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Energy & Sustainable Development

European Energy Efficiency Fund (EEEF)

Efficient renovation of buildings on the Sart-Tilman site.

Report on preliminary studies

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Sommaire

1. Introduction

The present report constitutes a brief descriptive summary of the preliminary studies that have been lead on several buildings located on the Sart-Tilman site. These buildings, which belong to the University of Liege (ULg) and the university hospital (CHU for "Centre Hospitalier Universitaire"), have been selected to be renovated in order to lower their energy consumption, according to the University's environment policies. Furthermore, a grant accorded by the European Energy Efficiency Fund could be obtained in order to motivate both the ULg and the CHU to undertake those studies.

First, we will give an overview of the chosen buildings (ULg and CHU), the reasons of these choices and a brief outline of the preliminary audits.

Then we will expose the different scenarios considered in the comparative studies, and the energy improvements that could be foreseen, should those scenarios be practically applied in the years to come. Finally, the economic prospect on the scenarios will be added in order to examine the financial interest of this project.

2. Buildings presentation

2.1. General presentation

When, in the 50's, it became obvious that the existing facilities in the centre of Liege could no longer contain the growing hospital needs, the University of Liege decided to build this "new" hospital" on top of a nearby, tree-covered hill. The ULg then decided to gradually develop an entire campus on this hill, building new facilities and moving departments. Needless to say, the lack of insulation and the poor overall energy performance of the 50's and 60's architecture became in later years a point of concern for the ULg, that now needs (for philosophic, economic, financial and practical reasons) to refurbish them.

The University of Liege owns a large number of buildings, spread between different locations, and it would be difficult (not to mention expensive) to consider the renovation of all these buildings. The project started with the CHU buildings, to which the ULg decided to join the oldest and biggest Sart-Tilman buildings, representing the main part of the overall consumption.

With the quotas given by Cofély (the company that manages facility and maintenance services for the University of Liege) and the average consumption of the CHU and ULg buildings on the Sart-Tilman (60834MWh[1]), it is easy to deduce the part of the selected buildings in the overall consumption. The CHU buildings represent 24.1% of this consumption (14661MWh), and the selected ULg buildings, 41.4% (25185MWh).

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[1] SARTOR, K., QUOILIN, S. and DEWALLEF, P., "Simulation and optimization of a CHP biomass plant and district heating network", International conference on applied Energy ICEA 2013, South Africa, 2013.

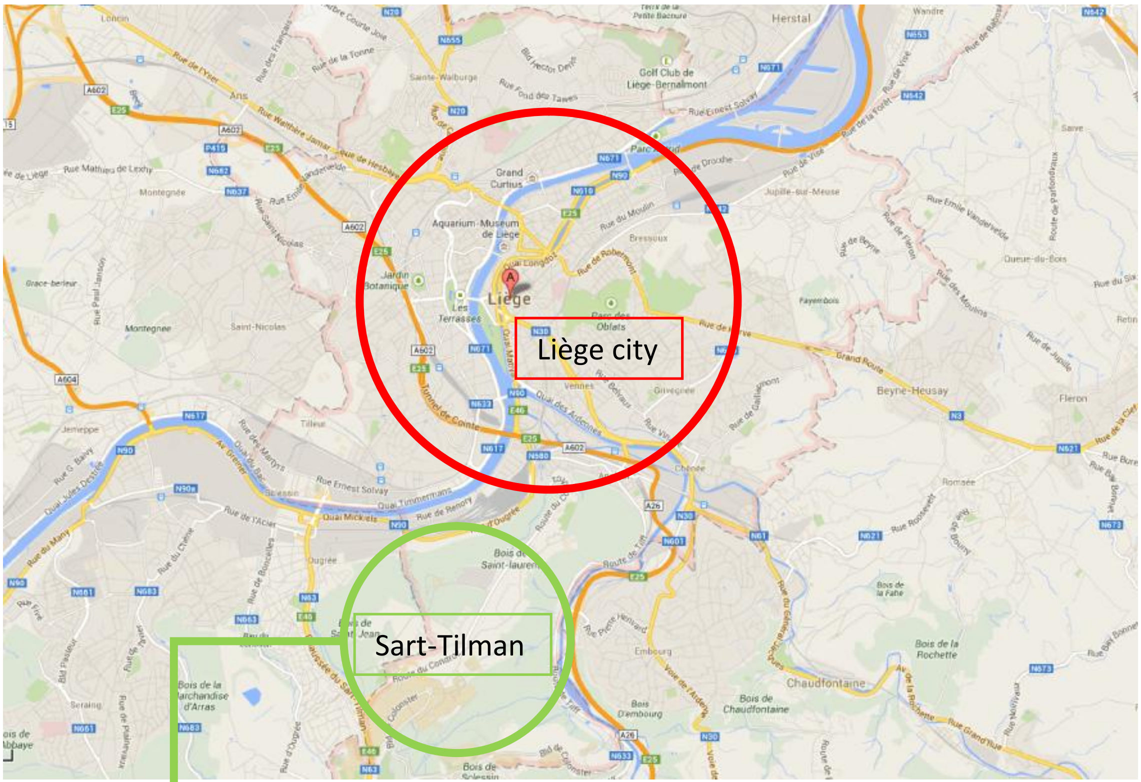

Fig. 1: Map of Liege (city and surroundings)

