ACTIONS FOR A SUSTAINABLE WORLD

FROM THEORY TO PRACTICE

BOOK OF PAPERS

ISDRS 2018

MESSINA

THE 24th INTERNATIONAL SUSTAINABLE DEVELOPMENT RESEARCH SOCIETY CONFERENCE

MESSINA · ITALY JUNE 13/15 2018

The 24th International Sustainable Development Research Society Conference (ISDRS 2018)

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13-15 June 2018, Messina (Italy)

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Edited by: The Organizing Committee of the ISDRS 2018 Conference

ISBN 978-88-943228-6-6

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A tool for urban sustainable retrofitting processes

A customizable and interactive index to support decision-making and cultural sustainability in urban areas

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Abstract

With half of the world population currently living in urban areas, the built environment plays a fundamental role in sustainable development, as well as the behaviour of its inhabitants. While retrofitting existing buildings is an efficient way to reduce environmental impacts, many European cities feature extended and relevant historic centres where energy efficiency improvements can be difficult to achieve without compromising the urban traits. The paper proposes a flexible, customizable and interactive index that takes into consideration both physical and cultural sustainability to support decision-making in urban design and retrofitting processes. It provides a detailed description of the methodology adopted to develop this index, its functionalities and further improvements, disclosing a new way to deal with the historic urban fabric in a sustainable perspective.

Keywords: Decision-making; Sustainability index; Retrofitting; Interactive tool; Cultural sustainability

1. Scenario: sustainability and urban fabric

The problems related to the energy / city relationship represent one of the major challenges that contemporary society will have to face in the coming decades. In fact, in terms of "final energy" consumption (the fraction of primary energy actually available after transformation) buildings use 32% of total consumption, while in terms of "primary energy" consumption (natural energy sources not having undergone any processing or transformation) the percentage rises to 40% (Condotta, 2015). Urban areas are the main consumers of energy, above all for heating and cooling necessities, and the variety and quality of their building stock are of primary concern when addressing the sustainable development topic.

The retrofitting process, both of single buildings and entire districts, is still an untapped opportunity that could considerably contribute to cut energy consumption in cities (Pili, et. al., 2013). However, such opportunity has to face the reality of our built environment. ‘Over 30% of the existing building stock in Italy consists of buildings built before 1945 (…) a proportion in line with the European average. Unlike for new edifices, where building processes and technological solutions already meet the principles of sustainability, in the case of historic contexts a deeper reflection is needed to define sustainable refurbishment and renovation of the building stock (…); that implies an affirmative agreement by different agents on different levels’ (GBC HB, 2016).

How is it possible to conciliate sustainability issues with the traits of existing European cities? To answer this question, it is worth recalling – as pointed out in “*La lunga durata del progetto e sostenibilità*” (Albrecht, 2014) – that ‘the first author to use the word "sustainability" with today's meaning was probably Hans Carl von Carlowitz (1645-1714), who in his book *Sylvicultura Oeconomica* of 1713 called for a *nachhaltende Nutzung*, that is a *sustainable use of forest resources’* (Grober, 2007). *Nachhaltigkeit* means “sustainable” in German, literally “durable”, and expresses the ability to keep control of something over time, as the French term “*durabilité*” does’ (Du Pisani, 2006). The concepts of “preservation”, “protection”, and “maintenance” are of fundamental relevance and globally accepted when referring to the sustainability of natural resources, but whenever we speak of sustainability of human surroundings and design, some of these concepts grow weaker, as in the case of “environmental design”. With different nuances and levels of awareness, the original aim of environmental design was the well-being of the people in their living environment. Yet, the emerging ecological challenge has affected this overall vision, comprehensive and rich in meanings and consequences (for example, the development of human-centred approaches to design, and the performance-based and participatory design methodologies), causing it to suffer a progressive flattening on issues regarding energy savings, environmental sustainability and governance' (Lauria, 2017). In this sense, even though it is generally acknowledged that sustainability spans several fields of interest – involving the economic, social, political and environmental domains – it appears that when it comes to building analysis, assessment systems used to determine whether a building is sustainable focus predominantly on quantitative issues and rarely consider the qualitative aspects of sustainability that involve the social and cultural domains and cultural heritage in particular (Powter, Ross, 2005).

This framework helps us to support a comprehensive vision of sustainability, also when it is related to buildings inside urban areas. Sustainability is not only a "green building" matter and the energy savings, environmental sustainability and governance aspects must be integrated with the preservation topic, in accordance with the concept of sustainability intended as *Nachhaltigkeit*. In the case of the urban environment, the elements that must be preserved and made "durable" to guarantee the 'well-being of the people in their living environments' are the urban space and its constituent parts. The latter can be historic listed buildings, but also existing buildings that are not heritage-listed play a fundamental role in shaping a nice, homely and cosy urban space and deserve our attention. Since historic centres took centuries to develop, they usually have a pattern whose structure has been forming through time using different construction techniques and materials, each one of them representative of a certain stage of the historical evolution of the city. 'The concept of heritage has expanded considerably in the past three or four decades. Previously confined to architectural and artistic masterpieces, heritage has evolved to include landscapes, industrial and engineering works, vernacular constructions, urban and rural settlements, and intangible elements like temporary art forms, skills and ways of life' (Powter, Ross, 2005). This widening dimension is stressed also by the EC Communication COM (2014) 477 about an integrated approach to cultural heritage for Europe, which maintains that 'heritage has many dimensions: cultural, physical, digital, environmental, human and social. Its value – both intrinsic and economic – is a function of these different dimensions and of the flow of associated services.' Moving beyond monuments or listed buildings, this perspective recognises the importance of all the elements composing urban space in a certain historic context. Therefore, if our aim is to improve the environment surrounding us, we should take into account a wider portion of a city's building stock- and that poses a bigger problem concerning how to act: most of the times buildings have poor energy efficiency and there is only a limited number of retrofitting options available that would not compromise their appearance and distinctive features.

