simply positive

D1.2. Key Performance Indicators for PED/PEN Implementation Assessment

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PV Works

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V3	Standards and Projects	SON	May 2023
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Executive Summary

The aim of the deliverable is to analyze available **Key Performance Indicator (KPI) sets** for the Simply Positive project, and to select a set of KPIs for the PED/PEN implementation assessment of the Simply Positive Focus Districts. For this we followed a two-step methodology, where we first preselected a set of KPIs based on extensive literature research, and secondly weighted the importance of these indicators from a Simply Positive focus district perspective.

Within the document we focused on three main categories for indicators:

i. **Energy related** performance indicators,
ii. **Environment related** performance indicators, and
iii. **User & Stakeholder acceptance related** performance indicators.

During the process with "mobility" an important sub-category of energy related indicators was identified. Economic indicators were identified too and put into a fourth category "others".

As a result, 7 profiling indicators, 10 primary indicators have been selected for the assessment of PED/PEN implementation. 15 secondary indicators show exemplary how to support the assessment based on Focus District needs and specialization.

Profiling indicators:

1. Size of Focus District [m²}
2. Population of Focus District [# of citizens]
3. Density of Focus District [# citizens / m² of total area]
4. Built-up density [m² of built-up area / m² of total area]
5. Heating degree days [#]
6. Cooling degree days [#]
7. Average household income [EUR]

Primary indicators:

1.	Overall Indicator	PED / PEN achievement rate [%]
2.	Energy related	Final energy consumption [kWh/a]
3.	Energy related	Primary energy consumption [kWh/a]
4.	Energy related	RES generation [kWh/a]
5.	Energy related	Degree of energetic self-supply by RES [%]
6.	Environment related	Greenhouse gas emissions [kgCO2eq/a]
7.	Acceptance	People reached [%]
8.	Acceptance	Success rate [%]
9.	Economic	Money spent [€]
10.	Economic	Return on investment [years]

The primary indicators have been divided into two subgroups: i.) external indicators assessing the performance of the outcome (the PED/PEN), and to be communicated externally (indicators 1 to 6), and ii.) internal indicators assessing the performance of the process (the PED/PEN implementation), and to be used internally for process management purposes.

List of Figures

List of Tables

List of Abbreviations and Acronyms

ASHRAE	American Association of Heating, Refrigerating and A-C Engineers
CATDAT	Catastrophes Database
CEN	European Committee for Standardization
DG CLIMA	Directorate-General for Climate Action
DG ENV	Directorate-General for Environment
EC	European Commission
EEA	European Environment Agency
Eionet	European Environment Information and Observation Network
EPB	Energy Performance of Buildings
ESS	European Statistical System
ESS (LUCAS)	Land Use and Cover by Area frame Sampling
ESS (SHARES)	Share of energy from renewable sources survey
ESS (SILC)	Statistics on Income and Living Conditions
EU	European Union
EVO	Efficiency Valuation Organization
ISO	International Organization for Standardization
ISO/TR	Technical Report of ISO
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
MJ	Megajoule
MPI	Multipurpose Indicator
MS	Member States
PED	Positive Energy District
RER	Renewable Energy Ratio
SDG	Sustainable Development Goal
SECAP	Sustainable Energy and Climate Action Plan
TtW	Tank to Wheel
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound
VOS	Vehicle Operation System
WBCSD	World Business Council for Sustainable Development
WP	Work Package
WtT	Wheel to Tank
WtW	Well to Wheel

Table of Contents

1 Introduction

The simply positive project aims at supporting the emergence of Positive Energy Districts (PEDs) and the transition to climate neutral cities. This is to be achieved by analyzing and supporting four different focus regions on their pathway and establishing tailored participation strategies to motivate further cities on their pathways toward climate neutrality.

1.1 Purpose of the document

The aim of the document is to present and describe key performance indicators developed to assess the starting point and progress of different districts and neighborhoods on their way towards becoming a PED or PEN. As aims of the project are to assess, monitor and visualize achieved results of the focus district on the one hand, and to motivate further cities joining the pathway towards reaching 1000s of PEDs and PENs all over Europe, indicators are necessary to quantify the progress.

1.2 Relation to other project activities

The set of Key Performance Indicators described and selected through the deliverable will be used for Work Package 3 – Practical Operationalization of the PED Framework definition and criteria in the Focus Districts, especially within Task 3.2 – Framework Status and Methodology development and Task 3.4 – Assessment of SIMPLY POSITIVE Focus Districts. Later, the KPIs will be used again within Work Package 5 – Monitoring, Controlling and Digitalization of individual PED-Pathways, especially within Task 5.2 – Toolsets and Resources needed to monitor changes and visualize results and Task 5.3 – Feedback Implications to the PED Definition Framework and selected SIMPLY POSITIVE Methodology.

1.3 Structure of the document

The document is divided into three main sections: after this introduction, the first key section is Section 2 with the description of the methodology. In Section 3 follows the detailed literature review and the results regarding Quantification of Energy Use, Quantification of Environmental Impact, and Quantification of User and Stakeholder Acceptance. In Section 4 the selection of KPIs is described according to application criteria, and the pre-selected KPIs are described. In Section 5 the rating of the preselected KPIs from the focus district perspective is shown. Section 6 concludes the document with a summarization of the results and outlook on further necessary work.

2 Methodology

Task 1.3 was originally intended as “desk research”. The literature review and its sources are described in detail in the following Chapter 3. During the process, the project team decided to enhance results of the performed desk research by KPI-ratings from the project specific focus districts perspective. This was done by presenting the results of the desk research in the form of pre-selected KPI´s, see Chapter 4. Through an interactive discussion with representatives of all SimplyPositive focus districts further indicators have been discussed, and all of them included in an online survey for rating both the importance of each indicator category, as well as rating the importance of each indicator itself. The results are presented in Chapter 5.

3 Literature Review

This chapter presents the literature review carried out to support KPI definition. After a general description of sources, it is structured according to the three domains of energy (energy efficiency, energy balance), environmental impact, and user and stakeholder acceptance.

3.1 Sources

3.1.1 Scientific literature

Scientific literature was used to frame the information found in existing standards and European projects with a broader perspective and, where needed, to provide deeper insight than could be found in standards or information regarding domains not yet standardized.

The review of literature was not confined to the performance of any one type of system. One may assess "building performance", or the performance of technical systems, or "the performance of an organization and its services". [1] The functionality of Key Performance Indicators (KPI) has made them one of the most popular and valuable tools among recorded literature regarding measurement of the level of sustainability of construction projects. [2]

Thus, scientific literature on this topic is well established for different applications, and guides as reference for the proper analysis and selection of the simply positive PED-related KPIs.

3.1.2 International Standards

International standards have been published in many areas related to this KPI selection: energy performance of buildings, environmental management, social responsibility, smart cities, and many more. The below table 1 highlights a selection of these published standards. The most relevant ones are then described in detail in section 3 of this document.

Table 1 - International Standards relevant for Simply Positive PED-KPIs

Organization	Number	Latest Version	Name
CEN	16258	2012	Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)
ISO	17741	2016	General technical rules for measurement, calculation, and verification of energy savings of projects
ISO	17742	2015	Energy efficiency and savings calculation for countries, regions and cities
ISO	17743	2016	Energy savings — Definition of a methodological framework applicable to calculation and reporting on energy savings
ISO	52000-1	2017	Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures
ISO/TR	52000-2	2017	Energy performance of buildings — Overarching EPB assessment — Part 2: Explanation and justification of ISO 52000-1

ISO	52000-3	2023	Energy performance of buildings — Overarching EPB assessment — Part 3: General principles for determination and reporting of primary energy factors and CO2 emission coefficients
ISO	52003	2017	Energy performance of buildings — Indicators, requirements, ratings, and certificates — Part 1: General aspects and application to the overall energy performance
ISO	50001	2018	Energy management systems — Requirements with guidance for use
ISO	50006	2023	Energy management systems — Evaluating energy performance using energy performance indicators and energy baselines
ISO	50007	2017	Energy services — Guidelines for the assessment and improvement of the energy service to users
ISO	50021	2019	Energy management and energy savings — General guidelines for selecting energy savings evaluators
ISO	50049	2020	Calculation methods for energy efficiency and energy consumption variations at country, region, and city levels
ISO	14001	2015	Environmental management systems — Requirements with guidance for use
ISO	14008	2019	Monetary valuation of environmental impacts and related environmental aspects
ISO	14031	2021	Environmental management — Environmental performance evaluation — Guidelines
ISO	14064-1	2018	Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals
ISO	37101	2016	Sustainable Development in Communities - Management System for Sustainable Development - Requirements with Guidance for Use
ISO	37120	2018	Sustainable cities and communities – Indicators for city services and quality of life
ISO	37122	2019	Sustainable cities and communities - Indicators for smart cities
ISO	37123	2019	Sustainable cities and communities - Indicators for resilient cities
ISO	21931-1	2022	Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social, and economic performance of construction works as a basis for sustainability assessment — Part 1: Buildings
ASHRAE	105	2021	Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions
ASHRAE	100	2018	Energy Efficiency in Existing Buildings
ASHRAE	90.1	2022	Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings
EVO	IPMVP	2022	International Performance Measurement and Verification Protocol

A variety of national standards and guidelines are also defined at the national level regarding energy efficiency and sustainability.

3.1.3 European Initiatives and Projects

The European Commission has funded many projects dealing with energy efficiency, the outcomes, and methods of which can be reused. In the CONCERTO initiative, demonstration activities at the city and neighborhood levels were funded by the European Commission without specific technology targets and assessed with a common methodology. The unified

assessment methodology developed for the CONCERTO initiative included rules defining system boundaries for performance assessment, performance indicators, ways to define baselines, and a structured method for data gathering and data processing. [3]

For the Smart City Information System (SCIS), successor of the CONCERTO initiative, KPIs were also defined and published in a guide. [4] SCIS is one of the smart city lighthouse project assessment frameworks specifically developed for this purpose and funded by the European Commission. Other such frameworks include CITYkeys and ESPRESSO (systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities).

Further relevant European Initiatives and Projects are listed below in table 2. The relevant input from the most important projects is described in detail in section 3 of this document.

Table 2 - European Initiatives and Projects relevant for Simply Positive PED-KPIs

Acronym / Name	Comment	Link
CONCERTO Initiative	22 projects with 58 communities from 2005	https://www.concertoplus.eu/
Smart Cities	Support and Knowledge Base of 89 successful European projects.	Creating smart cities together | Smart Cities Marketplace (europa.eu)
CITYkeys	Smart city performance measurement system	https://cordis.europa.eu/project/id/646440
ESPRESSO	Systemic standardization approach to empower smart cities and communities	https://cordis.europa.eu/project/id/691720
SCIS	Provide scientific expertise to monitor and analyze projects in the fields of smart cities, sustainable energy districts, and energy-efficient buildings	https://www.ait.ac.at/en/scis
bestenergy	improving the energy efficiency in buildings	http://www.bestenergyproject.eu/
inBetween	comprehensive energy monitoring for instant tailored energy saving advice via cloud services	https://www.inbetween-project.eu/
+CityxChange	Solutions for Positive Energy Blocks leading to Positive Energy Districts	http://cityxchange.eu/
RemoUrban	Sustainable urban regeneration model	http://www.remourban.eu/
mySMARTLife	Supporting EU cities in their transition into more sustainable places	https://www.mysmartlife.eu/
MakingCity	Energy efficient pathway for the city transformation	www.makingcity.eu
PED-ID	Increase implementation of Positive-Energy-Districts	https://jpi-urbaneurope.eu/project/ped-id/
POCITYF	Delivering Positive Energy Districts in mixed urban settings	https://pocityf.eu/
Sinfonia	Low Carbon cities for Better Living, with solutions on district levels	www.sinfonia-smartcities.eu

3.2 Sustainable Cities and Communities

3.2.1 UN Sustainable Development Goals

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now

and into the future. At its heart are the 17 Sustainable Development Goals (SDGs), which are an urgent call for action by all countries - developed and developing - in a global partnership. [5]. Behind the 17 goals lies at set of indicators, measuring their status per country. Since 2016 the outcome is published yearly within the SDG Progress Report, available online at https://sdgs.un.org/goals.

Figure 1 - The 17 Sustainable Development Goals

From a global perspective, the UN agenda 2030 document has foreseen different levels of SDG monitoring from the start. Therefore, different indicators exist for different parts of the world. The European set of indicators are aligned to around two thirds with the UN list of global indicators. However, one third has been adapted to the EU´s situation and to EU policies. [6]

For Europe, Eurostat oversees reporting the progress of reaching the 17 development goals and their sub targets. Eurostat also publishes regular monitoring reports on the progress towards the SDGs.

