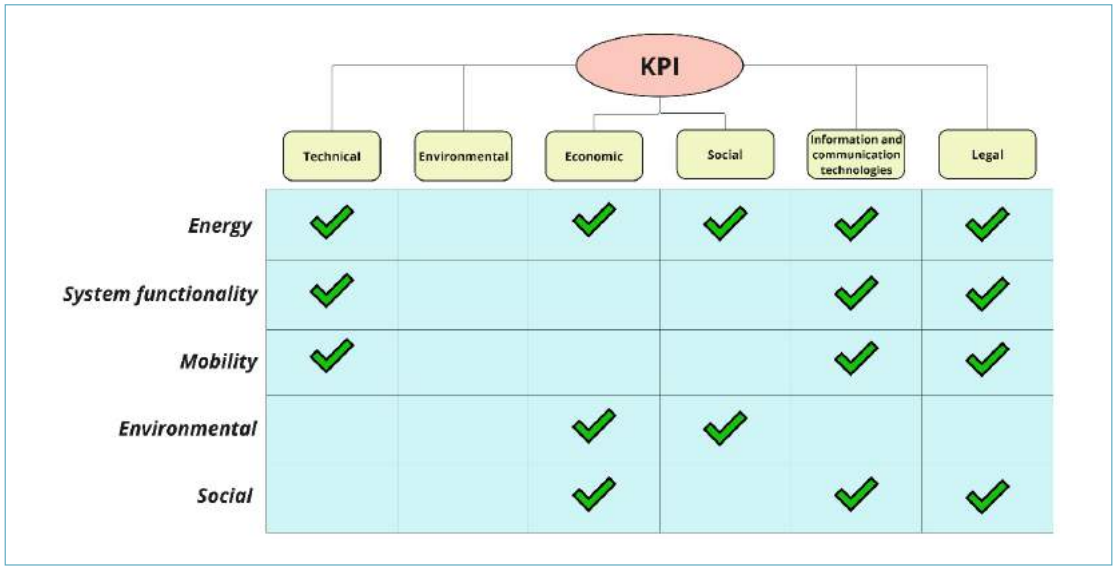

Figure 8: Categories and sub-categories of KPIs in the catalogue

NAME OF KPI AND DESCRIPTION

This is a label to describe the target of the KPI. In some cases it is not obvious what exactly is addressed by a KPI and thus, a Description column was added to provide additional details on the purpose of the KPI. All descriptions of KPIs were formulated based on descriptions provided in the literature (see References).

CHARACTERISTIC

The characteristic category includes 4 sub-categories (timeframe, scope, level, and type) and briefly describes each KPI according to its level of application. It is important to note that the KPIs can be applied at different points in time (or in different time frames) and can also be applied selectively or continuously (repeatedly). In addition, measurements are used both in advance, for example in the course of certifications, or at the end of the process. We refer to these cases as “ex-ante” or “ex-post” indicators.

Timeframe describes when a KPI is applied, whether it be ex-ante, ex-post or continued. KPI categories are distributed approximately equally according to the timeframe of application. Technical KPIs are most common while legal KPIs are rare (Figure 9).

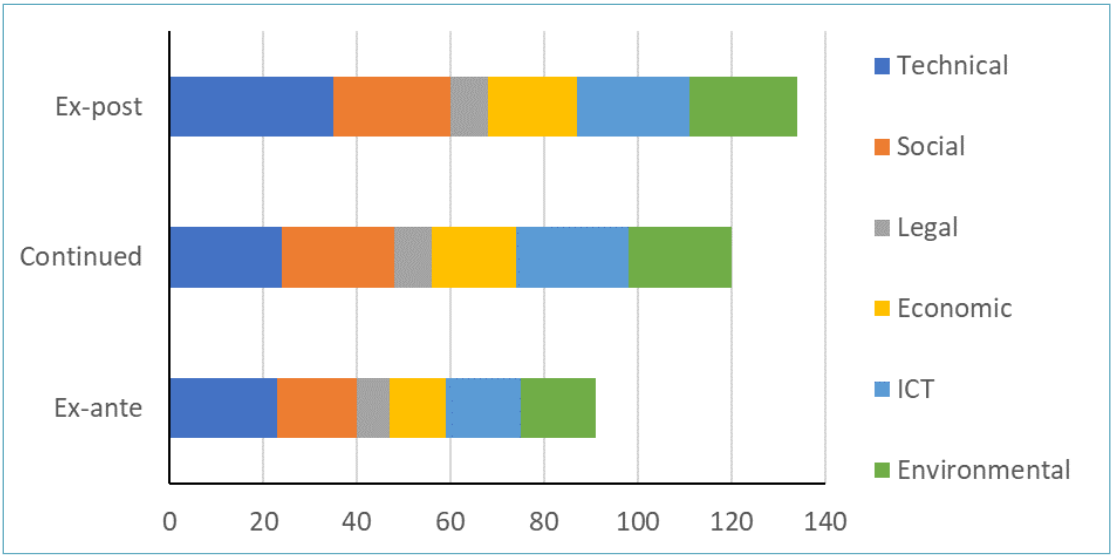

Figure 9: Categories of KPIs by stage of application

The scope is general if it could be applied to any PED and Project-specific / subjective / local if it strongly depends on the types of targets formulated for a PED. Figure 10 shows the distribution of general and specific KPIs. General KPIs are evenly distributed among technical, social, economic and environmental, with less representation in legal and ICT. Specific KPIs are mostly represented by the Technical and ICT categories. ICT KPIs are less represented in the scope of PED and their implementation strategies and are strongly dependent upon concrete project goals. Consequently, they are mostly situated on a general level. The wide representation of technical KPIs on both levels indicates the possibility to evaluate technical aspects of the PED’s objectives both normatively and specifically. Almost a third of all project-specific KPIs are technical.