In the light of the above, reconciling the principles of green building design with those of cultural sustainability appears essential. As reported by the Buildings Performance Institute Europe in the factsheet concerning the state of the EU building stock, 'a decarbonised building stock by 2050 means that the vast majority of buildings in the EU should be highly energy efficient, having, at least, an Energy Performance Certificate (EPC) label A' (BPIE, 2017). However, their analysis shows that less than 3% of the buildings really meet required criteria. Although the first EU building regulations on the subject were issued in the early 1990s, in the following two decades 'the standard of building envelope insulation was not sufficiently efficient' (BPIE, id.), and we have inherited a building stock in need of retrofitting larger than people usually think.

Being aware of the actual situation is essential: since buildings are responsible for around 40% of energy consumption (Condotta, id.) their residents and users play an active role in achieving improvements. To make occupants more aware of the 'energy behaviour' of the building they live or work in, it is necessary to provide them with information tools able to describe how the building-user interaction works, so that they can adopt informed behaviours and decisions. Moreover, reaching an appropriate level of awareness would mean to foster cultural sustainability in a wider perspective. On the other hand, collecting data about the urban fabric and its features - in terms of impacts, durability and energy waste - would be useful for general government (public administration-PA) actions intended to support energy savings policies and to provide guidance for renovation projects involving private properties, public areas and buildings. In this way, the urban environment would be improved in all its parts.

Setting out a general goal to reduce, by 2020, energy consumption by 20%, the 2010/31/EU directive addresses energy efficiency in buildings considering new constructions, major renovations (defined either in terms of a percentage of the surface of the building envelope or in terms of the value of the building) and installations. This regulation represents a major step forward towards sustainability with the introduction of the nearly zero-energy building (NZEB) criteria for every new construction, while in the case of existing buildings, a distinction is made between buildings officially protected as part of a designated environment and those which are not: for the former, Member States may decide not to apply minimum energy performance requirement – as their historic and artistic value is recognised and judged more important than energy efficiency. Any other existing building undergoing major renovation has to meet the energy performance criteria identified at national level, regardless of its features, construction period or distinctive traits. Given Europe's widely varied building stock, the lack of more specific regulations makes it difficult to identify the design approach that best fits the context: meeting sustainability goals is dependent upon economics, community, social values and culture (Powter, Ross, 2005).

On these grounds, we believe that sustainability is to be understood as a process that involves planning, environmental management activities and decision-making. There is clearly a need for a more comprehensive and pragmatic vision when approaching the retrofitting of a urban environment –one of the major challenges of contemporary society. In our opinion, an instrument is needed that can be tailored to the specific situation and is capable of analysing the urban pattern in all its features incorporating the sustainable perspective described in the previous paragraphs. That would allow citizens, designers and government authorities to decide where to operate, depending on the necessities.

2. Tools for urban sustainable retrofitting: State of the Art

The point of view illustrated above – and the need to go beyond energy performance issues when dealing with urban and building sustainability – has already been discussed both at regional and building level in some studies and by some work groups that deal with the topic of building sustainability. At territorial and urban level, a deeper knowledge of the features of the built environment can provide essential elements to guide local policies in all fields – cultural, economic, and environmental – contributing to a sustainable future of the communities involved. In this respect, some EU projects have looked at the topic from a wider and transnational perspective for the purpose of finding solutions to their shared interests after investigating complex systems in different areas.

The CAT-MED project (Changing Mediterranean Metropolises Around Time - http://www.catmed.eu) aimed to create a platform for sustainable urban projects for cities in the Mediterranean area. It was launched by a transnational partnership of eleven metropolitan cities in Southern Europe to identify operational solutions that could be used to change urban behaviours to lower the environmental impact of urbanisation and limit greenhouse gas emissions. The main goal was to promote a sustainable, compact and multi-functional urban model, showing the best characteristics of Mediterranean cities and highlighting their ability to save natural resources in the face of global climate change. The work methodology involved, as a first step, the identification of a common system of urban sustainability indicators belonging to four main fields: Territorial management and Urban design, Mobility and Transports, Natural resources management, and Social and economic cohesion (parameters such as the percentage of pedestrian streets or the proximity to basic facilities were considered). Such indicators were used to track the evolution of the urban systems over a certain period of time. An analysis of the results made it possible to determine if the indicators – which each partner applied to a pilot area - were approaching the desirable range or, conversely, were drifting away from it. The project aimed at showing how the classical European and Mediterranean city, historically compact and complex, can serve as an example of an urban sustainable organization, thanks to its potential efficiency in the use of natural resources and close interpersonal relationships.

