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A method for the retrofitting of pre-1914 Walloon dwellings with heritage value

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Abstract. The sustainable energy renovation of historical buildings and listed heritage is a challenge for Belgium and other European countries. These are crucial for urban and rural development and for the future of old buildings. This is the context of the ‘P-RENEWAL’ research project. It aims to develop a methodological tool for retrofitting historical Walloon dwellings built before 1914, to enhance their heritage values while implementing relevant energy measures. The originality of this research is to consider energy, environmental and heritage aspects in a complementary way, in order to help designers achieving a goal of greater sustainability. According to the listed heritage administration, dwelling types built before 1914 represent approximately 25 % of the Walloon stock. This project is related to the research work carried out under the Task 59 of SHC ‘Renovating Historic Buildings Towards Zero Energy’. The methodology used to achieve the research objectives is articulated in various steps. First, a typological analysis of buildings from the interest era is completed. Then, based on on-site studies performed on representative case studies, the evaluations of heritage values and performance are conducted. Finally, dynamic energy models are run to support the proposition and validation of retrofitting strategies.

1. Introduction

A ‘sustainable’ society cannot flourish without respect for its past, but it must also be anchored in the present and ensure a possible future. This explains why built heritage must be conserved and passed on to future generations. This transmission involves the restoration, the retrofitting, the rehabilitation and the maintenance of the built heritage. Conserving built heritage does not mean ‘freezing’ it because, unlike progress, this approach would make it unsuitable for present and future needs, in terms of use as well as from the perspective of comfort and performance. Conserving built heritage needs to take into account and adapt to the current economic, social, environmental and energy situation.

This is the context of the ‘P-RENEWAL’ research project. It aims to develop a methodological tool for retrofitting historical Walloon dwellings built before 1914 in order to enhance the heritage value and combine it with a suitable energy and environmental performance. Indeed, approximately 25 % of the Walloon stock has been built during this period [1] and gives to Wallonia its identity as well as its architectural and historical legacy.



The originality of this research consists in considering energy, environmental and heritage aspects in a complementary way, in order to help designers achieving a greater sustainability. This project is related to the research work carried out under the Task 59 of International Energy Agency Solar Heating and Cooling (IEA SHC) ‘Renovating Historic Buildings Towards Zero Energy’. This paper describes the five steps of the methodology used to reach the research objectives.

2. Towards a methodological tool for retrofitting old building

The methodological tool developed by the project aims to support designers, contractors and owners. Following a ‘bottom-up’ approach, the authors propose five steps to achieve its implementation:

- 1 Typological analysis. A typological analysis of dwellings built before 1914, including numerical and geographical distribution analyses, was performed on the Walloon building stock. Representative occupied buildings were selected based on the main building types.
- 2 Investigation of case studies. A technical analysis of case studies was carried out. During this step, heritage specificities were identified to elaborate appropriate strategies. Furthermore, an evaluation of the functionality/housing potential was made to propose alternative options.
- 3 Discussion of retrofitting objectives. For each case study, the ideal goals to achieve in terms of comfort, energy performances and environment was identified.
- 4 Listing of retrofitting measures. An inventory of all possible interventions on envelope and systems and the ones relevant for each case study was compiled.
- 5 Evaluation of retrofitting strategies. By combining measures, different proposals of retrofitting strategies are to be evaluated by the mean of dynamic energy models. The latter were calibrated using data stemming from the investigation phase

These five steps are presented in detail in the following section.

2.1. Typological analysis

The main types of pre-war dwellings in Wallonia were determined: the worker’s dwelling, the middle-class dwelling, the multicellular farm, and the farm with courtyard [2]. For each type, the main subtypes were also identified (Fig. 1).

The statistical distribution of the subtypes was determined using the Regional 2016 property register [3] (Fig.2). The variables selected as main indicators were the footprint of the building, the number of facades and floors, and in some case, the presence (or not) of an attic (Fig.3).

Ultimately, five case-studies, which embody this diversity of dwellings, were selected to propose, investigate and evaluate various retrofitting strategies.