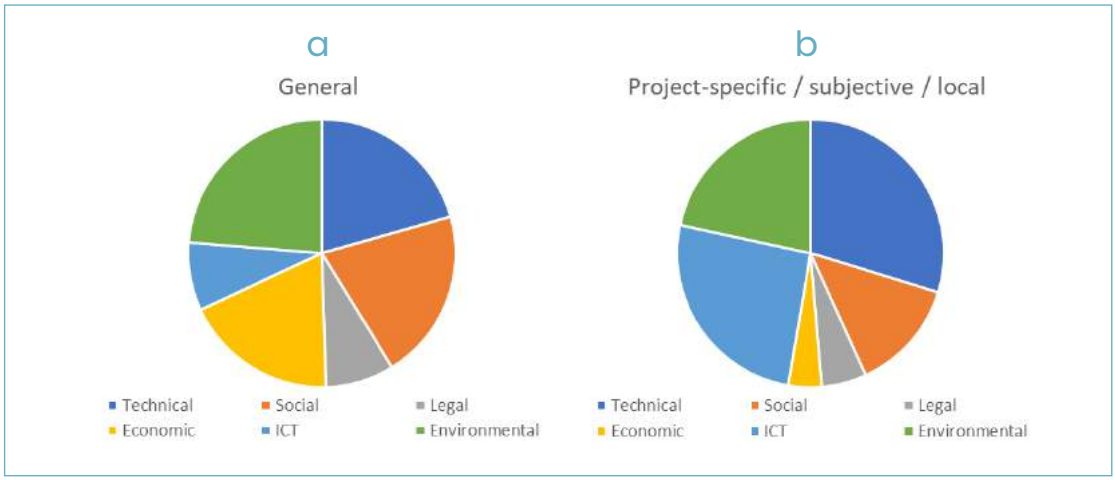

Figure 10: Category representation of (a) general KPIs and (b) specific KPIs

The Type category indicates whether a KPI is qualitative or quantitative. Figure 11 shows that 98 of the analysed KPIs are quantitative (73.1 %) while 36 are qualitative (26.9 %).

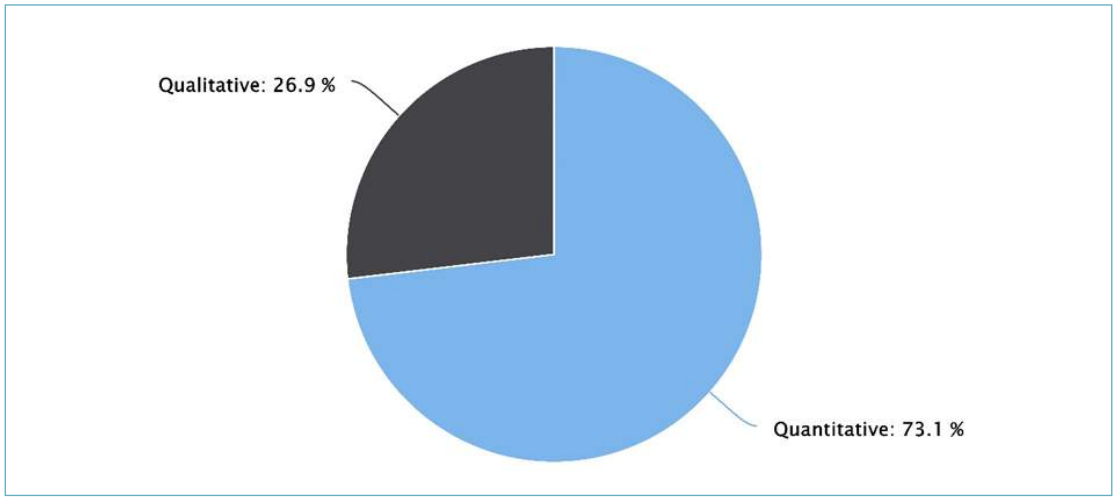

Figure 11: Qualitative and quantitative KPIs

The qualitative and quantitative KPIs are distributed by category in Figure 12. The legal category has no quantitative KPIs while the other categories have both quantitative and qualitative KPIs (although quantitative indicators clearly dominate).

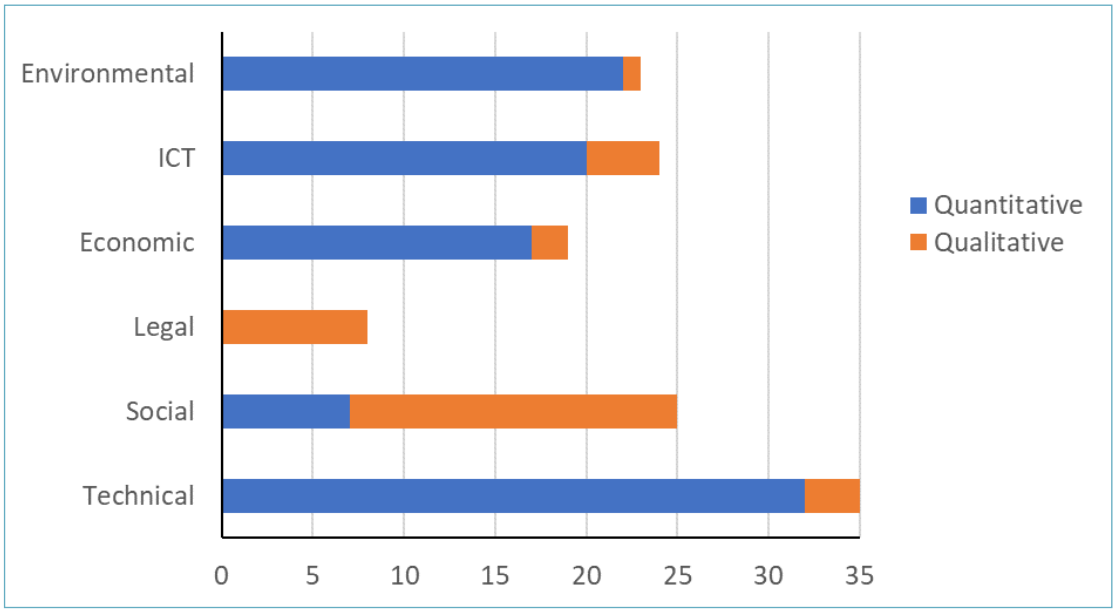

Figure 12: Qualitative and quantitative KPIs by category

The level category indicates the scale at which a KPI is applied and choices include building, set of buildings, energy supply unit, set of energy supply units, neighbourhood, and city (see Figure 13). The analysed KPIs mostly target the city level and quantitative KPIs are dominant, reflecting the overall distribution in the catalogue.