In a completely different context, the CESBA Alps Interreg project (http://www.alpine-space.eu/projects/cesba-alps) aims to improve sustainability in the built environment of the Alpine territory through the development of an assessment tool at a territorial scale (CESBA STT), contextualized to include regional specificities. This instrument will be the common base for the project partners to develop regional harmonized and compatible assessment tools able to rate the level of sustainability at a territorial level. It is conceived to support both decision-making policies and the monitoring of low-carbon policies over time. Indicators were selected, among other things, having regard to the EU 2020 targets, the UN 2030 Agenda and the EUSALP Action Plan. Each qualitative or quantitative indicator is associated to an assessment criterion, allowing to measure the performance levels reached by a certain territory. A first module concerns the effectiveness and quality of local policies in terms of participation and governance, while a second one is related to the performance in 5 main domains, namely: Territories and Environment, Energy and Resources, Infrastructures and Services, Society, Economy. This tool can be applied to support a decision-making process targeted to identify the best strategies to improve the sustainable qualities of a region.

Focusing on a smaller scale, several assessment tools concerning building sustainability have recently been developed to evaluate retrofits carried out in historic buildings. Environmental and energetic sustainability was once considered to be impossible to achieve in restoration projects, especially in the case of listed buildings. Not only is the range of materials and installations suitable for use rather limited, but the buildings themselves have features that are unlikely to meet current criteria, not to mention the fact that the location and orientation of the buildings are given data. Thus, these assessment tools had to balance ecological and energetic sustainability needs with cultural issues.

The GBC HB Italia (Green Building Council Historic Buildings®) aims at narrowing the gap between environmental sustainability and restoration knowledge and theories, to achieve the preservation and promotion of cultural heritage in its physical substance. That is why, in addition to the traditional categories of the LEED® rating system, the Historic Value domain was introduced to assess retrofit projects involving historic buildings, so as to determine if preservation needs can be reconciled with European energy efficiency requirements aimed at reducing the environmental impact of the building stock. In the 1.0.2016 version the percentage weight of the new Historic Value category on the total score is 18%, just behind Energy and Atmosphere (26%) and ahead of Indoor Environmental Air Quality (15%), with an equal focus on all the typical phases of the restoration project: the preliminary survey, the designing phase and the building site. An in-depth knowledge of the building’s construction features is essential for planning measures, as are the principles of reversibility, compatibility and durability, with special attention being paid to planned or preventive maintenance.

Also BREEAM® issued a protocol for the Sustainable Refurbishment of Heritage Buildings concerning the sustainable improvement of buildings which are either listed or located in conservation areas. Besides the complexity of renovation works, it is unlikely that historic buildings can be assessed using the standard metrics that apply to new buildings. This led to the introduction, in 2014, of several changes to the scheme layout with the intent of providing more flexibility for renovation projects: four new thematic categories (Fabric and structure, Core services, Local services, Interior design) allow the certification to focus on a certain dimension, depending upon the scope of the work. Moreover, several changes were made to the Energy, Materials and Water categories to take into consideration the specific features of the heritage building being assessed, focusing on all feasible physical improvements that can combine preservation and energy performance, fostering a qualitative approach rather than setting specific performance targets.

Since listed buildings are excluded from the 2010/31/EU directive, also European projects focused their research on the chance to improve the sustainability of historic buildings or neighbourhoods. The Intelligent Energy Europe project SECHURBA (Sustainable Energy Communities in Historic URBan Areas) involved partners from seven Member States, with the aim to investigate whether cultural heritage can be an opportunity for carbon reductions rather than a barrier. Audits conducted on historical buildings revealed large energy saving potentials. Moreover, a software-based multi-criteria tool was developed to help decision-makers with projects involving historic buildings and historic areas. Once the goal has been agreed upon, a building analysis is conducted and a hierarchy of the decisions to make can be established: it is possible to undertake the assessment achieving a final ranking of the alternatives. Social, financial and political points of view are also taken into account.

This overview of the State of the Art shows that, thankfully, cultural traits are becoming a relevant feature when considering sustainability: assessment schemes and urban quality indicators include the cultural and social issues in their ranking systems.

While on the one hand this represents a welcome improvement, on the other hand some of the tools lack flexibility. This is not due to a shortcoming of the tools themselves – in fact they all perfectly carry out the tasks they have been designed for – but they operate in their application field without considering a wider perspective. In fact, when looking at energy savings, physical improvements and environmental sustainability, these tools mainly consider actions planned for a single building (the focus being on the renovation project). Instead, when they adopt an urban scale point of view, they concentrate on policy making and the holistic vision fails to examine in depth the energy performance and improvement opportunities. Moreover, tools are not customizable and cannot be consulted by all the subjects involved, such as citizens.

3. Research and aims: The Urban Energy Pattern

The opportunity to work on these topics comes from two European research projects funded under the Interreg Italy-Austria programme. They are the "Urban Energy Web" project (www.urbanenergyweb.eu) and the "IDEE" project (www.interreg-idee.eu). The results of the "Urban Energy Web" research activities are currently being improved in the context of both the ongoing "IDEE" project and a PhD research work.

