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A transnational multicriteria assessment method and tool for sustainability rating of the built environment

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Abstract. A new open access multicriteria European built environment assessment method and tool to support the assessment, planning and decision-making process for rating the sustainability of buildings and neighbourhoods was developed in the framework of a European project – CESBA MED. It addresses the main sustainability issues for buildings and neighbourhoods (e.g. site and infrastructure, urban systems, energy and natural resources, emissions and environment, service quality, social aspects, economy), which are described and quantified with an "exhaustive" list of sustainability criteria/indicators, including a small number of mandatory key performance indicators (KPIs) that represent the priority sustainability transnational issues. Six national versions of the tools have been developed and are available in different languages, which are contextualized to national (local) priorities, and were successfully assessed during pilot projects in Croatia, France, Greece, Italy, Malta and Spain. . The paper presents a short overview of the method, tools, KPIs and benchmarks, along with the main results from the pilots. The tools are envisioned to fit public administrations' needs at a lower cost compared to other market available commercial systems and offer sufficient flexibility for adaptation to local needs and priorities.

1. Introduction

The built environment is at the center stage of European and national sustainability efforts to minimize the use of energy and natural resources, and to alleviate environmental impacts. The United Nations Sustainable Development Goals (SDGs) in the Agenda 2030 [1] sets the main global challenges that include those related to cities for making them inclusive, safe, resilient and sustainable (Figure 1). The 2030 Agenda integrates in a balanced manner the three pillars of sustainable development - economic, social and environmental. In particular, SDG 11 "Make cities and human settlements inclusive, safe, resilient and sustainable" 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.

The European Union was instrumental in shaping the global 2030 Agenda and is a frontrunner for the long term implementation of the SDGs that are further enhanced with EU's policies and integrated in all the Commission's priorities [2]. In the area of energy and climate, SDG 7 "Ensure access to affordable, reliable, sustainable and modern energy for all" and SDG 13 "Take urgent action to combat climate change and its impacts", the EU has set ambitious 2030 targets to reduce greenhouse gas emissions, improve energy efficiency and increase the share of renewable energy. The amended Energy Performance of Buildings Directive (EPBD) EU 2018/844 that entered into force on 9 July 2018 is an integral part of the "Clean Energy for All Europeans" package, encouraging energy efficiency and promoting cost-effective building renovation, with the vision of a decarbonised building stock by 2050. As we approach the new era of new nearly-zero energy buildings (nZEB) as of January 2021 according to EPBD, the next big challenge is the renovation of the million existing buildings to improve their energy and environmental performance. These large scale efforts could best be served by addressing groups of buildings in urban neighbourhoods. Furthermore, other aspects come in to play for sustainable development in an urban context, including transportation, infrastructure and services, land use, natural resources, and social well-being among others. The specific goals are further enhanced at national level through national action plans, regional level and finally local level in the various municipalities, for addressing the SDGs and specific priorities. However, developing, monitoring and assessing local, regional and national plans towards sustainable development at building and urban scale, with a plethora of SDGs and sustainability issues, are complex undertakings. Despite the complexities, a bottom up approach with local actions will effectively drive the process to meet SDGs, following the concept "Think Globally, Act Locally".

Figure 1. Illustration of the interconnections among the World-EU-National-Regional-Local Municipality levels towards global goals.

At building scale, various sustainability rating systems have been developed (e.g. BREEAM, CASBEE, Green Star, LEED, ITACA) to facilitate the process for reducing energy use and environmental impacts during construction, management and operational phases [3]. The systems include different performance indicators that are used as metrics to determine how well the sustainability objectives are achieved, facilitate the decision making process, assess specific project requirements, or ensure compliance with regulations and norms [4]. The indicators quantify what one is trying to achieve and depending on specific project needs and priorities one may need to use several of them at different stages of the work or process. The indicators can be expressed as numerical values (e.g. building's energy use intensity in order to compare different performances or against other benchmarks; water consumption per building occupant, etc), or ratios and percentages (e.g. percent of renewables that cover power or heat demand; percent of recycled waste, etc). A voluntary reference framework known as LEVEL(s) is also being developed by the Joint Research Centre for the European Commission (http://ec.europa.eu/environment/eussd/buildings.htm) providing a common European approach for assessing environmental performance in the built environment. Each indicator links the building's individual characteristics (currently referring to only residential and office buildings) and impacts to sustainability priorities, facilitating users to consider key concepts and building-level indicators, following specific guidelines and standardized calculations for each indicator.