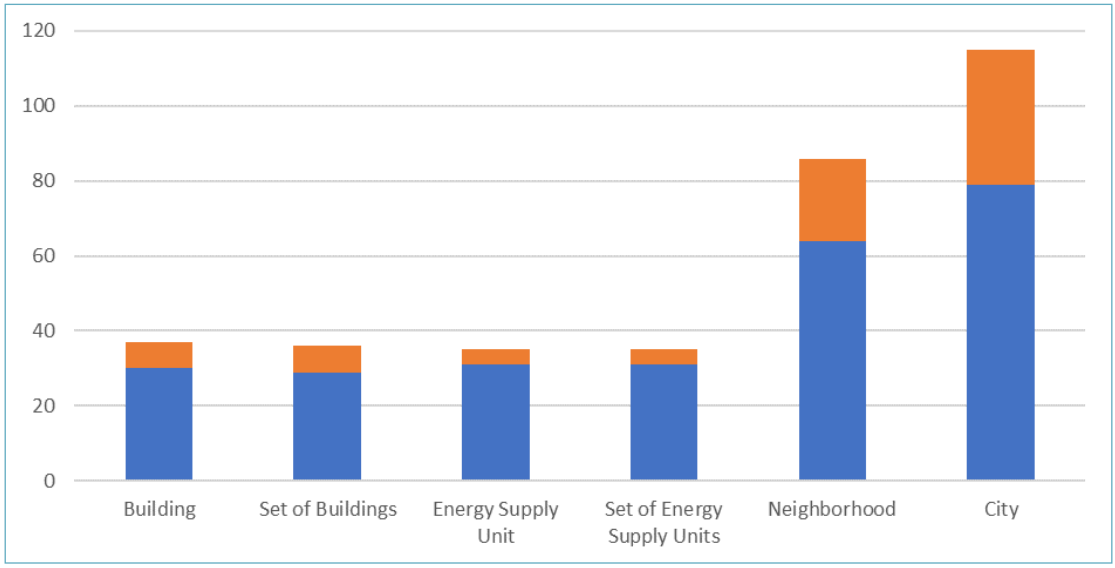

Figure 13: Qualitative and quantitative KPIs representation by level of application

The analysis of the KPI Catalogue shows that all KPIs can be applied once a PED is built while 91 can be applied before the PED project starts and 120 KPIs can be applied during PED development. Those KPIs that can be applied at any stage of PED project realization are indicated in the catalogue with a checkmark (✓) in all relevant columns.

The level of KPI application is relevant for the scope of the KPIs as well: 97 are general and 74 are specific. The same, multiple application is relevant to the KPI levels. 37 KPIs can be applied to buildings, 36 to sets of Buildings, 35 apply to Energy Supply Units, 35 to sets of energy supply units, 86 to neighbourhoods, and 115 to cities. Categories of KPIs at each level of application are shown in Figure 14.

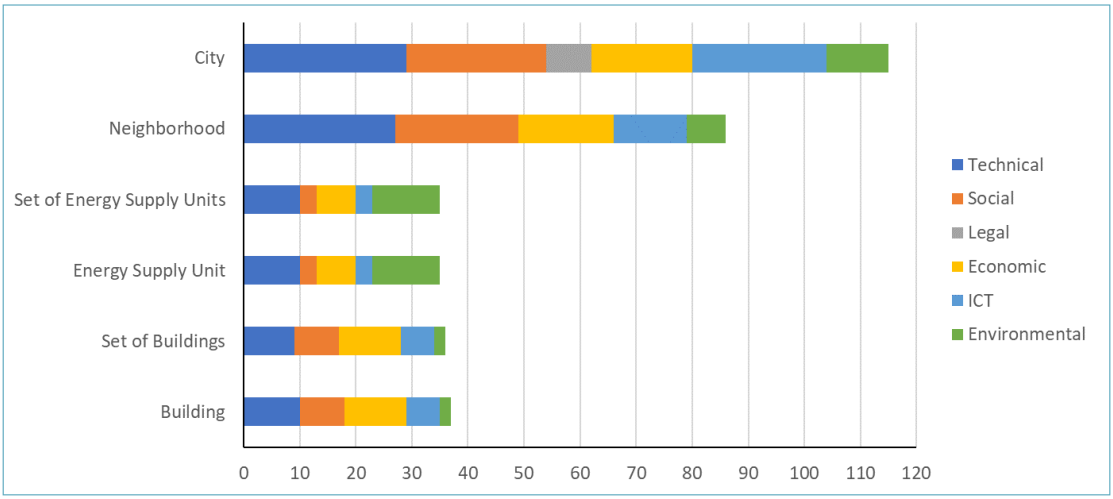

Figure 14: Categories of KPIs at each level of application

KPIs related to legal issues are represented only at the city level, which matches the common domain of rules and laws. It also indicates a lack of legal instruments at smaller spatial scales such as districts and neighbourhoods (except for specialised legal instruments involving district development contracts and citizen energy communities).

The small number of KPIs for energy supply units and sets of energy supply units are mostly addressed by environmental KPIs while other categories are less represented. Environmental aspects are of great importance at the city level, but there are significantly fewer indicators at the other application levels. Again, this indicates a lack of concrete targets and their operationalization at the scale between individual buildings (which are covered by national and regional building codes) and the city level (which is covered by local laws and regulations).

DOCUMENTATION

The final column in the catalogue provides references for the KPI where more detailed information can be found. It is important to note that some of the KPIs do not include descriptions and others do not include calculation methodologies. This makes these KPIs less useful.

DISCUSSION AND CONCLUSION

Unsurprisingly, technical KPIs to monitor PED performance are the most common followed by environmental, social and ICT KPIs. There are only a few legal KPIs (this category covers only 6% of the analysed KPIs). There were no legal KPIs related to the energy supply units in the literature and it is necessary to study specific PED projects to develop legal KPIs. This is of particular importance for the growth of the PED concept and to facilitate interactions between municipal and national stakeholders and project developers and practitioners on the ground. Most KPIs are quantitative and use metrics to facilitate comparison. Such KPIs can be used to standardize PED assessment procedures. Meanwhile, legal and social KPIs are predominantly qualitative KPIs and are more difficult to standardise. This indicates that social goals are more situational and context-dependent and for the most part do not involve quantifiable KPIs. Thus, a comparison between districts based on quantitative KPIs is unwarranted.
A topic for future research is the variation of stakeholders from one district to another and their associated KPI responsibilities. The participating experts of the investigated PED labs were very diverse and stakeholder groups were not represented equally. From such a sample it is not possible to draw general conclusions about KPI requirements and the organization of PED assessment, but it seems apparent that it varies based on which type of stakeholders are most involved in the PED process. It would also be helpful to assess the required infrastructure, data and know-how to utilize each KPI from the perspective of these different stakeholders. The catalogue provides an initial indication of the availability of operationalisation documentation but in practice, most PED stakeholders are probably unequipped to conduct certain assessments and require detailed guidance. This is related to the question of standardising PED assessments. The lack of standards can be attributed to the varying availability of data and infrastructure (or even need for that matter) to apply a given KPI. Figure 15 summarises the three requirements to assess a PED and highlights the challenges of standardising PED assessments across different project contexts. Given that PEDs are heterogeneous and vary in scope, goals and focus and subsequent approach, it seems unlikely that it will be possible to sharpen the international PED definition to a point where it could include a set of prescribed and well-defined metrics to be assessed. Instead, districts face very different challenges and the best way to address them is to work on a comprehensive and easy-to-navigate knowledge-base that can be customised to a specific district to guide choices about appropriate instruments and tools to apply.