The EU indicator set comprises 100 indicators that are structured along the 17 SDGs. Except for SDG 2 and 13, each goal has 6 indicators that are exclusively attributed to it. 33 of the 100 indicators are multipurpose, meaning they are used to monitor more than one SDG. All indicators are grouped in sub-themes to underline interlinkages and highlight different aspects of each SDG. [7]

Within the list of EU indicators for the 2023 monitoring report, the following KPI´s are most relevant for Positive Energy Districts and Neighborhoods:

Table 3 - Selected EU-Indicators for Sustainable Development Goals Reporting 2023

Goal	*Code*	*MPI*	*Indicator name*	*Unit(s)*	*Frequency of data collection*	*Geographical coverage*	*Data source*	*Data provider*

7	**Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all**							
7	07_10		Primary & final energy consumption	million tonnes of oil equivalent, index 2005 = 100 and tonnes of oil equivalent per capita	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
7	07_20		Final energy consumption in households per capita	kg of oil equivalent	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
7	07_30	mpi -> 12	Energy productivity	Chain linked volumes (2010) in EUR and PPS per kg of oil equivalent	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
7	07_40	mpi -> 13	Share of renewable energy in gross final energy consumption	% i. all sectors ii. transport iii. electricity iv. heating and cooling	every year	EU aggregate and all MS; plus other countries	ESS (SHARES)	Eurostat
7	07_50		Energy import dependency	% of imports in total gross available energy i. all products ii. solid fossil fuels iii. total petroleum products iv. natural gas	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
7	07_60		Population unable to keep home adequately warm	% of population i. total ii. below 60% of median equivalised income iii. above 60% of median equivalised income	every year	EU aggregate and all MS; plus other countries	ESS (SILC)	Eurostat
9	**Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation**							
9	09_50	mpi -> 11	Share of buses and trains in inland passenger transport	% of passenger-kilometres i. all collective transport modes ii. trains iii. motor coaches, buses and trolley buses	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
9	09_60		Share of rail and inland waterways in inland freight transport	% of tonne-kilometres i. all railways and inland waterways ii. railways iii. inland waterways	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
9	09_70		Air emission intensity from industry	Grams per euro, chain linked volumes (2010) i. Particulates < 2.5 µm ii. Particulates < 10 µm	every year	EU aggregate & all MS and other countries	ESS; Air Emission Accounts	Eurostat

11	**Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable**							
11	11_11	mpi -> 1	Severe housing deprivation rate	% of population i. total ii. below 60 % of median equivalised income iii. above 60 % of median equivalised income	every 3 years	EU aggregate and all MS; plus other countries	ESS (SILC)	Eurostat
11	11_20	mpi -> 3	Population living in households considering that they suffer from noise	% of population i. total ii. below 60% of median equivalised income iii. above 60% of median equivalised income	every 3 years	EU aggregate and all MS; plus other countries	ESS (SILC)	Eurostat
11	11_31		Settlement area per capita	square meters per capita	> 3 years	EU aggregate and all MS	ESS (LUCAS)	Eurostat
11	11_52	mpi -> 3	Premature deaths due to exposure to fine particulate matter (PM2.5)	number and number per 100 000 people (rate)	every year	EU aggregate and all MS; plus other countries	DG ENV	EEA
11	11_60		Recycling rate of municipal waste	% of total municipal waste generated	every year	EU aggregate and all MS; plus other countries	ESS	Eurostat
12	**Goal 12. Ensure sustainable consumption and production patterns**							
12	12_21	mpi -> 8	Material footprint	thousand tonnes and tonnes per capita	every year	EU aggregate and all MS	ESS	Eurostat
12	12_30	mpi -> 13	Average CO2 emissions per km from new passenger cars	g CO2 per km	every year	EU aggregate and all MS	Regulation (EC) No 443/ 2009	EEA / DG CLIMA
12	12_41		Circular material use rate	% of total material use	every year	EU aggregate and all MS	ESS	Eurostat
12	12_51		Generation of waste	kg per capita i. hazardous and non-hazardous - total ii. hazardous iii. non-hazardous	every 2 years	EU aggregate and all MS; plus other countries	ESS	Eurostat
13	**Goal 13. Take urgent action to combat climate change and its impacts**							
13	13_10		Net greenhouse gas emissions	index 1990 = 100 and tonnes of CO2 equivalent per capita	every year	EU aggregate and all MS; plus other countries	UNFCCC reporting	EEA
13	13_21		Net greenhouse gas emission of the Land use, Land use change and Forestry (LULUCF) sector	thousand tonnes of CO2 equivalent; tonnes of CO2 equivalent per capita; tonnes of CO2 equivalent per km2	every year	EU aggregate and all MS; plus other countries	UNFCCC reporting	EEA

13	13_40		Climate-related economic losses	million EUR (current prices) and EUR per capita i. Annual values ii. Average losses over 30 years	every year	EU aggregate and all MS	CATDAT - Risklayer	EEA
13	13_50		Contribution to the international 100bn USD commitment on climate related expending	million EUR (current prices)	every year	EU aggregate and all MS; plus EIB and European Commission	Regulation (EU) 2018/1999	DG CLIMA; Eionet
13	13_60		Population covered by the Covenant of Mayors for Climate and Energy signatories	million persons and % of population	every year	EU aggregate and all MS; plus other countries	The Co-venant of Ma-yors for Climate & Energy	JRC

3.2.2 Sustainable Cities and Communities

With "Indicators for city services and quality of life" the international organization for standardization (ISO) offers since 2014 a holistic and integrated approach to sustainable development, including indicators for city services, quality of life, smart cities, and resilient cities. The ISO standard 37120:2018 is part of a series of international standards to provide a uniform approach to what indicators are measured and how these measurements are taken. [8] The idea behind the standard is to unify existing indicators on a local level to make them comparable over time or across cities. The indicators can be used to track and monitor progress on city performance. They have been developed to help cities: i.) measure performance management of city services and quality of life over time; ii.) learn from one another by allowing comparison across a wide range of performance measures; and iii.) support policy development and priority setting. [9]

The ISO standard provides core indicators, supporting indicators and profile indicators within the 19 categories. Below table gives an overview of the indicators used. [10] The indicator types are abbreviated with CI (core indicator), SI (supporting indicator) and PI (profiling indicator).

Table 4 - ISO 37120 indicators for sustainable cities and communities

Category	Type	Description
Economy	CI	City´s unemployment rate
Economy	SI	Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties
Economy	SI	Percentage of persons in full-time employment
Economy	SI	Youth unemployment rate
Economy	SI	Number of businesses per 100.000 population
Economy	SI	Number of new patents per 100.000 population per year
Economy	SI	Annual number of visitors stays (overnight) per 100.000 population
Economy	SI	Commercial air connectivity
Economy	PI	Average household income
Economy	PI	Annual inflation rate based on the average of the past five years

Economy	PI	City product per capita
Education	CI	Percentage of female school-aged population enrolled in schools
Education	CI	Percentage of students completing primary education: survival rate
Education	CI	Percentage of students completing secondary education: survival rate
Education	CI	Primary education student-teacher ratio
Education	SI	Percentage of school-aged population enrolled in schools
Education	SI	Number of higher education degrees per 100.000 population
Energy	CI	Total end-use energy consumption per capita (GJ/year)
Energy	CI	Percentage of total end-use energy derived from renewable sources
Energy	CI	Percentage of city population with authorized electrical service
Energy	CI	Number of gas distribution service connections per 100.000 population
Energy	CI	Final energy consumption of public buildings per year (GJ/m^2)
Energy	SI	Electricity consumption of public street lighting per kilometer of lighted street
Energy	SI	Average annual hours of electrical service interruptions per household
Energy	PI	Heating degree days
Energy	PI	Cooling degree days
Environment	CI	Fine particulate matter (PM2.5) concentration
Environment	CI	Fine particulate matter (PM10) concentration
Environment	CI	Greenhouse gas emissions measured in tons per capita
Environment	SI	Percentage of areas designated for natural protection
Environment	SI	NO2 (nitrogen dioxide) concentration
Environment	SI	SO2 (sulfur dioxide) concentration
Environment	SI	O3 (ozone) concentration
Environment	SI	Noise pollution
Environment	SI	Percentage change in number of native species
Finance	CI	Debt service ratio (debt service expenditure as a percentage of a city's own-source revenue)
Finance	CI	Capital spending as a percentage of total expenditures
Finance	SI	Own-source revenue as a percentage of total revenues
Finance	SI	Tax collected as a percentage of tax billed
Finance	PI	Gross operation budget per capita
Finance	PI	Gross capital budget per capita
Governance	CI	Women as a percentage of total elected to city-level office
Governance	SI	Number of convictions for corruption and/or bribery by city officials per 100.000 population
Governance	SI	Number of registered voters as a percentage of the voting age population
Governance	SI	Voter participation in last municipal election (as a percentage of registered voters)
Health	CI	Average life expectancy
Health	CI	Number of in-patient hospital beds per 100.000 population
Health	CI	Number of physicians per 100.000 population
Health	CI	Under age five mortality per 1.000 live births
Health	SI	Number of nursing and midwifery personnel per 100.000 population
Health	SI	Suicide rate per 100.000 population
Housing	CI	Percentage of city population living in inadequate housing
Housing	CI	Percentage of population living in affordable housing
Housing	SI	Number of homeless per 100.000 population
Housing	SI	Percentage of households that exist without registered legal titles
Housing	PI	Total number of households

Housing	PI	Persons per unit
Housing	PI	Vacancy rate (residential)
Housing	PI	Living space (m^2) per person
Housing	PI	Secondary residence rate
Housing	PI	Residential rental dwelling units as a percentage of total dwelling units
Population	CI	Percentage of city population living below the international poverty line
Population	SI	Percentage of city population living below the national poverty line
Population	SI	Gini coefficient of inequality
Population	PI	Annual population change
Population	PI	Percentage of population that are foreign born
Population	PI	Population demographics
Population	PI	Percentage of population that are new immigrants
Population	PI	Percentage of city population that are non-citizens
Population	PI	Number of university students per 100.000 population
Recreation	SI	Square meters of public indoor recreation space per capita
Recreation	SI	Square meters of public outdoor recreation space per capita
Safety	CI	Number of firefighters per 100.00 population
Safety	CI	Number of fire-related deaths per 100.000 population
Safety	CI	Number of natural-hazard-related deaths per 100.000 population
Safety	CI	Number of police officers per 100.000 population
Safety	CI	Number of homicides per 100.000 population
Safety	SI	Number of volunteer and part-time firefighters per 100.000 population
Safety	SI	Response time for emergency response services from initial call
Safety	SI	Crimes against property per 100.000 population
Safety	SI	Number of deaths caused by industrial accidents per 100.000 population
Safety	SI	Number of violent crimes against women per 100.000 population
Solid Waste	CI	Percentage of city population with regular solid waste collection (residential)
Solid Waste	CI	Total collected municipal solid waste per capita
Solid Waste	CI	Percentage of the city's solid waste that is recycled
Solid Waste	CI	Percentage of the city's solid waste that is disposed of in a sanitary landfill
Solid Waste	CI	Percentage of the city's solid waste that is treated in energy-from-waste plants
Solid Waste	SI	Percentage of the city's solid waste that is biologically treated and used as compost or biogas
Solid Waste	SI	Percentage of the city's solid waste that is disposed of in an open dump
Solid Waste	SI	Percentage of the city's solid waste that is disposed of by other means
Solid Waste	SI	Hazardous waste generation per capita
Solid Waste	SI	Percentage of the city's hazardous waste that is recycled
Sport, Culture	CI	Number of cultural institutions and sporting facilities per 100.000 population
Sport, Culture	SI	Percentage of municipal budget allocated to cultural and sporting facilities
Sport, Culture	SI	Annual number of cultural events per 100.000 population
Telecommunication	SI	Number of internet connections per 100.000 population
Telecommunication	SI	Number of mobile phone connections per 100.000 population
Transportation	CI	Kilometers of public transport system per 100.000 population
Transportation	CI	Annual number of public transport trips per capita
Transportation	SI	Percentage of commuters using a travel mode to work other than a personal vehicle
Transportation	SI	Kilometers of bicycle paths and lanes per 100.000 population

Transportation	SI	Transportation deaths per 100.000 population
Transportation	SI	Percentage of population living within 0,5 km of public transit running at least every 20 min during peak periods
Transportation	SI	Average commute time
Transportation	PI	Number of personal automobiles per capita
Transportation	PI	Number of two-wheeled motorized vehicles per capita
Agriculture, Food	CI	Total urban agricultural area per 100.000 population
Agriculture, Food	SI	Amount of food produced locally as a percentage of total food supplied to the city
Agriculture, Food	SI	Percentage of city population undernourished
Agriculture, Food	SI	Percentage of city population that is overweight or obese
Urban Planning	CI	Green area (hectares) per 100.000 population
Urban Planning	SI	Areal size of informal settlements as a percentage of city area
Urban Planning	SI	Jobs–housing ratio
Urban Planning	SI	Basic service proximity
Urban Planning	PI	Population density (per square kilometer)
Urban Planning	PI	Number of trees per 100.000 population
Urban Planning	PI	Built-up density
Wastewater	CI	Percentage of city population served by wastewater collection
Wastewater	CI	Percentage of city's wastewater receiving centralized treatment
Wastewater	CI	Percentage of population with access to improved sanitation
Wastewater	SI	Compliance rate of wastewater treatment
Water	CI	Percentage of city population with potable water supply service
Water	CI	Percentage of city population with sustainable access to an improved water source
Water	CI	Total domestic water consumption per capita (liters/day)
Water	CI	Compliance rate of drinking water quality
Water	SI	Total water consumption per capita (liters/day)
Water	SI	Average annual hours of water service interruptions per household
Water	SI	Percentage of water loss (unaccounted for water)

3.2.3 SECAP – Sustainable Energy and Climate Action Plan

The Covenant of Mayors for Climate & Energy - Europe brings together local authorities voluntarily committing to supporting the implementation of the EU climate and energy objectives. [11] The vision is a fairer, climate-neutral Europe for all, focusing on decarbonized and resilient cities with access to affordable, secure, and sustainable energy. [12]

To reach this ambition, the Covenant of Mayors encourages municipalities and cities within Europe to sign up for their vision. By this official signature, the cities make a commitment to develop, implement and report on actions to reach their specific city targets towards the city visions 2030 (-40% CO2 emissions, adapting to climate change, alleviating energy poverty) and 2050 (citizens live in a decarbonized and resilient city with access to sustainable, secure, and affordable energy).

