BELGIUM

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Supply chain case study:

Development of an industrialised system for quick and easy replacement of urban modest houses facades

The Reno2020 project engaged all construction actors, from stock owners to local material producers, to imagine efficient refurbishment solutions of dwellings in the suburbs of Liege (BE), according to their typology. This industrialised solution has been developed to replace the street façades of old, often insalubrious urban modest "blue-collar" houses. Among its strengths: set-up rapidity, high energy performance without loss of private or public space, locally-sourced materials and urban-scale retrofit potential.

For more than a decade, the Walloon[1] government has developed plans of economic redeployment; among these, the "Marshall Plan" financed (from 2009 to 2013) the "Reno2020" project, with the objective to demonstrate that the existing Walloon residential stock provides a vast potential for improvement, especially as far as energy and environmental performances are concerned. Furthermore, Reno2020 gathered together different actors of the construction sector social microcosm:

- The client, private or public owners of dwellings to be renovated.
- The architect, author of the renovation project.
- The contractors, transferring the projected renovation into reality.
- The product manufacturers, developing ad hoc solutions to particular problems.
- The scientific committee, composed by the Belgian Building Research Institute (BBRI, Sustainable Renovation Department), the Technical Control Bureau for Construction (SECO) and the University of Liege, Energy and Sustainable Development (EnergySuD) research unit.

This gathering finds its reason in the principle that all the actors in the construction industry are needed in order to develop new, global and coherent strategies for dwellings rehabilitation, solutions that would reduce costs (to ensure economic feasibility), reduce time for production, delivery and completion and ensure technical performance. Local industrial partners were therefore often consulted to help find or develop solutions to particular or general problems in retrofitting.

[1] Wallonia is the South, French-speaking part of Belgium: regional governments are in charge of energy and environment matters, as well as housing, energy used in buildings, employment, transports, agriculture, public works, economic policy, trade etc.

In the first part of the project, the University of Liege investigated the urban, typological, energy and technical characteristics of the existing residential building stock of Wallonia, categorising it in order to identify priority typologies and the improvement potential, as far as energy and sustainable renovation is concerned. In its conclusions, the study highlighted the need to renovate working-class neighbourhoods in urban contexts. Although recent decades have seen an increase in the construction of suburban detached houses, the majority of the priority stock comprises urban dwellings built before 1945, categorised as:

- "Blue-collar" houses: typically small, simple brick row houses, with a more recent and insalubrious annex, built for blue collar workers involved in the steel industry;
- "Master" houses, built during the same period by wealthier citizens, with larger dimensions, better design, details, materials and healthiness.

Together this two typologies represent a third of the Walloon residential stock.

Figure 1. Examples of "blue collar" homes (left) and "master" homes (middle). On the right, a common example of such a building, divided in several apartments.

The "façade-replacement" solution that is described in this case study has been developed for the "blue collar" building chosen to be renovated in the Reno2020 project. Historically, these houses were built by industry owners for their blue collar workers, in close proximity with the plant. They were generally built simply and quickly, in rows, with small dimensions - small volume, narrow front façade, low ceilings – and local materials (stones, bricks and wood). Whole neighbourhoods appeared, mainly composed of low-income families; obviously these districts evolved during the years, as their dwellers did; small houses were extended by unregulated constructions of annexes in the back (to shelter kitchens, sometimes bathrooms). Half a century later, these houses often show general insalubrity, translating in humidity and cold air infiltrations, patches of mould and structural weaknesses. In the particular case of the Reno202 project, the poor condition of front façade of the house made the necessity of its replacement an opportunity to develop a solution potentially applicable to similar units and even whole rows of dwellings.

Figure 2. Front facade of the renovated building, before (left) and after (right) renovation.

During the renovation, props were are installed to support the loads that otherwise would rest on the façade. The original façade (30 to 40cm of bricks), windows and door were then removed with care for the neighbouring facades, the roof eave and the zinc works. Other preparation works included cement patching and the application of a layer of foam glass on a sealing coat to ensure the junction between façade and floor insulations.

The company Arcelor Mittal, historically present in the Walloon Region for decades, developed several years ago in its branch that focuses on developing and improving building solutions a light metal structure (called 'Styltech', indicated in pink on figure 3) , for several wall applications (structural or non-structural). Though a prefabricated light structure can be easily erected for small buildings facades, the assembly plan had to be carefully prepared, with respect to the architects design and local constraints (such as the upholding of the existing roof and zinc works, the slope of the street and the connections to neighbouring facades). Once in place, the structure was be completely enveloped in mineral wool insulation.

