HOLISTIČKO ISPITIVANJE ODRŽIVOSTI SISTEMA ZA ZGRADE I NASELJA

HOLISTIC SUSTAINABILITY ASSESSMENT SYSTEMS FOR BUILDINGS AND NEIGHBORHOODS

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U okviru evropskog projekta CESBA MED razvijeni su novi transnacionalni višekriterijalni metod i alatke za procenu izgrađene sredine sa otvorenim pristupom kao pomoć za ocenu, planiranje i celokupan proces odlučivanja u oceni učinka održivosti zgrada i naselja. Predloženi okvir pretvara sedam aspekata održivosti i više pokazatelja u praktičnu alatku za opštine, javne organe i ljude iz struke kako bi: i) dali dijagnozu trenutnog stanja ili novog projekta, ii) analizirali i rangirali različite scenarije renoviranja za izradu završnog plana, iii) pratili sprovođenje i napredak ka postizanju lokalnih ciljeva održivosti. Otvorena struktura omogućava prilagođavanje ove metode da bi se zadovoljili lokalni prioriteti, dok pasoš za zgradu ili naselje sa 16 obaveznih ključnih pokazatelja učinka omogućava dosledno poređenje prioriteta učinka održivosti na transnacionalnom nivou. Opšti okvir je dostupan na engleskom jeziku, a metoda je dalje dopunjena sa šest nacionalnih verzija alatki koje kontekstualizuju sadržaj prema nacionalnim (lokalnim) prioritetima u šest evropskih zemalja i na različitim jezicima. Devet pilot projekata se sprovodi u Hrvatskoj, Francuskoj, Grčkoj, Italiji, Malti i Španiji, kako bi se pokazala primenljivost ove metode u devet mediteranskih gradova. Takođe je dostupan i prateći elektronski obrazovni materijal u kojem su detaljno objašnjeni metoda, proces odlučivanja i različiti pokazatelji održivosti, a materijal je dostupan za internu obuku kako bi olakšao zainteresovanim stranama da utvrde i postignu ciljeve održivosti.

Ključne reči: održivost; ključni pokazatelji učinka (KPI); zgrade; naselja; odlučivanje

A new open access transnational multicriteria built environment assessment method and tools are being developed in the framework of a European project (CESBA MED) to support the assessment, planning and overall decision-making process for rating the sustainability performance of buildings and neighborhoods. The proposed framework translates seven sustainability issues and a plethora of indicators in to a practical tool for municipalities, public authorities and practitioners in order to: i) perform a diagnosis of the current state or a new design, ii) analyze, assess and rank different renovation scenarios for developing a final plan, iii) monitor the implementation and the progress towards achieving local sustainability targets. The open structure allows the adaption of the method to meet the local priorities, while a building and neighborhood passport with 16 mandatory key performance indicators allows a consistent comparison of sustainability performance priorities at transnational level. The generic framework is available in English, while the method is further complemented by six national versions of the tools that contextualize the content to national (local) priorities in six European countries and different languages. Nine pilot projects are being carried out in Croatia, France, Greece, Italy, Malta and Spain to demonstrate the applicability of the method in nine Mediterranean cities. Supporting electronic educational material that detail the method, the decision making process and the various sustainability indicators, are also available for in-house training to facilitate stakeholders in their efforts for setting and achieving sustainability targets.

Key words: Sustainability; Key Performance Indicators (KPIs); Buildings; Neighborhoods; Decision-Making

1 Introduction

Buildings have been at the centre stage of Europe's Energy Strategy and Energy Union since they account for 39.2% of the total final energy use [1], about 36% of CO₂ emissions. Furthermore, buildings use half of all extracted materials, one third of water and contribute to one third of waste generation [2]. A sustainable built environment is a key target of the European Commission's policies for a circular economy, moving away from the linear economic model of 'take, make, and waste' and towards resource efficiency.

In an urban context, additional aspects come in to play, like transportation, infrastructure and services, land use social well-being etc. The world's cities occupy just 3% of the Earth's land, but account for 60-80% of energy use and 75% of carbon emissions. The Basque Declaration [3] outlines new pathways for creating productive, sustainable and resilient European cities for a liveable and inclusive Europe by supporting and accelerating technological, socio-economic, and socio-cultural transformation. Specific actions include among others, efforts to decarbonise the energy

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systems and reduce total energy use, create sustainable urban mobility, protect and enhance biodiversity and ecosystem services, reduce the use of greenfield land and natural space, protect water resources, water and air quality, adapt to climate change and improve resilience, improve public spaces, create convivial and safe environments, guarantee social inclusion, strengthen local economies etc.

The United Nations Sustainable Development Goals in the Agenda 2030 [4] are the blueprint to achieve a better and more sustainable future by addressing the global challenges that include those related to cities for making them inclusive, safe, resilient and sustainable. In particular, Goal 11 for Sustainable Cities and Communities targets sustainable urbanization and transport systems, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, reducing adverse environmental impacts, safeguarding the cultural and natural heritage, providing green and public spaces.

