Energy retrofitting of building with a view to heritage values: The case of modernist buildings of ULiège in Belgium

Michel Prégardien[1, 2] and Anne-Françoise Marique[2]

[1] Architectural and urban engineering, Faculty of Polytechnics, University of Mons, Mons, Belgium, Michel.Pregardien@umons.ac.be

[2] Real estate department, University of Liège, Liège, Belgium, afmarique@uliege.be

Abstract

Energy retrofitting of buildings is an unavoidable way to reduce energy use and greenhouse gases emissions. In this paper, we argue that the need to retrofit buildings in a view to energy efficiency cannot occult the intrinsic quality and specificities of patrimonial buildings. Understanding the relation between matter, structure and constructive reality is fundamental to adequately orient the options of retrofitting without losing the soul of this heritage.

A framework is presented to address this challenge. It deals with four main interrelated categories: reduction of energy consumption in the use phase, life-cycle impact of retrofitting material (including reuse of material, in situ or from previous dismantled buildings), architectural and heritage values (with a particular attention on matter) and return on investment. A particular focus is put on the following architectural issue: what to do when maintaining the original matter of buildings' facades is not compatible with the necessary intervention to ensure energy reduction and necessary maintenance works?

This research was developed during the energy refurbishment of several significant modernist buildings of the University of Liège in Belgium, which are presented as case studies. The retrofitting works are now completed, allowing a critical return on the results, outputs and the framework.

Keywords: Energy efficiency – retrofit – matter – modernism – sustainability – reuse

1. Introduction

Energy retrofitting of buildings is an unavoidable way to reduce energy use and greenhouse gases emissions of our territories [1]. Buildings energy consumption still represents about 40% of the energy uses in Europe [2]. This issue has been widely documented since the 70's.

More recently, the energy performance of heritage buildings, from the modernist period (20's-80's) in particular, has gained growing interest in practise and also in the scientific literature and European guidelines [3], at a time where the maintenance works and renovation of these buildings become more and more pressing.

Although energy retrofitting of building is necessary in a sustainability view, the architectural and particular heritage qualities of these buildings cannot be denied. Such analyse, combining energy efficiency and architectural quality of heritage buildings is of crucial importance. We argue that this need to retrofit buildings in a view to energy efficiency cannot occult the intrinsic quality and specificities of these listed buildings.

To address this challenge, Section 2 first proposes a synthetic state-of-the-art of the scientific literature and some best practices dealing with the (energy) refurbishment of modernist buildings.

Then, Section 3 presents the case studies used as a basis of this research. They deal with the energy refurbishment of 11 significant modernist buildings of the University of Liège in Belgium. As far as architectural value is concerned, the case studies were built during the 60-80's and are major representative of modernist/brutalist architecture in Belgium. They present their own characteristics in terms of modern heritage and the associated responses proposed in the retrofitting project will be presented. The works are now completed, allowing a critical return on the results and outputs.

Section 4 introduces the framework developed to address the energy retrofitting of such buildings and its application to the case studies. The framework is made up quality criteria divided into main interrelated categories: (1) reduction of energy consumption and environmental impacts in the use phase, (2) life-cycle impact of retrofitting material, (3) architectural and heritage value, with a particular attention on matter and facades. And, last but not least, (4) the return on investment of energy refurbishment is analysed in this framework.

Section 5 concludes the paper with our main achievements and perspectives for further research.

2. State of the art

2.1 Modern architecture and main challenges

In recent years, increased attention has been paid to the twentieth century buildings from the great period of architectural modernity (1920 - 1980). These numerous buildings represent more or less 60% of the built heritage in Belgium and are, for many of them, of an architectural and technical quality often recognized. These buildings have been the subject of great spatial and aesthetic inventiveness, but even more of technical and constructive ingenuities. Steel, concrete, prefabrication ... have been tested, exploited ... not only as a technical answer, but also as an aesthetic act giving the building its image. There is no difference between the aesthetic and the technical response. This is a clear heritage of the Bauhaus thinking.