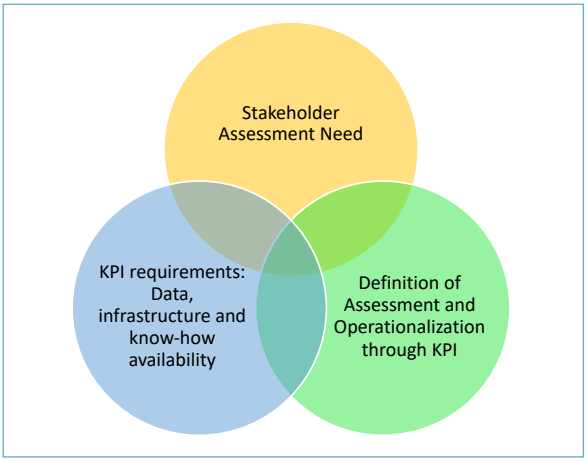

Figure 15: The three requirements to assess a PED

Nevertheless, this catalogue provides a summary of existing PED assessment options. There is a wide range of KPIs to address many aspects of district development at different spatial, temporal and qualitative levels. The catalogue serves as a basis for monitoring and evaluating PED performance over time. Stakeholders can browse through the catalogue, identify desired KPIs and access the required documentation. In the future, a more comprehensive guide would also be beneficial. Apart from the perspectives covered in this catalogue, it would be helpful to address the process of KPI selection and how they are defined.

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REFERENCES

1. Angelakoglou, K., Nikolopoulos, N., Giourka, P., Svensson, I. L., Tsarchopoulos, P., Tryferidis, A., & Tzovaras, D. (2019). A methodological framework for the selection of key performance indicators to assess smart city solutions. Smart Cities, 2(2), 269-306. DOI: https://doi.org/10.3390/smartcities2020018
2. Positive City ExChange https://cityxchange.eu (Accessed 05 May 2023)
3. Covenant of Mayors for Climate and Energy. Available online: https://www.covenantofmayors.eu/ (Accessed on 14 April 2023)
4. Vulog. What is the Potential Market of Free-Floating Carsharing. Available online: https://www.vulog.com/blog/free-floating-carsharing-the-potential-market-vulog/ (accessed on 14 April 2023)
5. European Automobile Manufacturers Association. Distribution of EV Charging Points across the EU. Available online: https://www.acea.be/press-releases/article/electric-cars-unrealistic-co2-targets-proposed-by-eu-parliament-ignore-lack (Accessed on 14 April 2023)
6. POCITYF https://pocityf.eu/ (Accessed on 05 May 2023)
7. Luthander, R.; Widén, J.; Nilsson, D.; Palm, J. Photovoltaic self-consumption in buildings: A review. Appl. Energy 2015, 142, 80–94
8. Dall'O, G.; Bruni, E.; Panza, A.; Sarto, L.; Khayatian, F. Evaluation of cities' smartness by means of indicators for small and medium cities and communities: A methodology for Northern Italy. Sustain. Cities Soc. 2017, 34, 193–202
9. GrowSmarter: Publications-D5.1: Evaluation Plan. Available online: https://grow-smarter.eu/inform/publications/ (Accessed 05 May 2023)
10. ITU. Collection Methodology for Key Performance Indicators for Smart Sustainable Cities; UNECE: Geneva, Switzerland, 2017.
11. International Organization for Standardization. ISO 37122: Sustainable Development in Communities-Indicators for Smart Cities; International Organization for Standardization: Geneva, Switzerland, 2017.
12. SmartEnCity https://www.smartencity.eu/ (Accessed 05 May 2023)
13. Li, Y.; O'Donnell, J.; García-Castro, R.; Vega-Sánchez, S. Identifying stakeholders and key performance indicators for district and building energy performance analysis. Energy Build. 2017, 155, 1–15.
14. MAtchUP https://www.matchup-project.eu/ (Accessed 05 May 2023)
15. IRIS Smart Cities https://irissmartcities.eu/ (Accessed 05 May 2023)
16. mySMARTLife https://www.mysmartlife.eu (Accessed 05 May 2023)
17. Bosch, P.; Jongeneel, S.; Rovers, V.; Neumann, H.-M.; Airaksinen, M.; Huovila, A. CITYkeys indicators for smart city projects and smart cities. CITYkeys Rep. 2017.
18. https://triangulum-project.eu (Accessed 14 April 2023)
19. Hara, M.; Nagao, T.; Hannoe, S.; Nakamura, J. New key performance indicators for a smart sustainable city. Sustainability 2016, 8, 206.
20. EC, 2013, Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organizations. OJ L124, 04.05.2013, pp. 1-210.
21. Smart Cities Marketplace https://smart-cities-marketplace.ec.europa.eu (Accessed 05 May 2023)
22. Nematchoua, M. K., Orosa, J. A., & Reiter, S. (2019). Life cycle assessment of two sustainable and old neighbourhoods affected by climate change in one city in Belgium: A review. Environmental Impact Assessment Review, 78, 106282.
23. Karunathilake, H., Hewage, K., Mérida, W., & Sadiq, R. (2019). Renewable energy selection for net-zero energy communities: Life cycle based decision making under uncertainty. Renewable energy, 130, 558-573.
24. European Environment Agency https://www.eea.europa.eu/en (Accessed 05 May 2023)
25. Freshwater eutrophication https://lc-impact.eu/doc/method/Chapter8_Freshwater-eutrophication.pdf (Accessed 05 May 2023)
26. Marine eutrophication https://lc-impact.eu/EQmarine_eutrophication.html (Accessed 05 May 2023)
27. Guarino, F., Longo, S., Vermette, C. H., Cellura, M., & La Rocca, V. (2020). Life cycle assessment of solar communities. Solar Energy, 207, 209-217
28. Ponomarenko, T.; Nevskaya, M.; Jonek-Kowalska, I. Mineral Resource Depletion Assessment: Alternatives, Problems, Results. Sustainability 2021, 13, 862.
29. ATELIER - Positive Energy Districts https://smartcity-atelier.eu (Accessed 05 May 2023)
30. Smart City performance measurement system https://cordis.europa.eu/project/id/646440 (Accessed 05 May 2023)
31. Yuqin Liu, Qingyan Meng, Jiahui Zhang, Linlin Zhang, Tamas Jancso & Rumiana Vatseva (2016) An effective Building Neighborhood Green Index model for measuring urban green space, International Journal of Digital Earth, 9:4, 387-409, DOI: 10.1080/17538947.2015.1037870

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THE PED KPI CATALOGUE

The PED KPI catalogue is publicly available for use, review and comment as an online Google sheet.