Addressing the plethora of issues for developing local, regional and national plans towards sustainable development at building and urban scale is a complex undertaking. It calls for a holistic decision making process by various stakeholders, whether addressing new building constructions and urban developments, or buildings renovation and urban redevelopments. To facilitate the process, various sustainability rating systems have been developed that include different performance indicators [5] that are used as metrics to determine how well the sustainability objectives are achieved. They can be used to benchmark different building and urban attributes or characteristics, and thus facilitate the decision making process, assessing specific project requirements, or ensuring compliance with regulations and norms. The indicators quantify what one is trying to achieve and thus may need to select and use several of them at different stages of the work or process. They can be expressed as numerical values (e.g. buildings' or neighborhoods energy use intensity in order to compare different performances or against other benchmarks; water consumption per building occupant or area resident) or ratios and percentages (e.g. percent renewables that cover power or heat demand; percent of recycled waste). Apparently, the selection of specific indicators will be based on the specific project needs and priorities.

The common approach of sustainability rating systems is to then assign credits/points for deriving a score for each performance indicator and by using different weights that account for local specific features it is possible to estimate a final score. International systems provide a common basis for a global comparison, although addressing local needs and adapting the systems to regional/national priorities has practical value, encouraging adaption and implementation.

At building scale, different systems (e.g. BREEAM, CASBEE, Green Star, LEED, ITACA) aim at reducing energy use and environmental impacts during construction, management and operational phases for different building uses [6-7]. Although the various systems have differences, the quantitative and qualitative performance indicators commonly include energy, water, environment, materials and resources, comfort, service quality, site strategies, economics and waste, which may have varying importance in different areas.

Recognizing the need for a common European framework of performance indicators for assessing and improving building sustainability, the European Commission has recently made public a comprehensive proposal in the framework of the European decision [8]. This voluntary reference framework known as LEVEL(s) is being developed on the basis of existing standards, providing a common European approach for assessing environmental performance in the built environment [2]. Each indicator links the building's individual characteristics and impacts to sustainability priorities, facilitating users to consider key concepts and building-level indicators, following specific guidelines and standardized calculations for each indicator. At this early stage, the methodology refers to only residential and office buildings.

An important initiative is also the Common European Sustainable Built Environment Assessment – CESBA (www.cesba.eu) that has been working to respond to the perceived confusion caused by the proliferation of various building assessment schemes. CESBA brings together various projects and platforms led by public authorities in an effort to facilitate diffusion and adaption of sustainable built environment principles through the use of harmonized assessment systems in the whole life cycle of the built environment. Finally, a notable industry-led initiative is that of the Sustainable Building Alliance (www.sballiance.org). SBA assembled various representatives from major building assessment schemes and developed a harmonized framework of common metrics that focus on four life cycle analysis indicators: non-renewable primary energy consumption, CO₂ equivalents, water consumption and waste production, as well as measures of thermal comfort and indoor air quality.

Several systems have also been extended to urban scale, e.g. BREEAM Communities, CASBEE for Urban Development, LEED for Neighborhoods. The main aspects for sustainable cities address similar performance indicators as the ones for building scale, and include more categories, for example, urban transport, supply and distribution networks, social factors etc [9].

This paper presents an overview of an ongoing European project (CESBA MED) that develops a holistic method and system for accessing sustainability of the built environment. It addresses the main sustainability issues for buildings and neighborhoods (e.g. site and infrastructure, urban systems, energy and natural resources, emissions and environment, service quality, social aspects, economy). A generic framework includes an “exhaustive” number of performance indicators from which one can select the ones that are relevant to a specific project and then use different weights to properly adapt them to local context. A minimum number of 16 key performance indicators are also defined. The overall approach has been successfully tested in nine European Mediterranean cities. A comprehensive training package is also available that includes electronic educational material for self and in-house training.

2 The Method

The fact that there is still not a consensus on the definition of the sustainability indicators creates some confusion of which ones to consider or what system to select. For this reason, the approach taken in this work was to first develop a generic framework that includes an “exhaustive” list of indicators from which one can select the desirable performance indicators that meet the local priorities and needs. The initial concept for the building scale is based on [10] and then extended at urban scale.

The goal of this work was not to introduce new performance indicators, but rather collect existing know-how, review and organize available information from projects and systems that focus on different sustainability aspects and adapt them in a comprehensive generic framework. Accordingly, a total of 14 transnational European projects and public assessment systems were reviewed from which a representative list of indicators at building and urban scale was derived, addressing the main dimensions of sustainability [11]. The practical aspects considered during this review were also related to the needs of the different stakeholders, the definition clarity, the time constraints, complexity for collecting the main input data and calculation accuracy for each performance indicator. A total of 216 indicators at building and urban scale were derived and considered during the following work for organizing the various performance indicators under the main sustainability issues.

The general structure of the method is illustrated in Figure 1, organized in Issues, Categories and Criteria-Indicators [12]. The “Issues” identify the general themes that are important for assessing the sustainability at building and neighborhood (urban) scales. The “Categories” describe specific aspects of an Issue that group relevant criteria and indicators. The “Criteria” detail the specific aspects of a category and represent the main assessment entries used to characterize a building or an urban area, from the very beginning of the assessment process. The “Indicators” quantify the performance with respect to each criterion. In principle, several indicators can be associated with the same criterion, since one can define multiple strategies to quantify the building or urban area performance with regard to a specific criterion. For example, building energy use intensity expressed as kWh/m² or kWh/m³ and in some cases energy use per employee (e.g. for an office building) or energy per bed (for hotels), depending on the characteristic functions of a building [13]. For simplicity in this work, only one indicator is associated with each criterion. The metrics are used to quantify the performance and determine how well the sustainability objectives are achieved.

