D3.1 Key Performance Indicators (KPIs) and needed data

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Project consortium

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EXECUTIVE SUMMARY

The project ExcEED aims to create a European database for measured and qualitative data on beyond the state-of-the-art buildings and districts. The final goal will be durable return of experience mechanism to advance knowledge from design to operational phase. In this context, Key Performance Indicators (KPIs) represent the base to quantify and benchmark the energy efficiency and the environmental quality at building and district level.

This deliverable presents the list of KPIs that will be implemented in the ExcEED tools to evaluate building and district performances. Different sources have been analysed (i.e. European projects, papers, and standards). A selection mechanism, which involved several players in the building sector such as system engineers, researchers, and energy managers, have been set up to define the 40 most useful KPIs to evaluate the different types of performance in buildings .

An excel tool that collects all the KPIs analysed to produce this document has been developed and shared in the Zenodo repository. In parallel to this work, an online searching and repository KPIs tool is going to be developed. The aims of this tool are:

- helping people with different background (i.e. energy manager, researcher, building owner, etc.) to use the same KPIs to consistently analyse the systems from different perspectives;
- collecting in a single tool all the possible indicators on buildings and districts performance already existing and developed in the future;
- Among the collected KPIs highlight the most used by the different players.

INTRODUCTION

Key Performance Indicators (KPIs) reflect project's goals and provide means for the measurement and management of the progress towards those goals for further learning and improvement. KPIs are defined in Statement-of-Requirements for a building, which guide design development, comparing design solutions and supporting the decision making process.

KPIs are defined to measure the performance of buildings and provide easily accessible and useful information about buildings and their parts. This last definition is the one than more than others reflect the KPIs needed in ExcEED. Aimed to create a stable return of knowledge from last generation of buildings toward building designers, energy managers, and policy makers, ExcEED needs proper performance indicators as backbone for this mechanism. The indicators will present to the different players easy to read and meaningful information that points toward weaknesses or strength points of a technical solution, control strategy, building system or policy.

The indicators selected in ExcEED undergo the following principles [1]:

- Assist the decision making process during the design phase;
- Be usable by different actors: policy makers, professional designers, building energy managers, and building owners;
- Allow database users to compare and contrast different options;
- Be flexible, multipurpose and generic in nature, and usable on different building typologies;
- Be easy to use and visualise with clear charts;
- Reflect specific issues that could have an impact on latest and future generation of buildings and on their diffusion;
- Be measurable and technically valid (quantitative criteria or qualitative converted to quantitative).

Dedicated KPIs have been chosen, based on the above-mentioned criteria, to evaluate performances from a single HVAC component to the building local grid interaction.

This deliverable describes the KPIs selected to evaluate buildings, systems and clusters. European projects, standards and scientific papers have been evaluated aiming to identify and collect the most important indicators used. The KPIs were classified according to six categories: thermal and electric Energy, renewable energy, comfort (Thermal, Acoustic, Air quality), economic, technological, environmental. For each category, the KPIs were catalogued based on four indexes: component classification, target group, building type, expert classification.

Among the KPIs collected from multiple sources (around 130) and with the help of experts from different fields, we selected the most useful indicators to evaluate the performances of last generation of buildings and districts.

SOURCES: PROJECTS, STANDARDS AND PAPERS

We analysed outcomes from previous works on building performance assessment. Seventeen European projects, fourteen standards, and thirteen documents between papers and books have been analysed. Following there is a description of each source.

Projects

- **CommONEnergy** [2]. An FP7 project ended in September 2017. It aims to re-conceptualize shopping malls through deep retrofitting, developing a systemic approach made of innovative technologies and solution sets as well as methods and tools to support their implementation and to assess their environmental and social impact in a life cycle approach. Within the project, Task 5.4 focused on evaluation and development of KPIs in shopping centres. The main reference is deliverable.D5.4: KPIs and post processing procedures. In this deliverable, a list of useful KPIs used to evaluate the performance of commercial centres, both on energy and comfort aspects, is taken into account.
- **Open House** [3]. The objective of this FP7 project is to develop and to implement a common European transparent building assessment methodology, complementing the existing ones, for planning and constructing sustainable buildings by means of an open approach and technical platform. The deliverable evaluated is the deliverable D1.3 "Definition of indicators, sustainability performance levels and procedures to evaluate them". In this document, a broad list of possible indicators cover different aspects of sustainability in buildings (e.g. environmental, economic, social, technical sustainability).
- **GE2O (Geo-clustering to deploy the potential of Energy efficient Buildings across EU)** [4]. The goal of Ge2O is to locate similarities across EU by combining single or multiple parameters and indicators organised in homogeneous layers and sub-layers. The main document analysed is the deliverable D2.2 "Identification of descriptors (quali-quantitative indicators and parameters)".
- **COST Action – TU 1403. Adaptive facades network.** The objective is to harmonise, share and disseminate technological knowledge on adaptive facades at a European level. The analysed report refers to Task 2.1 – Excel tool for metrics and requirements collection. The tool aims at creating a useful framework for the collection of new and existing metrics and requirements for adaptive façade.
- **Ecodistrict** [5]**.** This FP7 project developed an innovative decision support tool to assist district renovation planning, integrating the needs of different stakeholders: inhabitants, local authorities and business investors. The main sources are deliverable D3.1 "A first survey of existing tools and methods supporting evaluation of indicators for urban district retrofitting and renewal" and D3.2 "Scheme of chosen and verified decision support tools for indicators". The key elements in D.3.1 are the identification of sustainability aspects/issues based on pre-standardised metrics for sustainable buildings and an exhaustive review of existing support tools assessing key issues for sustainability performance of economic, environmental and social qualities for strict retrofitting. Furthermore, in deliverable D3.2 the findings of deliverable D3.1 are elaborate to generate a decision support tool.