On the internal side of the facade, a secondary metal structure was fixed on the main one with neoprene pieces, allowing to create thermal and acoustic breaks and a technical space, which can be filled by insulation if not needed for services.

The worldwide well-known producer of insulation and plaster-based materials Knauf, based in the region of Liege for several years, was also a big part of the development of this solution, which thus comprises mineral wool insulation (using the "Ecose" technology for a binder that reduces its environmental impact), an external fibre-cement panel (developed for external facade applications, fixed on the vertical metal structure through wooden battens for to avoid thermal bridging), external cement finishing and internal plaster boards.

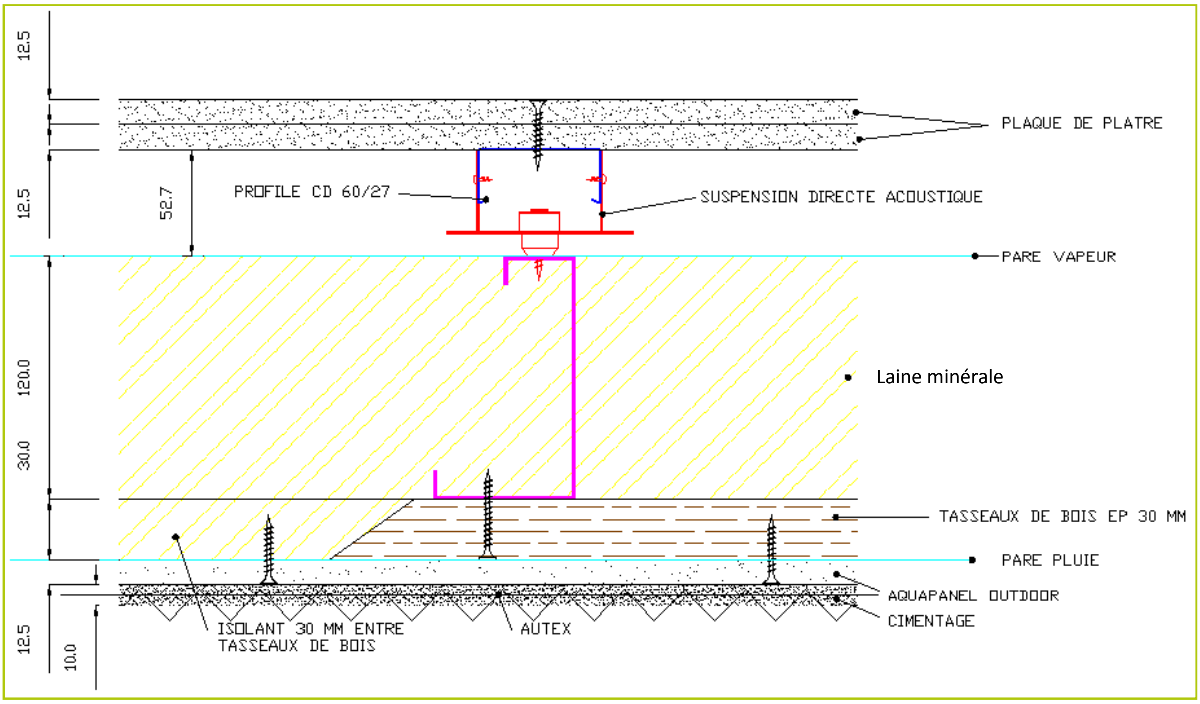

Figure 3. Composition (horizontal cut) of the new Styltech facade.

Figure 4. Facade of the building, before renovation (left), during structure erection (middle) and finishing covering (right).

Steel, plaster and mineral wool may not appear as "environment-friendly" materials, but it has to be pointed out that many improvements have been made to reduce their environmental impacts. First and foremost, Arcelor and Knauf have deep roots in the Walloon Region: raw materials are extracted nearby, so that the location of the industries near Liege reduces the impacts of transport. Also, if steel and mineral wool can be regarded as rather energy-consuming products, it must be noted that both companies have increased significantly the percentage of recycled materials in their processes. Knauf also improved the whole mineral wool production process by developing the new 'Ecose' technology that replaces hazardous binding components with natural sugar-based ones.