Figure 1: General structure of the CESBA MED method.

For example, under the Issue ‘Energy’, a Category ‘Non-Renewable Energy Sources’ that includes the Criterion ‘Building Thermal Energy Use’ is quantified with the Indicator ‘kWh/m²’. Under the Issue ‘Social Aspects’, a Category ‘Traffic & Mobility Services’ that includes the Criterion ‘Pedestrian Streets & Bicycle Paths’ is quantified with the Indicator ‘m/resident’. Sometimes qualitative criteria may also be used instead of quantitative ones. In this case, performance is expressed in terms of reference descriptions. For example, under the Issue ‘Social Aspects’, a Category ‘Cultural Heritage’ that includes the Criterion ‘Compatibility of urban design with local cultural values’ is qualitatively assessed with the Indicator ‘Architectural design features related to urban design’ are incompatible, marginally- or fully-compatible.

Among the various indicators, a number of key performance indicators (KPIs) were selected as minimum requirements in order to be able to address the main sustainability issues. For example, one commonly accepted metric to measure a building’s energy use performance is the energy use intensity (kWh/m²), which can be used to benchmark against similar buildings or with best-practices and assess energy efficiency measures within buildings [13]. The KPIs represent a limited number of performance indicators, which are defined and calculated following common standardized procedures. This work considered most of the LEVEL(s) indicators in the process of selecting the KPIs for the building scale. The results from the normative KPI calculations can then be used as a passport for comparing results from different buildings, areas, regions or countries, on a common basis.

The organization of the sustainability issues, the selection criteria, performance indicators, and KPIs followed an iterative process at various stages of the work by the CESBA MED partners (Figure 2). Starting with the results from the existing 14 EU projects & systems [11] and the LEVEL(s) indicators [2], each team of the partnership collaborated with national local committee experts in six countries to elaborate the issues and indicators, in order to strengthen future applicability in local context.

Figure 2: Illustration of the main steps for developing the CESBA MED system.

The work progress on the performance indicators and the proposed KPIs were also reviewed and elaborated with other European experts and project representatives during working sessions at a sprint workshop [14] in an effort to reach a wider consensus. The final list of the KPIs for building and neighborhood scale was determined following the nine pilot tests performed by the partners in seven European countries, thus ensuring their applicability and use in the field.

Accordingly, the CESBA MED Generic Framework (GF) includes seven sustainability issues for the building and neighborhood scales. The building scale includes 25 categories, while the neighborhood scale includes 23 categories. The total number of indicators that one can potentially use and are included in the GF reach 154 and 178, respectively. This “exhaustive” list of performance indicators is an excellent starting point for adapting national and local tools by selecting and including only the ones that are relevant according to national, local priorities and issues. The CESBA MED GF and national tools are elaborated in section 3.

2.1 Normalize Indicator Values and Score

All the environmental assessment systems use a normalization process in order to assign a score to the numerical values of an indicator. Due to the diverse nature of the criteria, the values of the various indicators have different units and different orders of magnitude. Moreover, indicators associated with qualitative criteria are without units since they do not represent any physical quantity. Accordingly, each indicator value is adimensionalized and rescaled (Figure 4) in an interval from -1 (performance below standard) to +5 (advanced performance), following a similar concept with [15]. Zero represents the minimum acceptable performance in compliance with minimum standard regulation mandates defined by law (or current practice in case of no regulations), +3 corresponds to best practice (or a significant improvement compared to existing regulations and common practice), while +5 reflects excellence (or ideal performance). The better the performance, the higher the normalized score. The specific scores are determined by linear interpolation between the specified limits determined at “0” and “+5”, for a given numerical value of an indicator. For some criteria the normalized score follows the rule that “Higher is Better” thus the slope is increasing (i.e. a higher value of the indicator corresponds to a higher performance and thus it receives a higher normalized score). This is illustrated with the solid black line in Figure 4 (e.g. percent contribution of renewable energy sources in the total primary energy consumption).

For other criteria, the rule is that “Lower is Better” thus the slope is decreasing (i.e. a lower value of the indicator corresponds to a higher performance level and thus it receives a lower normalized score). This is illustrated with the dashed gray line in Figure 4 (e.g. total final thermal energy use intensity (kWh/m²) for building operations). In all cases, the benchmarks at the two limits are defined at national, regional or even local levels, which comply with the different minimum acceptable or ideal performance, for each indicator. Finally, for qualitative criteria the normalized score can only attain discrete values in the normalization interval. In this case, each one of them corresponds to a reference description that is defined for the corresponding indicator at the different intervals (-1, 0, 3, 5). The normalized score is then determined by comparing the building’s or urban area’s performance with the specified reference description for compliance.

In general, for each indicator, the user provides the corresponding value for the appropriate local excellent practice (corresponding to “5” in the normalized score), the minimum acceptable performance (corresponding to “0” in the normalized score) and below standard (corresponding to “-1” in the normalized score). These values are used to benchmark each indicator on the -1 to 5 points scale and derive its corresponding normalized score. Already, the national versions of the method (see section 3) include national default values, but the user should adjust them according to the local characteristics (e.g. energy use intensities for the local buildings, water consumption in the area etc).