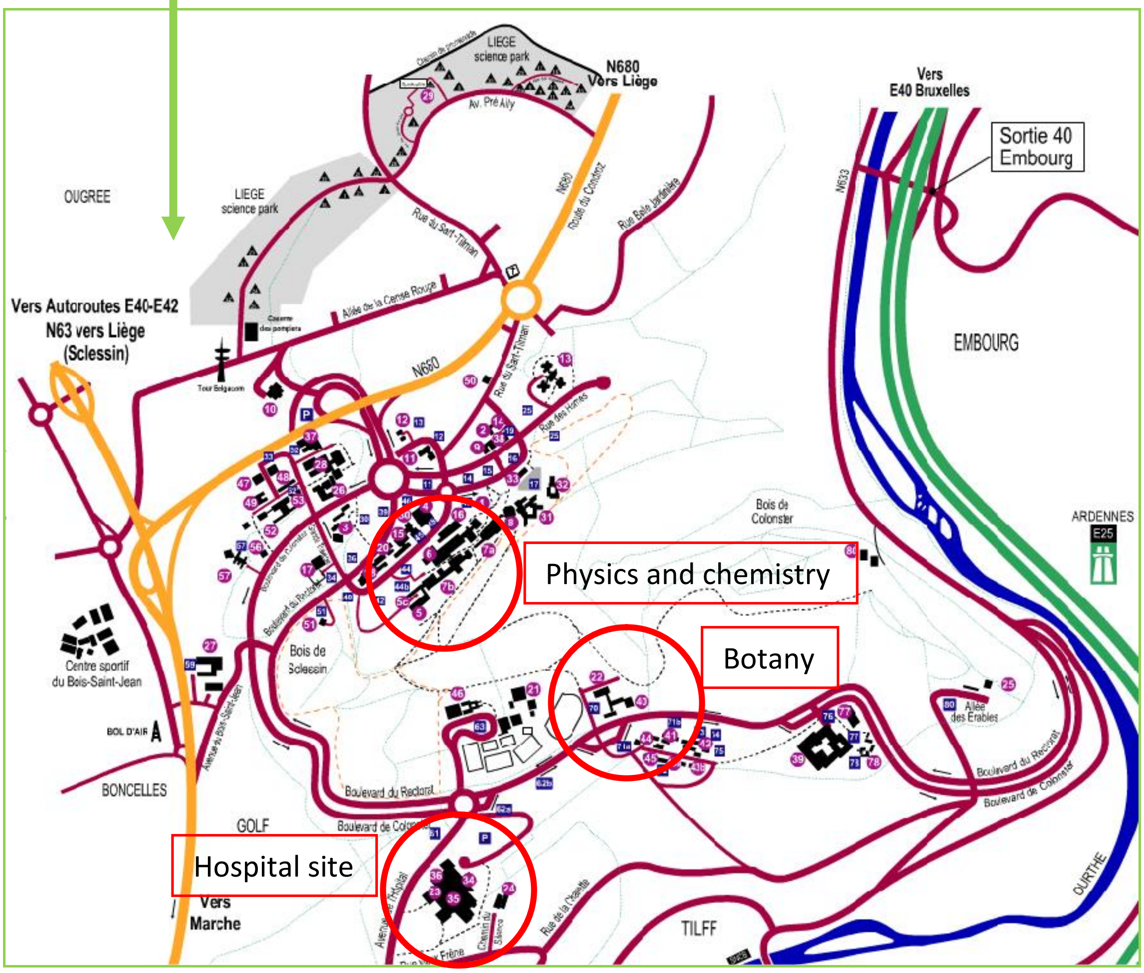

Fig. 2: Map of the Sart-Tilman site and highlight of the EEEF-concerned buildings

