Based on the reflective process of the standard EN 16883, how can the energy retrofitting of historic and traditional residential buildings be supported? Decision-making tools provided by the “P-Renewal” research project.

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Abstract.

Energy renovation of old traditional buildings with heritage specificities has become a major challenge for European regions. Over the past two decades, numerous scientific projects have focused on this issue. However, the professional practices have not evolved much in the renovation sector across Europe, despite significant advanced scientific knowledge, development of specific guidelines, and adoption of the standard EN 16883 on conservation and energy renovation performance of cultural heritage.
The “P-Renewal” project on the energy retrofit of pre-war Walloon housing with heritage value, aligned with the objectives of the standard, provides a more detailed reflexive planning process supported by various technical data and decision-making tools. These outcomes enable the selection of renovation strategies that effectively combine the preservation of heritage value with improvements in internal comfort, energy efficiency, and environmental performance. They can be regarded as a significant contribution towards the evolution of the standard EN 16833 and energy efficiency in historic buildings. This paper briefly describes the reflexive process of the project. Then it presents the different decision-making tools while discussing their practical and technical support. Finally, it discusses their contribution in enhancing the usability of the standard.

Keywords (5 mots)

Heritage and historic buildings; Energy retrofit; Standard EN16883; Decision-making tool; Multicriteria approach.

1. Introduction

Since 2018, European regulations have pushed EU member states to make their building stock highly energy-efficient by 2050 through long-term renovation strategie [1]. The European existing building stock includes a large number of dwellings [2] with a predominance of single-family houses [2, 3] and is diverse, encompassing both rural and urban areas, with many buildings built before 1960 [2] that are poorly insulated and highly energy intensive. A significant part of this stock includes historic and traditional buildings [4], for which insulation measures and commonly used technical systems are often more difficult to apply. Renovating these historic buildings in an energy-efficient and sustainable manner, whether they are protected by conservation measures or not, has become a major challenge for Wallonia and other European regions.

Over the past two decades, there has been a growing scientific interest in the energy renovation of historical and traditional buildings [5, 6], aiming to balance thermal comfort, heritage value, and energy efficiency. Numerous research projects across Europe have contributed advanced knowledge in areas such as building types, construction systems and materials, energy performance estimation, thermal behaviour, hygrothermal transfers, and their associated assessment models, and multidisciplinary approaches for thorough building's documentation and characterization. Some projects have also proposed solutions for enhancing energy efficiency, including building envelopes improvements and technical systems optimization, and renewable energy supplies. Despite significant scientific advancement and availability of specific guidelines across Europe, this knowledge has not yet been fully adopted by energy renovation practitioners [7]. To fill the gap between theory and practice, the standard EN 16883 "Conservation of cultural heritage, Guidelines for improving the energy performance of historic buildings" [8] was adopted in 2017. Focusing on historic buildings of all types and ages, it provides a systematic procedure to select appropriate measures during the planning stage of renovation, ensuring a sustainable balance between the building's use, energy performance, and conservation. However, various studies have shown that professionals rarely use the standard EN16883 [9, 10]. Those studies suggest improving its usability with decision-making tools to support all stages of the process, including the building survey phase, and providing examples of how to carry out the procedure steps [10].

Funded by the Energy Department of the Walloon Public Service, the P-Renewal research project [11] was conducted in collaboration with the Unit Building Performances & Renovation of the Belgian Building Research Institute (BBRI, actually Buildwise). The project shares the same objectives as the standard EN16883, but also raises complementary challenges: (1) facilitate and support the planning process during energy renovation of historical and traditional residential buildings (listed or not), and (2) provide decision-making tools to help owners and design professionals to characterize the qualities and needs of historic residential buildings and adequately select renovation measures to improve their internal comfort and overall environmental performance while preserving their heritage value.

While P-Renewal aligns with the guidelines of the EN 16883 standard, it also introduces specific innovations to improve the usability of the planning process. And most importantly, for each decision step, it offers one or more tools to assist users in making informed decisions.

2. Reflexive planning process and methodological steps of P-Renewal project

P-Renewal research project has developed, based on five representative study cases in Wallonia [12, 13], a holistic, reflexive planning process supported by decision-making tools to adequately address the challenges of energy performance improvement of pre-war traditional and historic residential buildings. The interest of the P-Renewal reflexive process is both its bottom-up and integrated approach as well as its multidisciplinary character [14] since it combines the improvement

of the building's energy performance with the diagnosis and remediation of pathologies, the occupancy potential of the building, the improvement of indoor comfort and the global environmental performance. The goal is to enhance sustainability and strengthen the application of renovation strategies specifically designed for historic buildings.