Figure 4: Normalization process and scoring; "Higher is Better" (solid line) and "Lower is Better" (dashed line).

2.2 Aggregation and Sustainability Score

The calculations for the sustainability score are weighted in terms of the priority or the desirable emphasis given on specific issues and performance indicators, in terms of their local context. For the issues, it is possible to define the level of priority from 1 (less important) to 3 (most important or more relevant) for each one of the seven sustainability issues. For example, for energy the assigned priority may be set at level 2 (average issue), while emissions in an area with major environmental problems the assigned priority may be set at level 3 (major issue).

Initially, following the selection of the desirable number of indicators, the remaining active number of indicators under each category and issue are equally distributed for a total of 100%. The coefficients may then be adjusted in order to place more emphasis on a specific indicator. In addition, each indicator is weighted according to four factors: Primary issue or system affected (rating using a 1 to 3 points scale depending on the level of priority for the different sustainability issues, i.e. 1-less important, 2-average, 3-most important), Impact of potential effect (rating using a 1 to 3 points scale, i.e. 1-minor, 2-moderate, 3-major), Extent of potential effect (rating using a 1 to 5 points scale depending on the spatial coverage, i.e. 1-block, 2-neighborhood, 3-district, 4-urban/region, 5-global), Duration of potential effect (rating using a 1 to 5 points scale, i.e. 1-for 1 to 3 years, 2-3 to 10 years, 3-10 to 30 years, 4-30 to 75 years, 5-greater than 75 years). For example, based on the above, an indicator for greenhouse gas emissions can be weighted with 3 (major issue for atmospheric emissions), 3 (major impact), 5 (global potential effect), 5 (duration >75 years). An indicator for final energy use can be weighted with 2 (as an average issue for energy), 3 (major impact), 2 (neighborhood potential effect), 3 (duration 10 to 30 years). Since the specification of these weighting factors is not a trivial process, the national versions of the method (see section 3) include national default values, although a user can always adjust them.

The normalized scores that are associated with each criterion are combined through a sequence of weighted sums to produce the final score (Figure 5). First, the normalized scores associated with all criteria in the same category are aggregated to produce a single score for each category. Then, the ones in the same issue are further aggregated to produce a single score for each issue.

Category, Criteria		Score		Weight Coefficient	Weighted Score
Energy	C1-Non-Renewable Energy	2.0		35%	0.7
	C2-Renewable & Clean Energy	1.5	X	65%	1.0
					1.7

Figure 5: Example for calculating the weighted score for the Energy issue.

The results from all the issues are aggregated to produce a final concise sustainability score for the project. This process provides the ability to use different weight coefficients (%) that may be adjusted up or down) for each criterion, category and issue, according to local environmental, social and economic priorities and scenarios under assessment.

3 The Tools

The CESBA MED Generic Framework (GF) Tool is the general, all-inclusive starting version of the tool that supports the assessment method. It includes seven sustainability issues for the building scale (i.e. A-Site & infrastructures, B- Energy & Resources, C-Environment, D-IEQ (Indoor Environmental Quality), E-Service Quality, F-Social,

Cultural & Perceptual aspects, G-Economy) and seven sustainability issues for the urban scale (i.e. A-Urban Systems, B-Economy, C-Energy, D-Emissions, E-Natural Resources, F-Environment, G-Social Aspects). Each issue includes a different number of categories (Figure 6) that describe specific aspects of the issue that it belongs to. The building scale includes 25 categories (e.g. under the issue “IEQ” there are four categories: Indoor air quality and ventilation, Air temperature and relevant humidity, Daylight and illumination, Noise and acoustics), while the urban scale includes 23 categories (e.g. the issue “Energy” includes two categories: Non-renewable energy sources, and Renewable and clean energy sources).

Different numbers of criteria-indicators are included under a given category, each one of them describing a particular aspect of the corresponding category. For example, for the urban scale, the category “Renewable and clean energy sources” includes fourteen criteria, e.g. Share of on-site renewables on total final or primary energy consumption for residential or non-residential buildings, Share of electricity production from renewables on public or private property, Total electricity from renewables that is exported from the area, Total electricity from renewables used in or exported from the area, Share of thermal energy from renewables on public or private property etc.

Figure 6: Structure of the CESBA MED GF sustainability issues and categories, for building scale (top) and neighbourhood scale (bottom).

Some representative examples of the method's generic framework structure are presented next. For the building scale: Issue "B-Energy & Resources", Category: "B1-Life Cycle Non-Renewable Energy", Criteria: "B1.1-Primary Energy", Indicator: "B1.1-kWh/m²/y"; Issue "C-Environment", Category: "C1-Greenhouse Gas Emissions", Criteria: "C1.3-Global Warming Potential", Indicator: "C1.3-kg CO₂ eq./m²/y". For the urban scale: Issue: "B-Economy", Category: "B2-Economic Activity", Criteria: "B2.3-Employment Rate", Indicator: "B2.3-% of working age adults in the area"; Issue: "C-Energy", Category: "C1-Non-Renewable Energy Sources", Criteria: "C1.1-Total final thermal energy consumption for all building operations in the area", Indicator: "C1.1-kWh/m²/y".

The mandatory KPIs represent the priority sustainability transnational issues. They are consistently defined and calculated with the same standardized procedures [16]. The 16 KPIs for the building and urban scales are outlined next. Most of the CESBA MED KPIs for the building scale refer to a LEVEL(s) reporting indicator and are identified with an asterisk next to their code number (e.g. B1.1*).