Several systems have also been extended to urban scale, e.g. BREEAM Communities, CASBEE for Urban Development, LEED for Neighbourhoods and Protocollo ITACA Urban Scale. 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 [5].

This paper presents an overview of an ongoing European project (CESBA MED) that enhances existing knowhow to develop a holistic method and system for accessing sustainability of the built environment. It addresses the main sustainability issues for buildings and neighbourhoods (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. The overall approach has been successfully tested in nine European Mediterranean cities that also revealed some practical insight on the common key performance indicators. A comprehensive training package is also available that includes electronic educational material for self and in-house training.

2. The CESBA MED Method

The initial concept of the assessment method and tool was a reference decision making process that was originally developed for the building scale [6] and then extended at urban scale. The following sections outline and briefly discuss the process for converging on the number of sustainability indicators that are considered in the method, the normalization and scoring process, the development of the generic framework and the national tools.

2.1. Sustainability indicators & KPIs

Given that there is still not a consensus on the definition of the sustainability indicators, 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. Accordingly, the first step was to review 14 transnational European projects and public assessment systems, in order to derive a representative list of indicators at building and urban scale that address the main sustainability pillars [7]. A total of 216 indicators at building and urban scale were identified and considered during the following work for organizing the various performance indicators under the main sustainability issues.

The general structure of the method is organized in Issues, Categories and Criteria-Indicators [8]. The "Issues" identify the general themes that are important for assessing the sustainability at building and neighbourhood (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 (EUI) can be expressed as kWh/m^2 or kWh/m^3 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. 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.

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/m^2'. 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.

A limited number of key performance indicators (KPIs) were selected from the various indicators as mandatory 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 (EUI in kWh/m^2), which can be used to benchmark against similar buildings or with best-practices and assess energy efficiency measures within buildings. The KPIs 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 (Figure 2). Starting with the results from the existing 14 EU projects & systems [7] and the LEVEL(s) indicators [9], each team of the partnership engaged and 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. The main steps for developing the CESBA MED system.

In an effort to reach a wider consensus, 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 two sprint workshops organized by CESBA (Common European Sustainable Built Environment Assessment https://www.cesba.eu/sprint-workshop) in Bezau, Austria (September, 2017) and Gozo, Malta (November, 2018). The final list of the KPIs for building and neighbourhood scale was determined following the nine national pilot tests performed by the partners in seven European countries. Some KPIs were excluded due to the limited availability of the necessary data, e.g. quantities of building construction materials and recyclable content that have been used for existing buildings or other public works in the area, thus ensuring the applicability of the approach and ease of calculating and using the KPIs in the field.

2.2. Normalization and Scoring

All sustainability assessment and rating systems use a normalization process in order to assign an individual score to the various indicators that have a diverse nature and numerical values with different orders of magnitude and units. Moreover, some indicators are even associated with qualitative criteria (without units since they do not represent any physical quantity). The assigned scores for individual indicator values are then aggregated to calculate a score for the corresponding categories, issues and finally an overall sustainability score.

2.2.1. Indicator Scores

Each indicator value is adimensionalized and rescaled (Figure 3) in an interval from -1 (performance below standard) to +5 (advanced performance), following a similar concept with [10]. The individual scores and their interpretation are summarized in Table 1. For example, the score value at "0" corresponds to the minimum acceptable performance of an indicator in compliance with minimum standard regulation mandates defined by law (e.g. an EUI for new buildings or the percentage use of renewables), or the value of current practice in case of no regulations (e.g. percentage of employment, length of pedestrian and bicycle paths). The score value at "+5" corresponds to excellence or ideal performance (e.g. an EUI for a nearly zero energy building, or very-high employment rate in a neighbourhood). Values of indicators below minimum standards or current practice are assigned to a score of "-1". A score of "+3" corresponds to best practice (or a significant improvement compared to existing regulations and common practice).

Table 1. The normalized scores and their interpretations.

Score	Interpretation
-1	The score corresponds to the value of an indicator that is below minimum acceptable performance.
0	The score corresponds to the value of an indicator that represents the minimum acceptable performance. It is usually defined according to relevant regulations and standards, or current practice.
1	The score corresponds to the value of an indicator that represents an improved performance over the minimum acceptable performance.
2	The score corresponds to the value of an indicator that represents a significantly higher performance relevant to the minimum acceptable performance.
3	The score corresponds to the value of an indicator that represents a best practice.
4	The score corresponds to the value of an indicator that represents an improved performance over the best practice level.
5	The score corresponds to the value of an indicator that represents an excellent and ideal performance.