The bottom-up and integrated approach has contributed to facilitating access to collected data and integrating technical information on various building types and renovation solutions. The discussions with renovation experts and professionals, in a "User Group", played a crucial role in considering the constraints and requirements of the field. They also fostered the development of a shared understanding among all stakeholders, from researchers to professionals.

The reflexive planning process was structured into various complementary methodological steps illustrated in Figure 1. Based on the standard EN 16883 guidelines, those various steps help building owners and/or renovation professionals in a variety of ways: (1) identify the reference building type, (2) document and characterize their building's specificities, (3) specify renovation target objectives, (4) highlight priority renovation interventions and (5) appropriately select and assess energy improvement solutions for their integration into a renovation strategy.

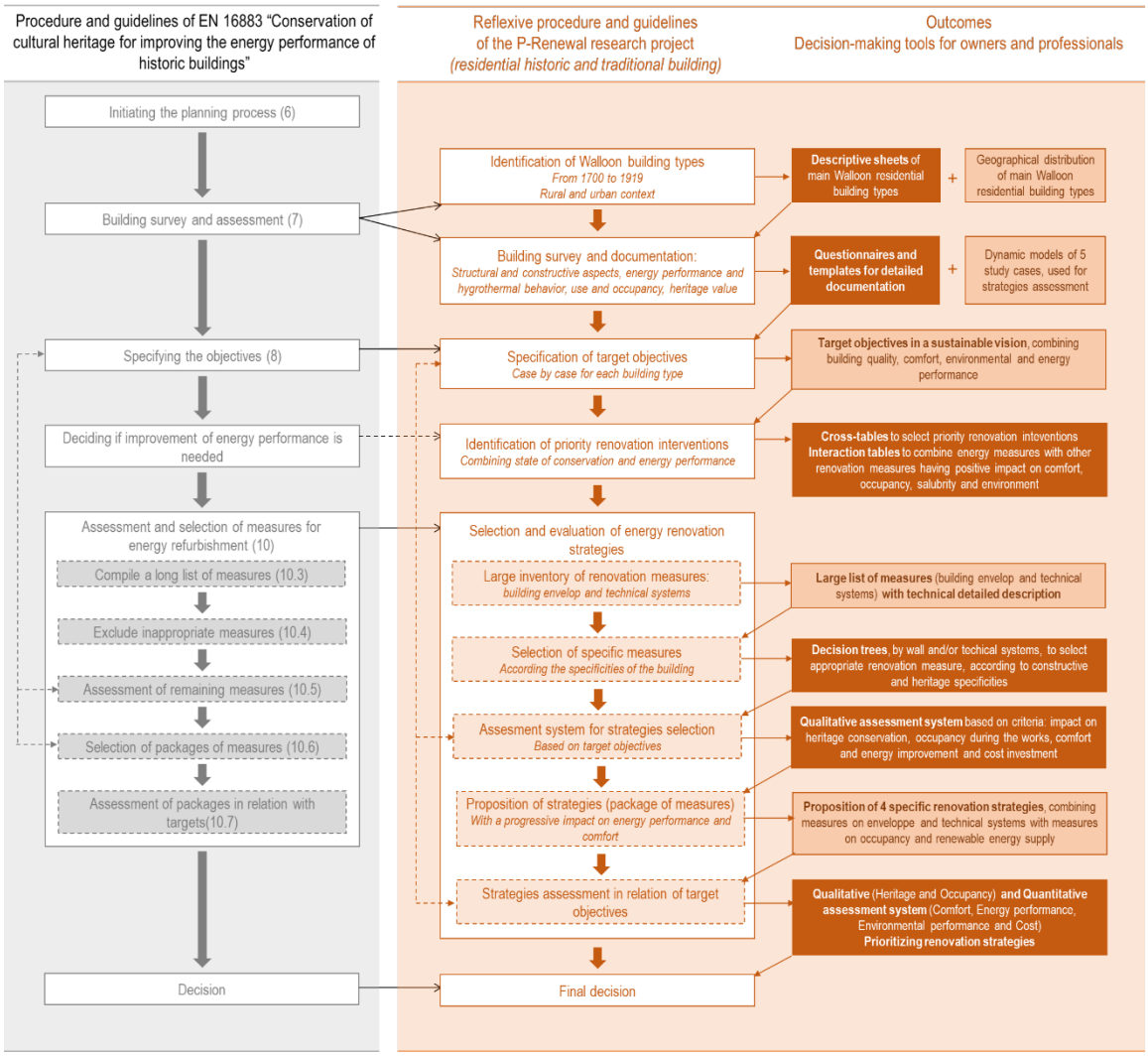


Figure 1: Renovation reflexive process proposed by the standard (in grey) in comparison with the process of P-Renewal project (in orange) as well as the various outcomes and decision-making tools.© S.Trachte

In addition to the standard, several new methodological steps have been proposed to strengthen the planning process. This is the case for step 7 of the standard process «Building survey and assessment» for which the P-Renewal project provides a step of identification of the built type before the step of survey and documentation of the studied building. This is also the case for step 10 of the standard process "Assessment and selection of measures for energy renovation", for which the P-Renewal project provides a methodological approach to select renovation solutions in adequacy with the specificities of the studied building as well as a set of evaluation criteria for selecting renovation strategies.