Impacts of the technology

The initial objectives of the project were to develop solutions impacting positively on:

- The technical performance: both companies have worked together to master materials associations, define assembly systems that would respect the required performances in terms of energy losses, acoustic insulation and speed of assembly. As a result, the façade was completely built in two days, and its performance assessed by the EnergySuD Research unit of the University of Liege, the Research and Development team of Arcelor-Mittal Construction and the BBRI.
- The duration of the on-site intervention: intensive prefabrication of the solutions also eases the on-site working process, increases workforce safety and decreases the inhabitant discomfort during the retrofitting process.
- The healthiness of old working-class neighbourhoods that lack of architectural interest: quite obviously, the renovation changes significantly the aesthetical aspect of the building, which means that this solution cannot be applied extensively on any urban building. The study of the different typologies and sizes defined some application potential, mainly in small row residential buildings.
- The cost of the applicable solutions: this particular solution has been developed for this building renovation, but every renovation case is different and needs to be studied carefully. Prefabrication and "easy" reproducibility of the solution are therefore difficult. The involved companies have nevertheless adapted this solution for new buildings, allowing for cost reduction through prefabrication and reproducibility.
- The environment: with reference to Life-Cycle Assessments (LCA) of the solutions and energy performance evaluation, before and after renovation.

The research teams from ArcelorMittal and BBRI published, as part of the Reno2020 project, an LCA of the renovation, and compared it with the LCA analysis of two other wall solutions, designed to present equal thermal transmittance (U= 0,3W/m²K), following three scenarios:

- The "BASE" scenario represent the "as-built" solution, where the main façade is replaced by the new construction, with other improvements including:
    - The insulation of the roof (15 cm of mineral wool in the existing structure), the floor (8 cm of polyurethane under new concrete slab) and the back façade (8 cm of polystyrene under plaster covering);
    - The replacement of all windows (Ug = 0,8 W/m²K);
    - The placement of a ventilation system;
    - The replacement of the boiler.
- "ALT1" describes a more traditional refurbishment solution, where the front façade is replaced by a wall composed of terracotta structural blocks, expanded polystyrene insulation and plaster covering; all other works are identical (see above).
- "ALT2" describes a more extreme solution, where the whole house is demolished and rebuilt using only the Styltech structural solution. The systems in this scenario are identical to the previous two above.

The comparison aims to evaluate the environmental impact of the different envelope renovation solutions, therefore the boundary of the LCA did not consider the energy consumption of the building in use (assumed as equal for all three solutions) but mainly the production, transport, replacement and end of life of materials, over a 60 years timespan.

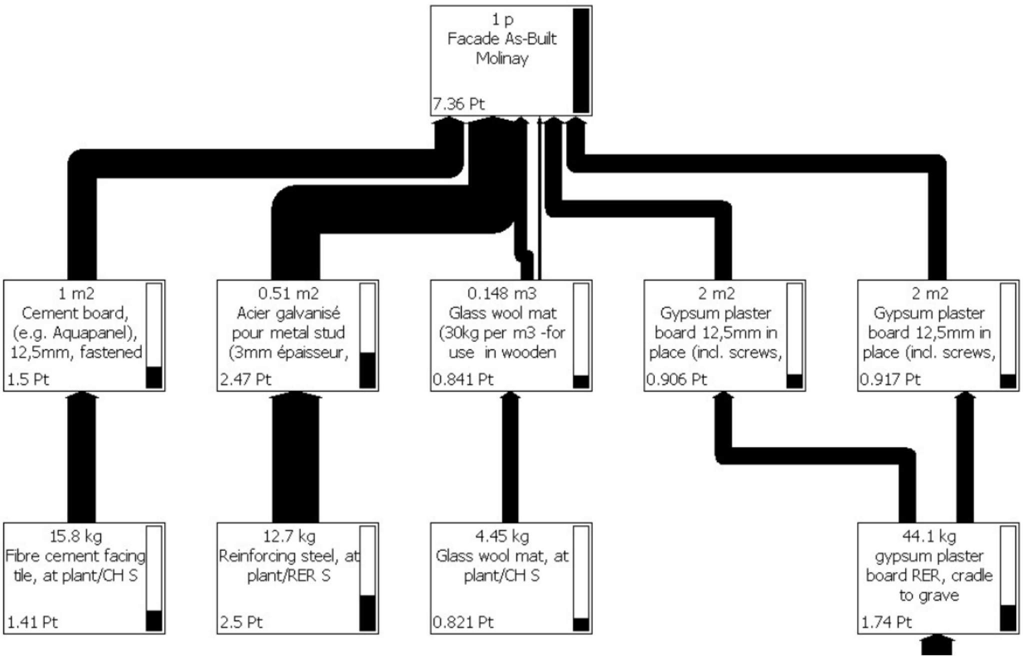

Figure 5. This Network diagram represents the main environmental impacts of the wall façade system. This analysis considers 1m² of façade composed of the system wall over its entire life cycle (cradle to grave) 1m² of façade has an impact of 7.36 ReCiPe points, with 33% contribution from the galvanised steel, 25% from the gypsum plaster boards, 20% from the fibre-cement external board and 11% from the insulation.