Resources for PED practitioners & researchers

For more resources and project results from the Trans-PED project, visit the results section on its website.

All about the Trans-PED project

Check out the Trans-PED website for details on the project, the international consortium of partners, as well as the participating PEDs.

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ANNEX A. CATALOGUE OF PED ASSESSMENT PARAMETERS AND METHODS (KPIS)

The table denotes each KPI with (✓) for each applying column characteristic and available documentation and (×) if the column characteristic does not apply or no such documentation type is available.

The PED KPI catalogue is publicly available for use, review and comment as an online Google sheet.

				CHARACTERISTIC														DOCUMENTATION			
				TIMEFRAME			SCOPE			TYPE		LEVEL						REFERENCE TYPE		AVAILABLE	
KPI CATEGORY	SUB-CATEGORY	NAME OF KPI (WHAT IS ASSESSED?)	DESCRIPTION	Ex-ante	Ex-post	Continued	General	Project-specific / subjective / local	Detailed description	Quantitative	Qualitative	Building	Set of Buildings	Energy Supply Unit	Set of Energy Supply Units	Neighborhood	City	Project	Reference	Description	Calculation methodology
Technical	Energy	Degree of energetic self-supply by RES	The 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.	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Reduced energy curtailment of RES and Distributed energy resources (DER)	Reduction of energy curtailment due to technical/ operational problems.	×	✓	✓	×	✓		✓	×	✓	✓	✓	✓	✓	✓	[2]	[1]	✓	✓
Technical	Energy	Average number of electrical interruptions per customer per year	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.	✓	✓	✓	×	✓		✓	×	×	×	✓	✓	×	×		[1]	✓	✓
Technical	Energy	Average length of electrical interruptions (in hours)	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.	✓	✓	✓	×	✓		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Energy Demand	The energy entering the system in order to keep operation parameters (e.g., comfort levels). The energy demand is based on the calculated figures	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Energy Consumption	The energy entering the system in order to keep operation parameters (e.g., comfort levels). The energy consumption is based on the monitored data.	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Energy Savings	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 a reference period.	×	✓	×	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Increase in Local Renewable Energy Generation	The indicator account for the increase of the renewable energy generation due to the intervention.	×	✓	✓	✓	×		✓	×	×	×	✓	✓	×	×		[1]	✓	✓
Technical	System functionality	Smart Storage Capacity	Includes all the energy storage technologies integrated in the city smart grid containing electricity, heating and mobility.	×	✓	×	×	✓		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Technical	System functionality	Battery Degradation Rate	The capacity losses of the batteries used in project, through use (some cycles) and through time (some years).	✓	✓	×	×	✓	🗁	✓	×	✓	✓	✓	✓	×	×		[1]	✓	✓
Technical	Energy	Storage Energy Losses	The energy losses because of battery storage, including the added voltage transformations.	✓	✓	×	×	✓	🗁	✓	×	✓	✓	✓	✓	×	×		[1]	✓	✓
Technical	Energy	Maximum Hourly Deficit (MHDx)	The maximum ratio of the difference between load and on-site renewable energy generation to load for each energy type. It is calculated taking the largest value of those ratios calculated for each hour of the year, for those hours when local renewable supply is smaller than the demand.	×	✓	✓	×	✓	🗁	✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Technical	System functionality	Technical Compatibility	An indication of the technical compatibility of the smart city solution, meaning the extent to which the solution fits with current practices, administrative and existing technological standards/infrastructures.	✓	✓	×	×	✓		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Technical	System functionality	Improved Interoperability	Interoperability is the ability of a system (or product) to work with other systems by providing services to and accepting services from other systems and to use the services so exchanged to enable them to operate effectively together (ISO/TS 37151). The indicator assesses the improvement in interoperability in a qualitative manner.	✓	✓	×	×	✓		×	✓	×	×	✓	✓	✓	✓		[1]	✓	✓
Technical	Mobility	Energy consumption data aggregated by sector fuel	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).	✓	✓	×	✓	×		✓	×	×	×	×	×	✓	✓		[3]	✓	✓
Technical	Mobility	Free Floating subscribers	This indicator assesses the increase in the number of subscribers to the free-floating car-sharing service.	×	✓	×	×	✓		✓	×	×	×	×	×	✓	✓		[4]	✓	✓
Technical	Mobility	Yearly km made through the e-car sharing system instead of private conventional cars	This indicator assesses the number of kilometres done using the car-sharing service.	×	✓	✓	×	✓		✓	×	×	×	×	×	✓	✓		[4]	✓	✓
Technical	Mobility	Number of efficient vehicles deployed in the area	This indicator assesses the level of service offered by measuring the number of efficient vehicles in the area.	✓	✓	×	×	✓		✓	×	×	×	×	×	✓	✓		[4]	✓	✓
Technical	Mobility	Number of EVs charging stations and solar powered V2G charging stations deployed in the area	This indicator assesses the level of service with regards to charging capabilities offered by measuring the number of electric vehicles charging stations deployed in the area. Additionally, it measures the number of solar powered V2G stations comparing it with the total number of stations.	×	✓	×	×	✓		✓	×	×	×	×	×	✓	✓		[5]	✓	✓
Technical	System functionality	Improved flexibility of service delivery following citizen feedback phases	This KPI measures the improved flexibility of service delivery following citizen feedback phase(s).	×	✓	×	×	✓		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Environmental		Carbon dioxide Emission Reduction	Difference between the delivered energy for energy carrier and the exported energy for energy carrier	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Environmental		Increased efficiency of resources consumption	This KPI measures the percentage reduction in material consumption of the project/initiative.	×	✓	×	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Technical	Energy	Reduction in annual final energy consumption	The final energy consumption of the project taking into account all forms of energy (e.g., electricity, gas, heat/ cold, fuels) and for all functions (transport, buildings, ICT, industry, etc.). The final energy consumption is the energy actually consumed by the end-user.	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Environmental		Decreased emissions of Particulate matter	This KPI measures the percentage reduction in PM10 and PM2.5 emissions achieved by the project/initiative.	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Environmental		Decreased emission of nitrogen oxides (NOx)	This KPI measures the percentage reduction in NOx emissions (NO and NO2) achieved by the project/ initiative.	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Environmental		Noise pollution	This KPI measures the noise levels before and after the activities of the project/initiative.	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Economic		Payback	The payback period is the time it takes to cover investment costs	✓	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic		Return on Investment	KPI defined as the ratio between the total incomes/net profit and total investment of the project.	×	✓	×	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic	Energy	Reduction of energy cost	The KPI measures the cost of the energy traded by an aggregator, both as a baseline and when ICT are implemented.	