3. Decision-Making Tools supporting P-Renewal planning process

The P-Renewal reflexive planning process was developed using data collected on five study cases representative of the Walloon built stock and technical information compiled from the literature and discussions with "User Group" experts [11]. The scientific interest in the P-Renewal project extends beyond the reflexive process, primarily residing in the decision-making tools offered to owners and practitioners to enhance their renovation planning. As depicted in Figure 1, these contributions serve the dual purpose of guiding the execution of each step, facilitating the collection of requisite data for progression to subsequent stages, and providing the necessary technical information for the selection of appropriate renovation interventions and measures. They are presented below, following the steps of the P-Renewal reflexive planning process.

3.1 Descriptive sheets of building types

The typological analysis conducted on the pre-war Walloon residential building stock [13], has partially bridged the data and knowledge gap concerning the materials and construction characteristics of traditional residential buildings in Wallonia. This information is now essential for gaining a better understanding of the thermal and hygrothermal behaviour of these buildings as well as constructive, heritage and historical specificities.

The analysis has produced detailed, visually supported descriptive sheets for the seven main pre-war Walloon residential building types, as shown in Figure 2.

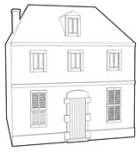
TYPES	WORKER'S DWELLING	MIDDLE-CLASS DWELLING			MULTICELLULAR FARM		FARM WITH COURTYARD
Subtypes	Modest house 	'Maison bourgeoise' 	'Villa' 	'Hôtel de maître' 	Lengthwise farm 	Farm in block 	Farm with parallel buildings, L or U-shaped farm, Square farm 
Context	Urban and rural	Urban			Rural		
Population	In the popular and industrial districts	Urban middle-class		Upper bourgeoisie and the aristocracy	Population in function of the size of the building		Powerful groups established by the stately and abbey farms
Spatial organization	Very basic Initially, only one room and a attic	Three different spaces: reception spaces, family spaces and services or domestic spaces			Same spatial organization but different in size and volume One or two levels divided in two or three (sometimes four) parts to host the family life, beasts and crops		Quadrilateral fully or partially closed which looks out onto a courtyard

Figure 2: Main pre-1919 housing (sub)types in Wallonia and their primary characteristics – © D. Stiernon

These sheets provide an in-depth overview of a specific building type, covering its historical development, dimensions, forms, spatial organization, relationship to public space, construction systems, and materials. It also highlights common heritage features and reference-built examples. Data and information provided by those descriptive sheets allow for quick identification of the specific type a building belongs to. Additionally, they help users understand the constructive and heritage characteristics of their building, which could significantly influence the selection of energy improvement solutions.

3.2 Documentation templates for building survey

The building survey and documentation conducted on the five study cases has yielded a significant volume of data for each study case, enabling the identification of all the constraints that need to be addressed within the renovation process as well as the opportunities that can be leveraged [14]. The collected data includes general information about the building site and its local environment, building materials and technologies, spatial organization, building services, and technical systems, as well as energy consumption statements. Additionally, the data incorporates findings from in-depth analyses conducted during the diagnostic phase, such as thermography, salt and moisture levels, and airtightness. It also includes data from energy monitoring and U-value estimations for the envelope walls.

These data have facilitated the creation of templates for building surveys and diagnostics. Adapted to a non-expert audience, these tools enable a general description of building by collecting data on each wall, encompassing material and construction aspects, state of conservation, and heritage features. While these data do not replace a comprehensive diagnostic and in-depth analysis of the building's energy performance, they present a realistic overview of the studied building and its specific characteristics. Moreover, these templates also include a qualitative assessment of heritage value, highlighting specific heritage elements that ideally should be preserved during renovation interventions. This qualitative assessment was carried out according to four criteria (authenticity, integrity, rarity, and representativeness) and eleven indicators proposed by the Walloon Heritage Administration assessment method [15].