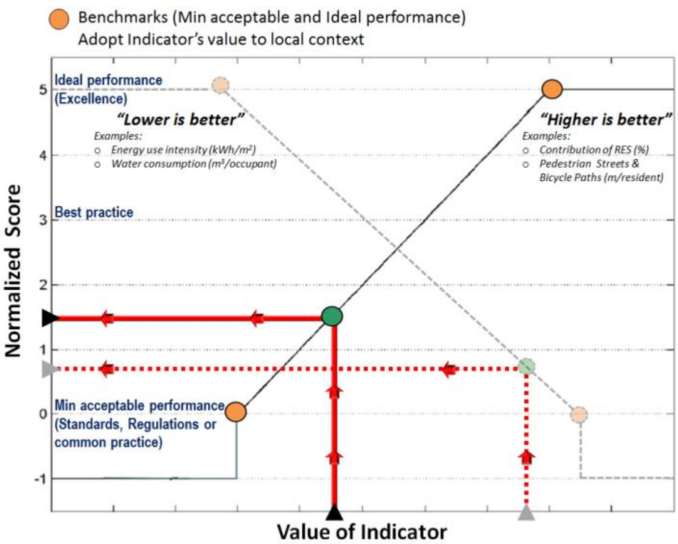


Figure 3. Normalizing and scoring process. For an indicator value following the principle "Higher is Better" the linear correlation is illustrated with the black solid line, while the principle "Lower is Better" is illustrated with the grey dashed line.

For simplicity, individual scores are defined by linear interpolation between the two limits (i.e. "0" and "+5"). For each indicator, the numerical values at the two limits are adapted to local context by using appropriate national, regional or local benchmarks. For some indicators, higher performance corresponds to a higher normalized score, following the rule that "Lower is Better" (e.g. a low EUI for buildings or low water consumption), so the linear correlation (from 0 to +5) has a negative slope. For others, the normalized score follows the rule that "Higher is Better", thus the slope of the linear correlation (from 0 to +5) is positive (e.g. the percentage use of renewables, the length of pedestrian and bicycle paths in a neighbourhood). In this case, a higher value of the indicator corresponds to a higher performance and thus it receives a higher normalized score.

The national and local benchmarks for each indicator have been predefined at the appropriate values for (ideal) excellent practice (corresponding to "+5" in the normalized score), the minimum acceptable performance (corresponding to "0") and below standard (corresponding to "-1"). These values are already included in the national and local versions of the method (see section 3). If needed, the user can adjust them according to the local characteristics (e.g. energy use intensities for the local buildings, water consumption in the area etc).

2.2.2. 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, to reflect regional variations and add local context. For each issue, 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, the issue of energy use may be set at level 2 (considered of average importance since the buildings have an average energy performance and a good exploitation of renewables), while for the issue of emissions in an area with major environmental problems the assigned priority may be set at level 3 (i.e. considered a major issue).

Selecting an appropriate number of active indicators (that always include the KPIs), which best fit the local needs and priorities of a project under each category and issue, the weighting factors are first equally distributed among the active indicators for a total of 100%. These 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 (neighbourhood 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 3.1) include national default values, although a user can always adjust them.

Next, the normalized scores associated with all criteria in the same category are aggregated to produce a single score for each category. Then, the scores for the categories in the same issue are further aggregated to produce a single score for each issue. Finally, the results from all the issues are then aggregated to produce a final concise sustainability score for the project. This process provides the ability to use different weight coefficients (a percentage 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.

2.3. The Generic Framework

The CESBA MED Generic Framework (GF) is the general, all-inclusive starting version of the tool that supports the assessment method (Figure 4). It includes seven sustainability issues for the building scale, i.e. A-Site & infrastructures, B-Energy and resources, C-Environment, D-Indoor Environmental Quality (IEQ), E-Service quality, F-Social, cultural and perceptual aspects, G-Economy, and seven sustainability issues for the urban (neighbourhood) 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 that describe specific aspects of the sustainability 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.