- **Building EQ** [6]**.** This project aimed at strengthening the implementation of the EPBD (Energy Performance of Buildings Directive) linking the certification process with commissioning and optimisation of building performance. The analysed reports are "The EPBD and Continuous Commissioning (CC)" and "Guidelines for the Evaluation of Building Performance". The latter based on the results of the first report describes a procedure for the cost effective performance analysis of buildings that follow a general top-down approach and which tries to combine the outcomes of the certification process according to the Energy Performance Building Directive (EPBD) and CC.
- **Smart Build** [7]**.** Some Italian, Slovenian and Greece public buildings were retrofitted with smart ICT concepts to reach up to 35% of energy savings in annual and peak consumption and to provide social-economic benefits to building users, managers, public authorities and distribution network operators. The analysed document is deliverable D5.1 "Guidelines for energy monitoring and control in public buildings", which presents guidelines for energy auditing, monitoring and control in public buildings, identifying a list of KPIs to be used during energy saving evaluation.
- **HERB** [8]**.** Holistic energy retrofit of buildings (HERB) was an FP7 project with the scope to develop and test new and innovative energy efficient technologies and solutions for retrofitting, monitoring a number of typical residential buildings in EU countries. In deliverable D4.13, KPIs to evaluate building performances were developed. In particular, the estimated KPIs were: number of degrees day, total radiation, air-tightness, specific energy consumption, energy signature and thermal comfort.
- **EPISCOPE** [9]**.** Energy performance indicator tracking schemes for the continuous optimisation of refurbishment process in European housing stocks**.** In the report "Energy performance Indicators for Building Stocks", the consortium identified a scheme of indicators for the building stock. The indicator scheme makes possible comparisons between different actions of energy performance tracking. Moreover, it is intended to define a generally applicable set of quantities which – in case of regular update – can deliver the basic information which is necessary to observe and understand the development of energy performance in residential building stocks
- **iSERVcmb** [10]**.** The iSERVcmb project has provided a unique approach to understanding and reducing operational energy use in building services across Europe. It has accumulated a unique set of operational data for building service components during its 3-year period. The project acquired data from 16 countries around Europe. In the reports "Total EU Measured Consumptions and Power Demands by HVAC Component and Activity report" and "Country Benchmark by HVAC Component and Activity", a set of indicators to benchmark HVAC system performance are considered.
- **EINSTEIN** [11]. Effective integration of seasonal thermal energy storage systems in existing buildings. The overall objective of the project is the development, evaluation and demonstration of a low energy heating concept for existing buildings based on Seasonal Thermal Energy Storage (STES) systems in combination with Heat Pumps for space heating and domestic hot water (DHW). The reference document is the deliverable D1.1: "Classification of EU building stock according to energy demand

requirements". In this report a list of possible KPIs used to classify building stock has been depicted, considering both energy and climate parameters.

- **DESIGN4ENERGY** [12]**.** The project aims to develop an integrated evolutionary design methodology that allows stakeholders to predict current and future energy efficiency of buildings (both at individual level and neighbourhood level) and make better informed decision in optimising the energy performance at building life cycle level. The main document is deliverable D2.1b "Indicators and success factors for holistic energy matching". In this report, the most relevant KPIs are listed. The deliverable suggests the principle rules for indicators of holistic design of buildings and neighbourhood.
- **BAAS- Building as a service** [13]**.** The BaaS system aims to optimize energy performance in the application domain of "non-residential buildings in operational stage". In the building operational life-cycle three significant tasks have to be continuously performed: i) collecting information and assess the buildings current state; ii) predicting the effect that various decisions will have to Key Performance Indicators (KPIs); iii) optimizing performance. Deliverable D1.1 "Definition of theoretical Case Studies including Key Performance Indicators" describes a list of KPIs useful to evaluate a building and its energy supply systems regarding energy efficiency and comfort. The defined KPIs are classified in six section, covering different aspects, such as energy, environment, comfort, economic, data-quality, and building systems performance.
- **FASUDIR** [14]**.** Friendly and Affordable Sustainable Urban District Retrofitting. The FASUDIR project was meant to develop new business models and financial tools, to support building-retrofitting market mobilization in Europe toward the EU-targets in 2020 and 2050. In the report "Key Performance Indicators", the consortium identified a list of indicators to guide the main players in the decision of the best energy retrofit measure by providing quantitative or qualitative information about building and district performance. The indicators assess the project along its environmental, social and economic performance, with focus on resource efficiency, low emissions, health, comfort and cost efficiency.
- **CITY keys** [15]**.** Smart City performance measurement system. CITYkeys developed and validated key performance indicators and data collection procedures for a common and transparent monitoring and comparison of smart city solutions across European cities. In the report "CityKeys indicators for smart city projects and smart cities", a selection of indicators for assessing smart city projects and corresponding indicators on city level has been described.
- **BESOS** [16]**.** Building energy decision support system for smart cities. BESOS is an EU Research and Development project funded by the EC in the context of FP7. The project proposes the development of an advanced and integrated management system, which enables energy efficiency in smart cities from a holistic perspective. The main document analysed for this document is deliverable D3.1 "Key Performance indicators", in which the consortium identified KPIs to audit the performance of smart city as a whole and its public services.
- **DIRECTION** [17]**.** Demonstration of very low energy new building. DIRECTION is a four-year EU-funded project that aims at demonstrating how the use of very innovative