2.2. Hospital site

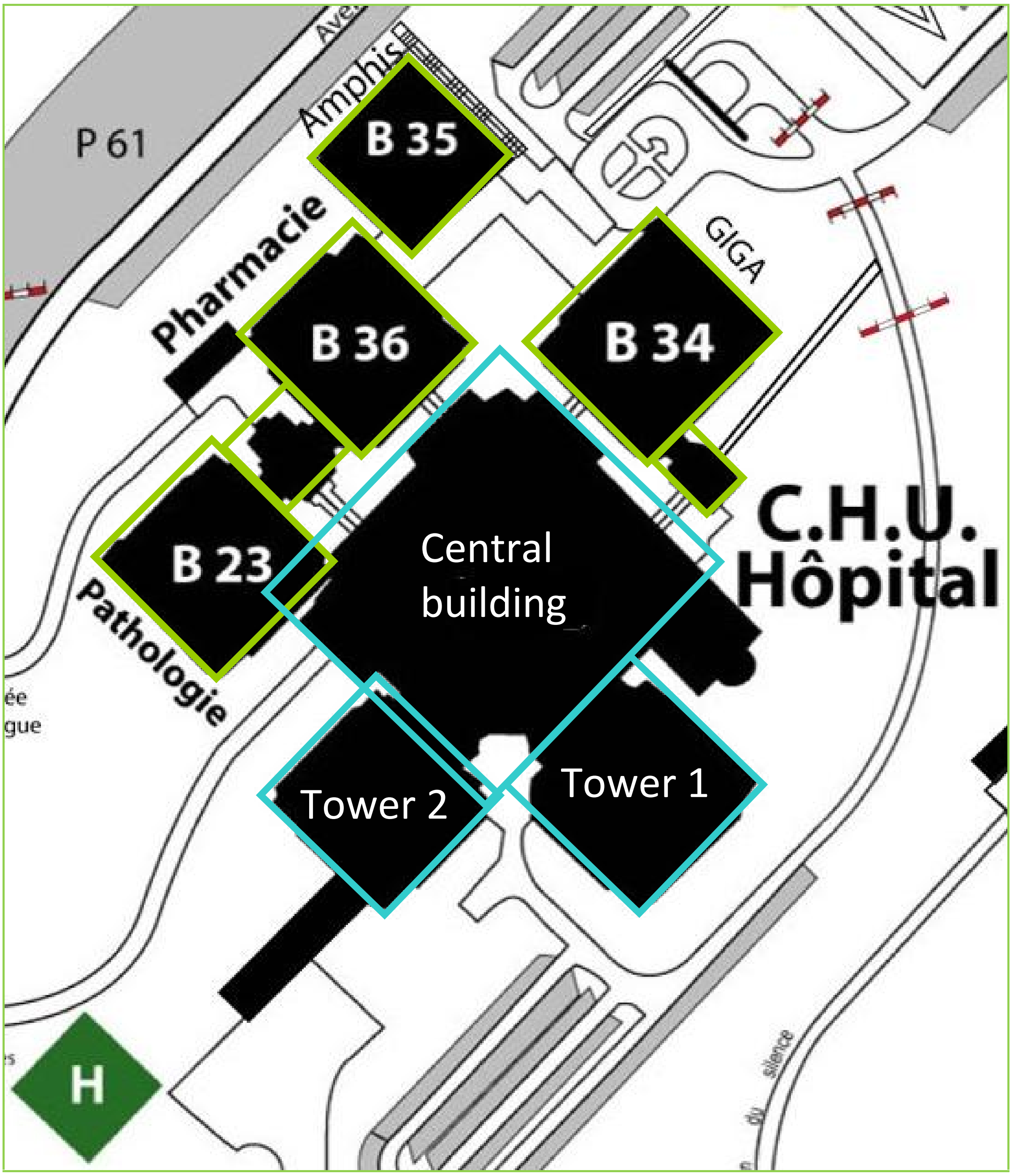

Fig. 3: view of the CHU site and highlight of the CHU (in blue) and ULg (in green) EEEF-concerned buildings

7 main buildings have been selected on this location: 3 belong to the hospital (central building, towers 1 and 2), 4 to the ULg (B23 or pathology building, B34 or GIGA building, B35 amphitheatres and B36 or pharmacy building). 3 smaller liaison buildings are incorporated: the GAM building for the CHU and, for the ULg, B23 to B36 liaison (or "animal house") and B34 to CHU liaison.

These buildings, together, represent 45.1% of the Sart-Tilman ULg-CHU heating and energy consumption, and 68.9% of the EEEF-selected buildings consumption.

2.3. Physics and Chemistry

The second location concerns the buildings sheltering the physics and chemistry departments, representing 17.9% of the Sart-Tilman consumption and 27.4% of the EEEF-selected buildings consumption.