For example, the brutalist movement (which will serve us later in our presentation) represented by architects such as Le Corbusier (Convent of La Tourette), Allison and Peter Smithson (Hunstanton School), Jean Prouvé (House for people of Clichy) place the constructive act as the first priority in the development of the building and its aesthetic finality: apparent reinforced concrete cast in place, apparent structure, curtain façade, prefabrication... made the building.

These great figures of modernity have marked the spirits, especially in Belgium. Architects such as Juliaan Lampens, Léon Stynen, René Bastin, André Jacqmain... have spread this attitude in their own buildings, perhaps less mediatized, but certainly not without interest.

This “intermediate” heritage, especially built between the 60’s and the 80’s, is currently the object of a growing attention due to its age. In fact, these buildings are 50 or 60 years old and are at a critical period in their live: 50 years is for a building the time of major renovations or demolitions, because it must be noted that these buildings are not doing well for various reasons:

- They suffered from a chronic lack of investment in maintenance works due to budget restrictions.
- The specific techniques used when they were built have not resisted to time. Exterior reinforced concrete is emblematic of this problem: the spalling due to the concrete carbonation is endemic in many buildings.
- The low consideration for energy aspects before the 70’s make these buildings obsolete : the buildings are no, or few insulated, which represent now huge exploitation cost to heat them.
- Psychological considerations is also a problem: often unloved by the general public, these buildings have met and still meet little interest of public authorities. They are thus rarely recognized or protected as heritage.

These buildings therefore require extensive renovations as well as energy refurbishment which results in many cases, in the adoption of one of the following choices:

- Demolition: the cost of renovation being high, many investors are taking the path of demolition / reconstruction to recreate a new energy efficient building. This operation poses two problems: it removes quality buildings and it forgets to present, in the energy balance, the part related to the demolition of an existing building.
- Heavy renovation: this operation responds to the problem of the energy balance of the first attitude by favoring the reutilization of existing structures, but it often does so regardless of the initial architectural quality. Energy renovation is the dominant criterion of intervention.

We argue in this article that beyond these two unambiguous attitudes it is possible to adopt a critical view, without energy or patrimonial dogmatism, to reconcile the necessary retrofitting of these buildings (from a sanitary as well as an energy point of view), while respecting the historical, cultural and social values of these buildings. More heavy interventions such as demolition are not excluded from the analysis, but must be carefully studied when it is justified. The aim of the framework we present in this paper is to objectify the constraints in presence in order to help to find an adequate balance between all these constraints and to promote the most fair and balanced solution.

2.2 Energy refurbishment of modernist buildings

The energy refurbishment of modernist buildings is still very limited at present [4]. Mazzarella [4] and Loli and Bertolin [5] point to the difficulties involved in renovating historic buildings, particularly the risk of loss of historical, cultural or social values if it is carried out for a purely energy purpose. Although some attempts are emerging to establish guidelines for combining historical and architectural values in energy retrofit projects in buildings (e.g. [6-9]), specific attention to modern architecture is lacking.

One of the first questions raised by such modern building’s retroffiting is to know what to take into account at and what to preserve. In older heritage buildings, more often recognized and protected, this question rarely arises because the historical value and age value [10] of the building is usually sufficient to focus on restoration and renovation. The modern buildings, with the exception of a few emblematic edifices, such as the one retrofitted by the Ghent University on the Library tower built in 1935 by Van de Velde, has less recognition. In addition, the modern edifices hold their specificity not from the image they offer, but from the construction process from which this image was built. This means that the constructive act contains in itself the quality of the building, more than the final image that should be preserved.

To intervene adequately on such buildings, it is therefore imperative to have an extremely precise knowledge, architectural as well as technical, to define the specificities allowing them to be modified. This implies not only an historical knowledge of the building but also a sharp technical knowledge because it is from the relationship between the matter, the structural, constructive and technical realities and the space that emerges the quality of the building. These buildings therefore imply a particular focus on their technicality and even more on the historical context of this technicality.