According to the LCA results, expressed in the ReCiPe[2] method used by BBRI, the overall environmental impact of 1m² of the new façade system (alt2 scenario, see figure 6) is almost double the impact of a more traditional brick wall (alt1 scenario, see figure 6).

The high impact can mainly be attributed to the production phase of the galvanized steel elements used for the loadbearing structure. Even if part of the material is recycled, it still has to be treated at high temperature to be re-shaped and used again. The double gypsum fibre boards, used on the inside of the system wall and considered replaced within the building's service life of 60 years, also generate a significant environmental impact.

It would be easy to conclude that the use of a system wall in the current configuration does not perform well from an environmental point of view. In order to generalize these conclusions, however, it would be good to consider that comparison should also be made with other façade construction techniques and materials, and that the difference between steel and brick solutions is hidden in the overall results and only clear where the whole house is fully demolished and reconstructed using steel structure.

[2] http://www.lcia-recipe.net/

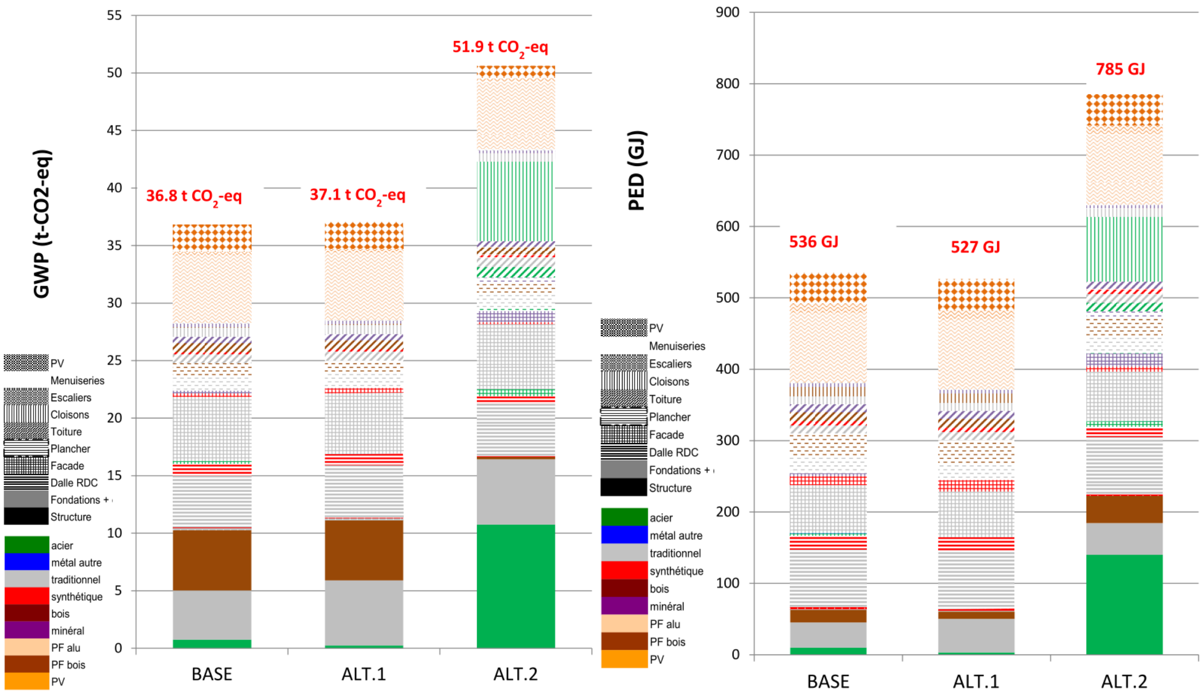

Figure 6. Distribution of Global Warming Potential (GWP, left) and Primary Energy Demand (PED, right) impacts on the life cycle of the building; "BASE" = as-refurbished, with front façade replaced by the studied new wall system; "ALT1" = traditional refurbishment (front façade rebuilt with traditional masonry); "ALT2" = complete Styltech reconstruction of the building) (see description above)

Though it is difficult to be categorical when it comes to interpret LCA results, a difference of more than 20% (as shown in the figures above) is nevertheless a solid base on which to found a comparison; the "extreme" alternative of whole reconstruction, using only "Styltech" structural solution (alt1 scenario), is less "environmental-friendly" than others.