- Building Scale
 - B1.1* Primary energy consumption (kWh/m²/y)
 - B1.2* Final thermal energy consumption (kWh/m²/y)
 - B1.3* Final electrical energy consumption (kWh/m²/y)
 - B1.5* Renewables in final thermal energy consumption (%)
 - B1.6* Renewables in final electrical energy consumption (%)
 - B1.11* Embodied non-renewable primary energy (MJ/m²)
 - B3.5 Recycled materials in total materials used (%)
 - B4.5* Water consumption for indoor uses (m³/occupant/y)
 - C1.3* Global warming potential (kgCO₂eq/m²/y)
 - C3.1* Construction & demolition waste generation (kg/m²)
 - C3.2 Solid waste categories recycled (%)
 - D1.4* TVOC concentration in indoor air (μg/m³)
 - D1.10* Ventilation rate (Lt/s/m²)
 - D2.2 Thermal comfort index (PPD %)
 - G1.4* Operational energy cost (€/m²/y)
 - G1.5* Operational water cost (€/m²/y)
- Urban Scale
 - A1.7 Land conservation (%)
 - B3.3 Operational energy cost for public buildings (€/m²/y)
 - C1.1 Total final thermal energy consumption for buildings (kWh/m²/y)
 - C1.4 Total final electrical energy consumption for buildings (kWh/m²/y)
 - C1.7 Total primary energy consumption for buildings (kWh/m²/y)
 - C2.1 On-site renewables in total final thermal energy consumption for buildings (%)
 - C2.7 On-site renewables in total final electrical energy consumption for buildings (%)
 - D1.2 Total GHG emissions from energy use in buildings (kgCO₂eq/m²/y)
 - E1.6 Water consumption in residential buildings (m³/occupant/y)
 - E1.7 Water consumption in public buildings (m³/occupant/y)
 - F1.3 Recharge of groundwater through permeable paving or landscaping (%)
 - F2.3 Ambient air quality of particulates (PM10) above acceptable limits (days/y)
 - G2.1 Proximity of residents to public transport (%)
 - G2.4 Pedestrian & bicycle network (m/100 inhabitants)
 - G4.2 Proximity of residents to key services (%)
 - G6.3 Community involvement in urban planning activities (qualitative level score)

The KPIs are collected and stored in a "Passport" that constitutes a depository of common and comparable data. These results enable a consistent comparison of the key sustainability performance of buildings and neighborhoods between different areas, cities, regions and countries.

All the indicators are analytically presented in the tool. The presentation of each indicator includes (Figure 7) an overview of calculation steps that one must follow for KPIs and may adapt or describe a different method for other indicators. Supporting references and other resources are also included and the user may also add other relevant notes. The user must enter the calculated value for the corresponding indicator (e.g. the energy use intensity in kWh/m²), for the specific project. Under the assessment criteria, the tool automatically transfers the benchmarks for the scale (-1, 0, 3, 5). These values can be adjusted, if necessary, in order to accommodate for some specific characteristics (e.g. adjust the energy use intensity benchmarks for historic buildings that may not be able to reach high performance standards).

Entering the numerical value of the indicator, the tool estimates the weighted score. The user may also include a target performance value for reference and comparative assessment. As an option, there is also a place holder for third-party score that can be used during verification.

Overview of calculation steps
(must follow for KPIs, may
adapt-describe for others)