The purpose of the research is therefore to devise an instrument to support decision making processes and to enhance sustainability inside urban environments through the identification of areas or buildings suitable for energy-saving improvements. From the conceptual point of view, the tool that we have designed is a mix between an assessment system and an interactive web index to be "installed" in a Public Participatory Geographic Information System (PPGIS). In fact, the goal is to make a sustainability assessment of all buildings in a certain urban environment in real time, gathering relevant and useful information to be made available to local authorities, house owners and citizens in general. The tool that we have devised is called "Urban Energy Pattern" (UEP). From a technical point of view, it is an index of energy-environmental sustainability features of buildings in relation to the urban context which they belong to. On the other hand, it is also an index of the potential/residual efficiency of a building or a portion of the urban area. Its aim is to measure how the performance of the "building system" - considered as a part of the "city system" - can vary depending on a number of variable urban and social contextual conditions. For this reason, its flexibility reflects the complexity of the urban pattern in a city.

4. Methods

The UEP is based on an index which includes several parameters: each one of them is a performance indicator concerning a specific feature and considered together they provide an indication of a building's sustainability level. It is worth noting that the Urban Energy Pattern doesn't aim to classify buildings according to a certain ranking scale, but rather to map and point out, at urban level, any areas, neighbourhoods, or individual buildings that are worth looking into because they have a non-efficient energy performance or because they could provide an opportunity of energy-saving improvements through retrofit. It should also be stressed that this index has been conceived as a decision-making tool to support the planning and management of different projects and actions in the urban environment aimed at fostering sustainability. For this reason, it has been designed as an "open" and "customizable" system that can be tailored to the specific urban context or issues under investigation.

With regard to the test conducted in the pilot area of the Urban Energy web project, the following four performance indicators were chosen:

- Actual heating energy consumption of the building. The parameter identifies the energy consumption for heating and sanitary hot water which involves the direct use of fossil fuels (natural gas, diesel oil, wood, etc.)
- Heat loss. The quality and performance of the building envelope are evaluated using the *urban thermomapping* procedure, an analysis of the building façades carried out through infrared thermography surveys in the pilot area. Output images reveal the performances and the criticalities of the building envelopes, allowing buildings to be ranked in classes according to their thermal behaviour.

- CO_2 emissions. By linking actual consumption and the actual amounts of fossil fuel used, it is possible to estimate the CO_2 produced by the buildings.
- People and practicality. This parameter takes in consideration behaviours or family patterns influencing consumption trends. In addition, based on the number of residents or regular users of the building, the consumption per person can be calculated. Unlike consumption per m^2 or per m^3, this is a preliminary or tentative measure of the individual environmental impact.

The following pages describe how the indicators can be combined to obtain the Urban Energy Pattern. Its application to the City of Feltre – the pilot area of the UEb project, a real test-bed for fine-tuning the scientific calculation method – will be used as an example.

Existing databases, large scale surveys and specific questionnaires were used to gather the necessary data. For instance, in the Feltre case study, the private local gas company provided the actual fuel consumption for every building, while a questionnaire concerning the alternative energy sources supplied the related documentation for the whole urban area. Information from the city authorities' databases and laser scanner aerial surveys allowed us to calculate the volumes of the buildings and to know the number of occupants for each one of them, so as to determine the consumption per person. A sample of around 100 buildings, both private and public, was investigated by means of infrared camera surveys in order to evaluate the heat loss of the building envelope. We are currently considering how to improve this case-specific methodology through kinematic thermographic surveys that allow to gather IR information of entire streets or neighbourhoods in a rapid way.

A full description of data acquisition methodologies used in the Feltre case study can be found in (Condotta, 2017).

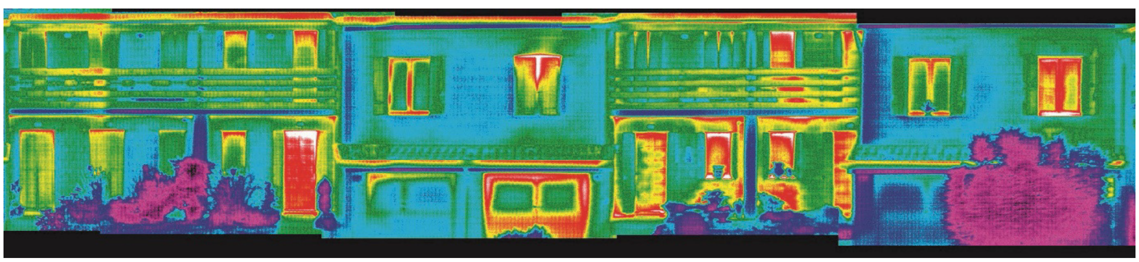

Figure 1. *Example of a test using kinematic thermographic surveys (image elaborated by Land Technology & Services s.r.l).*

The UEP is a dynamic and customizable index, where the weight of the performance indicators can be set by the users based on their specific needs. In this way, the study can focus on a specific feature of the building (e.g. the quality of building envelopes revealed by the heat loss parameter) overlooking others (because, for instance, the main goal is to identify buildings requiring façade maintenance). As mentioned earlier, four performance indicators were used in the case study: consumption [C], heat loss [D], emissions [E], people [P], and their values are calculated through the parameters shown in Table 1:

Table 1. *Performance indicators and parameters.*

Indicators	Parameters
Consumption	Annual consumption - kWh per m^3
Heat loss	Evaluation of the façade *thermomapping*
Emissions	Tons of CO_2 emissions per m^3
People	Annual kWh per person