and cost-effective energy efficiency technologies can lead to the achievement of very low energy new buildings. In the deliverables D3.1, D3.2 and D3.3 “Monitoring system project for demonstrator 1, 2 and 3” a set of KPIs to evaluate the energy saving obtained was identified. In particular, they used the net energy consumed, the net fossil energy consumed, primary energy consumed and net energy performance.

Standards:

- **UNI EN 15251**. Indoor environmental parameters for assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics.
- **EN ISO 13790:2008**. Energy performance of buildings – Calculation of energy use for space heating and cooling.
- **ASHRAE 55-2013.** Thermal environmental conditions for human occupancy.
- **UNI EN 15232.** Energy Performance of buildings – impact of Building automation, Controls and Building management.
- **EN 13792.** Thermal Performance of buildings – calculation of internal temperatures of a room in summer without mechanical cooling – Simplified method.
- **EN ISO 7730.** Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.
- **EN 15242.** Calculation methods for the determination of air flow rates in buildings including infiltration.
- **EN 16798.** Indoor environmental input parameters for the design and assessment of energy performance of buildings".
- **EN 13799:2007.** Ventilation for non –residential buildings. Performance requirements for ventilation and room-conditioning system.
- **EN 15217:2006.** Energy Performance of buildings. Methods for expressing energy performance and for energy certification of buildings.
- **EN 15316.** Heating Systems in Buildings. Method for calculation of system energy requirements and system efficiencies.
- **EN 15603:2008.** Energy performance of buildings. Overall energy use and definition of energy ratings.
- **ISO 5001:2011.** Energy Management System
- **ISO 16346:2013.** Energy Performance of buildings – assessment of overall energy performance

Other documents:

- KPIs for evaluation of energy conservation in buildings [18].
- Energy and other Key Performance Indicators for building – Examples for Hellenic Building [19].
- An energy Monitoring and management system based on Key Performance Indicator [20].
- Comfort metric for an integrated evaluation of building performance [21].
- Key Performance Indicators (KPIs) approach in building renovation for the sustainability of the built environment: a review [22].

- Keys Performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings [1].
- Key performance indicators in thermal energy storage: survey and assessment [23].
- KPIs and post-processing procedures [24].
- Key Performance Indicators (KPIs) for Continuous commissioning [25].
- ASHRAE Handbook – HVAC Application [26].
- Energy efficient design of building [27].
- KPIs for S.M.A.R.T cities [28].
- Validation methodology for a self-learning building Energy Management System [29].

Eurac has analysed other sources which are not mentioned because they describe the same KPIs that have been selected and detailed in previous paragraphs.

THE KPIS REPOSITORY AND CLASSIFICATION

The result of this work is a long list of more than 130 KPIs. For further analysis, it became necessary to store the indicators in a more structured way, using categories and providing information to their most standard attributes.

The method that we apply to collect, store and select the most relevant KPIs necessary for analysing performances of the last generation of buildings is described in the following paragraphs.

In order to make the results of this literature review open to the public, and to avoid a deliverable with a long list of indicator, we uploaded the Excel file with full list of indicator into the free-access repository "Zenodo", with the following DOI: 10.5281/zenodo.1034125.

CATEGORIES

Kylili et al [22] defined 8 categories of KPIs to assess building performances. The proposed list took into account different fields such as Economic, Environmental, Social, Technological, Time, Quality, Disputes and Project Administration. For each category, a list of sub-category was defined to further classify the indicators. The authors tried to cover all the generic categories without focalizing on specific aspects.

In ExcEED, we restricted the list of possible categories as follows:

Thermal energy, electric energy, renewable energy, indoor environmental quality (thermal comfort, acoustic comfort, visual comfort, and air quality), economic, technological, and environmental

For each category the KPIs have been further detailed using different classifications, such as:

- Component Classification
- Target Group
- Types of building
- Experts classification

COMPONENT CLASSIFICATION

This class is subdivided in five sub-elements, which can help to better characterize the use and scope of the KPI:

1. **Indicator/metric**: under this sub-category, it goes the title of the indicator, i.e. "*Annual heating or cooling demand per net useful area or net useful volume*, "*Annual heating and cooling demand per net area and FDD and CDD*", etc.
2. **Application Scale**: which is divided in two sub levels, *macro* and *specific application scale*. In the macro scale, the KPIs are indexed accordingly to the macro scale of application such as entire building, entire system, building and system together or component. The specific application scale defines the particular category to which the KPI apply such as "Window and glazing", "Wall", "Boiler", etc.
3. **Unit of measure**: i.e. "kWh/m^2", "kWh/m^3", etc.
4. **Description**: which is a brief description of the indicator, underlining how it is calculated.