TYPES	WORKER'S DWELLING		MIDDLE-CLASS DWELLING			MULTICELLULAR FARM		FARM WITH COURTYARD
SUBTYPES	Workers' cell 	Modest house 	« Maison bourgeoise » 	Villa 	« Hôtel de maître » 	Farm in block / lengthwise farm 	Farm with parallel buildings 	Square farm U-shaped farm L-shaped farm 

Figure 1. Main types of pre-war dwellings in Wallonia

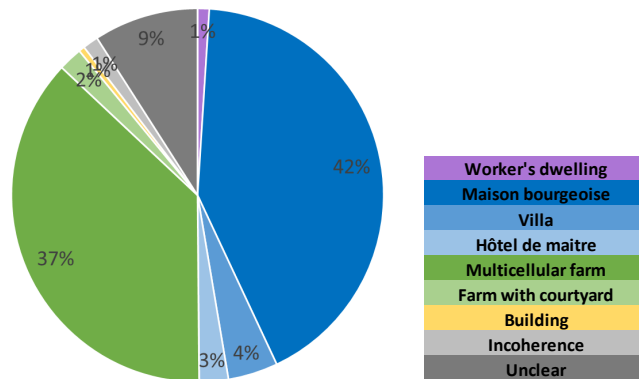


Figure 2. Distribution of main dwelling's types built before 1914 in Wallonia

Footprint		$0 < m^2 < 10$	$10 \leq m^2 \leq 50$	$50 \leq m^2 \leq 110$	$110 \leq m^2 \leq 150$	$150 \leq m^2 \leq 500$	$500 \leq m^2 \leq 1.000$	$> 1.000 m^2$
Number of facades:								
Unclear								
2 facades	Floor 0		Worker's dwelling		Multicellular farm		Farm with courtyard	
	. + 1			Maison bourgeoise	Hôtel / Farm	Farm		
	. + 2				Hôtel			
	. + 3							
3 facades	Floor 0		Worker's dwelling		Multicellular farm		Farm with courtyard	
	. + 1			Maison bourgeoise	Hôtel / Farm	Farm		
	. + 2				Hôtel			
	. + 3							
4 facades	Floor 0				Multicellular farm			
	. + 1				Villa (attic)/ Farm	Ferme	Farm with courtyard	
	. + 2				Villa			
	. + 3							
	. + 4 à + 13		Building					
	. > + 13							

Figure 3. Distribution of building types by footprint, number of facades and floors

2.2. Investigation of case studies

2.2.1. Technical analysis. Old buildings have specific characteristics: (1) their thermal behaviour is often characterized by a high thermal inertia and specific ventilation/infiltration patterns; (2) their construction materials have peculiar properties that are not always easy to model; (3) the state of these materials can influence the resulting performance; (4) the presence of building systems is often limited.

Each case study chosen was investigated and described in detail compiling as much technical data as possible, in order to highlight existing specificities in terms of hygrothermal behaviour. This analysis consisted in identifying and describing the buildings fabric and systems, surveying existing pathologies, monitoring temperature and humidity for an extended period, and quantifying the final performance (Fig. 4). Building's strengths and weaknesses in terms of energy and comfort were finally considered.

The data collected during these investigations also supported the creation of a dynamic energy model, for each studied building.

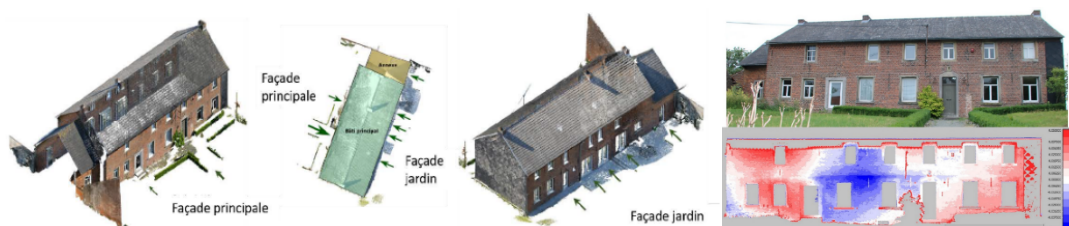


Figure 4. Example of photogrammetry and flatness test

2.2.2. Implementing dynamic energy models for the case studies. For each case study, dynamic energy models were developed in *DesignBuilder* and calibrated based on the results of the monitoring phase (Fig. 5). These calibrations depend on several data and assumptions: the orientation of the building and its environment, the climatic conditions, the geometry of the building and the composition of its walls, the occupation, thermal zones and heating instructions and air infiltration (thanks to a blower door test). This approach allowed to be as close as possible to reality and consequently to identify the most appropriate retrofitting strategies in a latter phase (energy, hygrothermal and environmental criteria).