Each one of the above-mentioned parameters produces a result in the form of a number but uses different units of measurement and physical quantities: to make all of them comparable, a common ranking was used to even out the results.

performance indicators:		consumption	heat loss	emissions	people
sustainability level compared to the average sustainability of the city	ranking	kWh/ym³	termomapping ranking	Ton CO_2/mc	kWh/y pers
bad sustainability	1	> 53	11 - 12	>0,010	>6000
low sustainability	2	>40 ≤ 53	9 - 10	>0,007 <0,01	>4000 ≤6000
medium sustinability	3	>30 ≤ 40	7 - 8	>0,005 <0,007	>2333 ≤40
good sustainability	4	>20 ≤ 30	5 - 6	>0,003 <0,005	>1600 ≤2333
high sustainability	5	≤ 20	4	0,003	≤ 1600

Figure 2. *Ranking and values used to even out different performance indicators of the UEP.*

First of all, as illustrated in Figure 2, a scale of five values of the Urban Energy Pattern index has been defined: from the best [5] indicating high sustainability and consequently excellent energy performance, to the worst [1] revealing a poor sustainability of the building – with three other levels in between. In order to set the value of each of the performance indicators, the same division into five levels was applied: the threshold values for the five classes are set by an analogous categorisation of the measurements specified by the respective parameters. In this way, every number expressed by a parameter falls into a category from [1] to [5] comparable to the categories of the other indicators. This division in classes is essential to ensure that the tool is highly customizable: the categorisation derives from the average urban values gathered in the analysis, making it possible to adapt the evaluation to different urban contexts with a tailored approach. Combining all the data, the Urban Energy Pattern index is obtained according to the following calculation formula, where 'α' represents the weight of the specific indicator:

$$\text{UEP index} = (C \times \alpha c + D \times \alpha d + E \times \alpha e + P \times \alpha p) / (\alpha c + \alpha d + \alpha e + \alpha p)$$

The formula produces a UEP value that may vary between [5], high sustainability and excellent energy performance, to [1], bad sustainability and poor energy performance. The values [C], [D], [E], [P], now all belonging in a range from [1] to [5], are the input data acquired, while the 'α' value depends on the importance that the user attaches to the specific indicators, allowing customization of the investigation. For instance, in the pilot area case, the values attributed to 'α' followed a doubling sequence, with each term after the first being twice the previous term: 1, 2, 4, 8, 16. Therefore it was possible to assign to each performance indicator an almost null impact [1], the highest weight [16], a medium importance [4] or two other intermediate weights, namely [2] or [8].

Figures 3, 4 and 5 are an example of the application of the Urban Energy Pattern in the Feltre case study. The pictures show some screenshots of the UEb Public Participatory Geographic Information System. The weight of the performance indicators can be adjusted directly from the web portal by moving the slider of each indicator (see the toolbox on the right of the map). The tool can change the value of α in real time and can automatically calculate the new value of the UEP.

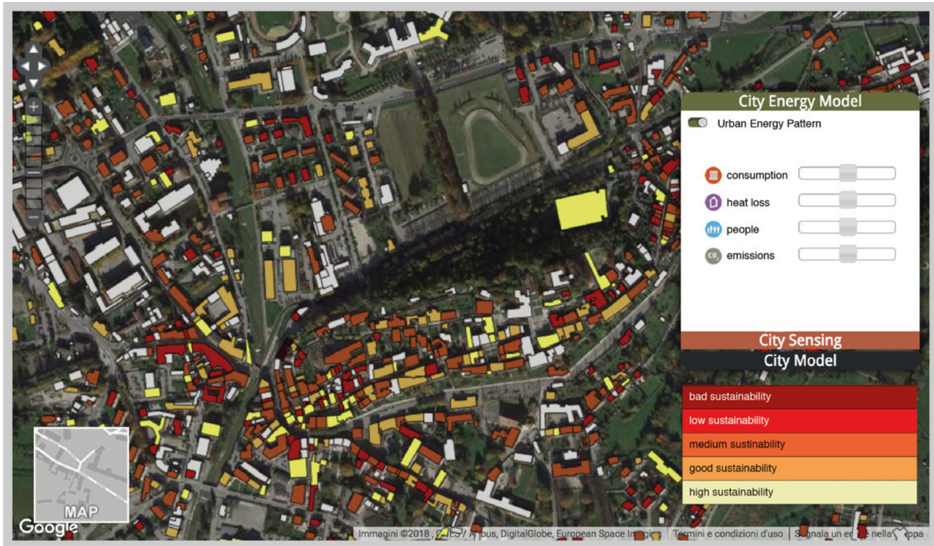

Figure 3. *A UEP screenshot from Urban Energy Web PPGIS tools. In this figure, the performance indicators are positioned at the same level- as shown in the toolbox on the map.*