Table 1. Qualitative evaluation of the architectural interest according to the four criteria of the Walloon Heritage Administration (SPW, 2020a)—study case "multi-cellular farm". It is structured with "++", "+" and/or "-" for each heritage interest, depending on its level of importance. NA is used when one of the criteria is not applicable

	Walloon Heritage Administration's criteria			
Architectural interest	Authenticity	Integrity	Rarity	Representativeness
Functional organization - outdoor	-	-	NA	+
Spatial organization - indoor	++	+	NA	++
Volume and size	++	++	NA	++
Constructive systems	++	+	NA	++
Main materials	+	+	NA	++
Façade composition	-	-	NA	+
Façade materials	+	+	NA	++
Roof materials	++	+	NA	+
Slab composition	-	-	NA	+
Floor composition	++	+	NA	++
Slab and floor materials	+	-	NA	+

3.3 Cross tables to identify priority renovation measures

Among the tools developed in the P-Renewal project, the most significant are probably the cross tables and the conceptual diagrams, developed for each wall of the envelope.

Cross tables combine data on both the state of conservation of the walls and its energy performance, specifically in terms of the thermal transmission coefficient (U-value). Initially, both sets of data were evaluated and assigned a ranking on a scale of 1 to 4, signifying the priority level for maintenance intervention and energy consumption [14]. For the U-value ranking, the rows, "very and energy intensive", present the values encountered in the case studies, and the last row, "energy efficiency", presents values slightly lower than those required by Walloon regulation but considered by experts as "energy efficient" and the third row "moderate energy consuming" presents values regularly found by the experts of the User Group and considered as moderately energy efficient.

Subsequently, these rankings were cross-referenced in a matrix, presented in table 2, for the front façade.

Table 2. Front façade - Cross-table for identification of renovation intervention's priority level

			State of Conservation			
			1	**2**	**3**	**4**
			Priority	**Necessary**	**Possible**	**Nonpriority**
Energy performance	**1**	**Very energy consuming** $U \geq 3$ W/m²K	Priority intervention	Priority intervention	Necessary intervention	Necessary intervention
	2	**Energy consuming** $3 \geq U \geq 1.8$ W/m²K	Priority intervention	Priority intervention	Necessary intervention	Necessary intervention
	3	**Moderately energy consuming** $1.8 \geq U \geq 0.5$ W/m²K	Priority intervention	Priority intervention	Possible intervention	Possible intervention
	4	**Energy efficient** $U \leq 0.5$ W/m²K			Nonpriority intervention	Nonpriority intervention

Conceptual diagrams have been developed for various energy improvement solutions, both on the envelop walls and technical systems. They enable the development of a pragmatic renovation works planning, by assessing the potential interactions between energy improvement measure and other renovation measures in terms of comfort, building quality, conservation, and environmental performance.

As presented in Figure 3, the energy improvement solution, for instance inside insulation of front façade, is regarded as the starting point of the energy renovation planning process, given its priority in addressing energy efficiency. The uncolored boxes in the diagrams depict elements (building and technical equipment) that directly interact with the roof insulation on habitability, building quality, health and environmental aspects.

These diagrams can assist owners and/or practitioners either in crafting a cohesive set of interconnected energy interventions for a specific wall or as part of a broader renovation plan. This approach helps them to optimize the renovation planning process and to reduce financial costs.