Such knowledge begins to emerge in the literature. E.g., Fanelli and Gargiani [11] are particularly interested in the history of modern architecture through "*conceptions and solutions to what makes the specificity of architecture, namely the relationship between space, structure and envelope*”. In the same vein, the research and analysis conducted by TSAM Laboratory at EPFL, aims at pointing out the specificities of the renovation of the modernist heritage, especially on matters relating to the conservation of the material of these buildings. In particular, Graf [12] demonstrated the conservation potential of innovative construction techniques in curtain façades, which drastically improve their energy performance, for a controlled and cost-effective overall cost, in a long-term sustainability process.

The projects and case studies we present in the following of this paper are inscribed in this research vein.

3. Presentation of the case studies and research question

The Sart Tilman is the main campus of the University of Liège (760 hectares among which 230 are listed as natural site). The Sart Tilman campus was developed in the early 60’s as a planning tool to prevent the growing residential urban sprawl that characterized Wallonia, following a huge masterplan [13] organizing the installation of the University in the Sart Tilman.

Most of the University buildings built in the first phase of development of the campus (60’s to 80’s) were designed by famous Belgian modern architects (Ch. Vandenhove, C. Strebelle, R. Bastin…). These buildings are all listed on the Patrimonial Inventory, a tool that is not binding, as representatives of modern architecture, and specially brutalist architecture. These buildings made of concrete highlight the opposition between their scarce geometry and the roughness of their texture, in a relationship between culture and nature ubiquitous in the overall campus design. The architects that intervened during the first phase of development of the campus took concrete as a referenced material, but experimented different kind of textures (shuttered, sanded, washed, added with other materials…) which gives each building its own aspect.

On an energetically point of view, these buildings are major energy consumers. After 50 to 60 years of use, these buildings built in apparent concrete, according to different constructive techniques, show signs of very advanced weakness of degradation (wrinkling, painting ...) that make impossible a restitution of the material as it was initially realized.

For most of the selected buildings, outdoor insulation is thus the best solution (especially also because the buildings must remain in operation during the works) but it imposes an in-depth reflexion on the architectural aspect of the new interventions (material, architectural reading, etc.) and thus to find the adequate balance between patrimony, energy and cost.

The cases studies (images are provided in the PowerPoint presentation) are:

- The Botany building was designed, in 1968, by the Belgian architect Roger Bastin. The main characteristic and quality of this building are its lack of reported façade: the external shuttered concrete wall are structural, all has been implemented directly in situ. The traces of the pine boards are visible on the facades (and inside the building) which offers a very interesting double architectural interpretation: a huge homogeneous monolith from afar, combined with the fine reading of the wood texture from close. This double reading is quite important to maintain, or to reinterpret properly. This building is clearly a reinterpretation of the Le Corbusier's La Tourette monastery: the roughness of its initial concrete – brutalist texture, different colours of concrete, defects… perfectly contrasts with the strong geometry of the building, showing a kind of battle between the perfect design of the architect and the imperfection of man's realisation, expressed by the maxim of Le Corbusier "*here, the hand of man has passed"* [14].
- The Physics buildings (B5a and B5b) were designed in 1968 by Pierre Humblet. The main characteristic and quality of these buildings are their precast concrete with a rough homogeny texture, added with deep streak concrete panel as solar protection. This deep streak concrete is also present in the staircase towers on each side of the buildings. Here, the massiveness of the building is not structural: the prefabricated concrete panels are hooked to a supporting structure behind the façade.
- The Chemistry Building (B6d) was designed in 1967 by Jean Maquet. The main characteristic and quality of this building is its washed concrete with blue stone gravel, contrasting again with the ascetic regularity of its windows and volumes. The blue stone and the concrete are also very present inside the building but in a disjointed way: smooth concrete wall, ground in polished blue stone. As in Physics buildings, the apparent massiveness reveals to be a reported façade: concrete walls were implemented in situ and anchored to the structural wall behind.
- The University Hospital complex (called C.H.U.) is considered as the major artwork of Charles Vandenhove, a famous Belgian architect, namely due to the homogeneity of the whole complex (8 buildings: 5 towers, a central building with a monumental listed glass canopy and amphitheatres). The complex currently hosts an hospital (900 rooms) and laboratories. The 5 towers were built with a prefabricated concrete system. Each tower is fully glazed on its periphery by wooden window frames in afzelia, which gives the patients and users a view on the quiet wooden environment.