Figure 2 - Vision of Covenant of Mayors: decarbonized and resilient cities by 2050

A Sustainable Energy and Climate Action Plan (SECAP) is the main tool to assess the progress on this journey for each city. After signing up and committing, within two years a first SECAP shall be developed and submitted, including at least the city strategy, an action plan, a baseline emission inventory, a risk & vulnerabilities assessment, and minimally 3 key mitigation actions. Within four years, the strategy needs to be reconfirmed, the risk & vulnerability assessment needs to be reconfirmed, the mitigation actions updated, and at least 3 key adaption actions and 1 key energy poverty action are to be defined. From the sixth year on, a monitoring emission inventory tracks the progress versus the submitted base emission inventory, and the other sections are constantly updated, renewed, and reconfirmed. [13]

The SECAP covers three major fields containing KPIs potentially relevant for the assessment of PEDs: i) the emission inventory, ii) climate adaptation measures, and iii) energy poverty measures. Each field is described below in more detail. [14]

3.2.3.1 Emission Inventory

By creating the emission inventory of the city firstly energy consumption within the city is described, then energy production within the city is described, thirdly the energy streams are recalculated to CO2 emissions, and as a last step non-energy related sectors are added.

Final energy consumption is reported in MWh based on the different energy carriers:

- electricity,
- district heating & cooling,
- fossil fuels (natural gas, liquid gas, heating oil, diesel, gasoline, lignite, coal, other fossil fuels), and
- renewable energies (biogas, plant oil, biofuel, other biomass, solar thermal, geothermal)

for three major sectors

- buildings, equipment/facilities, and industries (municipal, tertiary non municipal, residential, industry, and others)
- transport (municipal, public transport, private & commercial transport, and others)
- other (agriculture/forestry/fisheries, and others).

Energy supply is reported in MWh separately within four larger areas.

- Green electricity certificates are reported (purchased and sold).
- Locally produced renewable energy is reported by type (wind, hydroelectric, photovoltaics, geothermal, and others).
- For combined heat and power plants and district heating both sides are reported: the produced energy (electricity and/or heat from renewable and non-renewable sources), as well as the energy carrier input, with the same energy carrier differentiation as used in the final energy consumption above.

The **CO2 emissions** are created based on CO2 emission factors per energy carrier.

As a last step, non-energy related sectors are added to the CO2 emissions:

- waste management (solid waste disposal, biological treatment of solid waste, incineration and open burning of water, and others)
- wastewater treatment and discharge
- other non-energy related such as fugitive emissions.

3.2.3.2 Climate Adaptation Measures

For climate adaptation measures first a vulnerability analysis is performed, including the capacity to react on threats within the different sectors of the city. For both sides, the venerable sectors as well as the adaptive capacities, indicators are used to show the risks as well as mitigation possibilities. The below table 5 contain examples given by the Covenant of Mayors for the risk assessment, and below table 6 contains examples given by the Covenant of Mayors for the adaptive capacity.

Table 5 - SECAP indicators for climate adaptation assessing vulnerability of sectors

ID	Sector	Indicator	Measurement unit
1,1	Buildings	Number or % of (public/residential/tertiary) buildings damaged by extreme weather conditions/events	(per year / over a certain period)
1,2	Transport, Energy, Water, Waste, ICT	Number or % of transport/energy/water/waste/ICT infrastructure damaged by extreme weather conditions/events	(per year / over a certain period)
1,3	Land Use Planning	% of grey/blue/green areas affected by extreme weather conditions/events (e.g. Heat Island Effect, Flood, Rockfalls and/or Landslides, Forest/Land Fire)	%
1,4	Transport, Energy, Water, Waste, Civil Protection & Emergency	Number of days with public service interruptions (e.g. energy/water supply, health/civil protection/emergency services, waste)	No.

1,5	Transport, Energy, Water, Waste, Civil Protection & Emergency	Average length (in hours) of the public service interruptions (e.g. energy/water supply, public transport traffic, health/civil protection/emergency services)	hours
1,6	Health	Number of people injured/evacuated/relocated due to extreme weather event(s) (e.g. heat or cold waves)	(per year / over a certain period)
1,7	Health	Number of deaths related to extreme weather event(s) (e.g. heat or cold waves)	(per year / over a certain period)
1,8	Civil Protection & Emergency	Average response time (in min.) for police/fire-fighters/emergency services in case of extreme weather events	min.
1,9	Health	Number of water quality warnings issued	%
1.10	Health	Number of air quality warnings issued	No.
1.11	Environment & Biodiversity	% of areas affected by soil erosion / soil quality degradation	%
1.12	Environment & Biodiversity	% of habitat losses from extreme weather event(s)	%
1.13	Environment & Biodiversity	% change in number of native species	%
1.14	Environment & Biodiversity	% of native (animal/plant) species affected by diseases related to extreme weather conditions/events	%
1.15	Agriculture & Forestry	% of agriculture losses from extreme weather conditions/events (e.g. drought/water scarcity, soil erosion)	%
1.16	Agriculture & Forestry	% of livestock losses from extreme weather conditions	%
1.17	Agriculture & Forestry	% change in crop yield / evolution of the annual grassland productivity	%
1.18	Agriculture & Forestry	% of livestock losses from pests/pathogens	%
1.19	Agriculture & Forestry	% of timber losses from pests/pathogens	%
1.20	Agriculture & Forestry	% change in Forest composition	%
1.21	Agriculture & Forestry	% change in water abstraction	%
1.22	Tourism	% change in tourist flows / tourism activities	%
1.23	Other	€ annual direct economic losses (e.g. in commercial/agricultural/industrial/touristic sectors) due to extreme weather event(s)	€/year
1.24	Other	€ annual amount of compensation received (e.g. insurance)	€/year

Table 6 - SECAP indicators for climate adaptation showing adaptive capacity

ID	Adaptive capcity factor	Indicator	Measurement unit
2.1	Socio-economic	% of public funds available to address a climate hazard and its impacts (e.g. fire, flood, heatwave, etc)	%
2.2	Socio-economic	% share of vulnerable population groups (e.g. elderly (65+)/young (25-) people, lonely pensioner households, low-income/unemployed households, migrants and displaced people) - compared to national average in year X in country X	%
2.3	Socio-economic	Number of households educated in house energy/water/waste management	No.
2.4	Socio-economic	Population density (compared to national/regional average in year X in country/region X)	People per km^2

2.5	Socio-economic	% of population living in areas at risk (e.g. flood/drought/heat wave/ forest or land fire)	%
2.6	Governmental & institutional	% change in green & blue infrastructure/areas (e.g. through new urban planning regulation/policy)	%
2.7	Physical & environmental	Length of transport network (e.g. road/rail) located in areas at risk (e.g. flood/drought/heat wave/ forest or land fire)	Km
2.8	Physical & environmental	Average time needed to reach a health facility	Hours
2.9	Physical & environmental	% of areas non-accessible for emergency responses (e.g. firefighting services)	%
2.10	Physical & environmental	% of (e.g. residential/commercial/agricultural/industrial/ touristic) areas at risk (e.g. flood/drought/heat wave/ forest or land fire)	%
2.11	Knowledge & technology	Hours needed to inform population of a risk via an early warning system	hours

3.2.3.3 Energy Poverty Measures

For energy poverty measures first an energy poverty assessment is performed, covering six macro areas:

- climate
- facilities/housing
- mobility
- socio-economic
- policy and regulatory framework, and
- participation / awareness raising.

For each area indicators are defined to monitor the status. Furthermore, additional related indicators are suggested to show further information on special topics. The below six tables 7 to 12 describe the indicators used within the different macro areas, sorting them in monitoring indicators (M1, M2, … Mn) and informative related indicators (R1, R2, … Rn).

Table 7 - SECAP energy poverty indicators related to climate

#	Indicators	Description	Unit
M1	Frequency of heat waves	Frequency of heat waves per month in a year	Average per monthly/year
M2	Frequency of cold waves	Frequency of cold waves per month in a year	Average per monthly/year
M3	Number of heating degree days per year	Heating degree day is a measurement designed to quantify the demand for energy needed to heat a building, it is based on the outside temperature where heating is needed	Number of HDD and CDD /year
M4	Number of cooling degree days per year	Cooling degree day is a measurement designed to quantify the demand for energy needed to cool a building, it is based on the outside temperature where cooling is needed	Number of HDD and CDD /year

Table 8 - SECAP energy poverty indicators related to facilities / housing

#	Indicators	Description	Unit
M1	F+G + H band (EPC) dwelling / total number of dwelling	Percentage of buildings with Energy Performance Certifications bands F, G and H in the municipality	[%]
M2	Energy consumption (electricity + heating) per capita / national energy consumption (electricity + heating) per capita	Share of municipal energy consumption per capita out of national energy consumption per capita	[%]
M3	Share of buildings renovated per year	Share of buildings renovated per year ouzt of total buildings	[%]
M4	Share of households / population with presence of leak, damp, rot in their dwelling / total households or population	Share of population / households with leak, damp or rot in their dwelling, based on question "Do you have any of the following problems with your dwelling / accommodation? a leaking roof; damp walls/floors/foundation; rot in window frames or floor.	[%]
M5	Percentage of households / persons within the municipality experiencing heating discomfort	Share of household / persons experiencing heating discomfort out of total households	[%]
M6	Percentage of households / persons within the municipality experiencing cooling discomfort	Share of household / persons experiencing and cooling discomfort out of total households	[%]
M7	Households / persons connected to the electricity grid / total households or persons	Share of households /persons connected to the electricity grid out of total households	[%]
M8	Households / persons connected to the gas grid / total households or persons	Share of households / persons connected to the gas grid out of total households	[%]
R1	EPC bands of dwelling higher than B	Percentage of dwellings with EPC higher than B out of total dwellings with certificate	[%]
R2	Households with centralised heating system / total households	Share of households with a centralised heating system out of total households	[%]
R3	Ownership of heating and cooling systems	Share of households with heating and cooling systems out of total households	[%]
R4	Number of social housing apartments/total number of apartments	Percentage of social housing apartments in total number of apartments	[%]
R5	Average energy demand of social housing buildings / sq.m.	Share of energy demand of social housing of median national demand	[kWh/sqm]

R6	Low absolute energy expenditure (M/2)	The M/2 indicator presents the share of households whose absolute energy expenditure is below half the national median, or in other words abnormally low. This could be due to high energy efficiency standards, but may also be indicative of households dangerously under-consuming energy. M/2 is a relatively new indicator that has been used in Belgian to complement other expenditure and self-reported indicators. Note: this indicator is influenced by the underlying distribution of absolute energy expenses in the lower half of households. If the median is relatively high and the distribution below very unequal, the M/2 indicator is high	[%]
R7	Number of households with only oil boilers, wood calefactions, conventional gas boilers	Share of households with oil boilers, wood calefactions, conventional gas boilers out of total households	[%]
R8	Households with centralised cooling system / total households	Share of households with a centralised cooling system out of total households	[%]
R9	Households with centralised cooling system older than 10 y / total households with cooling system	Share of households with a centralised cooling system older than 10 years old out of total households with centralised cooling system	[%]
R10	Average age of the buildings	Average age of buildings per period of construction	Years
R11	Dwelling ownership	Percentage of households that own the dwelling out of total households	[%]
R12	Over and under occupation of dwellings	Percentage of households according to number of occupants	[%]
R13	Percentage of households / persons within the municipality with access to clean cooking fuels and technologies	Proportion of households / persons with primary reliance on clean fuels and technology is calculated as the number of people using clean fuels and technologies for cooking, heating and lighting divided by total population reporting that any cooking, heating or lighting, expressed as percentage. “Clean” is defined by the emission rate targets and specific fuel recommendations (i.e. against unprocessed coal and kerosene) included in the normative guidance WHO guidelines for indoor air quality: household fuel combustion.	[%]

Table 9 - SECAP energy poverty indicators related to mobility

#	Indicators	Description	Unit
M1	Population / households not having access to essential services within 1 hour by walking, cycling or public transport / total population	Percentage of population / households not having access to essential services (pharmacies, food stores, health facilities) within 1h by walking, cycling or public transport out of total population	[%]

M2	People / households living more than one 1 km from nearest public transport station / number of population	Percentage of people / households living more than one 1 km from nearest public transport station out of total population	[%]
R1	The local public transport travel frequently enough, covering the essential necessities the population	Yes or no answer to the question: "do the local public transport travel frequently enough, covering the essential necessities the population"?	Yes / No
R2	Social housing apartments not having easy access to public transport (*)/ all social housing apartments	Percentage of social housing households not having easy access to public transport out of total number of social housing	[%]
R3	Inhabitants / households receiving support to pay public transport services/public transport users	Percentage of inhabitants / households receiving support to pay public transport services out of total public transport users	[%]