References and
background information,
resources

C	Energy	Weighted Issue Score	1.44															
C1	Non-renewable energy	Weighted Category Score	0.35															
C1.1	Total final thermal energy consumption for building operations	4.3%	N															
Indicator	To estimate urban thermal energy consumption for building operations.																	
Indicator	The criterion refers to the estimated building's final thermal energy consumption in the use stage. Use stage energy consumption is in general responsible for most of life cycle energy use in the case of buildings constructed before the year of the indicator.																	
Relevant information	Major efforts are being made in many jurisdictions to reduce operational energy use for new buildings to zero. However, the existing building stock includes many older buildings which have much higher and more variable levels of energy use. A first step to lower the energy use intensity (EUI), is to establish proper energy use performance benchmarks and to compare against the existing EUIs.																	
Assessment method	To perform the calculation, it is possible to use metered or estimated data. The source of data must always be clearly disclosed. For the evaluation of the actual performance of the urban area it is preferable to use metered data. If metered data isn't available, estimated data shall be used. Estimated data shall be used for evaluating alternative scenarios in planning and decision-making processes. In reporting the indicator's value, the data source must be indicated.																	
Assessment method	Use of estimated data: 1. In the calculation of the final thermal energy consumption, the following energy use must be considered: heating, cooling, domestic hot water. 2. For each building in the local area, calculate the annual final thermal energy consumption in kWh/year. 3. Sum the annual final thermal energy consumption of each building up to an aggregated total annual final thermal energy consumption (kWh/year). 4. Sum the indoor useful area of each building in the area up to an aggregated indoor useful area value (m²). 5. Calculate the indicator's value as: aggregated total annual final thermal energy consumption/aggregated indoor useful area (kWh/m²/year). Use of metered data: 1. In the evaluation of the final thermal energy consumption, the following energy use must be considered: heating, cooling, domestic hot water. 2. For each building in the local area, collect the metered annual final thermal energy consumption in kWh/year. 3. Sum the annual final thermal energy consumption of each building up to an aggregated total annual final thermal energy consumption (kWh/year). 4. Sum the indoor useful area of each building in the area up to an aggregated indoor useful area value (m²). 5. Calculate the indicator's value as: aggregated total annual final thermal energy consumption/aggregated indoor useful area (kWh/m²/year).																	
Assessment method	5. Calculate the indicator's value as: aggregated annual total final thermal energy consumption/ aggregated indoor useful area (kWh/m²/year).																	
Assessment method	<table><tr><td>Values</td><td>Score</td><td>Weighted score</td></tr><tr><td>Target performance</td><td>20</td><td>5.0</td><td>0.21</td></tr><tr><td>Calculated performance (average EUI)</td><td>103</td><td>3.8</td><td>0.16</td></tr><tr><td>Third-party score (over-ride calculated value)</td><td>20</td><td>5.0</td><td>0.21</td></tr></table>			Values	Score	Weighted score	Target performance	20	5.0	0.21	Calculated performance (average EUI)	103	3.8	0.16	Third-party score (over-ride calculated value)	20	5.0	0.21
Values	Score	Weighted score																
Target performance	20	5.0	0.21															
Calculated performance (average EUI)	103	3.8	0.16															
Third-party score (over-ride calculated value)	20	5.0	0.21															
References	<p>ec.europa.eu/energy/en/topics/energy-efficiency/buildings</p> <p>https://www.iso.org/publications/frpublications/_buildings_certification.pdf</p> <p>www.thecet.org/infodetail/vol1/vol1_1/ICT-updates_EU-35grm_jan2014.pdf</p> <p>Calculations are based on EN 15780 using the quasi-steady state monthly method.</p>																	
Notes	As a good practice, note here the data sources used so that it is possible to repeat and confirm calculations.																	
Assessment criteria (from File A)	<table><tr><th>Assessment criteria (from File A)</th><th>Min/Max</th><th>Score</th></tr><tr><td>Negative</td><td>3776.0</td><td>-1</td></tr><tr><td>Minimum practice</td><td>3776.0</td><td>0</td></tr><tr><td>Good Practice</td><td>165.0</td><td>3</td></tr><tr><td>Best Practice</td><td>20.0</td><td>5</td></tr></table>			Assessment criteria (from File A)	Min/Max	Score	Negative	3776.0	-1	Minimum practice	3776.0	0	Good Practice	165.0	3	Best Practice	20.0	5
Assessment criteria (from File A)	Min/Max	Score																
Negative	3776.0	-1																
Minimum practice	3776.0	0																
Good Practice	165.0	3																
Best Practice	20.0	5																

Supporting information
for each Indicator

Enter the calculated
value of the indicator
for the specific project

- Target (for comparative assessment)
- Calculation results
- Third party score (for verification or control)

Adjust benchmark scale
for the specific project
(if necessary)

Figure 7: Presentation example for indicators.

3.1 Contextualization

The CESBA MED GF includes the complete list of all the performance indicators that one can potentially use, i.e. a total of 154 indicators for building scale and 178 indicators for urban scale. This long catalogue of indicators includes the mandatory KPIs, which is the minimum number of performance indicators that must always be used in a project. For practical purposes, one should select a manageable number of indicators from the complete list under the various issues and categories, which are most relevant and applicable according to the local issues, priorities and strategic policies of a given project. During the development of the national tools (refer to the following section) this exercise has already been elaborated for adapting the GF Tool and its contents in the national versions.

In general, the first step is to select among the 154 indicators at building scale and the 180 indicators at urban scale, the ones that are relevant according to the renovation project and local issues. The mandatory KPIs are always included. For each one of the selected indicators, the user can provide the local benchmarks, i.e. the values that correspond to the appropriate local excellent practice (corresponding to "5" in the normalized score), the minimum acceptable performance (corresponding to "0" in the normalized score) and below standard (corresponding to "-1" in the normalized score). This information is used to benchmark the values for each indicator and normalize them (see section 2.1) on the -1 to 5 points scale. The national versions of the method (see the following section) include national default values, but the user should adjust them according to the local characteristics (e.g. energy use intensities for the local buildings, water consumption in the area etc).

The user can also adjust the level of priority for each one of the seven sustainability issues from 1 (less important) to 3 (more relevant). The local priorities may change in time or can be adjusted for evaluating a sustainability score, based on different goals and objectives. For example, assigning energy issues a priority 3 in order to place more emphasis on energy related issues or assign a weighting factor of 3 for social aspects and focus more on public facilities and services. The national versions of the method (see the following section) include national default values, but the user should adjust them according to the local priorities, policies or project intent.

3.2 National Tools & Pilots

The CESBA MED GF Tools of the assessment system for buildings and neighbourhoods were adapted in local (national) context with default national values (e.g. including benchmarks for the indicators and weighting factors) and in national language for the seven participating European countries. The contextualized assessment tools for buildings (SBTools) and sustainable neighbourhoods (SNTTools) include the same KPIs, but have a different number of additional performance indicators that best fit in the national and local context and sustainability priorities.