✓	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic		Total Investments	An investment is defined as an asset or item that is purchased or implemented with the aim to generate payments or savings over time.	×	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic		Total Annual costs	The total annual costs are defined as the sum of capital-related annual costs, requirement-related, operation related costs and other costs.	×	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic		Financial benefit for the end-user	The extent to which smart city projects/initiatives generate cost savings for end-users	✓	✓	✓	✓	✓		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Economic		Grants	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.	✓	✓	✓	×	✓		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Economic	Energy	Fuel poverty	his KPI measures the change in percentage points of (gross) household income spent on energy bills.	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Economic	Environmental	CO2 reduction cost efficiency	Costs in euros per ton of CO2 saved per year.	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Economic	Social	Stimulating an innovative environment	The extent to which the project is part of or stimulates an innovative environment.	×	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Economic	Social	Awareness of economic benefits of reduced energy consumption	This KPI measures the awareness of economic benefits of reduced energy consumption	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Social		Consumers' engagement	This KPI includes the number of final users involved and/ or the number of people with increased capacity.	×	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Social		Professional stakeholder involvement	The extent to which professional stakeholders outside the project team have been involved in planning and execution.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Social Compatibility	The extent to which the project's solutions fit with people's 'frame of mind' and do not negatively challenge people's values or the ways they are used to do things.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Ease of use for end users of the solution	The extent to which the solution is perceived as difficult to understand and use for potential end-users.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Advantages for end-users	The extent to which the project offers clear advantages for end users.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Advantages for stakeholders	The extent to which the project offers clear advantages for stakeholders.	✓	✓	✓	✓	×		×	✓	✓	✓	✓	✓	✓	✓		[1]	✓	✓
Social		People reached	Percentage of people in the target group that have been reached and/or are activated by the project.	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Social	Energy	Thermal comfort	The quality of the delivered heating/cooling service as a matter of the opinion of the service receivers	✓	✓	✓	✓	×		×	✓	✓	✓	×	×	✓	✓		[1]	✓	✓
Social	Environmental	Increased environmental awareness	This indicator assesses the extent to which the project has used opportunities for increasing environmental awareness and educating about sustainability and the environment.	×	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Increased consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship.	×	✓	✓	✓	✓		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Increased participation of vulnerable groups	The extent to which the project has contributed in increasing contributions of groups, which are not good represented in society	×	✓	✓	×	✓		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Local job creation	KPI assesses the creation of direct jobs from the implementation and operation of the respective solutions.	×	✓	✓	✓	✓		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
Social		Local community involvement in the implementation phase	The extent to which residents/users have been involved in the implementation process.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Increased citizen awareness of the potential of smart city projects	Measures the increased citizen awareness of the socio-cultural potential of smart city projects.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
Social		Number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens	Measures the number of city officials and urban experts trained to conduct the meaningful and ethical engagement of citizens	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Social		Provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen Engagement activities	Measures the provision of a localised multi stakeholder co-creation and co-production Field Guide for Citizen Engagement activities (number of co-creation objects added to field guide).	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Social		Participation of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/ micro KPIs for Citizen Engagement for Smart Cities	Measures the participation (number) of citizens, citizen representative groups and citizen ambassadors in the co-creation of local/micro KPIs for Citizen Engagement for Smart Cities	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
ICT	Energy	Peak load reduction (ICT)	The percentage of peak load (the maximum power consumption of a building or a group of buildings to provide certain comfort levels) reduction due to ICT application	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
ICT	Social	Number of customers that are positive about how energy systems are controlled	The percentage of the end-users involved in the demonstrations that are satisfied with the provided services including the ICT systems	×	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓		[1]	✓	✓
ICT	System functionality	Reliability	Measures possibility to correct a potential misbehaviour of the system and unexpected stops avoiding due to ICT implementation.	✓	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓		[1]	✓	✓
ICT	System functionality	Increased system flexibility for energy players	The ability of the system to respond to—and stabilize/ balance—supply and demand in real-time, as a measure of the demand side participation in energy markets-energy efficiency intervention.	✓	✓	✓	✓	×		×	✓	×	×	×	×	✓	✓		[1]	✓	✓
ICT	System functionality	Increased hosting capacity for RES, EVs and other new loads	This KPI is intended to give a statement about the additional loads that can be installed in the network, when R and I solutions are applied, and compared to the BAU scenario.	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
ICT	Mobility	Impact of ICT apps into mobility	Impact of ICT apps into switching from non-sustainable mobility into sustainable mobility, this is, change on modal split.	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
ICT	Social	Developer engagement	Measures the use of open datasets by developers (Number of API calls per month).	×	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Data safety	Number of blocked malicious hacking attempts	×	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Data loss prevention	Lost data points in a period.	×	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Usage of open source software	The extent to which project use of open source software	×	✓	✓	×	✓		×	✓	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Expiration date of open data	Percentage of out-dated datasets on a city platform per timeframe	×	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Quality of open data	Percentage of data that uses DCAT standards	✓	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Platform downtime	Downtime per timeframe.	×	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality	Open data based solutions	Number of services based on open data	✓	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[1]	✓	✓