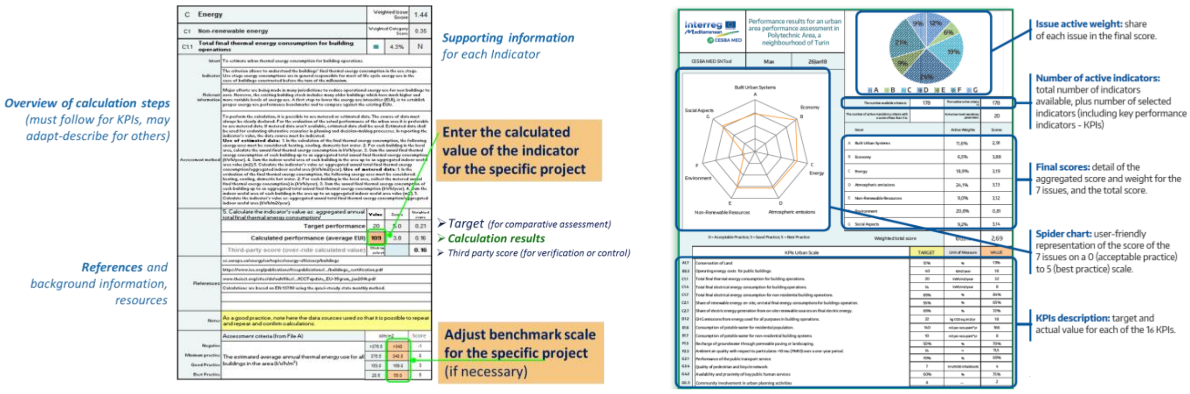
Some representative examples of the method’s GF structure are presented next. For the building scale: Issue “B-Energy and resources”, Category: “B1-Life cycle non-renewable energy”, Criteria: “B1.1-Primary energy”, Indicator: “B1.1-kWh/m^2/y”; Issue “C-Environment”, Category: “C1-Greenhouse gas emissions”, Criteria: “C1.3-Global warming potential”, Indicator: “C1.3-kg CO_2 eq./m^2/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/m^2/y”.

Figure 4. Structure of the CESBA MED Generic Framework (GF) sustainability issues (i.e. A-G), categories (total number of criteria-indicators in parenthesis) and key performance indicators (KPIs), for building scale (top) and neighbourhood scale (bottom).

The total number of indicators in the GF that one can potentially select from and use is 153 and 178 [11], 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. For practical purposes, one should select a manageable number of indicators from the complete list under the various issues and categories that best match the local sustainability issues, priorities and strategic policies of a given project. During the development of the national tools (refer to section 3) this exercise has already been elaborated for adapting the GF Tools in the national context. Since it is not necessary to use all the available indicators in a project, the GF provides a large pool of potential indicators from which one can easily select the ones that best match the specific local sustainability priorities and project intent. The minimum numbers of indicators are the key performance indicators that were determined as a result of the main steps and the iterative process for developing the CESBA MED GF (Figure 2) reached 13 KPIs for the building scale that includes most of the LEVEL(s) indicators, and 16 KPIs for the urban scale [12]. 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 neighbourhoods between different areas, cities, regions and countries.

2.4. The Generic Framework Tools

All the indicators are analytically presented in the building and urban scale GF tools. The presentation of each indicator includes an overview of calculation steps that one must follow for KPIs and may adapt or describe a different method for other indicators (Figure 5a). 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/m^2) for a specific project. Under the assessment criteria, the tool automatically transfers the default benchmark values that correspond to the scale (-1, 0, 3, 5). These values may be further 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 strictly comply with conventional high performance standards). Entering the numerical value of the indicator, the tool estimates a 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 a third-party score that can be used during verification. The final results (Figure 5b) 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 over-view of the KPIs.



(a) (b)

Figure 5. Exerts from the GF Tool; a) Presentation an indicator and interface for benchmarking and scoring; b) Overview of the main final results.

2.5. The Decision Making 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 [13]. 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 6) can support all phases of a project for major renovations or new developments. 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.

The first step is to define the physical boundaries and decide which of the surrounding infrastructures are of relevance (Figure 6). 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 neighbourhood 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 administrative bodies of the municipalities and other organizations (e.g. building authorities, cadastral office, land surveying office) and other resources like 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.