The "traditional" construction system (terracotta blocks) seems to absorb the difference in both GWP and PED impacts between "BASE" and "ALT1", so that the whole building performance is somewhat comparable. In other words, the relatively equivalent environmental impacts of the front façade in both "BASE" and "ALT1" configurations, bring negligible differences in the overall building environmental impact.

These results should also be moderated considering the local sourcing and transport of material. Belgium is struggling to obtain real data from its local material producers, so that average data is used in most LCA studies. Choosing a producer that uses locally-sourced raw materials, therefore, does not show in the results and this particular context is furthermore enlightening: Seraing, where this study took place, is located in the Meuse valley, a historical place for steelwork industry, with the presence of Arcelor Mittal industries and research centre. Knauf industries, providing locally-sourced cements, plasters and mineral wool insulation, are also located less than 50 km away from the renovation site. Unfortunately, the environmental performance data related to Ecose technology is for the moment unavailable and "regular" mineral wool data had to be used. AGC Flat Glass Europe, partner of the Reno2020 project and provider of new double glazing (with an U-value of 0.8 W/m²K), is also based in Wallonia.

Another study, led by the University of Liege assessed the performance of the system (U-value of 0.3 W/m²K), the efficiency of the insulation enveloping the structure and the performance of the thermal breaks in the plasterboard fixings. No superficial condensation is to be expected in the technical space, nor is internal condensation in the façade system, if a vapour barrier is added on the internal side of the insulation.

Using the regulatory and standardised method for the calculation of the energy performance of buildings in Belgium, the energy consumption of the house has been evaluated at 396 kWh/m².yr before renovation, and 151 kWh/m².yr after. The overall renovation of the building seem to allow a 73% reduction of its theoretical primary energy consumption; the new façade alone is responsible for 12% of the overall energy consumption reduction. If this solution could be applied to 200.000 similar houses in Wallonia, a reduction of around 1000 GWh per year in the regional primary energy consumption would be possible.

On the economic side, the life-cycle costing study realised by BBRI states that there is no significant difference in the economic performances of the two examined alternatives, namely the system wall façade and a brick wall façade. The values for investment, maintenance and operation costs are close to each other and within the margin error, thus both alternatives are considered performing equally.

These are, somewhat, good results; it has been proven that steel solutions are competitive when it comes to renovation, when cooperation and product development are encouraged in the upstream supply chain. In this case, replacing the front façade with the new solution or with traditional masonry seems to be comparable in terms of energy and environmental performances. However, the "Styltech" solution outdistances the traditional one when it comes to reducing renovation costs and duration. Steel hardly makes it to the top of environment-friendly materials list and will not easily replace wood and bricks among Walloon households' cultural choices and habits. The inertia of the residential construction sector and the dynamics of the steel market make it more difficult for this solution to be fully accepted within the current conditions. However, the potential for economies of scale, low transportation impact (due to regionally sourced materials) and fast technical assembly (requiring skills that construction workers already possess, as proven by the "regular" team that erected this wall on site) could display the full advantage of this product, with the opportunity to renovate complete rows of front facades at once, if projects are well organised and financed.

The supply chain is well established and provides an example of good practice. Its development has been made possible by the Reno2020 Research Project, supported by the Sustainable Building Department of the Walloon Administration and the Cap2020 Cluster. It is the meeting of two different industrial partners, the ULg and BBRI research units, the architects and the owners' renovation case study that led to the development of this solution and the analysis of its performances. It is possible to see the potential at a higher scale: Europe has announced important renovation policies in the years to come, in order to reach its targets of energy consumption and GHG emissions reductions; large scale renovation projects will be necessary in order to improve the building stock, and smart, easy and fast solutions will be needed.

Source: S. MONFILS, J.-M. HAUGLUSTAINE, (2014). *Réno2020: méthodologie d'insertion des nouvelles technologies dans la rénovation durable du logement wallon, rapport final*, University of Liege, Liege, Belgium.