Table 10 - SECAP energy poverty indicators related to socio-economic aspects

#	Indicators	Description	Unit
M1	Percentage of persons / households spending up to XX % their income on energy services	Share of persons / households spending more than an specific percentage of their incomes on energy services putting them in an situation of energy poverty	[%]
M2	Vulnerable households or persons / total households or persons	Households with lone parents, parents with more than three children, families with low income, households receiving social support, families with low level of education.	[%]
M3	Arrears on utility bills / total population or households	Share of (sub-) population / households having arrears on utility bills, based on question "In the last twelve months, has the household been in arrears, i.e. has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.) for the main dwelling?"	[%]
M4	Inability to keep home adequately warm	Share of population / households not able to keep their home adequately warm.	[%]
M5	Inability to keep home adequately cool	Share of population / households not able to keep their home adequately cool.	[%]
M6	High share of energy expenditure in income (2M)	The 2M indicator presents the proportion of households whose share of energy expenditure in income is more than twice the national median share. Note: where income distributions are more equal, variance in energy expenditure translates to higher 2M shares. High variance in energy/income shares can occur due to structural differences in energy	[%]

		expenditure between household groups, as well as in situations where energy is often, but not exclusively, included in rent.	
R1	Average price of electricity	Average price in [€] of the consumed electricity kwh in the municipal households	[€]
R2	Average price of gas	Average price in [€] of the consumed gas (m3/kwh) in the municipal households	[€]
R3	Energy related expenditure / local GDP	Relationship between the yearly energy cost the households and the local GDP, percentage average of the local GDP designated to the energy cost	[%]
R4	Citizens / households under poverty threshold / number of citizens / households	Percentage of the local population / households suffering from poverty, persons / households and families under the limit of incomes considering the family size	[%]
R5	At-risk-of-poverty rate	People / households at risk of poverty or social exclusion (% of population). The at-risk-of-poverty rate is the share of people with an equalized disposable income (after social transfer) below the at-risk-of-poverty threshold, which is set at 60 % of the national median equalized disposable income after social transfers.	[%]
R6	Citizens / households with social support	Number of citizens / households receiving financial assistance from administrative institutions	[%]
R7	Money spent to support energy poor households or persons / in relation to local GDP	Percentage of public funds spent in support programs out of total local GDP	[%]
R8	Energy poor households / persons supported / total energy poor households asking for support	Percentage of energy poor households / persons that benefit from some kind of support program out of total number of households asking for support	[%]
R9	Energy poor households / persons supported / total energy poor households detected	Percentage of energy poor households / persons that benefit from some kind of support program out of total number of energy poor households	[%]
R10	Unemployment rate	The unemployment rate is a measure of the prevalence of unemployment and it is calculated as a percentage by dividing the number of unemployed individuals by all individuals currently in the labor force	[%]
R11	Persons aged under 12	Persons aged under 12 / total population	[%]
R12	Persons aged over 65	Persons aged over 65 / total population	[%]
R13	Persons with respiratory and circulatory problems	Persons with respiratory and circulatory problems / total population	[%]
R14	Persons with an education level under lower secondary school	Taking in account the International Standard Classification of education (ISCED from the Unesco) a lower education level refers to an education level under lower secondary school	[%]

Table 11 - SECAP energy poverty indicators related to policy and regulatory framework

#	Indicators	Description	Unit
M1	Existence of energy poverty strategy	Yes or no answer to the question: "Is there a energy poverty strategy"?	Yes / No
M2	Existing rent regulation	Yes or no answer to the question: "Are there rent regulation"?	Yes / No
R1	Specific measures related energy poverty	Yes or no answer to the question: "Are there energy poverty specific measures"?	Yes / No
R2	Existing incentives of landlord's programs	Yes or no answer to the question: "are there incentives/programs for landlords"?	Yes / No

Table 12 - SECAP energy poverty indicators related to participation / awareness raising

#	Indicators	Description	Unit
M1	Awareness-raising campaigns targeting vulnerable households	Preventing rent increases due to energy retrofits, balancing the PRS with interest in homeownership and social housing	Yes / No
M2	Engagement and cooperation with local stakeholders on energy poverty	Yes or no answer to the question: "Is there engagement and cooperation with local stakeholders for energy poverty reduction"?	Yes / No

3.2.4 klimaaktiv districts and neighborhoods

The Austrian ministry of Climate Action, Environment, Energy, Mobility, Innovation, and Technology (BMK) was developing together with the Swiss Office of Energy and experts a quality standard for districts and neighborhoods und the name klimaaktiv. The klimaaktiv standard focuses on sustainability for larger building and renovation projects with an emphasis on climate neutrality and quality of life. [15]

The standard uses a point-based system for assessment over six defined action fields together with assessing the greenhouse gas emissions of the project. The maximum number of points is 1000, which are distributed across the action fields as follows:

- Management: up to 150 points
- Communications: up to 100 points
- Urban Planning: up to 250 points
- Buildings: up to 150 points
- Supply: up to 145 points
- Mobility: up to 205 points

At least 50% of the points of each action field in combination with greenhouse gas emissions below a given level a needed for a project to be able to the title of a “climate neutral district” or a “climate neutral neighborhood”. The system allows a certification scheme with bronze

(>50%), silver (>75%), and gold standard (>90%). The declaration can be received for planning, building and operational stage of the project.

The below table 13 shows the indicators established for each action field. They are all based on a qualitative assessment with four defined stages.

Table 13 - klimaktiv indicators to assess climate neutral districts and neighborhoods

Action Field	Indicator	Description
Management	Establish structures	Project team or steering team and their available resources
Management	Setting targets	Setting targets and an action plan for urban planning, buildings, supply and mobility.
Management	Committing to targets	Established means to commit stakeholders to the set targets
Management	Set up monitoring	Quality of monitoring system to follow up on set targets
Management	Project controlling	Existence of quality systems, change management and regular strategic updates
Communication	Participation	Stakeholder management and inclusion
Communication	Awareness raising	Raising awareness in the fields of energy, water, and waste
Communication	Role model status	Communicating best practices
Urban Planning	Structural density	Ratio of floor area versus building land
Urban Planning	Microclimate	Aspects of ventilation, humidity retention and microclimate
Urban Planning	Diversity of use	Usage concept, mixed uses, mixed users, impact on the area
Urban Planning	Public and semi-public spaces	Usage of ground floor and roof, usage of inner yards and semi-public spaces
Urban Planning	Open space	Quality, usage, and maintenance of open space
Urban Planning	Offer for daily needs	Distances to infrastructure and for daily needs
Buildings	Lifecycle costs	Assessment and comparison of Lifecycle costs for different building systems and energy systems
Buildings	Building standard	Building standards and external assessments
Buildings	Appropriate usage density	Flexibility of the building uses and planned area per usage and user
Supply	Heat supply level	Energy carriers, regionality, quality of planning
Supply	Electricity supply level	Energy carriers, regionality, quality of planning
Supply	Efficient water usage	Water usage indoors and outdoors
Supply	Waste management	Management of mixed and separated wastes
Mobility	Motorized private transport	Parking spaces and parking management
Mobility	Cycling and pedestrians	Bike parking spaces, walking- and cycling pathways, connection to higher ranking walking and cycling infrastructure, shares spaces, barrier free access
Mobility	Public transport and alternative offers	Access to public transport, availability of car sharing, other alternative mobility offers

Greenhouse gas emissions are assessed within three areas:

- grey energy (production, usage, replacements, and disposal of building material)
- operational energy (heating, DHW, airing, lighting, other used electricity)

- everyday mobility (related to everyday life, therefore excluding aviation and grey energy used for transportation means)

3.3 Quantification of Energy Use

This section reviews different methods used for the quantification of energy use and efficiency, focusing on mainly on buildings and transportation / mobility.

3.3.1 General Legal Framework

The European Union has a history of energy efficiency directives. The currently valid directive EU 2018/2002 [16] was created within the clean energy for all packages, was put into force by December 2018 and transposed into national law by February 2020, aiming at a reduction of primary and final energy consumption of 32,5% by 2030.

A first rework of the directive was requested by the European Commission in July 2021 as part of the Green Deal package. In line with the target to cut greenhouse gas emissions by 55% by 2030 and to become climate neutral by 2050 an increase of yearly efficiency targets by 9% till 2030 was suggested. A second suggested rework of the directive was requested in May 2022 to reduce dependency on energy imports from Russia, together with potential emergency measures in case of grave supply disruptions. [17]

Specific parts of the current European legal framework related to energy use in buildings and mobility are the directive 2010/31/EU and its amendment directive 2018/844 regarding energy performance on buildings [18], and the set of measures to reduce CO2 emissions related to mobility presented in the Sustainable and Smart Mobility Strategy. [19]

3.3.2 Energy Performance of Buildings – ISO 52000- family

The international standard ISO 52000-1:2017 establishes a systematic, comprehensive, and modular structure for assessing the energy performance of new and existing buildings (EPB) in a holistic way. [20] The ISO 52000- family is published as combined EN ISO standards under the so-called Vienna Agreement between CEN and ISO. In total 150 ISO numbers are reserved for the EPB standards in ISO, so that they will become equivalent to the EPB standards available at European (CEN) level. [21]

The overarching ISO 52000-1 standard asses the Energy Performance of a Building, focusing on energy used for provision of comfort conditions to people inside, and not on processes or activities performed within the building. The standard focuses on Heating, Cooling, Domestic hot water, Ventilation, Humidification and dehumidification, Lighting for non-residential buildings, and People Transport within the building as an option. [22]

The covered performance indicators of EN ISO 52000-1 are all types of weighting currently required by the EU directive EPBD: [23]

- non-renewable primary energy; Unit kWh, also kWh/m²y
- renewable primary energy; Unit kWh, also kWh/m²y
- total primary energy; Unit kWh, also kWh/m²y

- CO2-emissions; Unit kg CO2, also kg/m²y
- Costs; Unit €, also €/m²y

Furthermore, the standard enables the calculation of the Renewable Energy Ratio (RER), which determines energy efficiency based on showing the usage of energy that is derived from renewable sources as a percentage of total energy usage.

For determination of the energy performance of the building, EN ISO 52000-1 gives two options: exclusion of exported energy from the energy performance (kexp = 0) or inclusion of export energy directly into the energy performance of the building (kexp = 1), and therefore improving the energy performance by the excess energy locally produced with DERs.

Regarding the calculation period, EN ISO 52016-1 uses as a standard an hourly calculation of energy performance and in parallel also a monthly calculation with the same input data. From the hourly calculation correlation factors can be generated, helping with national correlation factors to deal with dynamic effects. [24]

3.3.3 Energy Performance of Transportation

The European Committee for Standardization (CEN) published in January 2013 the European Norm EN 16258 (Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers) [25], which is the only standard focused on carbon footprinting in transport and is therefore containing most specific methodology input for this calculation. [26]

The standard is focusing on calculation of energy consumption through the operation of the vehicles but includes energy consumption and related emissions also during the generation of the different types of fuels. By this, the standard is calculating energy based on the Well-to-Wheel (WtW) concept, which is including Tank-to-Wheels (TtW) and Well-to-Tank (WtT). On the other hand, the standard makes no allowance for the manufacture, maintenance and disposal of vehicles or the transport infrastructure as would a complete life cycle analysis (LCA)of transportation do. The overview of the different assessment approaches can be seen below in Figure 3.

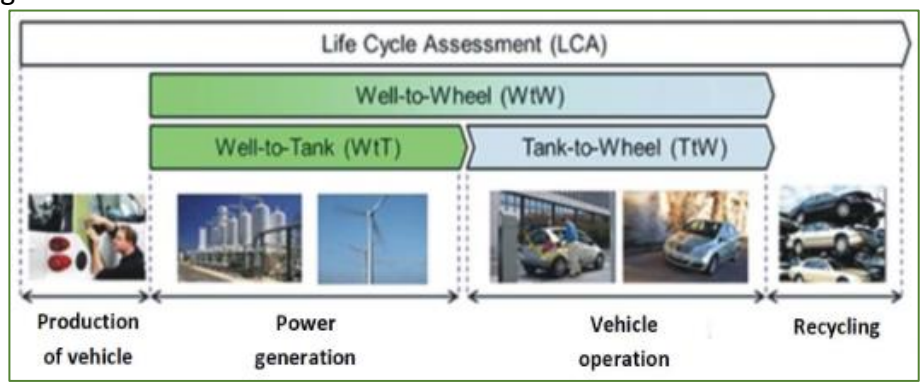

Figure 3 - System boundaries of mobility energy assessments27

The calculation of energy consumption and emissions for a transport service must be carried out in accordance with standard EN 16258 in three steps: [28]

- Step 1: Splitting the transport service into individual sections without changing mode of transport (legs)
- Step 2: Calculating energy consumption and emissions per leg:
  - Specifying the Vehicle Operation System (VOS) for this leg (actual vehicle round-trip, routes or vehicle type or for total network; including empty trips)
  - Quantitative determination of total energy consumption for this Vehicle Operation System (e.g., diesel consumption in liters)
  - Conversion of the measured energy consumption into standardized energy consumption (MJ) and greenhouse gas emissions (kg CO2 equivalents) for this Vehicle Operation System
  - Allocation of standardized energy consumption and greenhouse gas emissions to the transport service
- Step 3: Addition of the results of all legs of the transport service.