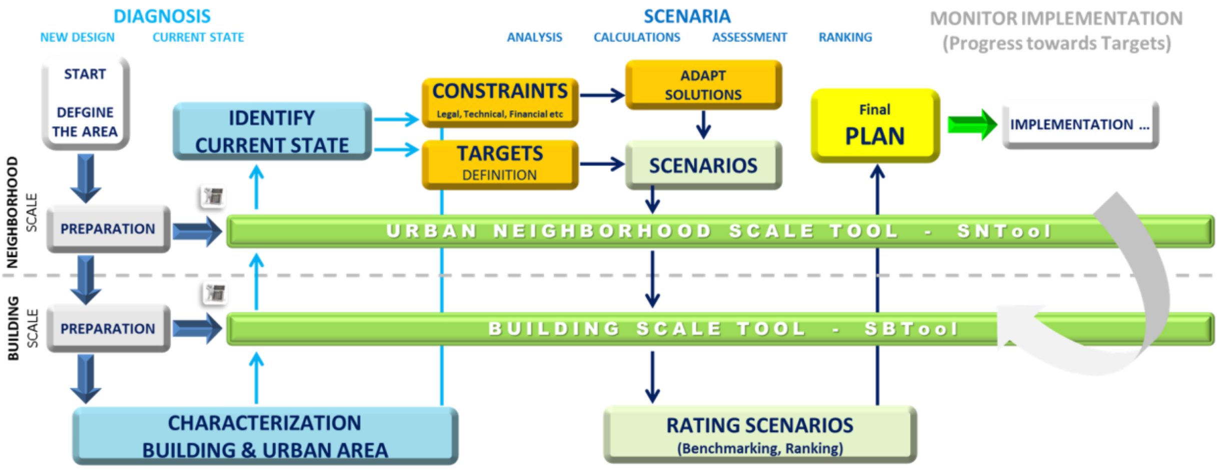


Figure 6. Schematic of the overall process.

The diagnosis phase is facilitated using the sustainable building tool (SBTool) and the sustainable neighbourhood tool (SNTool) to evaluate the actual performance and relative level of sustainability of the buildings and the neighbourhood. 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, man-dates 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 favour 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 retrofit-ting 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 labour force participation. Social targets should avoid gentrification that may result from the energy renovation of buildings and neighbourhoods, 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 neighbourhood 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 neighbourhood 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, one can 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 [14]. 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, and Spanish that is available on an open e-learning platform (https://cesba-med.research.um.edu.mt/moodle/course/index.php). The educational material was also used during 17 national pilot training courses that were held in the participating countries with about 275 participants.

3. Pilots

A total of nine pilots were performed in six countries, in Athens at the municipality of Fylis (Greece), Barcelona (Spain), Lyon (France), Msida (Malta), Marseille (France), Sant Cugat (Spain), Torino (Italy), Udine (Italy) and Solin (Croatia). These exercises served two main purposes. First, working together with local experts and municipalities, they allowed the development of national versions of the SBTool and SNTool, by selecting a suitable number of indicators, translating and adapting the tools with the appropriate national priority weights for the different sustainability issues and benchmarks for normalizing the values of the indicators. This way, the default values in the national versions of the tools are ready to be fine-tuned, if necessary, to better match the local characteristics (e.g. energy use intensities for the local buildings, water consumption in the area, etc.). Second, the pilot results revealed the most popular sustainability indicators that were selected by each national team that illustrate the emphasis and the priorities given by the different municipalities, allowed a practical verification of the applicability of the overall method and the decision making process, and finally verified the KPIs in the field in order to ensure that the necessary input data are available and that they can be consistently calculated.

3.1. National tools

The GF Tools are available in English, while the national contextualized assessment tools for sustainable buildings (SBTools) and neighbourhoods (SNTools) are available in different languages (Catalan, Croatian, French, Greek, Italian, Spanish). The national tools include the same KPIs, but use a different number of categories, criteria and indicators (Figure 7) that best fit in the national and local context and sustainability priorities.

As a first step, each national team selected from the Generic Framework the indicators that are most relevant according to their national sustainability priorities and are commonly encountered at regional-local issues. For example, the generic framework for the neighbourhood scale includes a total of 23 categories and 178 criteria-indicators, while for the national tool in Greece has a total of 16 categories and 44 criteria-indicators. The only core set of criteria that is mandatory, are the KPIs that represent internationally recognized priorities for sustainability assessment.

According to the pilot test results, the selected number of sustainability criteria averaged 28 indicators at building scale and 39 indicators at urban scale (Figure 7). The sustainability issue that has attracted more emphasis based on the number of selected indicators was “B-Energy and Resources” with 32% of the total number indicators used at building scale and “G-Social Aspects” with 26% of the total at urban scale.

For each one of the selected indicators, the national teams in collaboration with local committee experts specified the local benchmarks, i.e. the values that correspond to the appropriate local

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excellent practice (corresponding to “+5” in the normalized score), the minimum acceptable performance (corresponding to “0” in the normalized score) and below minimum standard (corresponding to “-1” in the normalized score). This information was used to benchmark the values for each indicator and normalize them (see section 2.2.1) on the -1 to 5 points scale.