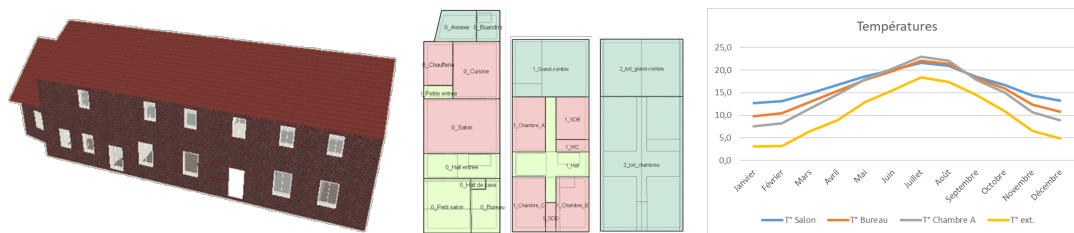


Figure 5. Simulation model of one multi-cellular farm

2.2.3. Analysis of heritage specificities / value. Most of the building studied in the research project are neither listed nor inventoried. However, they clearly present certain specificities that confer them a real heritage/historical/cultural value. The objective of this analysis was to define heritage specificities of the case studies which should be conserved and preserved during the retrofitting interventions. It is based on indicators and criteria from the Walloon Heritage Administration: uniqueness of the building or of a constructive technique, authenticity, integrity and representativeness.

2.2.4. Analysis of building functionality and rehabilitation potential. When considering the retrofitting of the case studies, it was interesting to question their current function and to evaluate their potential to be adapted to different use. In fact, most of those buildings are now dwellings but present a significant potential to evolve into different use-types (co-housing, guesthouse, office...).

2.3. Discussion of retrofitting objectives

From the results of the on-site analyses, the strengths and the weakness regarding comfort and energy performance have been defined, together with the heritage specificities that must be conserved and preserved. Based on this information, theoretical retrofitting objectives were discussed to improve comfort, energy and environmental performances.

2.3.1. Comfort objectives. Based on the criteria of the Walloon Housing Code [4] (healthiness, quality and condition of housing), strengths and weaknesses related to comfort objectives were identified for each case study. Indeed, the most common reason for renovating dwellings is often related to a sentiment of insecurity or poor quality.

2.3.2. Energy performances objectives. According to the energy performance of each case study, the potential to achieve the level “PEB-A” of the Walloon Retrofitting Strategy was evaluated, thus implying to achieve a primary energy consumption between 45 and 85 kWh/m².year. This goal is optimistic for old buildings with heritage value. Based on the building's energy weaknesses and the listing of retrofitting measures, some renovation works were recommended. Depending on the specific heritage features to be preserved, energy performance and comfort level can certainly increase, yet perhaps without achieving the objective recommended by the Walloon government.

2.3.3. Environmental objectives. The primary objective to be pursued by a process of renovation consists in extending the lifetime of existing building by increasing the functionality and the quality of its use but also the comfort and the quality of life of the occupants. Moreover, ‘sustainable’ renovation

has to limit the impact of the building and its use on the environment throughout its life cycle (including during construction and renovation operations) while considering also the economic viability of renovation measures. This is the reason why other sustainable priorities, as enriching natural resource stocks (sustainable energy sources, water, land resources and biodiversity) and reducing waste production (emissions and pollution, construction and domestic waste), were included in the project.

2.4. Listing of retrofitting measures

A list of the retrofitting measures that could be applied on the envelope (Fig. 6) and on the technical systems of the building (heating, hot water production, ventilation and lighting), and decision trees for each retrofitting measures (Fig. 7) have been compiled. First, a general overview of all the possible retrofitting measures was elaborated and illustrated with drawings and figures. Then, a shortened list of measures – adapted to each case study according to the building analysis, its heritage value and considering comfort objectives, energy performances objectives and environmental objectives – has been compiled. This last step represents the working base for the selection of retrofitting strategies.