5. **Time-dependency**: Indicators are categorized in *steady-state* or *transient*, according to their dependency with time. A *steady-state indicator* means that its value does not change over time (i.e. transmittance of the wall, g-value of window, etc.), whereas in *transient mode* the value of indicator could change over time (i.e. thermal or electricity consumption, max peak of cooling or heating, etc.).

TARGET GROUP

Different players in the building sector may use the ExcEED database and tools. According to their role, different users may need different indicators. For this reason, for each indicator a possible target user has been identified. Under target group there are five main categories representing the five main players: policy makers, investors, building designers, building owners, and energy managers. Each KPI can refer to one or more categories of target group.

TYPE OF BUILDING

Filtering the data according the building intended use could be a useful feature. If fact, not all KPI can be useful to evaluate all type of building.

The selection can be made among twelve different options: all types of buildings, residential, office, hospital, hotel, school, boarding school, library/museum, warehouse, shop/market, commercial malls, and gymnasium.

SELECTION OF THE SHORT LIST OF KPIS APPLICABLE TO THE EXCEED DATABASE

One of the key point of the work is the selection of the most useful KPIs to be used in ExcEED database. The selection involved several experts, who have scientific and/or technical background. The scope was to avoid the selection of useless or too complex indicators and focus on those that are considered by the experts the most useful and meaningful.

The experts (30) evaluate the indicators on their field on a three-point scale from 0 to 2:

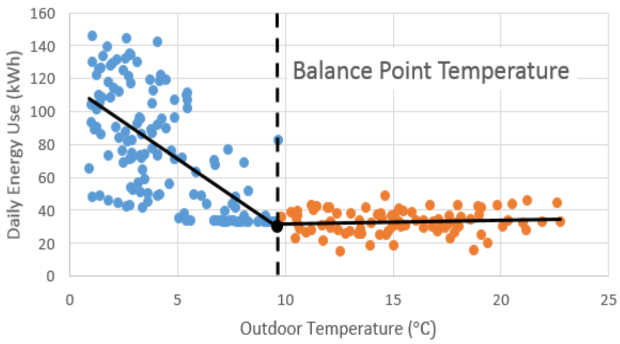
At the end of the evaluation process, a statistical mean was calculated considering the following values for each grade: 0 = 0%, 1 = 50%, 2 = 100%. In this way, it was possible to restrict the KPIs selection only to the resulting best ones for each category.

EXCEL TOOL

The list of the best KPIs selected by user can be seen in an Excel tool. Hereunder the description of the most important ones:

Table 1 Selected KPIs

N°	Indicator	Description
1	Annual Heating and cooling demand per net useful area or net useful volume	Thermal energy demand for net square meter or Volume [kWh/m^2 or kWh/m^3]*
2	Annual heating and cooling energy demand per net area and FDD or CDD	Thermal energy demand for net square or volume normalized with Heating or Cooling Degree Days $Q' = \frac{Q}{A(or\ V)*HDD(or\ CDD)}\ [\frac{Kwh}{m^2*HDD(or\ CDD)}]$ Where: Q' : Normalized thermal consumption $A\ (or\ V)$: Area or Volume [m2 or m3] $HDD(or\ CDD)$: Heating or Cooling degree Days* In case of Reference Location: $Q' = \frac{Q}{A(or\ V)} (\frac{HDD_R\ (or\ CDD_R)}{HDD_L\ (or\ CDD_L)})\ [\frac{Kwh}{m^2*HDD(or\ CDD)}]$ Where: $\frac{HDD_R\ (or\ CDD_R)}{HDD_L\ (or\ CDD_L)}$: Ratio between the reference location and local location. In this case, for the calculation of HDD or CDD of reference location, historical data of at least 5 years is required.
3	Energy Signature	Graph describing the correlation between the thermal consumption and the external temperature. It is a useful indicator to understand the "well" behaviour of the system.

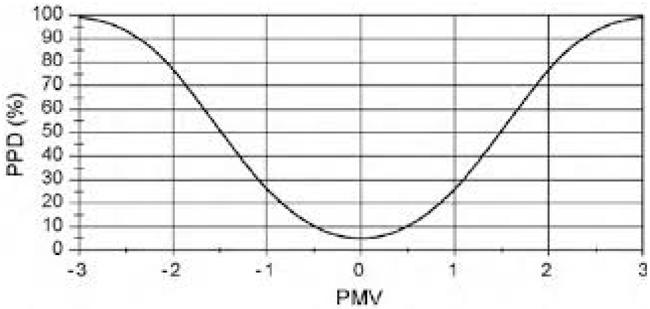
		 *Figure 1. Energy Signature* As shown in Figure 1, the outdoor temperature is on the x – axis while the thermal consumption is in y-axis. In this case, the heating consumption behaviour is depicted by the regression lines of the blue points. It is evident how the heating system stops to work when the external temperature is higher than 10°C. Moreover, If the generator is used to generate thermal energy both for heating and domestic hot water, the consumption of this latter is generally constant (orange points) during the year and independent from the external temperature.
4	Cooling/Heating Peak Power	Is the maximum peak of power for Cooling and Heating [W]
5	Energy need for cooling/heating, ventilation and domestic hot water.	Heat to be delivered to, or extracted from, a conditioned space to maintain the intended temperature conditions during a given period of time (UNI EN ISO 13790)
6	Primary energy consumption (ISO 16346:2013)	Primary energy factors vary in the world. Nevertheless, for an international comparison of the energy performance of buildings, a common “ISO” energy performance indicator may be used. In this case, the information given in Table 2 shall be used. The annual primary energy use, E_{ISO}, is calculated from the delivered and exported energy for each energy carrier: $E_{ISO} = \sum_{ci} E_{ISO;del;ci} - \sum_{ci} E_{ISO;exp;ci}$ With: $E_{ISO;del;ci} = E_{EPdel,ci} * f_{ISO,del,ci}$ (1) $E_{ISO;exp;ci} = E_{exp,ci} * f_{ISO,exp,ci}$ (2)