Based on the recommendations of the Sustainable Mobility Project 2.0 from the World Business Council for Sustainable Development (WBCSD), [29] energy performance of mobility within an urban area shall be calculated as well-to-wheels energy by all city passenger and freight transport modes, public and private. The total number of vehicle-kilometers is preferably collected by means of a traffic model, alternatively by field measurements or surveys, or existing city databases. If there is no such data available, consumed fuels and electricity might be used. This data can be estimated based on fuel taken from local fueling stations and translated to distance for private transport. For public transport companies normally report on the energy used.

Of course, lot´s of other indicators are available for assessing the overall performance of urban mobility, including for example mobility system performance, economic success, global environment, or quality of life. For this document with respect of developing a set of KPI´s for positive energy districts and neighborhoods, we restrict ourselves here to energy related performance, and within chapter 2.4. to the environmental related performance.

3.3.4 Energy Balance

Based on the UN recommendations for energy statistics, [30] an overall energy balance is an accounting framework for the compilation and reconciliation of data on all energy products entering, exiting, and used within a territory during a reference period. Such a balance must necessarily express all forms of energy in a common accounting unit and show the relationship between the inputs to and the outputs from the energy transformation processes. The energy balance should be as complete as possible so that all energy flows are, in principle, accounted for.

For the European Union, Eurostat is collecting all statistical data and provides energy balances for all member states on a country level. Furthermore, Eurostat provides online tools to create

the requested energy balances with the selected level of detail and allows for comparison over time and between member states. For Renewables and biofuels, the products and aggregates shown in Table 14 below are used by Eurostat within the simplified and the complete energy balance. [31]

Table 14 - Labels and hierarchy for renewables and biofuels of the Eurostat energy balance

Label	Simplified balance	Complete balance
Renewables and biofuels	✓	✓
Biofuels		
Solid biofuels		
Primary solid biofuels		✓
Fuelwood, wood residues and by-products		
Black liquor		
Bagasse		
Animal waste		
Other vegetal material and residues		
Renewable fraction of industrial waste		
Charcoal		✓
Liquid biofuels		
Biogasoline		
Pure biogasoline		✓
Blended biogasoline		✓
Biodiesels		
Pure biodiesels		✓
Blended biodiesels		✓
Bio jet kerosene		
Pure bio jet kerosene		✓
Blended bio jet kerosene		✓
Other liquid biofuels		✓
Biogas		✓
Biogases from anaerobic fermentation		
Landfill gas		
Sewage sludge gas		
Other biogases from anaerobic fermentation		
Biogases from thermal processes		
Renewable municipal waste		✓
Hydro		✓
Pure hydro power		
Mixed hydro power		

Pumped hydro power		
Tide, wave, ocean		✓
Geothermal		✓
Wind		✓
Wind on shore		
Wind off shore		
Solar		
Solar thermal		✓
Solar photovoltaic		✓
Ambient heat (heat pumps)		✓

The structure used by Eurostat can act as a guideline for reporting different sources of renewables of PED and PEN initiatives.

For the visualization of energy balances, Eurostat offers two different online tools:

1.) The energy balance builder: https://ec.europa.eu/eurostat/cache/infographs/energy_balances/enbal.html
2.) The Sankey diagrams tool: https://ec.europa.eu/eurostat/cache/sankey/energy/sankey.html

Below Figures 4 and 5 show examples of energy balances generated by Eurostat tools.

Romania
Total - main fuel families - 2021

eurostat

Year: 2021 Unit: GWh	Total	Oil and petroleum products	Natural gas	Renewables and biofuels	Solid fossil fuels	Nuclear heat	Non-renewable waste	Electricity	Peat and peat products	Heat	Manufactured gases	Oil shale and oil sands
Total energy supply	397 919	121 351	115 690	74 388	47 038	33 332	3 714	2 199	206	0	0	0
Transformation input - energy use	272 702	135 078	31 487	33 332	38 382	33 332	1	433	0	0	657	0
Transformation output	218 732	134 613	0	4 648	0	0	0	59 470	0	17 012	2 988	0
Energy sector - energy use	22 874	9 053	2 369	118	0	0	0	8 409	0	2 542	384	0
Distribution losses	9 995	7	598	11	0	0	0	6 198	0	2 983	197	0
Available for final consumption	311 080	111 826	81 236	45 576	8 657	0	3 714	46 628	206	11 487	1 750	0
Statistical differences	3 086	4 218	404	-1 659	116	0	6	580	1	-580	0	0
Final consumption - non-energy use	13 991	9 340	4 647	0	3	0	0	0	0	0	0	0
Final consumption - energy use	294 003	98 269	76 184	47 235	8 537	0	3 708	46 048	205	12 067	1 750	0
Final consumption - industry sector - energy use	79 739	7 995	1 750	0	0	12 652	28 376	2 359	3 679	0	21 103	1 826
Final consumption - transport sector - energy use	80 005	0	0	0	0	72 834	80	5 766	0	0	1 325	0
Final consumption - other sectors - energy use	134 259	542	0	205	0	12 783	47 728	39 110	29	0	23 620	10 241
Gross electricity production	59 470	756	9 907	26 677	10 689	11 284	0	0	0	0	158	0
Gross heat production	17 012	771	12 411	1 114	2 627	0	1	0	0	0	88	0

Figure 4 - Example of an energy balance in table form for Romania 2021 of Eurostat

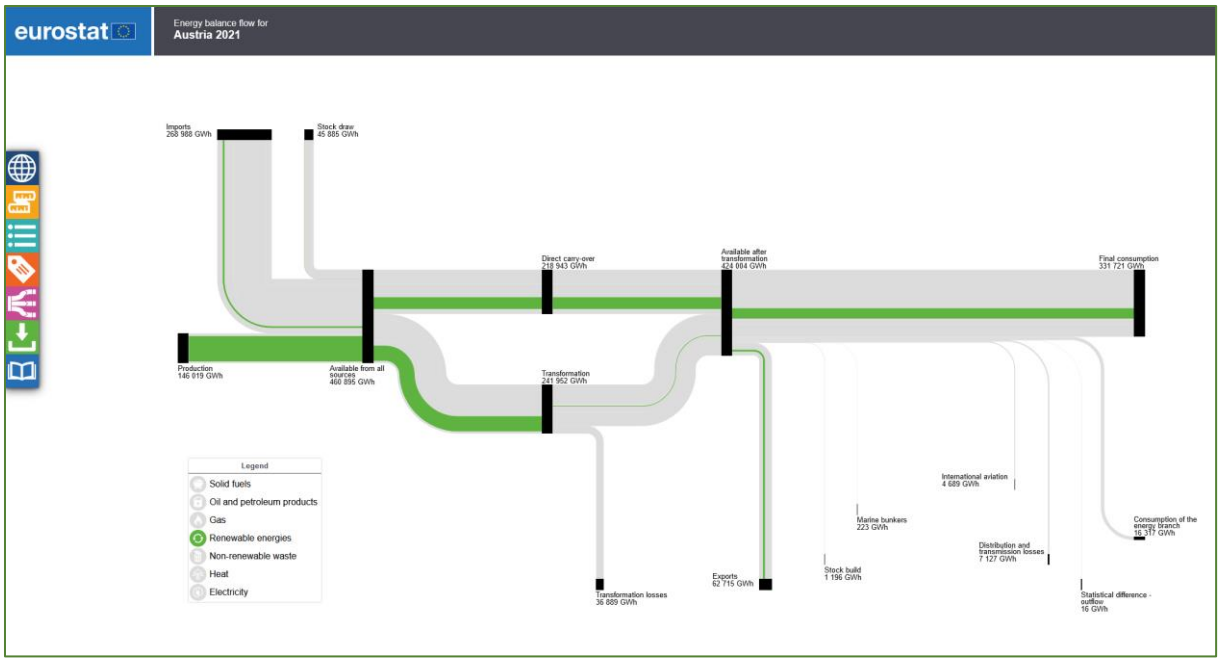

Figure 5 - Example of an energy balance as Sankey diagram for Austria 2021 of Eurostat

Within European Projects, for example Sinfonia, [32] first tries have been realized to create energy balance tools for district levels to show and visualize different refurbishment scenarios.

3.3.5 Calculation of Energy Savings

Next to the energy performance itself, also the evolution of the energy performance over time and the success of sustainability projects and actions are of major interest in the context of PEDs and PENs.

The energy savings of an intervention can be defined as the difference between the amount of energy used after the intervention and that which would have been used had the intervention not been carried out. This fictitious reference means that energy savings cannot be measured directly. [33]

The International Performance Measurement and Verification Protocol (IPMVP) represent a standard procedure for the evaluation of such energy savings from energy efficiency projects. Figure 4 below visualizes the process of energy saving calculation for such energy efficiency interventions.

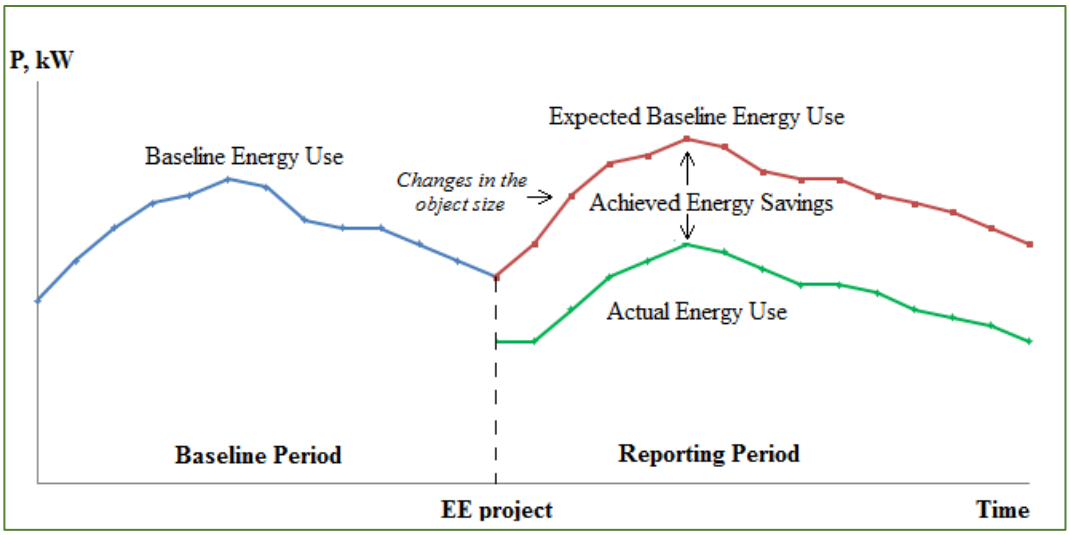

Figure 6 - Energy savings calculation in accordance with IPMVP core concepts34

Based on the core concepts of IPMVP [35], first the measurement boundaries are defined. Secondly, the measurement periods are selected, which should cover always at least one normal operating cycle, and should take place before and after the intervention. From the baseline period before the intervention by method of adjustments an expected energy use for the second period is calculated. Adjustments are done for routine changes, which were expected to change, but also for non-routine changes based on static factors. The savings can be accounted either as difference between the expected baseline and the actual measures, or as normalized savings based on normal conditions differing from the actual conditions. A last verification step ensures the proper quality of the performed assessment.

The methodology can be used either for single interventions, whereas the parameters expected to change by this intervention should be compared as directly as possibly, or for a set of multiple interventions with interactive effects. In the latter case, the whole system needs to be assessed to enable a proper savings assessment. [36]

Similar approaches to energy savings calculations are published from ISO as international standard for projects (ISO 17741:2016 - General technical rules for measurement, calculation and verification of energy savings of projects), for countries, regions and cities (ISO 17742:2015 - Energy efficiency and savings calculation for countries, regions and cities), and for organizations (ISO/DIS 17747 – Determination of energy savings in organizations) together with their methodological framework (ISO 17743:2016 - Energy savings — Definition of a methodological framework applicable to calculation and reporting on energy savings), see below Figure 7.