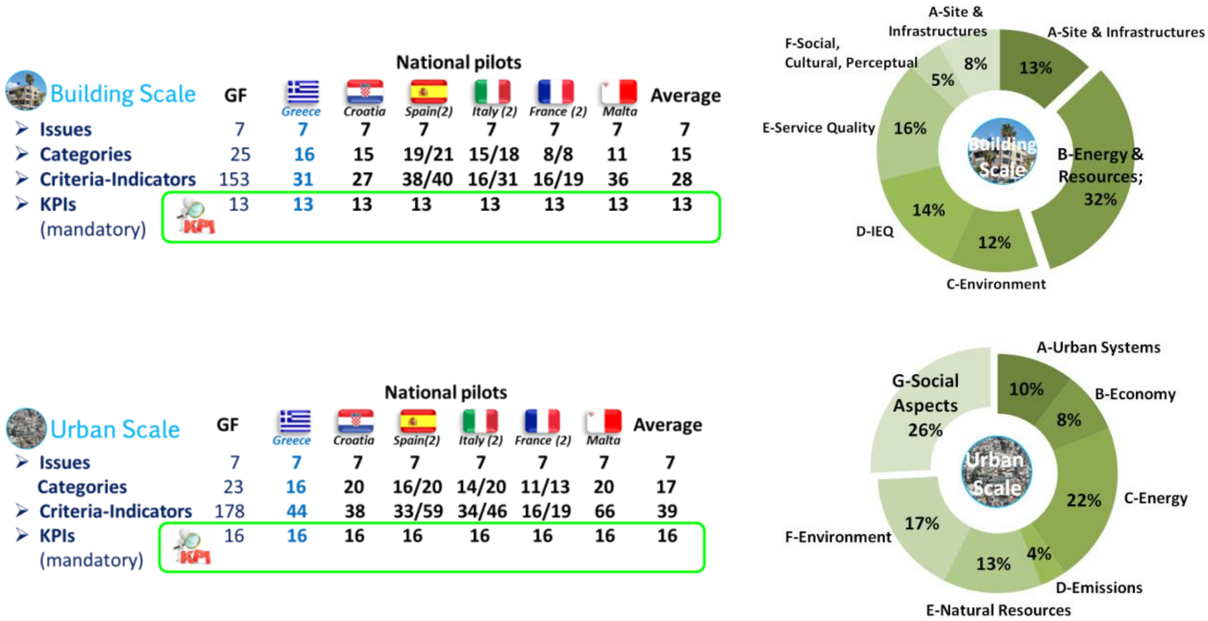

Figure 7. Overview of the sustainability issues, categories, and criteria-indicators used in the generic framework (GF) and the national framework tools.

The pilot test results and national tools also revealed some useful insight with regard to the range of benchmarks for the KPIs from the different regions (Table 2). The values can provide initial guidance for the future development of similar tools in other regions.

Table 2. Summary of KPI benchmarks (minimum and best values) for the building scale (top) and the urban scale (bottom) used in the national framework tools.

Code	Building Scale Key Performance Indicators (KPIs)	Units	Value	Torino	Udine	Marseille	Lyon	Barcelona	Sant Cugat	Fylis	Solin	Average
B1.1	**Primary energy use**	kWh/m²/y	*Minimum*	80	140	48	140	225	292	310.6	90	**165.7**
			Best Value	30	23	0	0	70	58	87.6	55	**40.5**
B1.2	**Final thermal energy use**	kWh/m²/y	*Minimum*	70	80	40	130	22	75	69.1	50	**67.0**
			Best Value	20	10	0	30	12	20	11.5	10	**14.2**
B1.3	**Final electrical energy use**	kWh/m²/y	*Minimum*	30	23	40	140	75	70	99.4	30	**63.4**
			Best Value	20	5	0	0	20	30	29.1	0	**13.0**
B1.5	**Renewables in final thermal energy use**	%	*Minimum*	30	25	25	10	30	30	16	20	**23.3**
			Best Value	100	50	100	100	100	100	80	90	**90.0**
B1.6	**Renewables in final electrical energy use**	%	*Minimum*	40	35	10	10	40	40	20	5	**25.0**
			Best Value	100	75	200	100	100	100	100	90	**108.1**
B1.11	**Embodied non-renewable primary energy**	MJ/m²	*Minimum*	2500		180	900			6230	14	**1964.8**
			Best Value	1000		90	504			3000	3	**919.4**
B4.5	**Water consumption for indoor uses**	m³/occupant/y	*Minimum*	40	47	40	90	100	11	6	5.5	**34.2**
			Best Value	25	23	20	20	20	5	1.5	2	**13.8**
C1.3	**Global warming potential**	kg CO_2 eq./m²/y	*Minimum*	30	28	20	80	30	96.31	7.5	40	**43.1**
			Best Value	0	5	5	5	10	19.26	2	5	**5.9**
C3.2	**Solid waste categories recycled**	%	*Minimum*	50	14	0.4	0.4	15		57	28	**23.5**
			Best Value	80	100	1	1	100		100	100	**68.9**
D1.10	**Ventilation rate**	Lt/s/m²	*Minimum*	10	0.35	0.5		6		0.29	2.77	**3.3**
			Best Value	20	0.49	0.9		12		0.83	6	**6.7**
D2.2	**Thermal comfort index**	%	*Minimum*	10	10	10	10	25	10	25	25	**15.6**
			Best Value	0	6	5	0	5	0	5	5	**3.3**
G1.4	**Operational energy cost**	€/m²/y	*Minimum*	20	10.7	15	15	60	35	18.9	7.5	**22.8**
			Best Value	10	1.75	5	5	40	10	4.7	1.5	**9.7**
G1.5	**Operational water cost**	€/m²/y	*Minimum*	5	1.55	10	13		5	0.59	0.5	**5.1**
			Best Value	1	0.7	3	2.3		1	0.15	0.2	**1.2**