		$$E_{EPdel,ci} = E_{EPus,ci} - E_{pr,EPus,ci} (3)$$ Where: E_{ISO} is the annual ISO weighted energy use for all energy uses included in the energy performance assessment, in MJ or kWh; $E_{ISO;del;ci}$ is the annual delivered energy in ISO weighted energy units, for energy carrier ci, in MJ or kWh, determined according to Formula (1); $E_{ISO;exp;ci}$ is the annual exported energy in ISO weighted energy units, for energy carrier ci, in MJ or kWh, determined according to Formula (2); $E_{EPdel,ci}$ is the annual delivered energy, for energy carrier ci, for all energy uses included in the energy performance assessment, in MJ or kWh, that is equal to the energy used for the energy performance ($E_{EPus,ci}$) minus the part of energy produced at the building site ($E_{pr,EPus,ci}$) that it is used to cover part of its own use -Formula (3). $E_{exp,ci}$ is the annual exported energy, for energy carrier ci, in MJ or kWh. $f_{ISO,del,ci}$ is the ISO factor for the delivered energy carrier ci, to be determined according to Table 2. $f_{ISO,exp,ci}$ is the ISO factor for the exported energy carrier ci, to be determined according to Table 2.
7	Energy Use: fuel consumed, breakdown by fuel type	Type and quantity of fuel used for heating and cooling
8	Thermal energy savings	Quantity of thermal energy saved after the application of .energy conservation measure
9	Energy use per room (kWh/room)	Quantity of energy required to heat or cool rooms.
10	Heating Design: Heating plant type. Boiler draft type (Mechanical/Other draft). Boiler distribution type (Fan Coil/Single-zone AHU/Multi-zone AHU). Heating equipment efficiency (Efficiency level and the applicable unit). Heating equipment capacity (Kbtu/hr), Heating type (no heating/central furnace/heat pump).	Description of the heating system installed in the building

11	Cooling Design: Cooling plant type (Chiller/ District chiller water). Chiller compressor type (Reciprocating/Screw/centrifugal). Chiller distribution type (Single-zone AHU/Multi-zone AHU/ Fan coil). Chiller condenser type (Air/Water), Cooling equipment efficiency (Efficiency level and the applicable unit). Cooling equipment capacity (tons), Cooling type (No cooling/Terminal DX / Central DX).	Description of the cooling system installed in the building.
12	DHW Design: Service Hot water, Fuel type (Electricity/Gas), Service Hot water, Use of Heat Pump? (yes/No), Service Hot water, Distribution type (Looped/Distributed/instantaneous) ,Service Hot water, Water heater efficiency (%), Service Hot water, Tank volume (Gallons), Service Hot water, Tank insulation thickness (in/ cm), Service Hot water, Tank insulation R-value (°F*Ft2*h/btu)	Description of the domestic hot water system installed in the building
13	Annual Electric energy per net area	Electric energy demand for square meter. Calculated in kWh/m^2
14	Electric consumption normalized for lighting during occupied or working period	$$E_{light,t}^{norm} = \frac{E_{light,t}}{A * I_t^{VC(av)}} \left[\frac{kWh}{m^2}\right]$$ $$E_{light,h}^{norm} = \frac{\sum_{t=1}^{\frac{60}{time\ step}} E_{light,t}^{norm}}{\left(\frac{60}{time\ step}\right)}$$ $$E_{light}^{norm} = \sum_{h=1}^{H} E_{light,h}^{norm}$$ Where: $E_{light,t}^{norm}$: Normalized electric consumption of lights at time t [kWh/m2]; $E_{light,h}^{norm}$: Average electric consumption normalized of lights at hour h [kWh];