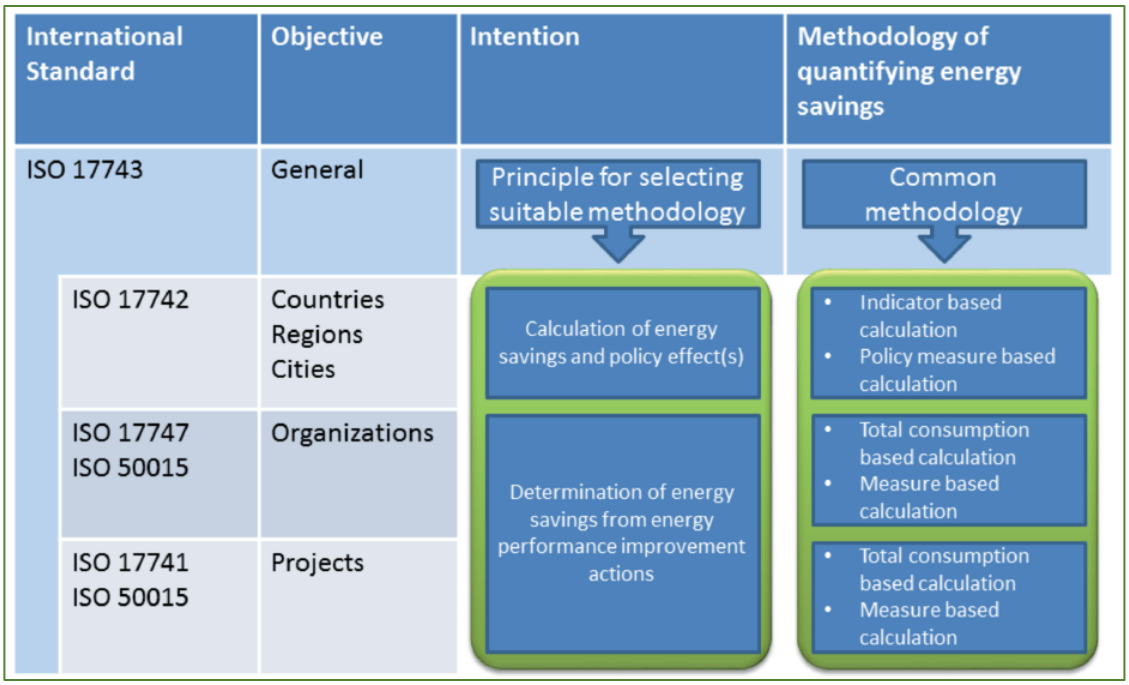

Figure 7 - Overview of international standards related to calculation of energy savings

Based on ISO 17742, for the energy savings calculation of countries, regions and cities, all end-use sectors, such as households, industry, tertiary (services, etc.), agriculture, and transport are considered. The standard does not incorporate calculation of energy efficiency and energy savings in energy supply sectors, such as power plants, refineries, and coal mines. Neither includes the standard feedstock energy, meaning energy from raw materials used for processing or manufacturing other products, such as oil products to produce plastics. [37]

This definition gives internationally comparable system boundaries which can be applied as well for Positive Energy Districts and Neighborhoods.

3.3.6 Dimensions of Energy Use quantification

3.3.6.1 Quantity of Energy

Energy is a physical quantity, expressed in joule (J) in the international system of units. For building-related applications, the unit mostly used in Europe is the kilowatt hour (kWh), with 1 kWh = 3.6 10^6 J.

3.3.6.2 System Boundaries

A prerequisite to the quantification of energy transfer is the definition of system boundaries. PED-ID differentiates for PEDs and PENs between spatial boundaries and energy use boundaries. [38] Schneider et al. include also temporal boundaries, and differentiate between PED Alpha, PED Beta and PED Omega. The definition options are shown in Figure 8 below.

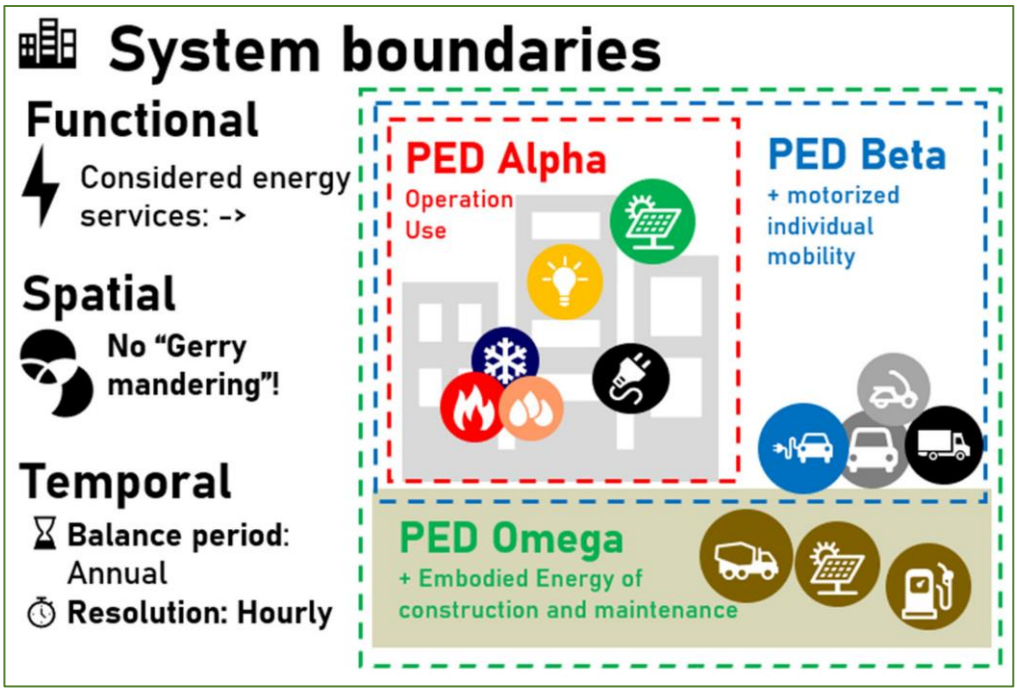

Figure 8 - System boundaries for PEDs and PENs for energy quantification [39]

3.3.6.3 Energy Quality

In systems with multiple sources and uses of energy, the "quality" of energy represents a significant issue in quantifying energy use. Amounts of low-quality energy such as waste heat and high-quality energy such as electricity are not equal. A possible measure of energy quality is exergy, a thermodynamic quantity defined for a system in each environment as the maximum useful work that might theoretically be extracted from it. However, methodological difficulties have until now prevented the exergy approach from being widely adopted for the assessment of energy quantification. [40].

3.3.6.4 Impact of Primary Energy Factors (PEF)

The coefficient for calculating primary energy and CO2 emissions impact strongly the expression of the energy performance, as these multiplicators are used for the whole calculated energy use. Exemplary we can show the factors for non-renewable energy of electricity purchased from the grid:

- 2,3 based on EN ISO 52000-1 [41]
- 1,8 in Germany, based on Building Energy Act (GEG), Annex 4, from 2021. [42]
- 3,14 based on EN 15603:2008
- 2,6 in Czech Republic (since 2020, before 3,0), based on the directive about energy performance of buildings (c. 78/2013, amendment 264/2020 Sb.)

Therefore, the determination of the PEF coefficient should be based on transparent assumptions. There can be a national political preference for one or another energy carrier

depending on the context, but such preferences should be explicitly expressed and not hidden in factors. [43]

3.4 Quantification of Environmental Impact

This section reviews different methods used for the quantification of environmental impact, which can be summarized in the following six categories: [44]

1.) Greenhouse gases

2.) Water

3.) Waste

4.) Materials and resource efficiency

5.) Biodiversity/ecosystem services

6.) Emissions to air, land and water

Measured and reported should by those categories, where the main environmental impact of the operation of PEDs and PENs occur.

3.4.1 Types of Emissions

Emissions are divided in three general categories: emissions to air, to land and to water. Each of the three categories are described below in more detail with potential KPIs to measure the environmental impact of each type of emission, based on the environmental KPIs developed by defra for the United Kingdom. [45]

3.4.1.1 Emissions to Air

A.) Greenhouse Gases

Greenhouse gases are the most measured emissions to air. The Kyoto Protocol covers the six main greenhouse gases: Carbon dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur Hexafluoride (SF6). For easier reporting practices, conversion of the individual greenhouse gases to CO2 equivalents are use and an aggregated value of greenhouse gas emissions in CO2 equivalents is given. Reported are two different types of impacts: direct greenhouse gas emissions, i.e., through burning large amount of fossil fuels, and indirect emissions, by using all types of energy. For PEDs and PENs this means, that indirect emissions are calculated based on quantified energy usage by energy carrier, plus direct emitted greenhouse gases within the area.

B.) Acid Rain and Smog Precursors

Acid Rain and Smog Precursors are Sulphur dioxide (SO2), nitrous oxides (NOx), ammonia (NH3) and carbon monoxide (CO). The main processes to emit acid rain and smog precursors are fossil fuel combustion, processes that release VOCs, and use of nitrogen-based fertilizers in agriculture.

C.) Dust and Particles

Dust and fine particles can be emitted directly into the atmosphere or can be created indirectly through emission of precursor gases like NOx and SO2. Particles smaller than 10 micrometers (PM10) are small enough to enter the airways and lungs. Limits are set for 10 micrometer particles as well as 2,5 micrometer particles. The main source of dust and particles is combustion of fossil fuels, as well as non-exhaust emissions from road traffic (brake and tyre wear), waste handling or mineral extraction.

D.) Ozone Depleting Substances

Ozone depleting substances are mostly phased out following the 1987 Montreal Protocol. Currently, only hydrochlorofluorocarbons (HCFCs) and in some special cases halons and methyl bromides can be used within the European Union. Therefore, emission of such substances is caused largely by accident, e.g., by leakage of air conditioning or refrigerating systems.

E.) Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOC) are a group of commonly used chemicals that evaporate when exposed to air. VOCs can act as a solvent, or carrier, for many substances and as such are widely used as cleaning and liquefying agents in fuels, degreasers, solvents, polishes, cosmetics, drugs, and dry-cleaning solutions. VOC emissions from fuel consumption can be calculated using the appropriate fuel conversion protocols. VOCs from other processes need to be calculated based on the individual processes and the used chemicals.

F.) Metal Emissions to Air

Certain heavy metals that are in common usage are often emitted to air as particulates or dust. Heavy metals can be emitted from the burning of coal or oil and are also emitted from a variety of industrial processes (foundries, auto-manufacturers, electronics), including power generation when fossil fuels are involved. Reporting standards are like VOCs, with conversion factors for burned fuels and specific measurements for industrial processes.

3.4.1.2 Emissions to Water

A.) Nutrients and Organic Pollutants

Organic matter is commonly found in groundwater and inland waters and can cause significant pollution and disruption to aquatic habitats. They are contained in organic effluents such as sewage discharges and discharges from the industrial sectors. Sources of nutrients commonly include human sewage, crops and animal production, food processing, pulp and paper manufacturing, detergents manufacturing and fertilizer manufacturing. Measurements take place by laboratory tests, and can include biochemical oxygen demand, total suspended solids, total organic carbon, or chemical oxygen demand.

B.) Metal Emissions to Water

Metals and metal compounds can be found in effluent, drinking water, cooling water and run-off water. Metal can affect the aquatic environment in different ways, and for some metals their concentration can increase in the food chain at each level. Reporting can be done by estimations, or with direct measurements.

3.4.1.3 Emissions to Land

A.) Waste

Waste is a key factor regarding environmental impact. Waste can be separated into to hazardous wastes and non-hazardous wastes, whereas the latter contains municipal (household) waste and commercial (office) waste. The common waste reduction hierarchy follows the process pictured in Figure 9, where only the utterly necessary not useable waste shall go to a landfill.

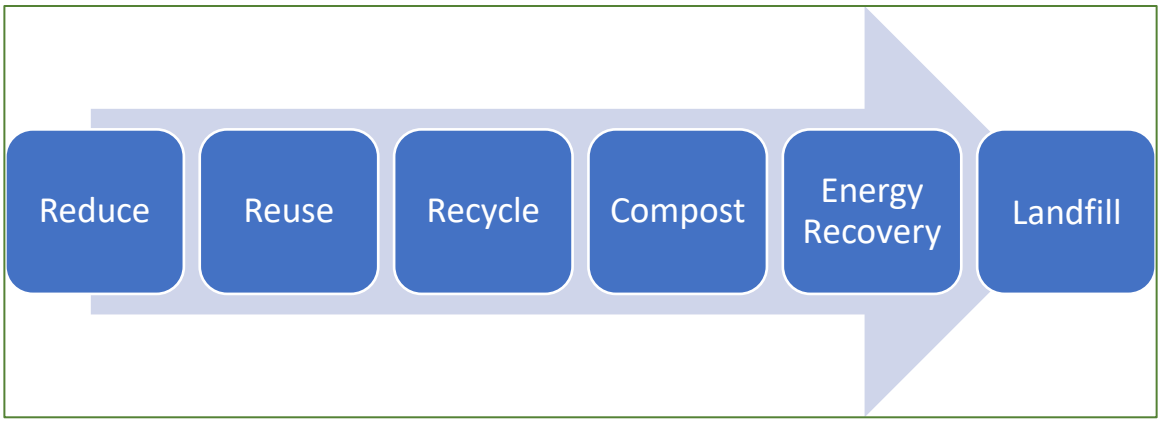

Figure 9 - Waste reduction hierarchical process

Waste can be measured by reports from the waste disposal companies, as well as through the self-reporting obligations from companies. The final waste management route should be also reported (e.g., 10 % to landfill, 40 % incinerated, 30 % recycled, 20 % re-used). Indicators regarding waste are used in several sustainable indicator sets described in section 2.2 above.

B.) Pesticides and Fertilizers

Pesticides and fertilizers are distributed predominantly on farmland and can have a significant impact on the natural environment, including the deterioration of land quality (fertilizers), and direct harming of the biosphere (pesticides). Reporting can be done directly through information from the agriculture sector, or indirectly based on the area of treated farmland.

C.) Metal emissions to Land

Emissions of metals to land by business processes can have a serious impact on the local environment. All metals can have adverse effects on natural habitats depending on the amount emitted and the acceptable biological limit. Metals are emitted directly to land by several industrial processes. Metals can also be found in sewage sludge used as fertilizer. Reporting can be done based on estimations, direct measurements, or mass balance calculations.

D.) Acids and Organic Pollutant Emissions to Land

There is a wide range of organic chemicals that can be emitted to land – for example, long chain hydrocarbons (from oil, petrol, or diesel) and organic chemicals from industrial processes (e.g., solvents such as formaldehyde and alcohols). Organic and inorganic acids are also used in many industrial processes and can be emitted to land. These emissions are usually

caused by accidental spillage. In case the spillage causes a disposal of contaminated land, this land shall be calculated as waste, too.