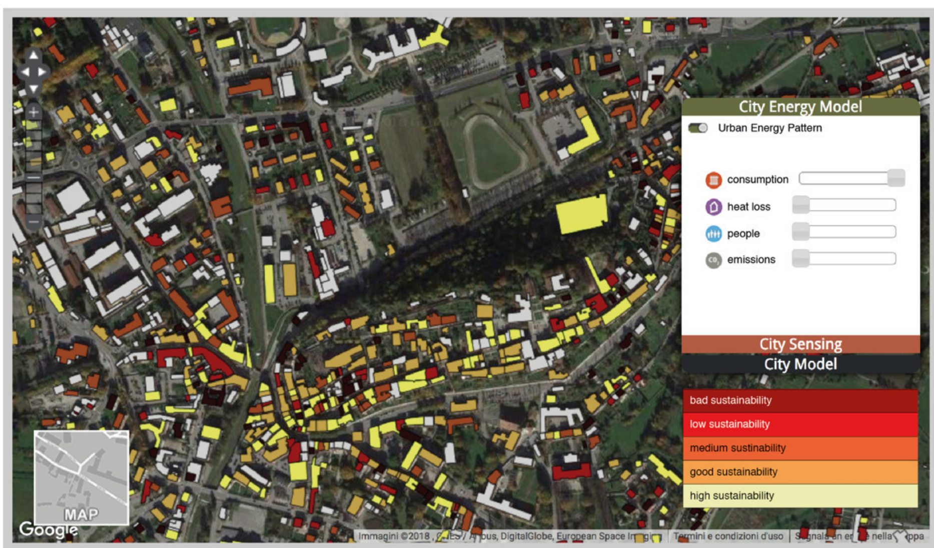

Figure 4. *A different analysis using the Urban Energy Pattern with performance indicators maximising the incidence of energy consumption.*

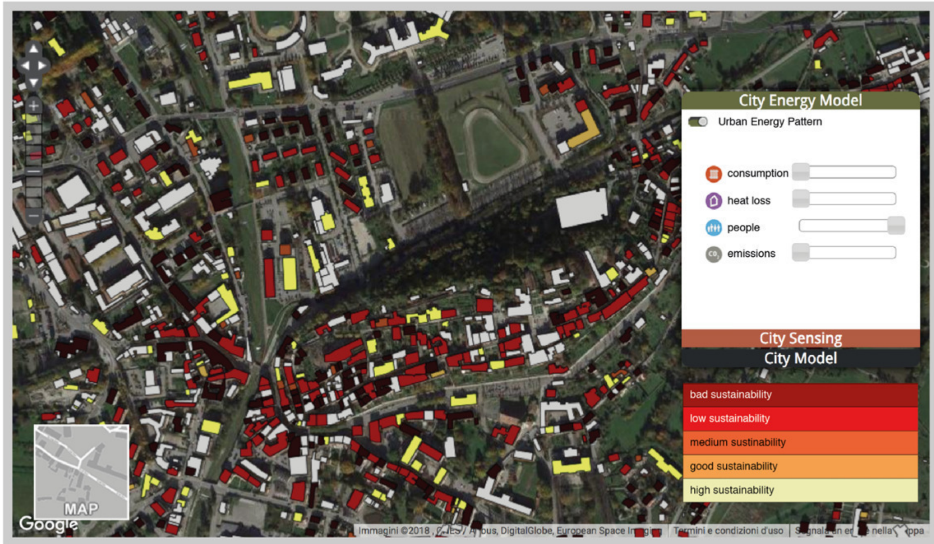

Figure 5. *Another alternative analysis with performance indicators maximising the incidence of the people indicator in the computation of the UEP.*

The Urban Energy Pattern proves to be a useful instrument in the analysis of the urban fabric and offers a comprehensive perspective to base policy-making on. Its flexibility results from the possibility to configure its performance indicators according to the specific aim of the research being conducted: this enables cultural sustainability features to be included in the analysed parameters. Since UEP takes into account citizens' behaviours and practices, it is already possible to use it to monitor sustainability awareness (keeping track of the outcomes of informative meetings or incentive schemes). A new performance indicator concerning the environmental and cultural features of the buildings represents a further improvement. Similarly to the other indicators, to ensure comparability a parameter and five levels are used for assessment. It should be noted that since the UEP parameters are based on the average measurements of the area of study and the tool is tailored to a specific urban context, also the assessment of the cultural value of a building must be referred to the environment and context where it is located.

To help assess the cultural value of a building, a variety of urban planning instruments can be used, including environmental permits and rules, provisions on conservation areas and listed buildings, on to municipal regulations. Every urban area is subject to a certain regulatory framework, whose aim is to preserve some distinctive traits of the historic or environmental background of the city. Since the rationale for municipal and regional analyses is the same, one can assume that the cultural evaluation is coherent and consistent within a wider territory. Moreover, this kind of multi-disciplinary approach that considers both environmental and heritage regulations reflects the cultural sustainability point of view. This perspective can be pictured in a multi-layered map, in which every level represents an urban planning tool that identifies the areas of interest: each one of the disciplines involved will highlight, on the relevant plan, the neighbourhoods or buildings being of value according to its branch of knowledge (see Figure 6). In this way, the more a district or building appears on the layers, the higher its cultural value - and the value of its close context; ultimately that will translate into a higher score for the specific parameter. To introduce the social field - another important feature of the comprehensive sustainable vision - it is necessary to see the territory as the place where a community lives and evolves and therefore to take into consideration the perception that people have of the places where they reside. Beside heritage assets officially recognised by the authorities for the purpose of managing or preserving them, it is important to consider also buildings and places whose cultural value is recognised locally and evidenced by the relationships between people and their environment. To visualize the local perspective, several participative approaches use so-called *"parish maps"*, which show peoples' tangible and intangible cultural assets within local landscapes (see for example Figure 7). Adding this layer to our analysis leads to a more comprehensive definition of the cultural value in the

Urban Energy Pattern. In this sense, also the LEED v4 stresses the importance of 'contributing buildings', or 'contributing resources', i.e. buildings without recognized historic value which nevertheless exhibit features that make them relevant in the neighbourhood and for the local community.