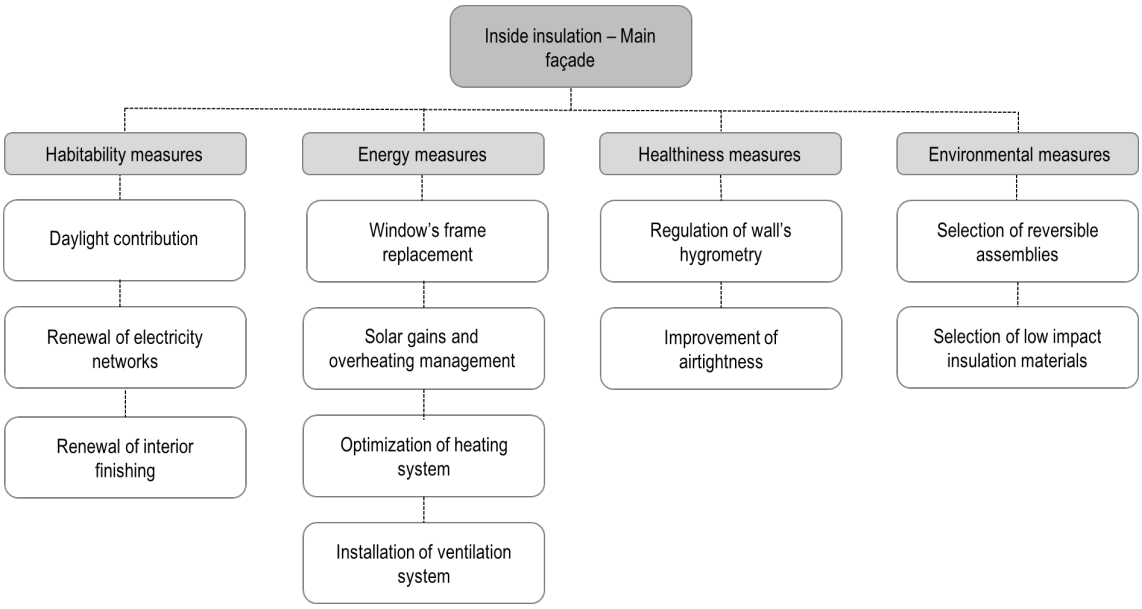


Figure 3: Conceptual diagram presenting potential interactions between front façade insulation and other improvement measures.

3.4 Inventory of energy improvement measures and Decision trees

A sizable inventory of technical improvement solutions, both for the building envelope and technical systems, was first meticulously compiled. For the energy improvement of the envelope, the inventory was categorized wall by wall. For each wall, a list of various insulation techniques, including options such as exterior and interior methods was proposed, highlighting its technical advantages and disadvantages, feasibility, and consideration for the heritage aspects.

The different possibilities in terms of building techniques and materials, as well as their procedures of implementation, were described in detail. The same methodology was applied to compile the inventory of solutions to improve or optimize the technical systems.

Then, decision trees were established for each envelope's wall and technical system to assist building owners or professionals, in the selection of appropriate energy improvement solution according to the state of conservation of the wall, the system studied in its construction, or its technical features and heritage specificities. The trees were structured based on a series of closed questions requiring a "yes" or "no" answer. The questions raised focus on the condition of the wall's conservation, the presence of heritage-specific features, and the technical feasibility of interventions.

Depending on the answers, a path was generated to reach a specific energy improvement solution adapted to the studied building. Key attention points are also presented to the user, particularly regarding the connection with other building elements or walls, as well as moisture and damp. These key points are described in more detail in the recommendation's sheets (see point 3.6) As an example, the decision tree for enhancing the energy performance of main façade is presented in Figure 4.