E.) Radioactive Waste

Radioactive waste is a by-product of the manufacture of nuclear fuel and results from the production of electricity and from the use of radioactive materials. The production of radioactive waste is in general highly regulated, and standard reporting procedures exist.

3.4.2 Resource Use in Urban settings

3.4.2.1 Land Use

Land use remained relatively stable in the EU, except for artificial surfaces such as built areas and roads, with an increase of over 6% during 2000-2018. The increasing land-take trend (change in agricultural, forest and other semi-natural land taken for urban and other artificial land development) puts pressure on biodiversity, degrades habitats and contributes to issues ranging from carbon sequestration to soil sealing, landscape fragmentation, increased flood risk and urban heat island effects. [46]

The European Commission's roadmap to a resource efficient Europe introduced a 'no net land take by 2050' initiative that aims to ensure that either all new urbanization occurs on brownfields, or any new land take is compensated for by reclaiming artificial land. [47]

From an urban perspective, land use can be measured as imperviousness and imperviousness change. Imperviousness means the covering of the soil surface with impermeable materials because of urban development and infrastructure construction. Cities and towns are most affected by sealing (42% and 30% sealed, respectively). [48]

Indicators regarding land use are included in several sustainable indicator sets described in section 2.2 above.

3.4.2.2 Water Use

Water is an essential resource that is required for a healthy environment and is used as drinking water, as well as in the production and provision of numerous goods and services, including electricity. Abstraction of water can have significant local, or more widespread, impacts on the environment. The threat of climate change, resulting in severe droughts, floods, and storms, also constitutes a challenge for water resources management. Countries around the world are aware of the need to use water resources more efficiently and reduce waste to ensure availability of the resource in the long term.

Indicators related to water use include water consumption, water quality, access to drinking water, wastewater collection, wastewater treatment, water retention capacity, and many more. Indicators regarding water use are included in several sustainable indicator sets described in section 2.2 above.

3.4.2.3 Other non-energy related Resources Used

A.) Metals

Metals are non-renewable resources and are necessary raw materials for many economic activities. The most used metallic resources are iron, aluminum (bauxite), copper, lead, nickel, zinc, gold, and silver. Metals are extracted through mining (surface or underground). The indicator only includes metal commodities that are extracted rather than those that are recovered through recycling.

B.) Aggregates

Natural aggregates, which consist of crushed stone, sand, and gravel, are natural resources used as a basic raw material by many industries including construction, agriculture and industries employing complex chemical and metallurgical processes. Despite the low value of the basic products, aggregates mining is one of the most important mining industries in the world. Aggregates are extracted by quarrying and mining operations. This indicator only includes aggregates that are extracted from a primary source, rather than those that arise from secondary sources e.g., demolition waste.

C.) Minerals

Minerals are naturally occurring inorganic substances which have a characteristic and homogeneous chemical composition, definite physical properties and, usually, a definite crystalline form. Minerals include graphite, gypsum, phosphate, potash, salt, or talc. The indicator only includes minerals extracted rather than those that are recovered through recycling.

D.) Forestry

This KPI focuses on timber and the harvesting of various wood products. Although forestry and wood are often considered renewable resources over-exploitation of these resources, especially from plantations which are not sustainably managed, threatens the environment and biodiversity. Reported should be every operation that harvests wood, including operations that clear forests to change the land use.

E.) Agricultural Produce

Agricultural produce includes any product harvested from land or water, excluding wood. It is including foodstuffs such as meat and fish, tobacco, rubber, and other crops that form the raw materials of many products. Companies that harvest crops, botanical and zoological resources are encouraged to report on their use of the natural resources and often do so. Consuming resources at a sustainable rate ensures that stocks do not decline, and therefore continue to provide food and other amenities.

3.4.3 Dimensions of Environmental Impact quantification

3.4.3.1 Quantity of Environmental Impact

In contrast to Energy, the different fields of environmental impact cannot easily be described by a single unit. Measured effects can be quantified in weight, volume and size, and conversion factors are used where possible to ensure an easier understanding of outcomes, as with kgCO2 equivalents as unit for greenhouse gas emissions. Material and resource consumption measured with Material Footprints or Material Flow Analysis are expressed in kilotons, and made comparable e.g., through kilotons/capita. [49]

3.4.3.2 System Boundaries

A prerequisite to the quantification of environmental impact is the definition of system boundaries in the same way as for the quantification of energy use. In general, the system boundaries defined for the specific PED or PEN shall be kept same for all assessments, energy, environment, user and stakeholder acceptance, and others.

3.4.3.3 Priorities and Visibility

Because environmental impact has that many facets it is highly recommended to set priorities regarding reporting based on the needs of the PED/PEN in question, in addition to a smaller set of standardized environmental KPI´s. This will add visibility to the topics relevant for the specific PED/PEN while ensuring comparability on a general level.

3.5 Quantification of User & Stakeholder Acceptance

This section reviews different methods used for the quantification of user and stakeholder acceptance, focusing mainly on the process of implementing a PED/PEN within a focus district.

3.5.1 Definition of Stakeholders and Users in Urban development settings

Depending on the type of PED development project, different stakeholders are involved, and in some cases, especially for greenfield-development projects, part of the users of the final system (future residents) might not be known at the time of the project realization.

Of course, users are not the same as stakeholders. **Users** are organizations or individuals utilizing the Positive Energy District, e.g., as residents by living there, or as companies by operating there. **Stakeholders** are organizations or individuals having an interest and/or concern in the Positive Energy District because it impacts or might impact them.

User acceptance therefore should be an important indicator for the long-term success of the operation of a PED/PEN.

Stakeholder acceptance should be important indicator for the successful execution of a PED/PEN development project.

Based on the multi-stakeholder method described in Deliverable D1.1. Report on operation scenarios, technical characterization and identified stakeholders of Focus Districts, the following stakeholders have been identified per PED development strategy:

3.5.1.1 High target, city-coordinated energy districts

- Owners of the land to be redeveloped,
- various local and/or regional administrative departments,
- interdepartmental working groups,
- private as well as public developers,
- future residents.

3.5.1.2 Satellite, company coordinated smart energy districts

- Owners of the land to be redeveloped,
- various local and/or regional administrative departments,
- regional and/or national administrative departments,
- special purpose company,
- public developer,
- private developer,
- citizen owned development groups,
- research facilities,
- neighborhood management,
- private consultants,
- future inhabitants.

3.5.1.3 Mixed-use, company coordinated energy districts

- Owners of the land to be redeveloped,
- various local and/or regional administrative departments,
- public developer,
- private developer,
- future inhabitants,
- existing residents,
- private consultants.

3.5.1.4 Uniform, locally supported district with energy as a lever for further development

- Various local and/or regional administrative departments,
- local initiatives (e.g., neighborhood cooperatives etc.),
- existing residents,
- housing cooperations,
- research institutions,
- private consultants.

3.5.1.5 Historical, block-by-block, city-coordinated energy districts

- Local administrative departments,

- one-stop-shop point of contact (special purpose company and/or city department)
- existing residents,
- local initiatives (e.g., trade or touristic),
- research institutions,
- private consultants.

3.5.1.6 Diverse energy districts without central coordination

- Local administrative departments,
- coordination platform (overseen by the city),
- existing residents,
- local initiatives,
- neighborhood management,
- utility provider,
- private consultants.

3.5.1.7 Citizen-owned infrastructure in a village energy district

- Local administration,
- citizen-owned energy cooperative,
- existing residents,
- local initiatives,
- utility provider,
- private consultants.

3.5.2 User Acceptance Tests

User Acceptance Testing is a process used in engineering, for examples software development, to determine whether a system satisfies acceptance criteria, and whether users and customers will accept the system. [50].

In the best case the criteria for acceptance are defined upfront of the development process, together with the users and stakeholders in an interactive and communicative process. Several processes are described to improve the quality of defined acceptance criteria, as it is not an intuitive process for users of a not-yet available system to clearly define them. Potential means include the creations of user-stories, or the description of negative scenarios. Scenarios can include preconditions (*given* specific circumstances), user actions (*when* I do this or that), and expected results (*then* the outcome should be as follows). [51]

As PED projects are complex and evolving over a long-term period, it is recommended to perform acceptance tests on a regular basis and not only before finalizing the project. Also, it should be decided at the beginning of the development process, what success rate must be formally met to successfully complete the project.

3.5.3 Dimension of User & Stakeholder Acceptance quantification

3.5.3.1 Quantity of Impact – Reach:

Reach is defined as the breadth (how far, such as the total number of intended users reached) and saturation (how deep, such as the proportion of intended users reached) of dissemination, distribution, or referral of the PED-development output/process physically, in print and/or electronic forms. Measuring reach quantifies how far an output was disseminated. This can provide valuable information on the extent to which the output gets into the hands of intended users. Also, these data inform the planning, promotion, and budgeting, and can improve management of project development and realization. [52]

Indicators to quantify the reach of PED projects can include for example:

Table 15 - Indicators to measure the reach of PED projects [53]

#	Indicator
1	Number of individuals served by an output, by type
2	Percentage of targeted individuals reached by an output, by type
3	Number of copies of an output distributed to existing lists, by type of output
4	Number of delivery methods used to disseminate content, by type
5	Number of media mentions resulting from promotion
6	Number of times an output is reprinted/reproduced/replicated by recipients
7	Number of file downloads
8	Total number of pageviews
9	Total number of page visits
10	Number of links to online output from other websites
11	Number of people who made a comment or contribution
12	Number of approaches, methods, tools, or events implemented
13	Number of actionable recommendations identified or collected

3.5.3.2 Quality of Impact – Satisfaction

Satisfaction can be defined as “the fulfilment or gratification of a desire, need, or appetite” [54]. In some cases, satisfaction may be quantified with objective measurements, for example regarding indoor climate (temperature and humidity). When it comes to satisfaction with a more complex issue, as is the development and realization of a PED project, we need to determine in which measure the need or desire for more energy efficient and ecological living - or whatever individual users may expect from the PED project - is fulfilled. This is much more subjective and difficult to measure.

Surveys represent the most frequent method used to assess satisfaction with services. In the context of surveys, the Likert scale, whose purpose is to measure "attitude", is often used to report and quantify satisfaction [55].

Several different indicators have been developed to measure user or customer satisfaction. Here a summary of few different indicators:

Table 16 - Indicators to measure customer satisfaction for products and services [56]

#	Indicator / Comment
1	**Net Promoter Score**
	Calculated based on the willingness of users to promote the project to their peers, on a scale from 0 – very unlikely to 10 – very likely. Promoters respond with 9 or 10. Detractors respond with 0 to 6. Others are Passives. The net promoter score is the percentage of promoters minus the percentage of distractors.
2	**Customer Service Satisfaction**
	This measure comes from ex-post surveys after the user-interaction. The survey can be done via forms, pop-ups, live-chat, or online surveys. It is recommended to keep the rating system stable over time, thus enabling to track performance changes over time.
3	**Customer Effort Score**
	The idea is to make the usage of the product or service as easy as possible, and track the effort invested by users through a questionnaire. The question could be something like "How easy was it to understand the impact of the planned PED project for yourself today?" with a rating from very easy to very difficult.
4	**Customer Satisfaction Score**
	With the help of survey conducted ideally at the point-of-interaction, a satisfaction rating is requested by the customers. The scale can differ in range and even or odd possibilities to choose. The customer satisfaction score is calculated as the percentage of "happy" customers from the total number of customers.
5	**Customer Churn Rate**
	This indicator tries to measure the loyalty of customers to a specific offer. Over a given period, the customer churn rate counts the initial users at the start of the period and the final users at the end of the period. The number of users lost during this period divided by the total amount of users is the customer churn rate.
6	**Customer Reviews**
	Last but not least, customer reviews are a very important measure for customer satisfaction. Users can rate a received product or service by stars/points (for example between 1 and 5), express positive and negative experience, and

comment the process and/or offered product or service. These reviews are visible online for other potential users and guide them at their own selection process.

3.5.3.3 System Boundaries

A prerequisite to the quantification of user and stakeholder acceptance is the definition of system boundaries in the same way as for the quantification of energy use and environmental impact. In general, the system boundaries defined for the specific PED or PEN shall be kept same for all assessments, energy, environment, acceptance, and others.

3.5.3.4 Usage of User and Stakeholder Acceptance Ratings for PED projects

Because environmental impact has that many facets it is highly recommended to set priorities regarding reporting based on the needs of the PED/PEN in question, in addition to a smaller set of standardized environmental KPI´s. This will add visibility to the topics relevant for the specific PED/PEN while ensuring comparability on a general level.

4 Selection of Key Performance Indicators

4.1 Application criteria

In line with the dedicated CITYkeys project and their research on indicators for smart cities projects, the following criteria have been used to create the below short-list of pre-selected SimplyPositive KPIs for PED-development projects: [57]

4.1.1 Relevance

Each indicator should have a significant importance for the evaluation. They should be selected and defined in such a way that the implementation of the PED project will provide a clear signal in the change of the indicator value.

4.1.2 Completeness

The set of indicators should consider all aspects of the implementation of PED projects.

4.1.3 Availability

Data for the indicators should be easily available. As the inventory for gathering the data for the indicators should be kept limited in time and effort, the indicators should be based on data that either:

- are available from the project leader or others involved in the innovation case that is being evaluated,

- or can easily be compiled from public sources,

- or can easily be gathered from interviews, maps, or terrain observations.