The selection of the criteria-indicators is flexible (Figure 8) and allows for the combination of different number of categories, criteria and indicators. For example, the GF for the neighbourhood scale includes a total of 23 categories and 178 criteria-indicators, while for the national tool in Greece a total of 16 categories have been selected, with 42 criteria-indicators. The only core set of criteria that is mandatory, are the KPIs that represent internationally recognized priorities for sustainability assessment.

Figure 8: Selection of different criteria-indicators from the GF Tools to derive the national frameworks.

The GF Tools are available in English, while the national tools are available in different languages (Catalan, Croatian, French, Greek, Italian, Maltese, Spanish). More important, the national tools have been adapted to local context by incorporating in the SBTool and SNTTool the priority weights for the different sustainability issues and benchmarks for the indicators. This way, the default values in the national versions of the tools are ready to be fine-tuned, if necessary, for local applications.

The final results (Figure 9) summarize the performance assessment for the building or the urban area. The main information includes an overview of the aggregated scores for each one of the seven issues and a detailed overview of the KPIs.

To test and demonstrate the applicability and adaptability of the method and tools national pilots were held in Athens (Greece), Barcelona (Spain), Lyon (France), Msida (Malta), Marseille (France), Sant Cugat (Spain), Torino (Italy), Udine (Italy) and Zagreb (Croatia). The work was performed using the national tools, which have been translated and adapted to national and local context.

Figure 9: Overview of the main final results.

In Greece, the pilot was performed at the Municipality of Fylis, north-west of Athens. Over the years, the Municipality of Fylis has exhibited genuine efforts, activities and communicated plans for improving its energy and carbon footprint, by implementing various initiatives on energy conservation and sustainable development aiming to regenerate into a thriving area. The pilot includes the area near the town hall and a school complex. The scenarios considered different development plans including among others the new main natural gas supply network, the renovation of municipal buildings for improved energy performance, the installation of PVs and solar thermal in schools and sports facilities, the strengthening of collection and recycling of waste, the expansion of pedestrian and low traffic roads, along with bicycle lanes, municipal local transportation and public parking, the energy efficient public lighting, the engagement of citizens and the development of green areas for the urban regeneration of neighborhoods.

3.3 The Decision Process

The CESBA MED Tools are intended to support decision-makers and the managers of public and municipal building stocks in the implementation of more efficient renovation plans combining the building and the urban scale. The process should consider the building in its urban context and look for synergies between the groups of buildings in order to optimize energy planning in the context of a sustainability performance assessment.

The overall process (Figure 10) considers all phases of a project for major renovations or new developments [17]. Assessing the actual performance at the current state takes a snap shot of the existing condition and characteristics and identifies the critical sustainability issues. One can assess the potential performance following the implementation of renovation scenarios in order to identify the most cost effective and sustainable one. Similarly, for new developments, it is possible to assess the potential performance of alternative planning options in order to identify the most cost effective sustainable development scenario. In both cases, after implementation, it is possible to monitor and evaluate the effectiveness of implemented actions and the achievement of the sustainability performance targets.

To start, one needs to define the physical boundaries and decide which of the surrounding infrastructures are of relevance (Figure 10). The physical boundaries of the urban area may be derived considering the spatial coverage along with the legal and administrative lines, the property ownership status and land use, the social and economic characteristics of the area, the period of building construction, and the energy supply infrastructure etc. The neighborhood of a small urban scale area (e.g. block/cluster of buildings) may include 5-15 buildings with a traditional composition extending over 200-400 m in size that can be crossed in 10-15 min walk, with 200-1500 inhabitants.

During the preparation phase, it is necessary to collect the necessary data in order to create a sufficient working basis. This is a very important phase and may be time consuming. Information may be scattered among different departments or even other organizations. Potential resources include the administrative bodies of the municipalities (e.g. building authorities, cadastral office, land surveying office), census data, municipality and regional reports (e.g. operational programs), existing energy performance certificates, energy supply companies, along with publically accessible resources (e.g. Google Earth, Open Street Map), and if necessary, field inspections.

Figure 10: Schematic of the overall process.

The diagnosis phase is facilitated using the SBTTool and SNTTool to evaluate the actual performance and relative level of sustainability of the buildings and the neighborhood. A SWOT analysis can be used to identify the main strengths and key weaknesses in terms of sustainability and identify any legal-technical-financial-environmental constraints that may limit the range of possible retrofit strategies. Legal constraints may result from building codes, mandates for improving the energy performance of buildings, and cultural heritage protection regulations. Technical constraints may limit the use of some technologies in building renovations, e.g. space availability for on-site installation of renewables on building rooftops or facades or near-by areas. Financial constraints are often the largest obstacles in renovation projects. Available funding sources must be secured early in the planning phase, taking advantage of different financing instruments. For building renovations, one needs to consider the financial status of the building owners, as well as the tenants, in order to avoid negative social impacts like gentrification. Environmental constraints are usually related to the local climatic conditions which may not favor some technologies or the exposure of building roofs and facades to solar radiation for the proper exploitation of thermal solar or photovoltaics.