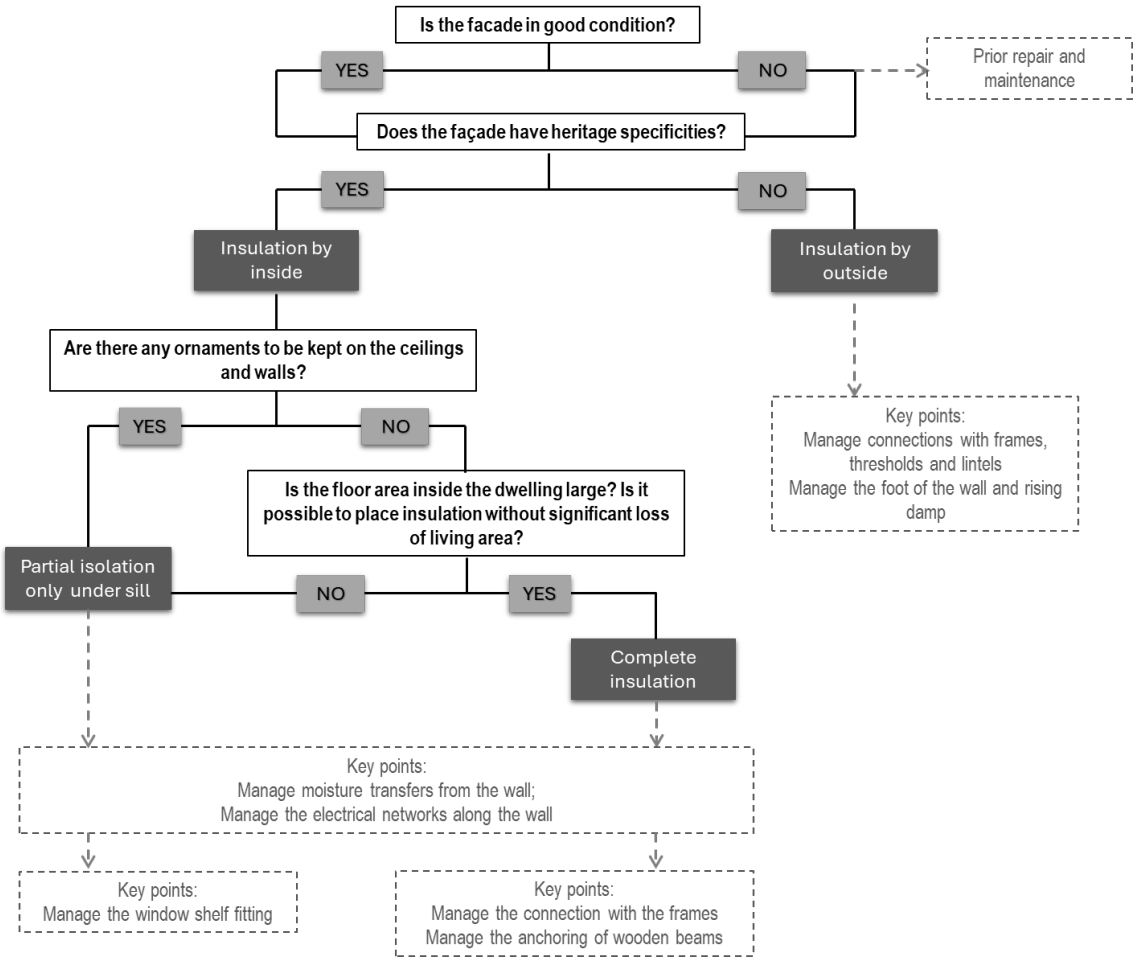


Figure 4: Decision tree for the energy improvement of the main façade.

3.5 Qualitative assessment of energy improvement measures

In addition to a quantitative assessment focusing on energy performance, environmental performance and financial costs, P-Renewal project has introduced qualitative assessment system for evaluating energy renovation measures and strategies. Conducted through a graphic scale, it has examined three key aspects presented in Figure 5: the potential risk of heritage value depreciation, the enhancement of indoor comfort, and the impact of retrofitting on housing occupancy. While these criteria are crucial for evaluating the effectiveness of the proposed renovation strategies, they cannot be easily quantified by owners or professionals. The graphic scale, ranging from green to red, helps users easily compare the current condition of the building with the expected results after implementing the proposed improvement solutions. It also provides the capability to swiftly evaluate the advantages or drawbacks resulting from an energy improvement solution. In fact, while the primary goal of the P-Renewal project is to enhance the energy performance of buildings and significantly improve indoor comfort, this priority must be balanced with other important considerations. This involves comparing different renovation scenarios according to several criteria, such as preserving the heritage value of buildings, ensuring cost-effectiveness, minimizing the impact on occupants, and incorporating alternative solutions such as renewable energy production or building densification.

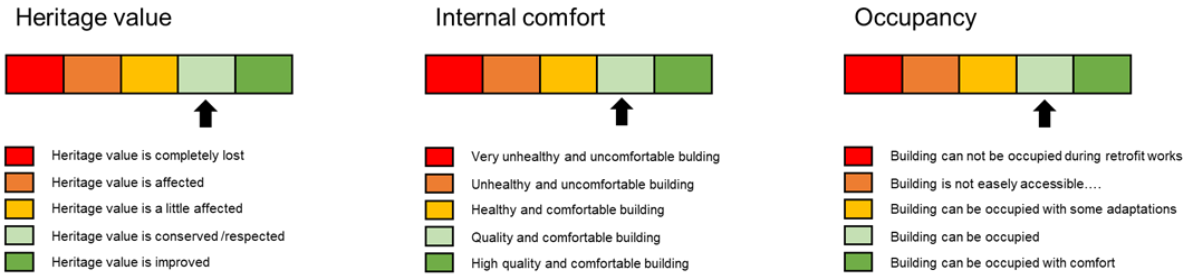


Figure 5: Qualitative criteria used for the evaluation of energy improvement measures.

3.6 Recommendations sheets

Recommendation sheets have been specifically drafted for owners, based on the constructive and heritage specificities of the main seven pre-war residential building types. They guide them, step-by-step, in the reflexive process developed by the research project, utilizing the developed technical support and tools to provide justification or facilitate the choice of energy improvement solutions.

The first recommendation sheet outlines the political context, and the challenges associated with energy renovation. It also emphasizes the project's philosophy, the importance of a reflexive planning process, and presents its key stages. The next two sheets describe the various types of buildings found in the Walloon region and address the issues of thermal and hygrothermal behaviour, highlighting the need for a thorough diagnosis before any intervention. Finally, four sheets provide detailed descriptions of different insulation options for roofs, façade walls, slabs, and floors. Each insulation option is examined with a focus on its advantages and disadvantages, feasibility, and consideration for the historic aspects of the building. For every insulation technique selected, the different possibilities in terms of construction techniques and building materials, as well as their procedures of implementation, were described and illustrated.

4. Discussion

The P-Renewal project has yielded diverse decision-making tools that support the reflective planning process, as suggested by Leijonhufvud, Broström, Buda, et al . [9, 10]. In fact, beyond the support provided to owners and energy renovation practitioners, these outcomes can be considered robust scientific contributions, fostering the enhancement of the usability of Standard EN 16883 planning process.