The necessary retrofitting of these building is inscribed in the research vein developed above, addressing this specific research question: while conservation of the material is an ideal to achieve, the in-depth analysis of these buildings shows an incompatibility between, on the one hand, the objectives of reducing energy consumption and the necessary maintenance works to ensure the future of the buildings and, on the other hand, the initial desire for a more conservative minimalist intervention. Thenceforth, the main question posed by this experiment is that of an intervention respectful of the existing when energy reduction and maintenance objective do not allow to preserve the original aspect of the building, for technical and functional reasons. This assumes a kind of reinterpretation of the specificities of these building through new kinds of materials in order to perform the necessary works to ensure the life of these buildings without betraying their soul and to define the adequate balance and choices between objectives than can be antagonist.

4. A framework to address the energy refurbishment of modernist buildings

4.1 Criteria and methodology

In the context presented in the previous section, the project team developed a framework to highlight and assess the main criteria to take into account in the retrofitting project of the four case studied. This framework is based on the four following linked challenges: (1) reducing energy uses in the use phase, (2) favouring a life-cycle approach and in particular the reuse of material, (3) respecting the architectural and patrimonial value of the buildings and (4) the economic viability of the projects.

4.1.1 Reduction of energy uses and environmental impacts in the use phase

The European Energy Efficiency Fund (eeef) that funded the research and study phase of the project, imposed at least a 20% reduction in energy consumption and to actively participate to the 20/20/20 policy of The European Union [15]. To assess this objective, the following indicators were developed and assessed:

- EU1 - Energy consumption for heating in the use phase, in final energy (ECh, in MWh/year)
- EU2 - Energy consumption for electricity in the use phase, in final energy (ECe, in MWh/year)
- EU3 - Total energy consumption of the building, in primary energy (TEC, in MWh/year)
- EU4 - Emissions of CO_2 in the use phase (ECO_2, in tons of avoided CO_2/year)
- EU5 - Production of renewable energies in situ (RE, in MWh/year)

In the absence of energy metering for heating consumption during the study phase, these indicators, before and after works, were assessed theoretically through detailed energy audits performed by an independent energy consultant. Most of the Sart Tilman buildings are however heated by a central thermal power plan, feeding a heating network of about 24 kilometre. In 2011, a biomass cogeneration system was integrated into this central thermal power. The theoretical results of the energy audits were thus calibrated with the total energy consumption of the central power plan and the quota attributed to each building by the maintainer. For electricity consumption, meters provides monthly consumption. The theoretical results were calibrated with real consumption and derivate to obtain consumption for lighting, laboratory devices, etc.

4.1.2 Life cycle impact, a focus on reuse of material

Energy consumption in the use phase still represents the major part of the energy consumption of a building, excepted for new passive or zero-energy buildings in which construction and end-of-life phases overpass the use phase [e.g.16]. The scientific literature has also highlighted that an in-depth energy retrofitting of buildings is environmentally more profitable than demolition – reconstruction [e.g.17-18]. Beyond these scientific results, performing an in-depth life-cycle analysis of the buildings was not possible in the project due to time constraints and lack of adequate data.

However, in the project, we intended to put a particular focus on the reuse of material and to test the following indicator, especially on one pilot project (the Botany building):

- LC1 - Reuse of material dismantled on site
- LC2 - Reuse of material from external sites
- LC3 - Reuse of existing technical infrastructures

4.1.3 Architectural and heritage value

Respecting the architectural and heritage value of the buildings was the main point of attention of the project, especially due to the context explained above. In this project, we propose the following indicator to take into account the original architecture of the building and to reinterpret it properly.

- AH1 – Texture of the façade in relation with structural and compositional aspect, specific to the building, but also in its historical and spatial context
- AH2 – Material of the façade components in relation with their implementation techniques
- AH3 - Relations between facades and windows (dimensions, alignment…)
-

It is worth telling that these indicators presuppose an important prior knowledge of the building, its constructive specificities, its history and the context in which it was developed.