		E_{light}^{norm}: Total energy consumption normalized used for lighting over H hours; $\boldsymbol{A}$: Area of illuminated space [m2]; $\boldsymbol{I_t^{VC(av)}}$: Average value of visual comfort indexes at time t [0.01, 1]. It is calculated as: $\boldsymbol{I_t^{VC(av)}} = \begin{cases} 0.01 \text{ if the whole building is discomfortable at time } t \\ \boldsymbol{\frac{1}{N}\sum_{i=1}^{N} I_{i,t}^{VC}} \text{ otherwise} \end{cases}$ Where: ***N*** is the number of points where visual comfort is evaluated, or the number of points that are considered. $\boldsymbol{I_{i,t}^{VC}}$: Index of visual comfort for each sensor installed in the monitored illuminated area [0.01,1] at the time t, calculated as: $\boldsymbol{I_{i,t}^{VC}} = wf_{i,t}$ $\mathbf{wf_{i,t}}$: is 1 if there is visual comfort in zone i at time t, 0 otherwise. Energy for lights during closing period (i.e. night, days off) $E_{light}^{norm} = \frac{E_{light}}{A} [\frac{kWh}{m^2}]$
15	Electric consumption normalized for appliances	Energy for appliances calculated as: $\boldsymbol{E_{app,t}^{norm} = \frac{E_{app,t}}{A} [\frac{kWh}{m^2}]}$ $\boldsymbol{E_{app,h}^{norm} = \frac{\sum_{t=1}^{\frac{60}{time\ step}} E_{app,t}^{norm}}{\left(\frac{60}{time\ step}\right)}}$ $\boldsymbol{E_{app}^{norm}} = \sum_{h=1}^{H} \boldsymbol{E_{app,h}^{norm}}$ Where

		$E^{norm}_{app,t}$: Normalized Electric consumption of appliances during the time step t [kWh/m2]; E^{norm}_{app}: Electric consumption of appliances during H hours[kWh] A: Area of monitored zone [m2];
16	Electric consumption of mechanical ventilation	$E^{norm}_{fan,t} = \frac{E_{fan,t}}{A} * I_t^{CO_2(av)} [\frac{kWh}{m^2}]$ $E^{norm}_{fan,h} = \frac{\sum_{t=1}^{60/timestep} E^{norm}_{fan,t}}{\frac{60}{time\ step}}$ $E^{norm}_{fan} = \sum_{h=1}^{H} E^{norm}_{fan,h}$ Where: $E^{norm}_{fan,t}$: Energy consumption of fans normalized consumed during the time step t [kWh/m2]; $E^{norm}_{fan,h}$: Energy consumption of fans normalized consumed in one hour; E^{norm}_{fan}: Energy consumption for fans normalize used in H hours A: Area of ventilated space [m2]; n : is the number of time steps considered $I_t^{CO_2(av)}$: Average value of CO2 level indexes in the monitored ventilated space at the time t. It is greater than or equal to 1. It is calculated as: $I_t^{CO_2(av)} = \frac{\sum_{i=1}^{N} I_{t,i}^{CO_2}}{N}$ Where: N: number of measurement points $I_{t,i}^{CO_2}$: Index of CO2 for sensor i at time t: $I_{t,i}^{CO_2} = \begin{cases} 1\ if\ (CO_2^{real})\_(i,t) \le CO_2^{Threshold} \\ \frac{(CO_2^{real})_{i,t}}{CO_2^{Threshold}}\ otherwise \end{cases}$ $(CO_2^{real})_{i,t}$: CO2 level in zone i at time t;

		$CO_2^{Threshold}$: CO2 limit varying according to national standards
17	Total electricity savings	Total amount of saved electricity after application of energy conservation measure
18	Owner-Occupier Utility Arrangements	Quantity of electrical energy (kWh) obtain from a supplier.
19	Common Thermal comfort indicators: Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD)	The **PMV index** predicts the mean response of a larger group of people according the ASHRAE thermal sense scale: +3 hot; +2 warm;+1 slightly warm;0 neutral;-1 slightly cool;-2 cool;-3 cold The PMV index is expressed by P.O. Fanger as PMV = (0.303 e-0.036M + 0.028) L where PMV = Predicted Mean Vote Index M = metabolic rate L = thermal load - defined as the difference between the internal heat production and the heat loss to the actual environment - for a person at comfort skin temperature and evaporative heat loss by sweating at the actual activity level Predicted Percentage Dissatisfied - PPD - index is a quantitative measure of the thermal comfort of a group of people at a particular thermal environment.  At least approx. 5% of people in a group will be dissatisfied with the thermal climate - even with PMV = 0.
20	Number of overheating hours during cooling season	Total number of hours in which the temperature inside the thermal zone is higher than the set point
21	Comfort for natural ventilation building	The indoor comfort is evaluated according to the UNI 15251

22	Index of CO2 (Air quality)	The most commonly assessed parameter is the level of carbon dioxide (CO2), commonly used as an overall proxy for contamination and lack of adequate ventilation. European countries suggests different national threshold levels. Some of them are indicated in the Annex. Based on that, an index of air quality based on CO2 evaluation is developed. As shown in the formula below (eq.20) the $\boldsymbol{I_{t,i}^{CO_2}}$ is equal to 1 when its values is lower then the limit, otherwise it is calculated as the ratio between the real value and the threshold. $\boldsymbol{I_t^{CO_2(av)}}$: Average value of CO2 level indexes in the monitored ventilated space at the time t. It is calculated as: $$\boldsymbol{I_t^{CO_2(av)}} = \frac{\sum_{i=1}^{N} \boldsymbol{I_{t,i}^{CO_2}}}{\boldsymbol{N}}$$ Where: N: number of measurement points $\boldsymbol{I_{t,i}^{CO_2}}$: Index of CO2 for sensor i at time t: $$\boldsymbol{I_{t,i}^{CO_2}} = \begin{cases} \mathbf{1}\ if\ (CO_2^{real})\_(i,t) \leq CO_2^{Threshold} \\ \dfrac{\left(\boldsymbol{CO_2^{real}}\right)_{\boldsymbol{i,t}}}{\boldsymbol{CO_2^{Threshold}}}\ otherwise \end{cases}$$ $\left(\boldsymbol{CO_2^{real}}\right)_{\boldsymbol{i,t}}$: CO_2 level in zone i at time t; $\boldsymbol{CO_2^{Threshold}}$: CO_2 limit varying according to national standards
23	Number of air changes	It is a measure of the air volume added to or removed from a space (normally a room or house) divided by the volume of the space
24	The total operation and maintenance cost of energy resources in a building	$$C_{ann\_op} = \sum_{h=1}^{8760} \sum_{i=1}^{n} [k_{f_i} \cdot P_i(h) + k_{m_i} \cdot P_i(h)]$$ where: C_{ann_op} is the annual operation cost of the energy resources in the building; k_{fi} is fuel cost of the i^{th} unit ($/kWh), k_{mi} is the average period and reative maintenance cost of i^{th} unit ($/kWh) and Pi(h) is the power consumed by the i^{th} unit