Early in the process it is necessary to define clear and measurable targets that should be achieved by the project, covering all main aspects of sustainability, e.g. environment-energy, economy, social. The targets must be SMART, i.e. Specific (clearly defined), Measurable (quantifiable), Attainable (realistic and achievable), Relevant (for energy retrofitting of urban districts), Time-bound (with a specific time plan of when they can be achieved). Environmental targets should consider the means to improve energy performance, reduce greenhouse gas emissions, increase the share of renewables, prioritize the use of sustainable materials, reduce soil sealing and increase open natural areas. Targets related to the economy should consider means to improve return on investment, exploit the use of different instruments for financing, maintain affordable property and value of land, secure resources to strengthen economic feasibility and secure sustainable growth, and enhance local labor force participation. Social targets should avoid gentrification that may result from the energy renovation of buildings and neighborhoods, improve district surroundings (e.g. open spaces,

accessibility, heat island), improve transport infrastructure and mobility, encourage community involvement and citizen's engagement in near- and long-term planning, strengthen public services, improve safety and security.

The scenarios for improving the performance of a neighborhood should consider all the buildings in the area and seek synergies and opportunities to increase energy performance by prioritizing central energy supplies and district energy systems versus individual solutions, use environmentally friendly materials, enhance open green public spaces, improve public transport and mobility, and improve public infrastructures. At building scale, the priority is to improve energy performance of public buildings, reduce energy use and emissions from non-renewables, integrate renewables (e.g. consider thermal solar for domestic hot water or combi systems, use photovoltaics with appropriate energy storage and/or smart grids), expand central energy supply (e.g. natural gas network) and increase energy efficiency by prioritizing central energy networks over individual solutions. Engaging the citizens and building occupants in the process can provide valuable input to the experts and technical teams.

Different scenarios will be evaluated in a holistic approach along the following lines: a) selecting and optimizing energy renovations at a building and neighborhood scale (i.e. reducing energy demand, increasing energy performance by prioritizing central energy supplies versus individual solutions, integrating renewables with appropriate energy storage and/or smart grids); b) considering other interventions for improving public transportation and mobility, enhancing green spaces, and other public infrastructures; c) exploiting different business models and financing instruments; and finally d) identifying the desirable scenario that will address the municipality's objectives and priorities.

Considering the aggregated sustainability score for each scenario, it will be possible to select the best one that meets expectations and plans of the municipality or the public authority having jurisdiction, in-line with the local sustainability objectives and priorities, or the owner's intent (e.g. an authority that manages public buildings). The results can be easily communicated to the decision-makers to document the current state, summarize the proposed strategies of the final plan and illustrate the anticipated improved sustainability performance. Once a decision is taken to proceed with implementation, the concept will have to be elaborated in more detail including a cost-benefit analysis, exploit different business models and financing instruments, issue tenders and conclude with a contract. Following implementation, the local tools are ready to be used to assess whether the goals and objectives have been met and document actual progress for improving sustainability and monitor progress towards the performance targets. It is important that the results are properly publicized and communicated.

The overall process is supported by a comprehensive electronic CESBA MED Training Package for self and in-house education and training. The material facilitates the proper use of the method and tools, improve knowledge base, enhance the understanding of the various sustainability issues by the main target groups (e.g. engineers, technical staff, decision and policy makers) to set up and implement high quality and sustainable urban plans, and support continuous learning [18]. The training material is organized in different modules, including the GF concept and the multicriteria assessment methodology, the decision-making process, case studies, the assessment criteria of the contextualized tool at building and urban scale with a detailed presentation of the KPIs along with calculation examples. The electronic training material is available in different languages (e.g. Catalan, Croatian, English, French, Greek, Italian, Maltese, Spanish). The educational material was also used during national training courses that were held in the participating countries. To facilitate dissemination, the material will be available on an open e-learning platform for future use.

4 Conclusions

A multinational collaborative effort developed an open and transparent multicriteria assessment system for rating sustainability issues at different scales (i.e. building and urban neighbourhood). The tools can support the various stages of the decision making process in order to initiate, organize, adapt, evaluate and identify the best sustainable renovation strategies buildings or urban areas, and monitor progress towards sustainability.

At building scale, seven sustainability issues are addressed, including: A-Site & infrastructures, B-Energy & resources, C-Environment, D-Indoor environmental quality, E-Service quality, F-Social, cultural & perceptual aspects, and G-Economy, which are described and quantified with 154 sustainability criteria/indicators. Among them, 16 KPIs have been selected as mandatory indicators, which represent the priority sustainability transnational issues. At urban scale, seven sustainability issues are addressed, including: A-Urban systems, B-Economy, C-Energy, D-Emissions, E-Natural resources, F-Environment, and G-Social aspects, which are described and quantified with 178 sustainability criteria/indicators, including 16 KPIs for urban scale.

The common tools are available in English and different languages, while the assessment and rating approach have already been contextualized to national (local) context (Croatia, France, Greece, Italy, Malta and Spain). The method and the overall process have been successfully assessed during pilot projects in nine European cities. Detailed electronic educational material are also available in different languages that can be used for in-house training in order to improve the knowledge base and understanding on the various sustainability issues and indicators. The toolkit can be used by different target groups (e.g. engineers, technical staff, decision and policy makers) for setting up and implementing high quality sustainability urban plans.

CESBA MED can be tailored to fit public administrations' needs at a lower cost compared to other market available commercial systems, offering sufficient flexibility for adaptation to local needs and priorities, which strengthens a sense of local ownership. The ambition is to facilitate and improve the effectiveness and impact of sustainability policies, planning activities and action plans for local authorities, municipalities, cities and public authorities.

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