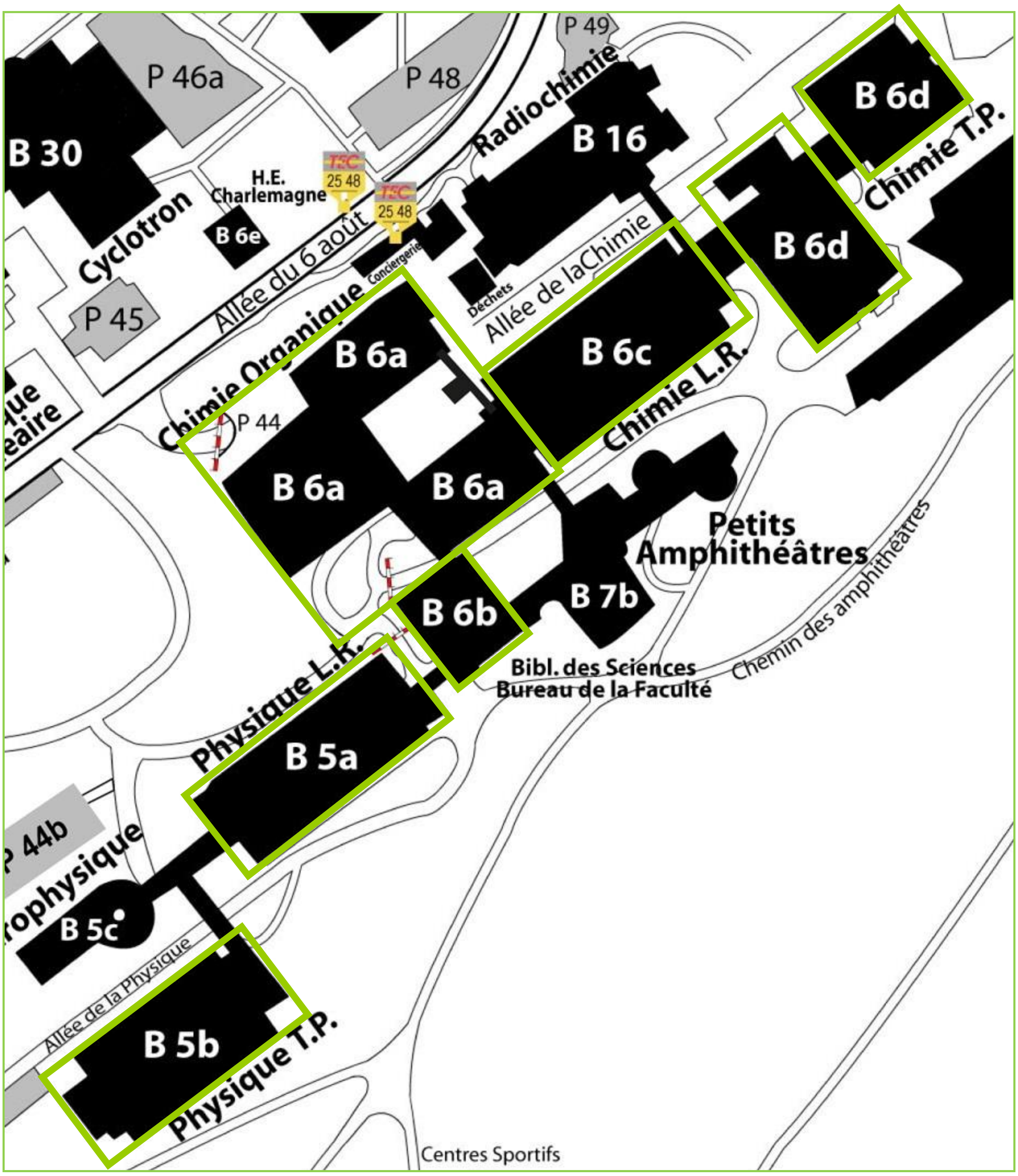

Fig. 4: view of the "physics and chemistry" buildings, and highlight of the ULg EEEF-concerned buildings (in green)

2.4. Botany

Lastly, it has been decided to add the "botany" building in the selection, because of its age and potential, in spite of its "small" part in the consumptions (2.5% of the Sart-Tilman, 3.8% of the EEEF-selected buildings).

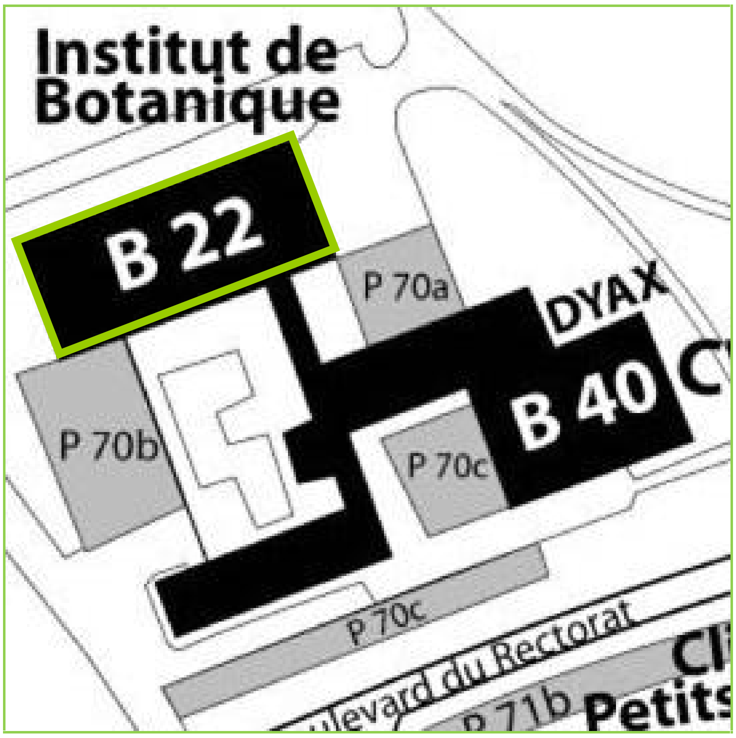

Fig. 5: view of the "botany" site and highlight of the EEEF-concerned building.

3. Preliminary audits: hypotheses

In order to appreciate the potential energy savings, a preliminary audit of the buildings was necessary. Here are its hypotheses:

- The Walloon EPB calculation method and default values are used (for example, air leakages flows of $12m^3/h.m^2$ for a 50Pa pressure difference between in and outside). The calculation procedure and methodology can be seen in the official documents[2].
- The existing walls compositions have been agreed between the EnergySuD research unit and the administration of real estate resources of the ULg. For example, uninsulated walls are composed of 30cm of concrete slab and 1cm of inside plaster covering;
    - Insulated walls were considered with the U-value that was imposed at the moment of their renovation; for example, the B34 roof, which has been renovated in 2008, has been given a $0.4W/m^2K$ U-value.
- Windows are made of old (U_g= $3.1W/m^2K$) double glazing in wooden frames (U_w= $3.13W/m^2K$); it has been decided to not consider occasional newer or older glazing, for they are hardly representative of the overall situation.

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[2] 2008/04/17 Walloon Government Decree, its 2012/05/10 version of the second appendix (calculation method for the primary energy consumption level, for offices, services and teaching buildings).