25	Thermal resistance or transmittance of Wall	Thermal transmittance, the U -value, describes the insulation capacity of a building structure. The lower the U-value is, the better insulated the structure is. The U-value of a structure depends of the heat transfer resistance (R) of each layer in the construction. The heat transfer resistance depends on the thickness (d) and heat conductivity (λ) of the material. The lower the value of heat conductivity is the better the insulating value of the material. In addition, the thicker the insulation is the greater the thermal resistance. if the heat transfer resistance of each building structure and the thermal resistance of the surfaces are known, the U-value of the building structure can be calculated as: $U = \frac{1}{R_{si}+R_1+\cdots+R_N+R_{se}} \ [\frac{W}{m^2K}]$ Where: R_{si} : is the thermal resistance of indoor surface [m^2K/W] R_N: is the heat transfer resistance of each layer of wall [m^2K/W] R_{se} : is the thermal resistance of external surface [m^2K/W]
26	Heat transfer coefficient U_w	The heat transfer coefficient U_w relates to the entire window. This value also incorporates the U-values for the glazing and the frame U_f. The overall value U_w is also influenced by the linear heat transfer coefficient (g = glazing) and the size of the window.
27	Wind to wall ratio	Ratio of the window area to the gross exterior wall area.
28	Solar heat gain coefficient from windows (SHGC)	The second major energy-performance characteristic of windows is the ability to control solar heat gain through the glazing. The origin of solar heat gain is the direct and diffuse radiation coming from the sun and the sky (or reflected from the ground and other surfaces). Some radiation is directly transmitted through the glazing to the building interior, and some may be

		absorbed in the glazing and indirectly admitted to the inside. Some radiation absorbed by the frame will also contribute to overall window solar heat gain factor. Other thermal (non-solar) heat transfer effects are included in the U-factor of the window. Solar Heat Gain Coefficient (SHGC), which is defined as that fraction of incident solar radiation that actually enters a building through the entire window assembly as heat gain. The SHGC is also affected by shading from the frame as well as the ratio of glazing and frame. The SHGC is expressed as a dimensionless number from 0 to 1. A high coefficient signifies high heat gain, while a low coefficient means low heat gain.
29	Visible Transmittance for windows	The visible transmittance (VT) is an optical property that indicates the fraction of visible light transmitted through the window. This is separate from the Solar Heat Gain Coefficient (SHGC), since many modern windows include spectrally selective coatings that can allow different amounts of visible, infrared and ultraviolet light.
30	Renewable energy installed capacity	Biomass (wood) installed capacity Biomass (waste) installed capacity Geothermal installed capacity Solar PV installed capacity Solar CSP installed capacity Wind on-shore installed capacity Wind off-shore installed capacity Hydroelectric (dam) installed capacity Hydroelectric (river run off) installed capacity Incineration installed capacity hydroelectric pumped storage installed capacity Calculated in Watt
31	Annual electric power production from renewable	$E_{aepp} = H_{south,45°,zone} * R_s + 0.75$ Where:

	energy system – PV Panels performance Indicator	$H_{south,45°,zone}$: Solar annual energy on a south oriented are with a 45°slope [kWh/m^2*years] R_s : Peak power ratio [Wc/m^2]
32	Renewable energy generation	Biomass (wood) generation Biomass (waste) generation Geothermal generation Energy produced by PV installation Solar PV generation Solar CSP generation Energy produced by wind turbine(s) installation Wind on-shore generation Wind off-shore generation Energy produced by hydroelectric installation hydroelectric (dam) generation hydroelectric (river run off) generation Incineration generation hydroelectric pumped storage generation Calculated in Watt
33	Onsite (produced on site) renewable fuel types	wood wood pellets fiber fuel biodiesel ethanol biogas landfill gas
34	Imported (sourced off-site) renewable fuel types	wood wood pellets fiber fuel biodiesel ethanol biogas

		landfill gas
35	Energy Use of renewable energy	On-site renewable thermal energy used to heat or cool the building
36	Energy self-sufficient from renewable energies	Ratio between local production of renewable energy/ total energy demand
37	Total Primary Energy Demands and Percentage of Renewable Primary Energy	This indicator aims at the reduction of the Total Primary Energy Demand and at the increase of the share of renewable Primary Energy Demand.
38	Energy self-sufficiency from renewable energies	Is the ratio between local production of renewable energy and total energy demand. In percentage.
39	Total Urban Water consumption (including distribution losses)	Ratio between Water from municipal supply network [l] and number of inhabitants of municipality $UrbWaterCons = \frac{Water\ from\ municipal\ supply\ network[l]}{number\ of\ inhabitants\ of\ municipality}$
40	Green Public space per capita	Ratio between Green Surface [m^2] and number of inhabitants