ICT	System functionality; Social	Number of active 'touch points' identified	Measures the number of active 'touch-points' identified where citizens have a degree of interaction with solution.	×	✓	✓	×	✓		✓	×	×	×	×	×	✓	✓		[1]	✓	✓
Legal	Energy	Green Building self-consumption Legal Framework Compatibility	The level of suitability of the legal framework for the integration of self-consumption RES generation solutions in buildings.	✓	✓	✓	✓	×		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	Energy	Symbiotic waste heat Legal Framework Compatibility	The level of suitability of the legal framework for the integration of symbiotic waste heat solutions	✓	✓	✓	✓	×		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	Energy	Energy flexibility policies Legal Framework Compatibility	The level of suitability of the legal framework for the integration of energy flexibility policies such as incentives for peak-shaving.	✓	✓	✓	✓	×		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	Mobility	Smart EVs Legal Framework Compatibility	The level of suitability of the legal framework for the integration of private EVs and public transport EVs in the city mobility policies.	✓	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	System functionality; Social	City platform Legal Framework Compatibility	The level of suitability of the legal framework for the integration of a web city platform for the energy management and citizen engagement.	✓	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	Social	Change in rules and regulations	It shows the extent to which the project is able to change the context in which they were applied, by providing a different interpretation of existing rules and regulations.	✓	✓	✓	✓	×		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Legal	Social	The extent to which privacy by design is ensured	Measures the extent (number of measures) to which privacy by design has been ensured.	×	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[1]	✓	✓
Technical	Energy	Self-Sufficiency Ratio	The degree to which the on-site generation is sufficient to fill the final energy needs of the building/system	✓	✓	✓	✓	×		✓	×	×	×	✓	✓	✓	✓	[6]	[7]	✓	✓
Technical	Energy	kWp photovoltaic installed per 100 inhabitants	Installed capacity of photovoltaic interpolated to 100 inhabitants	✓	✓	✓	×	✓		✓	×	✓	✓	×	×	✓	✓	[6]	[8]	✓	✓
Technical	Energy	Heat Recovery Ratio	The KPI refers to the percentage ratio of the total thermal energy output of the system (MWh) to the thermal energy recovered through a waste heat recovery technology (MWh)	✓	✓	✓	✓	×		✓	×	✓	✓	✓	✓	✓	✓	[6]	[9]	✓	×
ICT	Energy	Integrated Building Management Systems	Percentage of buildings using integrated ICT systems to automate building management and create flexible, effective, comfortable and secure environment	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[6]	[10]	✓	✓
ICT	Energy	Percentage of buildings in the city with smart energy meters	Percentage of buildings using smart energy meters to record and display the consumption of energy in real time, thus providing energy providers data to better plan and conserve energy	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[6]	[11]	✓	✓
Technical	Energy	Specific Yield	Metered output energy of a supply system related to the size (capacity) of the system	✓	✓	✓	✓	×		✓	×	×	×	✓	✓	×	×	[12]		✓	×
Technical	Energy	Thermal Load Reduction	Reduction of heating/cooling load caused by envelope insulation in specific thermal zone.	✓	✓	✓	✓	×		✓	×	✓	×	×	×	×	×		[13]	✓	✓
Technical	Energy	Peak Load reduction	The indicator compares the peak demand before the aggregator implementation (baseline) with the peak demand after; per final consumer, per feeder, per network.	×	✓	✓	✓	×		✓	×	×	×	✓	✓	✓	✓		[13]	✓	✓
ICT	Mobility	Street lighting management	Percentage of street lighting managed by a light performance management system	✓	✓	✓	×	✓		✓	×	×	×	×	×	✓	✓		[11]	✓	✓
Environmental		Greenhouse Gas Emissions	The KPI calculates the amount of emissions for six major GHGs: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6).	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓	[2]	[10]	✓	✓
Environmental		Air Quality Index	The indicator provides a relative measure of the annual average air quality in relation to the European limit values (annual air quality standards and objectives from EU directives)	✓	✓	✓	✓	✓		✓	×	×	×	×	×	×	✓	[14]	[10]	✓	✓
Technical	Energy	Primary Energy Demand	The indicator of the primary energy demand of every metered system encompasses all the naturally available energy that is consumed in the supply chain of the used energy carriers.	✓	✓	✓	✓	×		✓	×	×	×	×	×	×	✓	[16]; [14]		✓	×
Technical	Energy	Primary Energy Consumption	The indicator of the primary energy consumption of every metered system encompasses all the naturally available energy that is consumed in the supply chain of the used energy carriers.	✓	✓	✓	✓	×		✓	×	×	×	×	×	×	✓	[16]; [14]		✓	×
Environmental		Climate Resilience Strategy	This indicator assesses to what extent the city has a resilience strategy and action plan to adapt/respond to climate change, by providing a qualitative measure.	✓	✓	✓	✓	×		×	✓	×	×	×	×	×	✓		[17]	✓	✓
Environmental		Municipal Solid Waste	This indicator provides a measure of how much waste a city is producing and the level of service a city is providing for its collection	✓	✓	✓	✓	✓		✓	×	×	×	×	×	×	✓	[18]	[11]	✓	✓
Environmental		Recycling Rate of Solid Waste	This KPI estimates the percentage of city's solid waste that is recycled, calculated as the total amount of the city's solid waste that is recycled in tons divided by the total amount of solid waste produced	✓	✓	✓	✓	✓		✓	×	×	×	×	×	×	✓	[18]	[11]	✓	✓
Economic		Average Electricity Price for Companies	The indicator represents the average minimum cost at which electricity must be sold so as to balance the costs with profits	✓	✓	✓	✓	×		✓	×	×	×	✓	✓	×	×	[18]		✓	✓
Economic		Average Electricity Price for Consumers	The indicator represents the average minimum cost at which electricity must be sold so as to balance the costs with profits	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓	[18]		✓	✓
Economic	Energy	Percentage of the Total Distributed Energy Resources Capacity Traded	This KPI measures the amount of Distributed Energy Resources (DERs) capacity traded as a percentage of the total DERs capacity available	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓	[2]		✓	×
Economic		Energy Poverty	The KPI evaluates the extent to which households are at risk of poverty or deprivation by calculating the change in percentage points of (gross) household income spent on energy bills.	✓	✓	✓	✓	×		✓	×	✓	✓	×	×	✓	✓	[15]	[1]	✓	✓
Economic	Environmental	Carbon Dioxide Reduction Cost Efficiency	The specific KPI estimates the costs in euros per ton of CO2 saved per year. This KPI can be estimated capitalizing on information already available in other KPIs (carbon dioxide emission reduction and total annual costs).	✓	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓	[16]	[1]	✓	✓
Economic		New Business Creation	The indicator assesses the number of new businesses created (including start-ups) as one point of overall business climate in a jurisdiction and entrepreneurship.	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓		[17]	✓	✓
Economic		Expenditures by the municipality for a transition towards a smart city	Smart city expenditures include process-relevant expenditures and findings. Estimates should also include the percentage of municipal budget allocated to the ICT facilities	×	✓	✓	✓	×		✓	×	×	×	×	×	✓	✓	[14]	[17]	✓	✓