4.1.4 Economy

The economic profitability of the project was logically imposed by the University who funded the retrofitting works (30 millions euro). In addition to the objectives imposed by eeef in terms of energy savings, the Board of the University imposed that the retrofitting works must be reimbursed on the energy savings within maximum 20 years. To assess this objective, a net present value model was develop and the following indicator were assessed:

- EC1 – Investment (in euro)
- EC2 – Lifetime of the investment (in years)
- EC2 – Cost savings due to energy savings (in euro)
- EC3 – Cost savings due to maintenance works avoided in the next 20 years (in euro)
- EC4 - Return on investment (in years)
- EC5 – Net present value at 20 years

Assumptions related to the expected evolution of energy prices, inflation, loans' rate were gathered from different sources (the Federal Plan Office, the head of the financial department of the University, energy consultants). These calculations allowed the Authorities of the University to validate the investment program with a deep understanding of the overall impact on their budget over the next 20 years. On this basis, it was also decided to finance the overall investment on own funds.

4.2 Results

4.2.1 Reduction of energy uses

More than 100 possible energy savings measures were proposed and assessed for the 11 selected buildings. They deals with the following main categories: insulating the envelope (roofs, walls, slabs, window frames and glazing), improving the ventilation system, improving heating production, improving hot water production, improving cooling system, improving indoor lighting, improving electricity production and others. For each measure, the energy (EU) and economic (EC) indicator presented in the previous sections were assessed as well as the feasibility of each measure. Figure 1 presents the results for the Physics (B5a and B5b) and Chemistry (B6d) buildings.