* See definition of terms in the Table 3

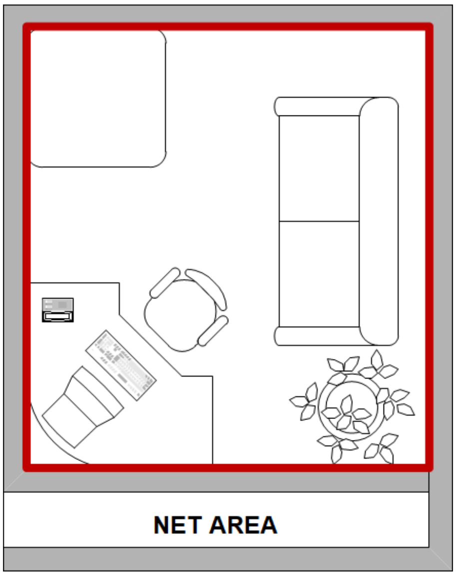
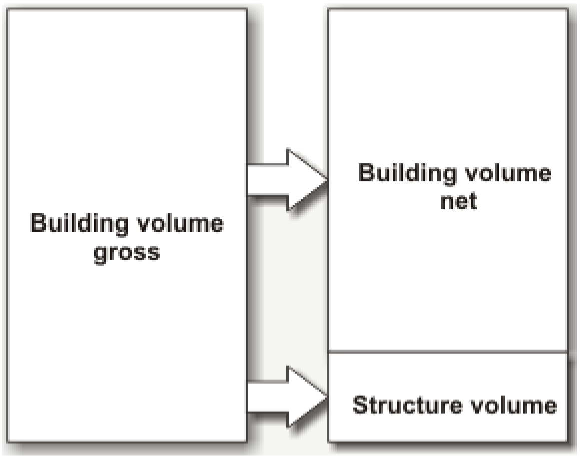
Table 2 Conversion factors for ISO weighted energy use $f_{ISO,del,ci}$ and $f_{ISO,exp,ci}$. According to UNI ISO 16346:2013

	Total energy factor	**Non –renewable energy factor**
Fossil fuels	1,2	1,2
Electricity	3,0	2,5
Log	1,1	0,1
Liquid biomass and biogas	1,5	0,5

TERMS AND DEFINITION

In the table hereunder a list of terms used to identify some KPIs are defined:

Table 3 Terms and definition

Term	Definition
Net Area [m^2]	Gross floor area of a building, excluding the area occupied by walls and partitions, the circulation area (where people walk), and the mechanical area (where there is mechanical equipment).  *Figure 2. Net Area of a building room*
Net Volume [m^3]	Volume of the air space of a building  *Figure 3. Building Volume gross and net (http://www.new-learn.info/packages/euleb/en/glossary/index3.html)*
HDD and CDD	The calculation of Heating Degree Days (HDD) and Cooling Degree Days (CDD) follow the new directive defined by International European Agency (IEA):

	"HDDs and CDDs are defined relative to a base temperature - the outside temperature – below which a building is assumed to need heating or cooling. They can be computed in different ways, depending, among other things, on the specific target application and the availability of sub-daily temperature data. The previous version of this indicator applied the methodology of Eurostat, which uses daily mean temperature only and has a jump discontinuity when daily mean temperature falls below the base temperature. This indicator uses an approach developed by the UK Met Office, which uses daily mean, minimum and maximum temperatures and does not exhibit a discontinuity. Note that this approach, being based on both minimum (T) and maximum (T) temperatures and not solely on the mean temperature (T), increases the accuracy of HDDs and CDDs for the purpose of gauging the impacts of climate change on energy demand, because the cooling of the environment depends more on T than on T, while T is more relevant for heating. The baseline temperatures for HDDs and CDDs are 15.5 °C and 22 °C, respectively. As a result of the methodological changes, the magnitudes of the trends between the previous version and this version of the indicator cannot be directly compared."[31]

KPIS ONLINE TOOL

In November 2017, Eurac will develop a dedicated KPIs online tool. The toll is a repository of Key Performance Indicators found in several European projects and programmes, such as ExcEED, CommONEnergy, 4Rineu, COST actions, International Energy Agency annexes, and so on, as well as standards and scientific articles.

The tool will be organized in a way that users can find specific KPIs using a series of filters as shown in the previous paragraphs.

Furthermore, the users will have the ability to contribute introducing new KPIs (after Eurac approval) or voting and comment on the ones already present in the tool.

The aims of this tool are:

- helping people with different background (i.e energy manager, researcher, building owner, etc.) to use the same KPIs to consistently analyse the systems from different perspectives;
- collecting in a single tool all the possible indicators on buildings and districts performance already existing and the ones that will be developed in the future;
- Among the collected KPIs highlight the most used by the different players.

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