The P-Renewal descriptive sheets offer a simplified accessible resource for identifying the specific type of the studied building. They also help owners to better understand the construction and heritage characteristics of their building, which are crucial factors in selecting appropriate energy improvement solutions. Considering that such sheets can be readily generated at both the European and regional levels, based on existing various studies [16] conducted on historical building types, they could easily be incorporated into the standard.

The questionnaires provided by the research project, for building survey and documentation, offer a strong technical basis for analyzing an existing historical building before considering renovation measures. This kind of questionnaire could be appended to the standard as an illustrative example of the procedure to be followed for the documentation and surveying phase of a building.

The cross tables and the conceptual diagrams can be viewed as practical support for the renovation planning process. These tools enable non-technical users to identify priority energy improvement measures and incorporate them into a global renovation planning process alongside other actions. They enhance the efficiency of the planning process by reducing time and costs and can serve as valuable support in aligning with the roadmaps set out by European long-term renovation

strategies. With appropriate adjustments based on the energy performance requirements specific to each European country, those decision-making tools could also be appended to the standard.

The detailed and illustrated inventory developed within the P-Renewal project provides essential knowledge on various technical solutions to enhance the energy performance of walls or technical systems present in traditional and historic buildings. This knowledge is crucial in motivating owners to enhance the energy efficiency of their buildings, aligning more effectively with Europe's zero-carbon objectives. In addition, the decision trees offer a valuable technical support, assisting owners or professionals in selecting energy improvement measures adapted to the specificities of their building. An evolution of the standard could involve incorporating these inventory and decision trees, with adjustments made according to the heritage and constructive specificities of different building types, drawing upon various studies conducted on historical structures.

In addition to the necessary quantitative assessment, the P-Renewal qualitative evaluation system can be considered as a foundation for a more comprehensive and holistic evaluation of renovations on traditional and historic buildings. However, it must be specified that there is no consensus on assessing heritage value [17], despite various proposed methods [18, 19]. This lack of agreement and a common framework hinders the widespread adoption of the EN 16883 standard by professionals.

Finally, the entire reflexive planning process, along with technical data and tools, has been incorporated into various recommendations sheets. These sheets could serve as detailed standard guidelines, as they outline the process, key steps, and tools necessary for selecting an energy improvement measure or, even better, a comprehensive energy renovation strategy adapted to the studied building.

5. Conclusion

Relying on an innovative bottom-up, inclusive, and multi-criteria approach, the P-Renewal project aimed to assist owners and professionals in the energy renovation of historic Walloon residential buildings with heritage value. In contrast to the standard EN 16883, which renovation professionals perceive as a set of obligatory rules, the P-Renewal project and its outcomes are regarded as practical and technical support to ensure compliance with legal energy requirements and more sustainable renovation objectives.

The P-Renewal reflexive planning process can serve as an exemplary model and complement existing local and European regulations. The additional steps introduced by the research project could be incorporated into the future evolution of the standard EN 16883 to enhance the renovation planning procedure. Technical information and decision-making tools offered by the research project, act as practical support for renovation professionals and practitioners, facilitating the seamless integration of the renovation planning procedure outlined in the standard. These outcomes can be easily adapted to various contexts and building types, drawing upon the wealth of studies conducted on European built types and energy improvement measures.

Moreover, the project has developed analytical tools to examine the constructional and heritage characteristics of old and traditional buildings, including those that are not officially classified. For such buildings, it is both urgent and essential to advance collaboratively at the European level in assessing their heritage value and evaluating the impact of renovation measures on heritage-specific features. Without such progress, there is a significant risk that our landscapes and urban areas will lose a substantial part of their historical, scenic, and cultural quality. This quality must be recognized as a tangible heritage, which should be preserved and passed down to future generations.

In conclusion, the P-Renewal project has demonstrated it is possible to improve energy performance and occupants' comfort while preserving heritage values of historical and traditional

buildings, using a more comprehensive planning process and a range of specific decision-making tools. Historic and traditional buildings possess inherent assets and specificities that, once acknowledged, should guide the priorities of each renovation project. To achieve this objective, it is crucial to analyze the existing materials and components more in detail, to better characterize the thermal and hygrometric behaviors of walls and validate proposed improvement solutions. However, the generalization and transfer of solutions demand substantial data from available case studies, emphasizing the need for extensive research in the future.

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Not being English native speakers, the authors used IA Technologies (Chat GPT) to improve the English linguistics of some parts of this contribution.