- Cofély gave technical information on each building, in order to be able to consider real ventilation flows; this was important, for they reached important values, very different from the regulatory nominal air renewal rates. For example, in the chemistry department (B6a building), where the difference is biggest, the real air ventilation rate reached 320,000m³/h (nearly 300,000 of which are extracted through many independent laboratory extractor hoods), where the regulatory standards asked for around 20,000m³/h (if we consider only offices). Were also considered:
  - The part of recycled ventilation flow (for the CHU buildings only, the information was hardly significant in the ULg buildings);
  - The presence of heat recovery units (especially in the CHU buildings), considering a 70% theoretical recovery rate (which has been reduced to 42%, due to ventilation characteristics);
  - The permanent ventilation of hospital spaces, and partial (8AM to 6PM) ventilation of university facilities.
- The EPB by-default value for lighting installations (an installed power of 20W/m²) is known for being quite detrimental, even compared with real installations in old buildings. The average lighting consumption is therefore based on the audit made by Jacques Fryns[3], who concluded that the real installed lighting power reaches an average installed power of 12W/m².
- The heat production is centralised for every building of the Sart-Tilman site. A unique central boiler room contains a new biomass-fired cogeneration system (7MW) and back-up (54MW) natural gas-fired boilers, which are not to be renovated in this project.

4. Renovation scenarios

Here is a list of the potential works that could be applied on the buildings:

- The insulation of the loss areas is the first work to be considered in order to improve energy performance. Two levels of insulation were considered: the 2014 regulatory U-values, and another level considering thicker insulation layers (for example, the 2014 U-value for an external wall is 0.24W/m²K; a better insulation corresponds to the second insulation level considering a 0.18W/m²K U-value). Further on during the studies, it has been decided to drop the second insulation level, for profitability reasons.
- The replacement of windows by new efficient ones is the obvious work to undertake. Two types of windows were considered:
  - "Traditional" double glazing (U_g= 1.1W/m²K, and U_w= 1.53W/m²K)
  - Efficient double glazing (U_g= 0.8W/m²K, and U_w= 1.24W/m²K).
- The improvement of insulation, the replacement of windows and the general

[3] Lighting design engineering office Jacques Fryns, Liège

work on facades will, if proceeded correctly, modify the airtightness of the whole building. This hypothesis has been taken into account (the air leakages flows for a 50Pa pressure difference between in and outside are decreased from 12m³/h.m² to 6m³/h.m² in the first scenarios, to 4m³/h.m² in the last ones).

- The ventilation-related losses are important in these buildings, as said before. However, it will not be possible to invest for the replacement of every ventilation system, as most of them have to keep on working permanently or are made of independent, localised but separated supply and exhaust fans. At least, in-depth studies will have to be lead later on to evaluate the real feasibility of this kind of work (e.g. installation of heat recovery units in B23 and B34 buildings, thanks to their large part in the overall consumption, and their improvement potential). In the mean times, "small" interventions can be foreseen, for example in the flows regulation systems and schedules.
- The heating system is not to be deeply changed. As for the renovation systems, the main (and more profitable) work will be undertook on temperature control and global improvements of circulators.
- The lighting systems can be improved, according to the preliminary audit led by Jacques Fryns. The installed power is foreseen to decrease from 12 to 8W/m², thanks to the placement of more efficient lighting units, and regulation systems. Additionally, it has been decided to modify the external lighting system in order to make it more efficient.

5 scenarios were finally selected:

1. The first scenario sees the roofs insulated (U= 0.24W/m²K), the windows changed (U_w= 1.53W/m²K), and the lighting system improved.
2. The second scenario is similar to the first one, with a "light" work added on ventilation and heating systems.
3. The third scenario considers the possibility to add 20% to the invested amounts for changing the windows, in order to place more efficient ones (U_g= 0.8W/m²K and U_w= 1.24W/m²K). It also takes into account a deeper renovation of ventilation systems in the B23 and B34 university buildings.
4. The fourth scenario is quite similar to the second one, with two notable differences:
    a. On the hospital site (CHU and ULg buildings), the "easy" insulation of vertical walls has been considered. "Easy" insulation is here defined as the thermal insulation of large flat areas of walls (surrounding stairwells for example), without balconies or other architectural details that greatly complicate the insulation, increase the investment and threaten the financial profitability.
    b. On the botany site (B22 building), the investment is increased by 20% in order to allow an architectural gesture.
5. The fifth scenario, finally, is a combination of the third one (with more efficient windows and deeper work on the B23 and B34 ventilation systems) and the fourth one (with the "easy" insulation of vertical walls and the architectural gesture on the B22 building).

For each scenario, investments have been evaluated, based on past economic data from recent renovation works realised on university buildings. These investments also take into account the improvement of external lighting and the additional cost for studies and administrative work.

5. Results

The detailed results of this study will not be shown here, but a summary of the expected energy consumptions and CO_2 emissions reductions, and investments:

EEEF: EPB Study			
Summary			
	Units	ULg buildings	CHU buildings
Starting point			
Protected volume	[m³]	598,838	437,248
Heated Floor Area	[m²]	146,857	109,312
Part of the overall Sart-Tilman consumption, based on Cofely quotas	[%]	41.4	24.1
Estimated "real" heating consumption based on Cofely quotas	[MWh]	25,185	14,661
For all scenarios			
Lighting consumption reduction	[%]	38	32.2
	[MWh]	2,113	1,590
Scenario 1			
Estimated reduction of heating consumption	[%]	25.4	36.3
	[MWh]	6,485	5,322
Estimated reduction of electricity consumption (lighting and auxiliaries)	[%]	12.5	10.1
	[MWh]	2,113	3,674
Estimated equivalent CO_2 emissions reduction	[%]	13.9	5
	[teqCO2]	1,367	227
Total investment	[M€]	16.47	12.54
Scenario 2			
Estimated reduction of heating consumption	[%]	39.8	47.5
	[MWh]	10,024	6,964
Estimated reduction of electricity consumption (lighting and auxiliaries)	[%]	14.4	10.4
	[MWh]	2,429	1,910
Estimated equivalent CO_2 emissions reduction	[%]	22.9	7
	[teqCO2]	2,253	317
Total investment	[M€]	19.22	13.31