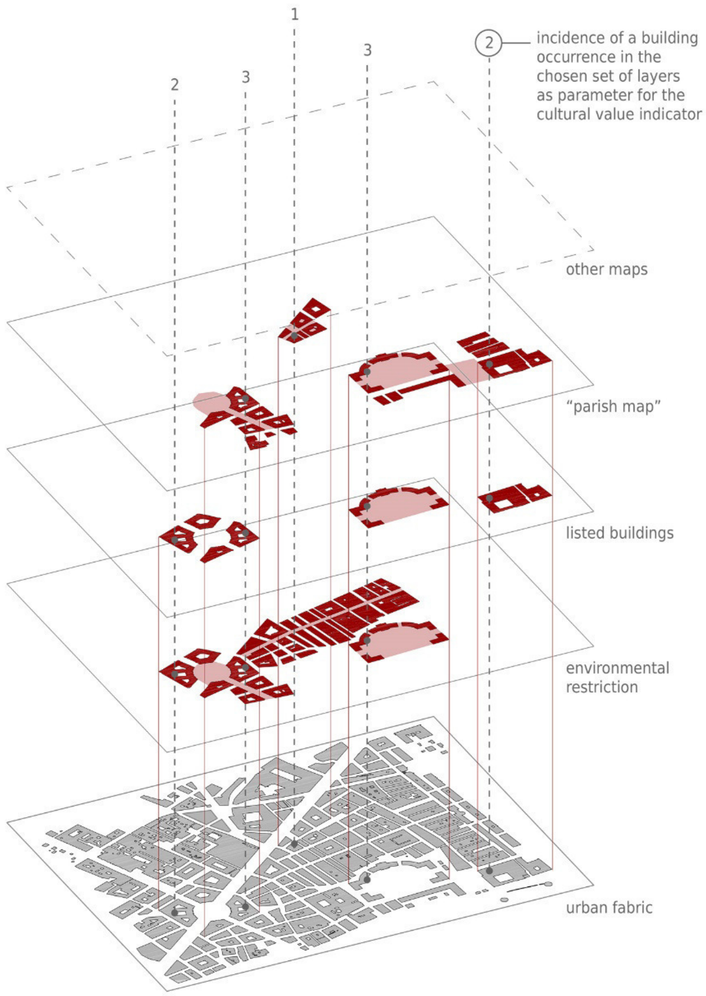

Figure 6. *An example about how planning and preservation instruments, as well as the community identity, could allow the identification of buildings' cultural value in the urban context*

***Figure** 7. An example of a "parish map" (source: PSR Regione Autonoma Friuli Venezia Giulia 2007-2013, Ecomuseo della val Resia)*

The flexibility of this approach allows incorporating additional layers deriving from other researches, offering a real chance to integrate cultural sustainability with the urban planning and heritage perspectives. As previously mentioned, given a certain set of layers chosen to map the urban fabric, individual buildings will appear on the map with different frequency depending on their relevance for the layer under consideration. This incidence can define the cultural value of buildings as a further indicator in the UEP index, as shown in Table 2.

***Table 2.** Implementation of the performance indicators and respective parameters.*

Indicators	Parameters
Consumption.	Annual consumption - kWh per m^3
Heat loss	Evaluation of the façade *thermomapping*
Emissions	Tons of CO_2 emissions per m^3
People	Annual kWh per person
Cultural value	Incidence of a building occurrence in the chosen set of layers

While designing the UEP, we looked at many other projects that dealt - or were dealing with - the dimensions we were investigating: energy retrofit, blending of innovation and preservation in historic buildings, flexibility and customization of policy-making tools in urban areas. This helped us implement the new indicator. In fact, in spite of the shortcomings we identified in the current investigations (see State of the Art paragraph), they proved useful at the time of designing a strategy suitable for historic contexts that could balance energy issues and improvement with the sustainability perspective. Concerning the regional and urban policy-making point of view, both CAT-MED and CESBA projects aimed at lowering the environmental impact of urbanisation through the monitoring of indicators and their trends in time, so as to assess potential performances and fine-tune the methodology. We determined that our tool should be able to provide a regular and up-to-date data report from the field with maximum user flexibility. Indeed, the Urban Energy Pattern is conceived to be a public information resource whose data are available not only for government authorities and policy-makers, but also for all citizens because we believe that fostering the social trait of sustainable development is of the essence. In more specific terms, we share the BREEAM® perspective to pursue a qualitative approach in historic building retrofit rather than setting specific performance targets: the acknowledgment of the cultural value of the building makes it possible to combine preservation and energy efficiency requirements without meeting all the criteria that usually apply to new buildings. In this sense, also the SECHURBA project focuses on the cultural value in the preliminary analysis of the building to determine a ranking of all possible alternatives for efficiency improvements. Like the UEP, it is conceived to be a decision-making tool about interventions in historic buildings or areas, taking account of different data, topics and branches of knowledge that are involved in the process.