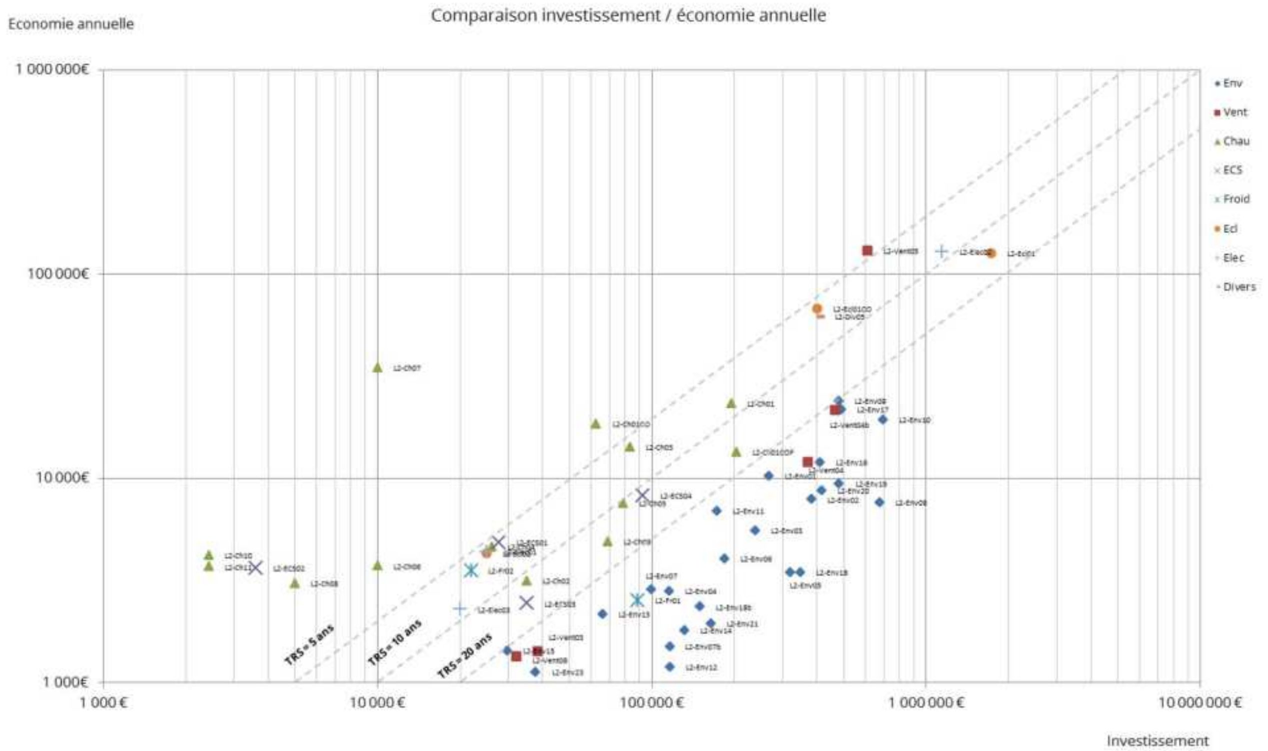


Figure 1: 65 energy savings measures were proposed and assessed for the Physics (B5a and B5b) and Chemistry (B6d) buildings. They are classified according to the investment (X axis) and the yearly expected energy savings (Y axis).

The main results of the energy analysis are that working on the building envelopes (insulating roofs, walls and replacing windows and windows frames) are necessary to reach significant energy reduction and respect the objective imposed by eeef. However, these measures present a long return on investment (often more than 20 years). Working on systems (glycol loops, revamping, improvement of compressors, heat pump, etc.) and lighting allows to reduce the total return on investment of the projects and also highlight the interest on working on a pool of buildings.

4.2.2 Life cycle impact and reuse

The Botany building was used as a pilot project for this topic, with the following results for the considered indicators:

As far as LC1 - Reuse of material dismantled on site is concerned, the metal roof cladding (400 m²) and the 60/60 concrete slabs in floor layout (120 m²) were carefully dismantled before the works, stored, cleaned and then replaced in the retrofitted project.

For LC2 - Reuse of material from external sites, the façade were insulated with 30 cm of mineral wool, and a reused Barnwood cladding from Eastern Europe, collected and distributed in Austria and resold in Belgium. This is up to now, the most ambitious project dealing with reuse of material in Belgium, with 2,600m² of facades cladding. Azobé boards from old docks of Dutch ports, resold in Belgium, were used for the realization of an outdoor terrace of 140m ²

For LC3 - Reuse of existing technical infrastructures, the former ventilation system was partially refurbished allowing to reduce costs, duration and difficulty of works.

Last but not least, it is worth telling that investing in the retrofitting of existing buildings, instead of buildings new infrastructures on a non-occupied site is also one important choice in favour of reuse and sustainability.

4.2.3 Architectural and heritage values

As explained in the section related to energy uses, insulating the building envelopes is needed to reach the energy savings goals. Indoor insulation was investigated but not considered in the following of the project for technical (lack of inertia, thermal bridges) and organizational reasons (all the buildings must remain occupied during the works). Interventions on the building envelopes were thus carefully studied and designed, for each specific building, to adequately combine huge energy savings and architectural quality. For the Botany building, this was done with the help of a new cladding in reclaimed wood, allowing to properly reinterpret the rough texture of the initial concrete. For the Physics buildings, a rough tender material was used, in different textures, in order to reinterpret the former concrete of the buildings. Peripheral towers of these buildings (circulation, stairs) were not insulated from outside to maintain their particular aspects. Solar protections were also kept, even if they present limited thermal bridges, for architectural and technical reasons. For the Chemistry building, the former façade made up concrete with blue stone inserts was reinterpreted by the used of an innovative façade cladding developed with two local enterprises, on the basis of PUR panels in which crusted stone wastes were inserted. These stone waste come from a local quarry. Considering that producing 1m³ of traditional stone cladding produces 4m³ of waste, our goal was to develop a new material valorising these waste into a new product that should be now commercialized.

For the C.H.U. complex, the peripheral towers of these buildings were not insulated (circulation, stairs) and all the windows (representing the most important part of the facades) were replaced. Large existing windows (2.4*2.4m) were divided into four parts with a stainless steel profile in order to distinguish the contemporary intervention from the original conception. This division was necessary for maintenance constraints and also to allow working from inside the buildings. In fact, the Hospital and laboratories must remain operational during the works which not allowed to work façade by façade (e.g. Maximum 2 hospital rooms by services can be closed simultaneously). Existing wood (afzelia) columns were maintained, in a view to sustainable development and economy of resources. Most of the exiting pieces of wood were also maintain in a patrimonial, economic and environmental approach. The roofs were insulated.