Code	Urban Scale Key Performance Indicators (KPIs)	Units	Value	Torino	Udine	Marseille	Lyon	Barcelona	Sant Cugat	Msida	Fylis	Solin	Average
A1.7	Land conservation	%	*Minimum*	0.5	7	15	10	4	10	10	10	2	**7.6**
			Best Value	2	42	30	20	15	20	28	20	10	**20.8**
B3.3	Operational energy cost for public buildings	€/m^2/yr	*Minimum*	7.4	10	14	14	20	13.56	100	17.7	100	**33.0**
			Best Value	4	3	3.5	3.5	10	3.33	0	4.1	0	**3.5**
C1.1	Total final thermal energy consumption for buildings	kWh/m^2/yr	*Minimum*	70	80	40	50	75	76.23	50	314	100	**95.0**
			Best Value	30	10	0	0	20	33.8	0	21.1	50	**18.3**
C1.4	Total final electric energy consumption for buildings	kWh/m^2/yr	*Minimum*	50	23	12	55	70	29.85	25	64.2	75	**44.9**
			Best Value	20	5	0	5	20	10.88	5	7.9	50	**13.8**
C1.7	Total primary energy consumption for buildings	kWh/m^2/yr	*Minimum*	322	72	40	140	225	152	50	461.9	100	**173.7**
			Best Value	242	50	0	0	70	15	15	38.2	70	**55.6**
C2.1	On-site renewables in total final thermal energy consumption	%	*Minimum*	20	25	25	30	25	25	25	4	5	**20.4**
			Best Value	100	50	100	100	90	90	90	14	30	**73.8**
C2.7	On-site renewables in total final electrical energy consumption	%	*Minimum*	20	35	25	35	15	15	35	1	20	**22.3**
			Best Value	100	75	200	75	75	75	75	47	35	**84.1**
D1.2	Total GHG Emissions from energy use in buildings	kg CO_2 eq./m^2/yr	*Minimum*	22.5	13	20	30	30	30	80	46	22	**32.6**
			Best Value	0	11	5	10	10	10	30	5	15	**10.7**
E1.6	Water consumption in residential buildings	m^3/occupant/yr	*Minimum*	65	47.45	40	68	150	150	15	62.1	250	**94.2**
			Best Value	61	23.7	20	30	40	60	5	18.6	100	**39.8**
E1.7	Water consumption in public buildings	m^3/m^2	*Minimum*	1	1.3	5	1.1	15	15		0.65	5	**5.5**
			Best Value	0.5	0.6	2	0.4	5	5		0.33	3	**2.1**
F1.3	Recharge of groundwater through permeable paving/landscaping	%	*Minimum*	20	40	20	20	20	20	20	15	20	**21.7**
			Best Value	40	60	70	100	70	70	100	80	80	**74.4**
F2.3	Ambient air quality (PM10) above acceptable limits	days/yr	*Minimum*	35	35	30	30	15	15		35	20	**26.9**
			Best Value	25	0	11	11	11	11		0	15	**10.5**
G2.1	Proximity of residents to public transport	%	*Minimum*	70	60	50	0	30	30	30	50	5	**36.1**
			Best Value	100	100	100	100	100	100	100	100	40	**93.3**
G2.4	Pedestrian & bicycle network	m/100 inhabitants	*Minimum*	14	43	15	200	20	5	5	2	0	**33.8**
			Best Value	42	129	40	50	80	40	40	20	500	**104.6**
G4.2	Proximity of residents to key services	%	*Minimum*	80	30	30	30	30	50	50	50	20	**41.1**
			Best Value	100	80	100	100	80	100	100	90	70	**91.1**
G6.3	Community involvement in urban planning (qualitative score)	level (score)	*Minimum*	0	3	0	0	0	0	0	0	0	**0.3**
			Best Value	5	5	5	5	5	5	5	5	3	**4.8**