5. Possible applications of the Urban Energy Pattern tool: Results and Discussion

During the practical application of the Urban Energy Web project to the pilot area, great importance was given to the synergic perspective of the project for the purpose of promoting a socially shared culture of sustainability. This led to the creation of a collaborative web platform that should encourage networking between local authorities, citizens and other stakeholders (researchers, technical experts, architects and building companies): they were given the chance to discuss the Urban Energy Pattern results. This online platform (actually a PPGIS) was launched during one of the several informative meetings that were part of the dissemination work package of the project, while other organisational meetings were held between partners to design and refine the collaborative methodology. The city platform allows to read the measurements of single performance indicators, as well as to customize the UEP Index deciding which of the indicators to highlight. The pilot area was the city of Feltre, in particular its historic centre, and the results were displayed building by building, making it possible for every citizen to understand the energy performance of his/her house and for the municipal authorities to show the state of the public building stock. The urban fabric consists of buildings built from the XV century to nowadays: the collected data clearly showed how the construction features typical of a certain historic period interact differently with contemporary energy demands and habits. This gave the inhabitants the chance to understand which steps they could take for a retrofit and sometimes to discover that, even in more recent houses, the heat loss of the building envelope is underestimated (the surveys took place in winter). The collaborative framework led to an increased awareness both of the sustainability issue and of the possible actions to undertake in an historic context, while the urban scale analysis fostered studies in the field of district energy supply.

As already mentioned in the introduction, the reasoning and the research so far described have been carried out in the framework of the “Urban Energy Web” and of the “IDEE” projects. At the same time, the IDEE research group is working on the development of an open source tools called RIVUS: a ‘linear mixed-integer optimization model for urban energy infrastructure’ (Dorfner, 2016). The tool has been conceived to support the design of district heating systems considering different types of energy suppliers and of energy vectors, trying to determine the exact energy demand for each building. The planned procedure involves several steps. The first step is the identification of a study area: a neighbourhood, a district or a specific zone inside the city. Area-specific data must be entered in the Rivus tool: the road network, the location of energy sources and buildings, the buildings energy demand values and a set of investment, maintenance and use costs. It is then possible to run the Rivus procedure that analyses different possible scenarios and returns the optimal one with the best cost-benefit value.

As we have seen, the Rivus tool automatically selects the best district energy system solution, but the definition and delimitation of the intervention area must be done in advance. This phase is very important, and it must be done accurately to get useful results at the end of the whole process. The identification of the study area is left to policy makers, planners, architects or any other stakeholder in charge of implementing retrofitting measures at urban level. It is in this phase that the Urban Energy Pattern tool – enhanced with the "cultural sustainability features" we are going to implement – can be used to support the selection of some study areas that can be later analysed in-depth by means of the Rivus tool.

Usually, the process of identifying the area to be analysed begins by looking at the zones having the largest number of buildings with high energy demand. In these areas, in fact, the high energy demand amortizes the investment costs to build the network. On the other hand, however, the investment costs could be used to improve the energy performance of the buildings through substantial retrofitting, thereby saving money and energy. This second option is viable and easy to implement if the buildings have poor architectural and cultural quality, otherwise it is very hard to improve their energy performances through substantial retrofitting. The Urban Energy Pattern index can help identify potential urban areas suitable for district heating. The tool can be used in two different steps with two different purposes. In the first step, it can be used to identify areas where buildings with low energy efficiency and low cultural values are more concentrated. In these areas, in fact, the best solution is to invest in retrofitting policies – also for private buildings – making use of incentive schemes and tax reliefs. After having examined – and excluded – these areas, a further analysis could be performed. The flexibility and customization features of the index make it possible to track down those buildings that according to the Urban Energy Patter index already have a medium/good sustainable energy performance but that could reach an excellent sustainability level if their energy efficiency was improved. Urban areas or districts that host a relevant number of these buildings can therefore be good candidates for holistic energy master plans and worthy of an in-depth analysis through simulation tools such as the Rivus.

6. Conclusions

This research presents a preliminary methodology framework to design a dynamic and flexible indicator whose aim is to analyse building sustainability at the urban scale inside urban retrofitting processes. It introduces two important innovative features: first, high customization possibilities - since users can select and highlight the result dimension they are more interested in; secondly, the fact that the tool is not addressed only to local government authorities or researchers, but to the whole community. Also, its data can be consulted almost in real time: in fact, the information provided by the performance indicators can be updated within a certain time span, depending on the subject. The tool so far developed (in the Urban Energy Web project) and applied to the pilot area of Feltre, aims at managing an index mainly focused on the energy saving theme, with a first indicator related to the socio-cultural sustainability issue, meaning citizens' behaviours and awareness. The next step in the process is to gain a better insight into the cultural and environmental evaluation of the urban fabric by refining related indicators and sub-indicators. The latter must be suitable for large-scale application involving several buildings at the same time: that means that they can be handled through a geographic database and the information they provide can be reconciled with that contained in existing urban databases. This investigation, with the additional intended improvements, will result in a multi-disciplinary research involving several fields: building technology (addressing construction, energy and cultural quality), building physics and spatial planning.

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