In addition to the insulation of buildings envelopes (walls, roofs, slabs, and windows), the ventilation systems (out of service) were totally renewed in Botany and Physics buildings. The indoor lighting of all buildings were partially renewed.

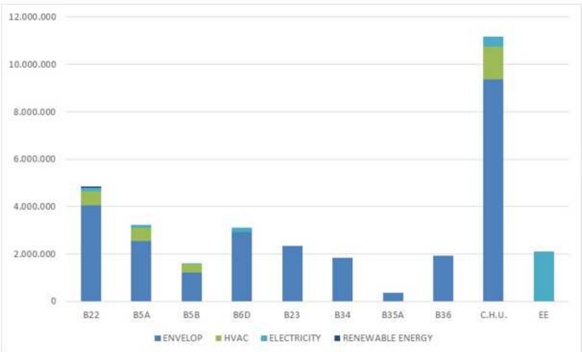
4.2.4 Economy

The final investment, VAT included, for the whole project (eleven buildings) raises 32,582,828.73 €. Figure 2 presents the split of this investment by building and by work type.

Most of the works deal with thermal insulation of the buildings' envelop (representing 81.8% of the total investment). HVAC and electricity investment are more limited (about 9% of the total investment each) and mainly concentrated on the Botany building, the Physics buildings and especially the Hospital. The implementation of renewable energy is limited to the installation of PV panels on the Botany roofs.

Thermal energy savings achieved is 12,219 MWh/year. Electricity savings achieved is 2,823 MWh/year. This represents a cumulative energy savings of 19,277 MWh/year in primary energy. This is equivalent to 2,718 tons of equivalent CO_2 saved per year. The PV panels on the roofs of B22 are expected to produce 25 MWh/year. The following table and figure summarize the energy savings (thermal, electricity and in primary energy) by building. As most of the investment is dedicated to the improvement of buildings' envelope thermal savings are important.

These energy savings were imputed in the NPV model which showed that the project is profitable within 20 years, even with a 1% opportunity cost. The University and the University Hospital both decided to finance the works on their own cash flow in 2017.



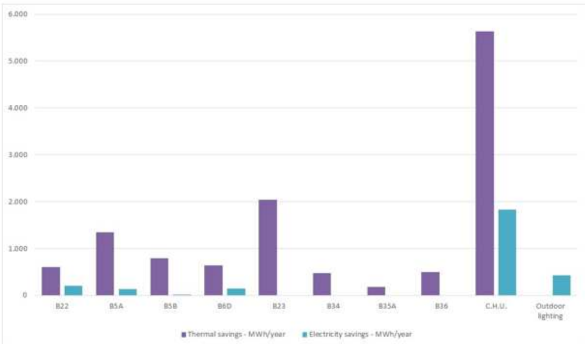


Figure 2 (left): Implemented investment split by work types and by building
Figure 3 (right): Final energy savings in MWh/year (thermal and electricity) split by building

4.3 Discussions

4.3.1 Links between criteria – example for the Botany Building

The framework presented in this paper intends to provide guidelines to help project authors and building owners but, as in any architectural project, beyond general trends, specific attention and solutions must be carefully studied and designed.

It is worth telling that this framework and the indicators are not sufficient as such. The architect capacities to take the constraints of an indicator as an opportunity for another and to link these indicators remain central. This implies that the potential of the different parts interacts directly with the others, not as separate parts in the balance, but more as an organic structure where each part creates the potential for the emergence of the others. It is especially the case for LC2 (Reuse of material from external sites) and AH1 (Texture of the façade). In fact, especially for the Botany building, the new texture (AH1) of the building takes advantage of the recycled wooden cladding (LC2) to propose a new type of texture as a reinterpretation of the old one: the battle between matter and worker that gives an imperfect texture is displaced in the recycled matter which propose a new kind of imperfection (imperfection from further use). So, recycled material was not only a durable attitude, it is also an architectural solution for patrimonial purpose. It lets also to the Botany building a new king of age value: this 50 year old building has a patina, the mark of time passing. The choice of a re-use material, itself patinated, ravined, attacked ... avoids the effect of a facelift and keep the building dignity of his age.