The weights defined in the national versions of the tools for each one of the seven sustainability issues from 1 (less important) to 3 (most important or more relevant) reveal the regional priorities and policies or project intent. As summarized in Table 3, for the building scale, the sustainability issue "B-Energy & Resources" stands out with the strongest priority. Along with "C-Environment" they are the two most prominent issues, averaging together ~80%. For the urban scale, lower weights were consistently used for "B-Economy" illustrating that once there is a commitment for sustainable development, the economic criteria have a lower priority. The sustainability issue related to "C-Energy" stands out by averaging 26.6% among all the pilots, although different regions focus on diverse sustainability issues by allocating higher weights based on their local priorities.

Table 3. Summary of the weights on different sustainability issues, for the building scale (top) and the urban scale (bottom) used in the national framework tools.

Building Scale Sustainability Issues	Torino	Udine	Marseille	Lyon	Barcelona	Sant Cugat	Msida	Fylis	Solin	Average
A-Site & Infastructures	0.0%	0.0%	0.0%	0.0%	4.9%	11.6%	7.0%	6.5%	7.6%	**4.2%**
B-Energy & Resources	58.0%	69.8%	72.0%	72.0%	62.9%	54.9%	31.6%	28.5%	51.2%	**55.7%**
C-Environment	23.0%	24.3%	25.0%	25.0%	19.5%	20.4%	23.6%	36.6%	19.5%	**24.1%**
D-IEQ	11.0%	4.2%	2.0%	2.0%	2.1%	1.5%	2.0%	0.5%	8.0%	**3.7%**
E-Service Quality	0.0%	0.0%	0.0%	0.0%	7.9%	8.1%	20.7%	12.6%	3.2%	**5.8%**
F-Social, Cultural, Perceptual	0.0%	0.0%	0.0%	0.0%	1.9%	2.7%	12.0%	4.3%	5.1%	**2.9%**
G-Economy	8.0%	1.8%	2.0%	2.0%	0.8%	0.8%	3.1%	11.0%	5.5%	**3.9%**
Lowest weight										
Highest weight										

Urban Scale Sustainability Issues	Torino	Udine	Marseille	Lyon	Barcelona	Sant Cugat	Msida	Fylis	Solin	Average
A-Urban Systems	11.6%	10.4%	18.9%	0.0%	6.5%	10.2%	13.5%	4.6%	12.2%	**9.8%**
B-Economy	1.7%	6.6%	5.0%	1.8%	9.1%	3.6%	1.8%	3.9%	4.6%	**4.2%**
C-Energy	41.1%	18.4%	30.5%	28.2%	26.7%	25.9%	16.2%	31.1%	21.5%	**26.6%**
D-Emissions	6.9%	14.3%	23.6%	33.9%	7.3%	12.7%	5.8%	13.6%	13.3%	**14.6%**
E-Natural resources	6.9%	14.1%	3.4%	8.7%	7.3%	10.1%	11.7%	10.7%	14.3%	**9.7%**
F-Enviornment	18.3%	15.7%	9.4%	9.9%	31.3%	23.8%	28.7%	16.8%	9.0%	**18.1%**
G-Social Apsects	13.4%	20.5%	9.1%	17.4%	15.4%	13.6%	22.3%	19.3%	25.0%	**17.3%**

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 neighbourhoods.

4. Conclusions

A new open and flexible multicriteria assessment system for rating sustainability issues has been developed that can be used to support the various stages of a decision making process in order to initiate, organize, adapt, evaluate and identify the best sustainable renovation strategies for buildings or urban areas, and monitor progress towards achieving sustainability targets.

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 153 sustainability criteria/indicators. Among them, 13 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.

The common tools are available in English and different languages, while the assessment and rating approach have been contextualized to national (local) context for Croatia, France, Greece, Italy, Malta and Spain. The method and the overall process have been successfully assessed during pilot projects in nine European cities. Supporting 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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