References

1. European Commission. *Long-term renovation strategies*. 2014. Available from: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en; (accessed on 26/09/2024).
2. Economidou, M., Atanasiu, B., Staniaszek, D., Maio, J., Nolte, I., Rapf, O., Laustsen, J., Ruyssevelt, P., Strong, D., and Zinetti, S., *Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings*. 2011, Buildings Performance Institute Europe (BPIE): Brussels, Belgium.
3. Cassilde, S., Report: *Performance énergétique du parc de bâtiments résidentiels en Wallonie*. 2019: Charleroi, Belgique.
4. Webb, A.L., *Energy retrofits in historic and traditional buildings: A review of problems and methods.* Renewable and Sustainable Energy Reviews, Elsevier, 2017. **vol. 77(C)**: p. 748-759 DOI: 10.1016/j.rser.2017.01.145.
5. Lidelöw, S., Örn, T., Luciani, A., and Rizzo, A., *Energy-efficiency measures for heritage buildings: A literature review.* Sustainable Cities and Society, 2019. **45**: p. 231-242 DOI: https://doi.org/10.1016/j.scs.2018.09.029.
6. Martínez-Molina, A., Tort-Ausina, I., Cho, S., and Vivancos, J.-L., *Energy efficiency and thermal comfort in historic buildings: A review.* Renewable and Sustainable Energy Reviews, 2016. **61**: p. 70-85 DOI: https://doi.org/10.1016/j.rser.2016.03.018.
7. Buda, A., Hansen, E.J., Rieser, A., Giancola, E., Pracchi, V., Mauri, S., Marincioni, V., Gori, V., Fouseki, K., Polo, C., Lo Faro, A., Egusquiza, A., Haas, F., Leonardi, E., and Herrera, D., *Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach.* Sustainability, 2021. **13**: p. 2927 DOI: 10.3390/su13052927.
8. EN16883, *Conservation of cultural heritage*, in *Guidelines for improving the energy performance of historic buildings*. 2017, European Commission.
9. Leijonhufvud, G., Broström, T., and Buda, A., Report: *An Evaluation of the Usability of EN 16883:2017* ed. SHC Task 59 - EBC Annex 76 Report D.B2. 2021, International Energy Agency (IEA): Paris, France.
10. Leijonhufvud, G., Broström, T., Buda, A., Herrera, D., Haas, F., Troi, A., Exner, D., Mauri, S., Hansen, E.J., Marincioni, V., and Vernimme, N., *Planning energy retrofits of historic buildings. EN16883:2017 in practice*. 2021, International Energy Agency (IEA): Paris, France DOI: 10.18777/ieashc-task59-2021-0003.
11. Stiernon, D., Trachte, S., Dubois, S., and Desarnaud, J., *A method for the retrofitting of pre-1914 Walloon dwellings with heritage value.* Journal of Physics Conference Series, 2019. **Volume 1343**(Conférence 1) DOI: 10.1088/1742-6596/1343/1/012179.
12. Stiernon, D. and Trachte, S., *Quel avenir pour les logements d'avant-guerre à valeur patrimoniale en Wallonie?* Lieux dits, 2020. **18** DOI: https://doi.org/10.14428/ld.vi18.55853.
13. Stiernon, D., Trachte, S., de Bouw, M., Dubois, S., and Vanhellemont, Y., *Heritage value combined with energy and sustainable retrofit: representative types of old Walloon dwellings built before 1914.* Energy Procedia, 2017. **122**: p. 643-648.
14. Trachte, S. and Stiernon, D., *P-Renewal Project: A Reflexive Contribution to the Evolution of Energy Performance Standards for the Renovation of Historic Buildings.* Heritage, 2024. **7**(3): p. 1539-1568.
15. AWaP. *Agence wallonne du Patrimoine*. 1988. Available from: https://agencewallonnedupatrimoine.be/; (accessed on 26/09/2024).

16. TABULA. *Typology Approach for Building Stock Energy Assessment*. 2009-2012. Intelligent Energy Europe (IEE) Project: European Union. Available from: https://episcope.eu/iee-project/tabula; (accessed on 26/09/24).
17. Bos, M., Claeys, D., Vandenbroucke, D., and Stiernon, D., *Vers une dynamique d'objectivation de l'évaluation patrimoniale.* "Lieux dits" 2023. **23**: p. 32-44 DOI: https://doi.org/10.14428/ld.vi23.76853.
18. EFFESUS. *Energy Efficiency for EU Historic Districts' Sustainability*. 2012-2016. Available from: www.effesus.eu; (accessed on 26/09/2024).
19. Fredheim, L. H., & Khalaf, M., The significance of values: Heritage value typologies re-examined. International Journal of Heritage Studies, 2016, 22(6), 466-481.