ICT	System functionality	Improved Data Privacy	This indicator refers to the level of improvement of data privacy and safety, analyzing the extent to which data collected by the project are protected, for instance, by following regulations on data protection and implementing proper procedures to protect personal or private data.	✓	✓	✓	×	✓		×	✓	✓	✓	×	×	✓	✓		[17]	✓	✓
ICT	System functionality	ICT Response Time	The response time of ICT infrastructure is related to the services developed and the payload (information exchanged) between them, applicable to the various ICT actions and services in the project.	✓	✓	✓	×	✓		✓	×	✓	✓	✓	✓	✓	✓	[12]		✓	×
ICT	System functionality	Improved Cybersecurity	The indicator refers to the extent to which the project ensures cybersecurity of its systems.	✓	✓	✓	×	✓		×	✓	✓	✓	✓	✓	✓	✓	[14]	[17]	✓	✓
Technical	Mobility	Electric Vehicles & Low-Carbon Emission Vehicles deployed in the area	Number of electric vehicles (EV) and low-carbon vehicles (PHEV and hydrogen) registered in the area in relation to the total number of motorized vehicles (four and two wheels)	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[14]	[11]	✓	✓
Technical	Mobility	Annual Energy delivered by charging points	The KPI refers to the level of use of the EV charging infrastructure implemented in the city, calculating the total kWh recharged by all types of EVs during a year in the public charging stations	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[14]		✓	×
Technical	Mobility	Annual number of passengers using the new vehicles and/or infrastructure	The level of utilization of the new vehicles or infrastructure should be expressed by the number of passengers or users traveling during a year with the new vehicles (e.g., EVs and e-buses) or on the new infrastructure deployed	×	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[16]		✓	×
Technical	Mobility	Shared Electric Vehicles Penetration Rate	Number of e-vehicles that operate in the platform and in the community car-sharing concept	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[16]		✓	×
Technical	Mobility	Clean mobility utilization	The indicator assesses the number of km in clean vehicles and number of trips in clean vehicles as a means of sustainable mobility	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[2]		✓	×
Technical	Mobility	Modal Split (Passengers/ Vehicles/Trips)	The indicator determines the distribution of transport over the modalities of public and collective transport, private vehicles, biking and walking.	✓	✓	✓	✓	✓		✓	×	×	×	×	×	✓	✓	[21]		✓	×
Social		Connection to the existing cultural heritage	The extent to which making a connection to the existing cultural heritage was considered in the design of the project	✓	✓	✓	×	✓		×	✓	✓	✓	×	×	✓	✓	[16]	[17]	✓	✓
Social		Degree of satisfaction	The level of satisfaction and acceptance of people affected by the actions in the project, from a technical point of view; perceived adequateness, benefit (e.g., comfort), usefulness, ease of use and aesthetics; economic point of view; and cost, risk and benefit.	✓	✓	✓	✓	×		×	✓	✓	✓	×	×	✓	✓	[16]	[19]	✓	✓
Social		Percentage of citizens' participation in online decision-making	The indicator assesses the percentage of citizens that take part in online decision-making	×	✓	✓	✓	✓		✓	×	✓	✓	✓	✓	✓	✓	[14]		✓	×
ICT	Social	Online visits to the municipal open data portal	Number of visits to the municipal open data portal in a year per 100,000 population.	✓	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[11]	✓	✓
ICT	Social	Percentage of city services accessible and that can be requested online	The total number of city services offered to people and businesses through a centralized Internet interface compared to the total number of city services offered by the city.	✓	✓	✓	×	✓		✓	×	×	×	×	×	×	✓		[11]	✓	✓
Social		Monitoring and evaluation	The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported.	×	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[17]	✓	×
Legal		Legal Framework Compatibility	The level of suitability of the legal framework for the integration of a) RES generation, b) symbiotic waste-heat, c) energy flexibility, d) private and public EV penetration and e-mobility and e) CIPs for energy management and citizen engagement; policies	✓	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[1]	✓	×
ICT	Social	Open government dataset	The indicator measures the number of open government datasets per 100,000 inhabitants, showing how involved the local government is in building a smart city.	✓	✓	✓	×	✓		✓	×	×	×	×	×	×	✓	[14]	[10]	✓	✓
Economic		Market demand	The extent to which there is a general market demand for the solution. An important characteristic is if the innovation meets the needs of its potential adopters.	×	✓	✓	✓	✓		×	✓	×	×	×	×	×	✓		[17]	✓	×
Social		Diffusion to other locations	The extent to which the project is copied in other cities and regions.	✓	✓	✓	✓	✓		×	✓	✓	✓	✓	✓	✓	✓		[17]	✓	✓
Environmental		Human toxicity, non-cancer effects	Accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionising radiation	×	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[20]	✓	✓
Environmental		Human toxicity, cancer effects	Accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to cancer.	×	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[20]	✓	✓
Environmental		Acidification	Reduction in the pH over an extended period of time, caused primarily by uptake of carbon dioxide (CO2) from the atmosphere	✓	✓	✓	✓	✓		✓	×	✓	✓	✓	✓	×	×		[22]	✓	×
Environmental		Ionizing radiation	Level of ionizing radiation created by on-site energy units	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[23]	✓	×
Environmental		Ozone depletion	KPI defines the ozone depletion potential of different gases relative to the reference substance chlorofluorocarbon-11 (CFC-11), expressed in kg CFC-11 equivalent	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[22]	✓	×
Environmental		Photochemical ozone formation	Accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[20]	✓	✓
Environmental		Terrestrial eutrophication	Enrichment of an ecosystem with a limiting nutrient	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[24]	✓	×
Environmental		Freshwater eutrophication	The enrichment of fresh water by nutrients, especially compounds of nitrogen and phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water concerned.	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[25]	✓	✓
Environmental		Marine eutrophication	The reaction of a marine ecosystem to an excessive availability of a limiting nutrient	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[26]	✓	✓
Environmental		Freshwater ecotoxicity	The toxic effects of chemical on an ecosystem, in this case in the freshwater, causing biodiversity loss and/or species extinction	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[26]	✓	✓
Environmental		Land use	Describes how the area is used for urban, agricultural, forestry and other uses	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[27]	✓	×
Environmental		Mineral-fossil resource depletion	The consumption of a resource faster than it can be replenished	✓	✓	✓	✓	✓		✓	×	×	×	✓	✓	×	×		[28]	✓	✓
Social		Progress towards energy citizenship	The change of extent to which citizens actively participate in energy systems and preferably have a positive impact on the energy transition	×	✓	✓	×	✓		×	✓	×	×	×	×	✓	✓	[29]		✓	×
Social		City instruments	The extent to which the project has benefitted from city instruments	✓	✓	×	×	✓		×	✓	×	×	×	×	×	✓	[30]		✓	✓
Social		Affordability	The extent in which total cost for the combination of housing and energy evaluated by citizens.	✓	✓	✓	×	✓		×	✓	×	×	×	×	×	✓	[30]		✓	✓
Environmental		Green space index	The percentage of the green area in the buffer zone of a single building	✓	✓	✓	✓	✓		✓	×	✓	✓	×	×	✓	✓		[31]	✓	✓

1 Highly depends on applied solutions/technologies