In some cases, high relevance combined with low data availability may occur. In that case, the indicators are still included as data gathering methods and data availability are in general improving quite rapidly.

4.1.4 Measurability

The identified indicators should be capable of being measured, preferably as objectively as possible.

4.1.5 Reliability

The definitions of the indicators should be clear and not open for different interpretations. This holds for the definition itself and for the calculation methods behind the indicator.

4.1.6 Familiarity

The indicators should be easy to understand by the users. Therefore, the ideal set of indicators relies on already existing indicator sets.

4.1.7 Non-Redundancy

Indicators should not measure the same aspect of a topic.

4.1.8 Independence

Small changes in the measurements of an indicator should not impact preferences assigned to other indicators in the evaluation. This does not hold completely for energy efficiency and reduction of greenhouse gas emissions. As the current energy system is still largely based on fossil fuels, there is a direct relation between a reduction in the use of energy and the reduction of the emission of carbon dioxide. This will lead to a certain extent to double counting the impact.

4.2 Overview of selected KPIs

In line with the established measuring system of ISO 37120, we propose to divide the selected KPI´s in profiling indicators, primary indicators, and secondary indicators.

4.2.1 Profiling Indicators

Profiling indicators shall allow for a better understanding of differences between focus districts, and therefore improve the understanding and analysis of the KPIs evaluation results.

The proposed seven profiling indicators are derived from the ISO 37120 indicator set:

Table 17 - Selected 7 Profiling Indicators

#	Name	Measuring Unit
P1	Size of Focus District	m²
P2	Population of Focus District	# of citizens
P3	Density of Focus District	# citizens / m² of total area
P4	Built-up density	m² of built-up area / m² of total area
P5	Heating degree days	#
P6	Cooling degree days	#
P7	Average household income	EUR

Further profiling indicators are defined by the ISO 37120 indicator set and may be added based on the focus district needs. These include for example total amount of households, living space per unit, unemployment rate, city budget per capita, number of trees, population change, etc.

4.2.2 Primary Indicators

Primary indicators should be mandatory for the assessment of PED-development projects. We developed the below set of ten primary indicators. External indicators should be publicly available and assess the PED achievement in general, internal indicators should be used for project management and assess the process of PED development.

Table 18 - Selected 10 Primary Indicators

#	Name	Measuring Unit	Type
Overall Indicator			
1	PED / PEN achievement rate	%	External
Energy related			
2	Final energy consumption	kWh/a	External
3	Primary energy consumption	kWh/a	External
4	RES generation	kWh/a	External
5	Degree of energetic self-supply by RES	%	External
Environment related			
6	Greenhouse gas emissions	kgCO2eq/a	External
User & Stakeholder acceptance			
7	People reached	%	Internal
8	Success rate	%	Internal
Others (economic)			
9	Money spent	€	Internal
10	Return on investment	years	Internal

The **PED/PEN achievement rate** tracks the overall progress of a focus district on the way of becoming a positive energy district. The baseline is focus-district specific, depending on data availability. It may be for example the year 1990, as used by the EU climate targets. The achievement target is given by the PED definition: more local energy production coming from renewables than consumption over a year and zero greenhouse gas emissions. Both conditions are measured by other primary indicators, specifically number 5 and number 6. The baselines (e.g., year 1990 values) for the KPIs 5 and 6 equal 0%. A self-supply-degree of 100% equals 100% of condition 1 of the PED/PEN achievement. Greenhouse gas emissions of 0 kgCO2eq/q equal 100% of condition 2 of the PED/PEN achievement. The current PED/PEN achievement rate is calculated as the average of condition 1 and condition 2 achievement at a given time.

Energy related and environment related primary indicators calculate and define the success of reaching a Positive Energy District.

User & Stakeholder acceptance and economic indicators calculate and define the quality and efficiency of the process. They should be used mainly internally to assess the quality of the project management, the perceived quality of the project outcome, and the economic impact

of the project from the specific perspective (e.g., district-wide triggered investments and created jobs, or reduction of energy bills per household).

4.2.3 Secondary Indicators

Secondary indicators are suggested further indicators to spotlight specific topics important for sustainable cities. The following secondary indicators are proposed based on the literature research as well as discussion with the focus district representatives of Simply Positive. They are only an exemplary list, and shall be selected based on specific emphasis per district:

Table 19 - pre-Selected 15 Secondary Indicators

#	Category	Name	Measuring Unit
1	Energy	Storage capacity of the supply grids	kWh
2	Energy	Energy Savings	kWh/a
3	Mobility	Modal split of electric private vehicles	%
4	Mobility	Number of electric vehicles in circulation	#
5	Mobility	Diffusion of public charging infrastructure	#/km²
6	Mobility	Diffusion of private charging infrastructure	#/km²
7	Environment	Solid Waste generation	kg / capita
8	Environment	Recycling Rate	%
9	Environment	Air Pollution (PM 2,5 concentration)	µg/m³
10	Environment	Land consumption rate to population growth rate	%
11	Environment	Greenhouse gas emissions savings	kgCO2eq/a
12	Environment	Climate adaption vulnerable area	m² vulnerable area / m² total area
13	Acceptance	Increased citizen awareness	Scale 1-5
14	Acceptance	Stakeholder satisfaction	Scale 1-5
15	Economy	Energy poverty	energy costs / household income

The pre-selected set of secondary indicators below should be discussed by the focus districts and enlarged / reduced based on the specific needs during the initial phase of a PED-development project in line with gathered user and stakeholder expectations.

5 Focus District Rating of Simply Positive KPI-Set

5.1 Evaluation Survey Description

To verify the relevance of the selected primary and secondary KPIs we performed a survey within the project team, asking the focus district representatives and their opinion regarding the importance of the five categories of KPIs:

- Energy related
- Environment related
- Mobility
- Social / Acceptance
- Economical

Following to the general importance, the specific importance of each primary and secondary performance indicator was assessed.

For all questions a ranking in four steps was used:

1. Very important
2. Important
3. Low importance
4. Not important

For evaluation of the results, a number was assigned to each ranking, with 1 being the best (very important) and 4 being the worst (not important).

The survey was completed by a total number of 13 persons (n = 13), representing the focus districts as follows:

- Resita, Romania: 2 persons
- Settimo Torinese, Italy: 3 persons
- Amsterdam, Netherlands: 4 persons
- Großschönau, Austria: 4 persons

5.2 Assessment of KPI categories

The below table shows the outcome of the assessment of the five KPI categories.

Table 20 - Focus District Assessment of 5 KPI categories

#	Name	Average Rating
1	Energy related	1,00
2	Environment related	1,85
3	Mobility	1,85

4	Social / Acceptance	2,38
5	Economical	2,38

The result shows very clear the high importance of energy related KPIs for all focus districts. This is followed with some distance by environmental related and mobility related KPIs. The social acceptance and economic indicators on the other hand are in average of medium to low importance.

5.3 Assessment of 10 primary KPIs

The below table shows the outcome of the assessment of the 10 primary KPIs.

Table 21 - Focus District Assessment of 10 primary KPIs

#	Name	Average Rating
1	PED/PEN achievement rate	1,23
2	Final energy consumption	1,38
3	Primary energy consumption	1,46
4	RES generation	1,38
5	Degree of energetic self-supply by RES	1,46
6	Greenhouse gas emissions	1,31
7	People reached	1,92
8	Success rate	1,69
9	Money spent	2,08
10	Return on investment	2,31

Again, the results show a very clear high importance of energy related KPIs for all focus districts, as well as the greenhouse gas emissions, scoring from 1,23 to 1,46.

The social acceptance and economic indicators show on a high level a bit lower importance from 1,69 to 2,31, with success rate leading the score.

5.4 Assessment of 15 secondary KPIs

The below table shows the outcome of the assessment of the 10 primary KPIs.

Table 22 - Focus District Assessment of 15 secondary KPIs

#	Name	Average Rating
1	Storage capacity of the supply grids	2,23
2	Energy Savings	1,69
3	Modal split of electric private vehicles	2,15

4	Number of electric vehicles in circulation	2,08
5	Diffusion of public charging infrastructure	2,00
6	Diffusion of private charging infrastructure	2,15
7	Solid Waste generation	2,92
8	Recycling Rate	2,69
9	Air Pollution (PM 2,5 concentration)	2,00
10	Land consumption rate to population growth rate	2,62
11	Greenhouse gas emissions savings	1,54
12	Climate adaption vulnerable area	2,54
13	Increased citizen awareness	1,77
14	Stakeholder satisfaction	2,08
15	Energy poverty	2,38

The results show on a high level a bit lower importance than the primary indicators, scoring from 1,54 to 2,92. Top 5 ranked secondary indicators are greenhouse gas savings, energy savings, increased citizen awareness, diffusion of public charging infrastructure and air pollution.

5.5 Weighted ranking of importance of all 25 selected KPIs

Taking into consideration the ranking of each individual KPI together with the ranking of each category, the below overall ranking of importance of the 25 described primary and secondary KPIs was derived.

Table 23 - Weighted Ranking of Importance of all 25 selected SimplyPositive KPIs

#	Name	KPI Rating	Category Ranking	Weighed Index of Importance	Type of KPI
1	PED/PEN achievement rate	1,23	1	1,23	Primary / External
2	Final energy consumption	1,38	1	1,38	Primary / External
3	RES generation	1,38	1	1,38	Primary / External
4	Primary energy consumption	1,46	1	1,46	Primary / External
5	Degree of energetic self-supply by RES	1,46	1	1,46	Primary / External
6	Energy Savings	1,69	1	1,69	Secondary
7	Storage capacity of the supply grids	2,23	1	2,23	Secondary
8	Greenhouse gas emissions	1,31	1,85	2,42	Primary / External

9	Greenhouse gas emissions savings	1,54	1,85	2,85	Secondary
10	Diffusion of public charging infrastructure	2	1,85	3,70	Secondary
11	Air Pollution (PM 2,5 concentration)	2	1,85	3,70	Secondary
12	Number of electric vehicles in circulation	2,08	1,85	3,85	Secondary
13	Modal split of electric private vehicles	2,15	1,85	3,98	Secondary
14	Diffusion of private charging infrastructure	2,15	1,85	3,98	Secondary
15	Success rate	1,69	2,38	4,02	Primary / Internal
16	Increased citizen awareness	1,77	2,38	4,21	Secondary
17	People reached	1,92	2,38	4,57	Primary / Internal
18	Climate adaption vulnerable area	2,54	1,85	4,70	Secondary
19	Land consumption rate to population growth rate	2,62	1,85	4,85	Secondary
20	Money spent	2,08	2,38	4,95	Primary / Internal
21	Stakeholder satisfaction	2,08	2,38	4,95	Secondary
22	Recycling Rate	2,69	1,85	4,98	Secondary
23	Solid Waste generation	2,92	1,85	5,40	Secondary
24	Return on investment	2,31	2,38	5,50	Primary / Internal
25	Energy poverty	2,38	2,38	5,66	Secondary

The results confirm the high importance of the selected external primary KPIs. With respect to the energy and environmental overall goals of PED development projects, secondary KPIs in these fields have been ranked more important than internal primary KPIs measuring the success and quality of the process itself.

We recommend performing a similar selection and analysis during the initial stage of a PED-development project, as it gives important insights on the strategic targets of the project, how they are perceived by the different participating stakeholders, and how success of the project can be measured over different categories.

6 Conclusions

The literature research shows that extensive information and material on Key Performance Indicators is available, well defined, and in use on different reporting levels (UN sustainable development goals on a national level, ISO sustainable cities indicators and SECAP emission inventories on a city level, energy performance assessments on a building level, etc.). Also, several research projects have been developing extensive KPI sets for the assessment of projects on sustainability actions within urban settings (e.g., CITYkeys as one of the most important).

In line with existing KPI sets, we recommend a set of profiling indicators to describe the specific circumstances of the PED/PEN projects in a uniform way and ease the analysis of assessment results. **The 7 selected profiling indicators are:**

1. Size of Focus District [m²}
2. Population of Focus District [# of citizens]
3. Density of Focus District [# citizens / m² of total area]
4. Built-up density [m² of built-up area / m² of total area]
5. Heating degree days [#]
6. Cooling degree days [#]
7. Average household income [EUR]

Furthermore, we recommend a limited set of primary performance indicators, focusing on the energetic and environmental results of the district in line with the PED/PEN definition, and the quality of the implementation process itself. **The 10 selected primary indicators are:**

1.	Overall Indicator	PED / PEN achievement rate [%]
2.	Energy related	Final energy consumption [kWh/a]
3.	Energy related	Primary energy consumption [kWh/a]
4.	Energy related	RES generation [kWh/a]
5.	Energy related	Degree of energetic self-supply by RES [%]
6.	Environment related	Greenhouse gas emissions [kgCO2eq/a]
7.	Acceptance	People reached [%]
8.	Acceptance	Success rate [%]
9.	Economic	Money spent [€]
10.	Economic	Return on investment [years]

Secondary indicators shall be defined during the initial phase of a PED/PEN implementation project together with the stakeholders of such projects, to align strategic targets and measure them specifically. These indicators might focus on mobility, implementation targets of specific DERs, energy saving targets or others.

The performed cross-check on the selected KPIs from a focus district perspective confirmed the importance of energy and environment related KPIs for the implementation assessment.

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