Such connexion can also be made with LC1 (Reuse of material dismantled on site) and EC1 (Investment): the reuse of material dismantled on site revealed to be less expensive than using new equivalent material or reusing material from external sites. In contrast, each LC2 (Reuse of material from external sites) reveals to be more expensive than using new material, as far as the sole economic criteria is concerned, without taking into account the environmental cost of waste treatment and the production of a new material.

4.3.2 Identified problems and risks

Implementing the energy retrofitting projects of 11 complex (architectural value, functions, size, occupancy, etc.) buildings is a quite long and complex process, including many time-consuming tasks (data collection, energy studies, designation of the consultants, definition and validation of the technical and architectural projects, obtaining the building authorizations, writing the administrative and technical requirements for the tendering procedures, analysing the received proposals, etc.). In addition, tendering procedures (for studies and then for works) are quite long (around 5-6 months from the submission of the administrative and technical requirements to the order of the works.

Most of the retrofitting projects had to receive a planning authorization, delivered by the Regional administration and the city, before the attribution of the works tendering. Appeal on the architectural projects could also have been introduced. In order to avoid appeal procedures and delays, numerous consultations were organized and projects were carefully designed to respect and reinterpret properly their architecture.

The technical complexity of some buildings was also a risk for implementation. The presence of asbestos in these buildings built from the 60’s was carefully analysed and taken into account in the work planning and costs. Intervening on exiting buildings (especially for the ventilation system) is also a challenge.

All the works were done in buildings that remained occupied. This was a huge challenge especially within the Hospital but also for University buildings where exams or important research cannot be interrupt. This require a time-consuming and careful attention to the preparation of the work planning, in close interaction with the users of the buildings.

4.3.3 Best achievements and awards

The project is considered as a success. Occupants of buildings, after two years of works, can now benefit from an improved comfort, especially in winter.

The project was awarded, in 2018, the Belgian Energy Award special prize and the Botany building was published as a best practice by ROTOR, a Belgian society whose aim is to favor reuse in the construction sector [19].

5. Conclusion and perspectives

This paper presented a framework developed during the energy refurbishment of 11 modernist buildings of the University of Liege in Belgium. This framework deals with four main challenges: (1) reducing energy uses in the use phase, (2) favoring the reuse of material (life-cycle approach), (3) respecting the architectural and patrimonial value of the buildings and (4) ensuring the economic profitability of the works.

In the energy retrofitting of the 11 buildings, all major witnesses of Belgian modern architecture, the four challenges of the framework were adequately combined in an ambitious project, with a return on investment lower than 20 years, demonstrating than high energy goals, architectural quality, respect of heritage and economic profitability are not incompatible.

The framework developed during this project will be used in further projects of the University of Liège and can also be reproducible to other projects. As discussed in section 4.3.1, we argue that beyond the general guidelines provided by the framework, the architects and the project team must be perfectly aware of all the four dimensions included in the framework, especially on the interactions between criteria, as well as conscious of the complexity of the architectural and technical answers which cannot be reduced to the final image or the energy result only. This imply a constant analysis of what is made during the whole phase of conception as well as construction.

Finally, beyond patrimonial buildings, such as the one considered as case studies in this paper, this framework could also be useful more generally to address the more and more pressing challenge of the energy retrofitting of “traditional” buildings, such as city district, social housing… to avoid losing the soul of our architectural heritage under the pressure of economic lobbies surfing on the current green wave. In this view, the role of the architects and project engineers must remain central.

6. Acknowledgement

The study phase was funded by the European Energy Efficiency Fund (eeef - https://www.eeef.eu/home.html). The retrofitting works were funded by the University of Liege and the University Hospital of Liege. Audits were performed by Greisch&Neo-Ides and EnergySuD lab of the ULiège.

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