Scenario 3			
Estimated reduction of heating consumption	[%]	43.8	48.3
	[MWh]	11,031	7,081
Estimated reduction of electricity consumption (lighting and auxiliaries)	[%]	16.6	10.8
	[MWh]	2,688	1,962
Estimated equivalent CO_2 emissions reduction	[%]	25.9	6.2
	[teqCO2]	2,541	281
Total investment	[M€]	26.7	15.04
Scenario 4			
Estimated reduction of heating consumption	[%]	47.3	55.5
	[MWh]	11,913	8,137
Estimated reduction of electricity consumption (lighting and auxiliaries)	[%]	13.6	9.9
	[MWh]	2,326	1,842
Estimated equivalent CO_2 emissions reduction	[%]	28.8	8
	[teqCO2]	2,829	363
Total investment	[M€]	21.07	14.07
Scenario 5			
Estimated reduction of heating consumption	[%]	52.3	56.7
	[MWh]	13,172	8,313
Estimated reduction of electricity consumption (lighting and auxiliaries)	[%]	16	11.3
	[MWh]	2,607	2,023
Estimated equivalent CO_2 emissions reduction	[%]	31.9	7.7
	[teqCO2]	3,129	349
Total investment	[M€]	28.6	15.79

Fig. 6: results table for each simulated improvement scenario (heating and electricity consumption, and CO_2 emissions reduction).

6. Financial study

In order to evaluate potential financial profitability, a simple study has been led; here are the hypotheses behind:

- A “status quo” scenario has been added to the previously described ones; it shows the evolution of costs if the renovation projects would not be realised.
- On a “worst case” state of mind, the investment is supposed to be entirely borrowed. The parameters considered for the loan are:
    - A duration of 15 years;
    - A fixed 5% interest rate.
- The energy bills are supposed to evolve with the energy prices during the 30 years study period, starting from the 2013 prices the University of Liege paid

for, and taken into account in the 2014 budgets:

- Natural Gas: 47€/MWh
- Electricity: 150€/MWh

The evolution rates are considered as follow[4]:

- Natural Gas: 6% until 2020, 2.5% afterwards
- Electricity: 6.6% until 2020, 2.3% afterwards

- For each scenario, the energy bills will also evolve (downwards), thanks to the improvement of the overall energy performance. These improvements will of course be taken into account: in a first approach (that ignores the detailed works planning), it has been assumed that 50% of the energy performance improvement will be available during the first five years, while complete improvement is considered from the 6th year.

The results are shown hereunder: annual costs for the next 30 years, and cumulated costs over the same period.

For the University of Liege:

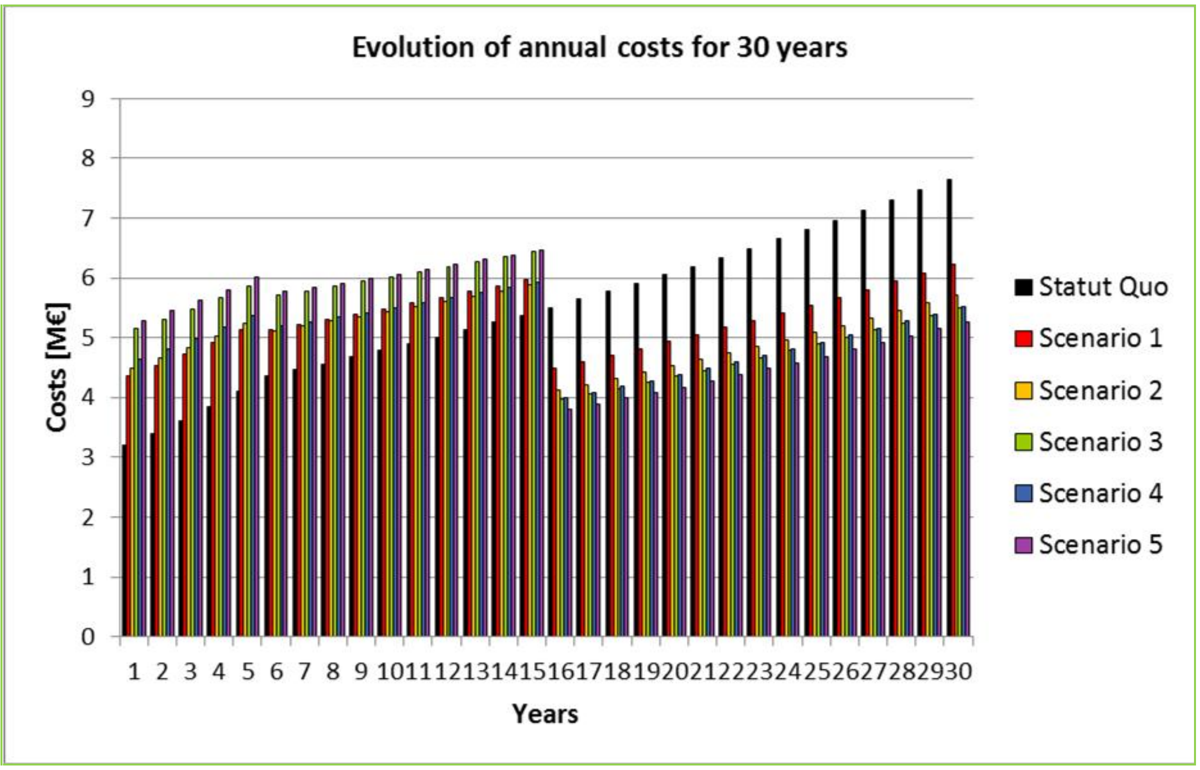

Fig. 7: graph showing the evolution of annual costs (for the University of Liege) for the 30 years period beginning with the renovation works.