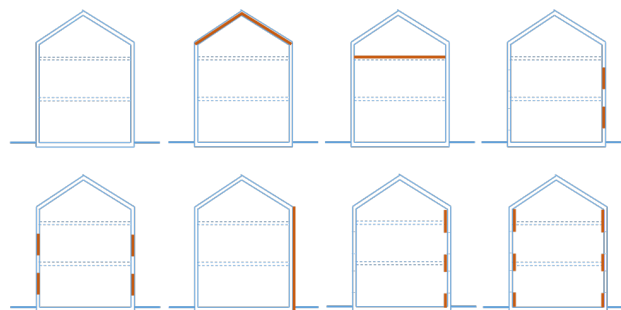


Figure 6. Envelope energy retrofitting measures

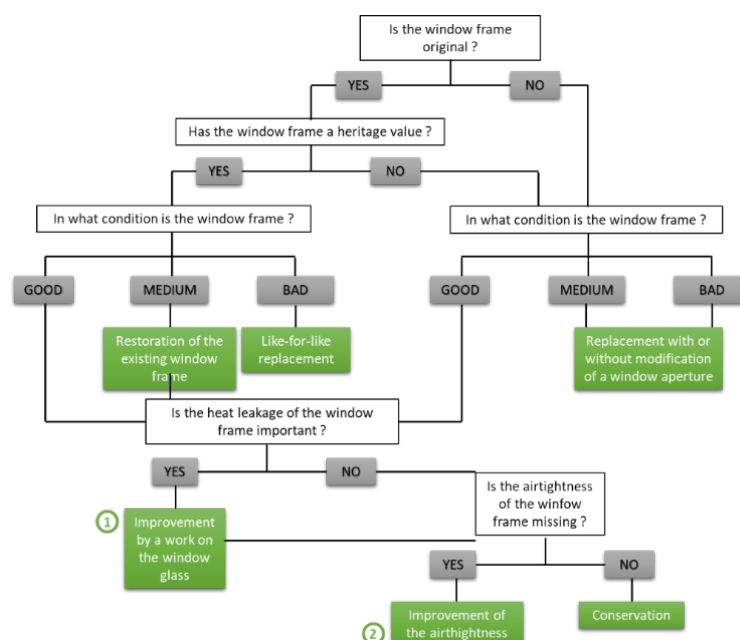


Figure 7. Decision tree for windows frame retrofit

2.5. Evaluation of retrofitting strategies

Following a ‘bottom-up’ approach, various retrofitting strategies for each case study were elaborated by combining individual retrofitting measures (on the envelope and on the technical system) in order to

improve energy performance and comfort. At the time of writing this document, the project had reached this phase, but the upcoming project phases are well defined.

First, three to five relevant strategies will be selected and evaluated according several criteria: economic criteria (e.g. cost), social criteria (e.g. impact on use during the retrofitting interventions), energy and comfort criteria (e.g. reduction of heating energy demand), environmental criteria and heritage values preservation and valorization criteria.

For all aspects related to energy and comfort, the dynamic energy models (which were developed during the investigation phase) will be used. Those tools allow to virtually implement the retrofitting measures and anticipate the impact on indoor conditions and energy consumptions.

In a last step, and for each strategy, identification of benefits and losses will be weighed through the proposed multi-criteria analysis, while considering the technical and financial reproducibility of the proposed strategy.

3. Conclusion

The ‘P-Renewal’ project has been set up to develop a methodological tool to support the energy retrofitting of old Walloon dwellings. This methodology highlights the need to thoroughly investigate each old building and to spread a lot of information before being able to define one or more renovation strategies. This would allow users to assess the benefits obtained by retrofitting strategies in terms of energy, comfort and environmental performances.

This paper presented and discussed the different steps of retrofitting methodology proposed to achieve this goal. This approach could serve as an example and provide significant complements to current European standards. Given the substantial effort to be made in pre-retrofitting studies, the authors point to the current lack of support offered by energy administrations to help owners and practitioners.

4. Acknowledgments

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