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[4] Bureau Fédéral du Plan : Federal Office for economic analysis and forecasting

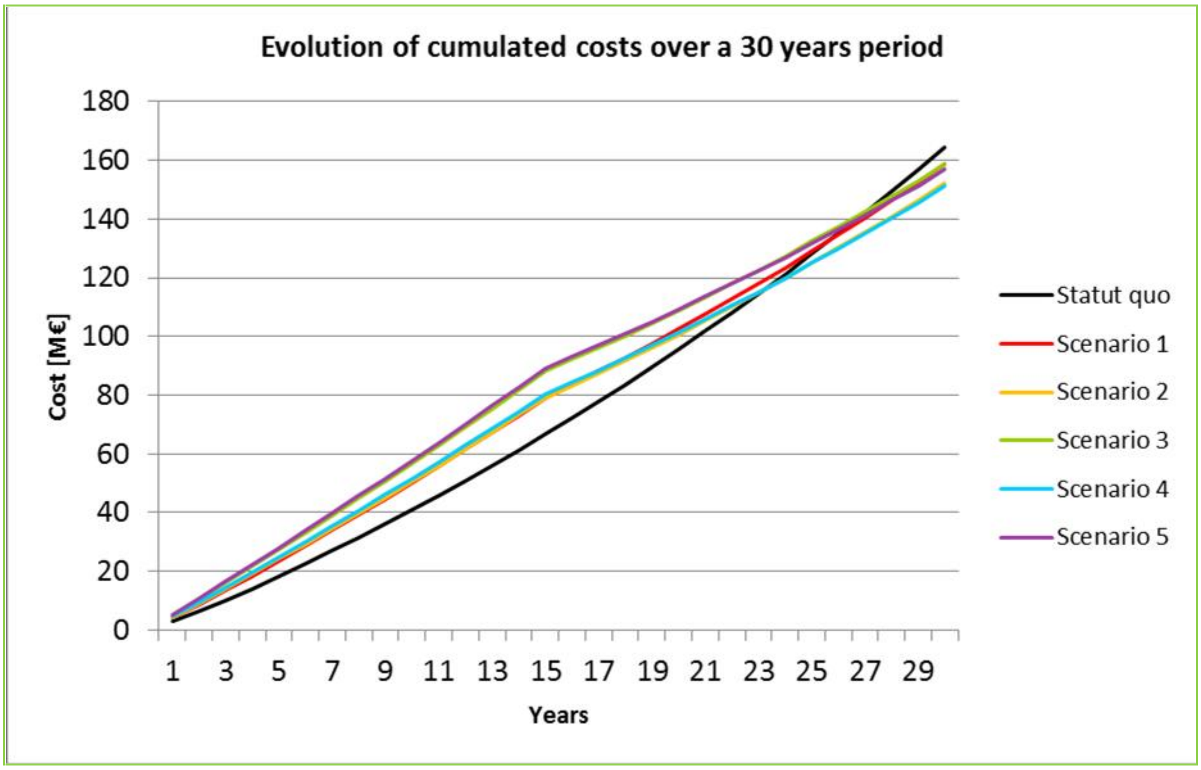

Fig. 8: graph showing the evolution of cumulated costs (for the University of Liege) for the 30 years period beginning with the renovation works.

For the Hospital:

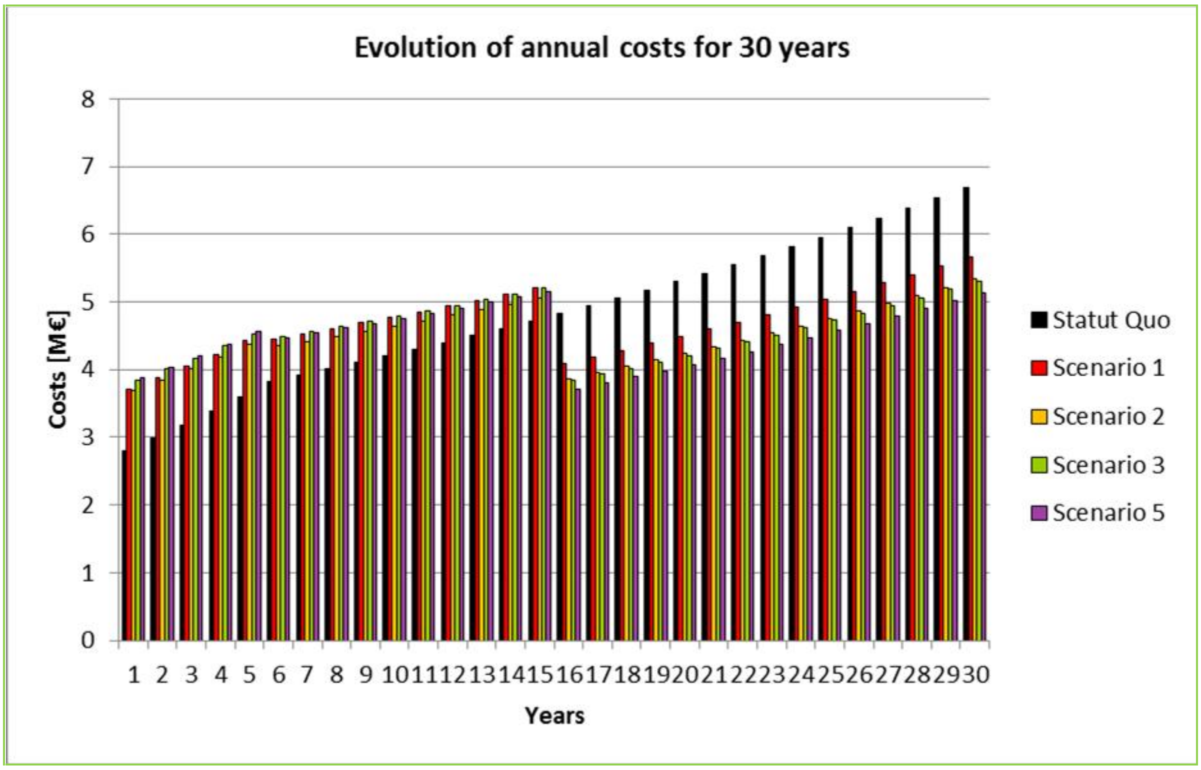

Fig. 9: graph showing the evolution of annual costs (for the university hospital) for the 30 years period beginning with the renovation works.

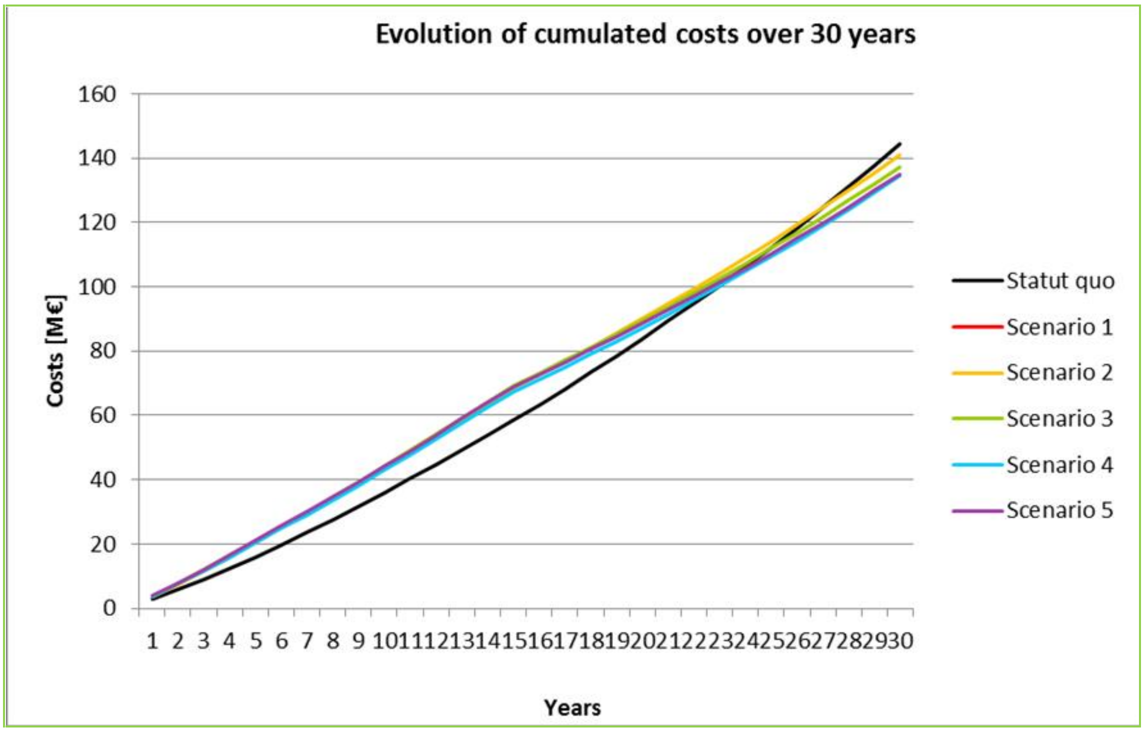

Fig. 10: graph showing the evolution of cumulated costs (for the university hospital) for the 30 years period beginning with the renovation works.

7. Conclusions

The goal of this preliminary study is not to already choose between a scenario and another, but to give an overview of the potential. It will obviously be deepened, should the works be undertook in the future months.

However, we can here already agree with main conclusions:

- Some intermediate simulations have been made in order to reach the results shown above, but have been dropped because of the technical or financial difficulties they generated.
- The scenarios exposed above show important renovation potential in the Sart-Tilman buildings. The heating consumptions, for example, are expected to diminish by 25.4 to 52.3% for the ULg, and 36.6 to 56.7% for the CHU, in accordance with the considered scenario.
- The expected results of reduced consumptions, expressed in financial terms, are largely sufficient to encourage their achievement. The study above shows that profitability could come later than expected, but let us remind here that this part of the study should also be deepened. For example, the curative maintenance costs should be (greatly) diminished for these buildings. Part of the ULg annual maintenance budget could also be used for part the foreseen works, diminishing the amount of the loan.
- The CHU and University authorities are convinced by the validity of these studies and the improvement potential, on both environmental performance and public image levels.