The selection of 3 renovation packages

The decision making process for selecting the renovation packages

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Table of contents

Introduction

This is an internal work report that will document and verify the process and the decisions made in the consortium and among the partners of INDU-ZERO to select three renovation packages. The knowledge base supporting the choice of the selected renovation packages is found in the process of requirement gathering carried out in each of the NSR regions dedicated to the INDU-ZERO project (The Netherlands, Belgium, Germany, Sweden, Norway and the UK). The point of departure for our selection is the focus on the numbers of outdated houses, current CO_2 emissions from those houses and current renovation costs. The numbers of outdated houses between 1950 and 1985 of the NSR partners are: Belgium 500.000, The Netherlands 4.3 Million, Germany 4,8 Million, UK 9,6 Million, Norway 810.000 and Sweden 1,2 Million and the environment burden of CO_2 emission of each house is estimated to be about 3,6 tons per year per house. To meet the EU 2030 objectives, almost two million houses per year would have to be renovated in the period 2018-2030 in the NSR region. Current renovating costs for renovating houses to energy-neutral range based on a manual local approach represent costs between € 80.000 and €120.000 per house/apartment. Today there is a gap for standardized renovation solutions at high volume and low costs for the EU market.

The decision to select the renovation packages must therefore consider the following conditions:

- To obtain the overall project objective to innovate, to upscale and to industrialize renovation packet solutions towards energy-neutral for NSR homes built in the 1950's to 1985's,
- To reach substantial cost reductions of 50 %.

This implies standardization of the renovation packages but at the same time flexibility because the renovation packages should not only be suitable for one type of house or one type of country but consider the requirements of different countries.

The steps of decision-making

One of the central tasks to obtain the main objectives of the INDU-ZERO project is to select and to develop a maximum of 3 renovation packages. The decision process to do this has followed guide lines of the application and the prescribed decision structure. The decision has been done in the INDU-ZERO Consortium core group meeting at 23-24th of October 2018, in Bodö 28-30th of January 2019. Furthermore, information and knowledge has been given through several internal Webinars.

Based on national data from each partner on building statistics, building regulations, and national construction praxis' and traditions, an aggregate report (Dwelling stock that is suitable) has been written. The conclusion made on behalf of the evidence of the cross-national building statistics and references was to focus on three types of houses:

- Detached houses;
- Terraced houses;
- Apartments.

For developing of wall and roof elements for these types of houses, the structure of the elements and the materials to be used must be determined. Four types of composing elements were considered as a starting point: Timber frame structure (TF), metal frame structure (MF), structured sandwich panel (SSP) and structural insulation panel system (SIPS).

At the consortium group meeting in Bodö a decision process was gone through in order to choose the best solutions of renovations packages. A workshop in the lead of the industrial design bureau D'Andrea & Evers gave a presentation about insulation and circularity. All project partners were divided into 4 groups to discuss the 4 types of structures mentioned above. These structures were evaluated against cost/circularity and cost/effectiveness of the panels and roofs. After a short description of the potential structures of the roof and wall elements, the evaluation and decision process of the choice of structure is described in the following chapter.

An overview on structures of wall and roof elements

To understand the advantages and disadvantages of the four structures they were compared based on different construction methods and materials.

1. Timber frame structure (TF): Wood framing, in construction, is the fitting together by pieces of wood and sheets to give a structure support and shape. Modern light-frame timber structures gain strength from rigid panels (plywood and other plywood-like composites such as oriented strand board (OSB) used for parts of wall sections). In between the gaps joists insulation like glass- or mineral wool is placed. To meet stringent insulation demands, like for example in the Nordic countries, an additional insulation layer made from expanded polystyrene foam (EPS) can be placed on one side of the element. On this, the outer cladding is applied. A ventilation gap is needed to keep the timber and insulation dry. [1]
2. The metal frame structure (MF): The main structural components of light metal or steel framing are made of galvanized cold formed steel sections. These can be prefabricated into panels or modules. In between these metal frame sections insulation like glass- or mineral wool is placed. On an additional insulation layer on the outer side, the outer cladding can be applied. Depending on the insulation that is used, a ventilation gap could be needed. [2]
3. The structured sandwich panel (SSP): SSP, like structural insulation panel systems (SIPS), are used in the construction industry. [3] The SSP is a sandwich structured composite which consists of an EPS insulation and an OSB sheeting positioned between two layers of fiberglass. The OSB serves as a mechanical attachment layer to provide fastening opportunities. These layers form a light but very strong panel. Like in the other panels, an outside cladding is possible.
4. The structural insulation panel system (SIPS): SIPS, like SSP, is a sandwich structured composite. It usually consists of an insulation layer of rigid core glued between two OSB panels. The core insulation might be expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane foam (PUR).

Assessment

As mentioned before the methodology used to prioritize was based on a semi-structured decision process in 4 expert groups. Those groups were challenged to develop the next steps of structure of the wall and roof elements. For the assessment of different structures and materials each group of experts had to assess the design of the structures timber frame (TF), metal frame (MF), structured sandwich panel (SSP) and structural insulation panel systems (SIPS) on the following predefined criteria:

- Costs: The concept of total cost of ownership (TCO) is used for the assessment of each technology. Total cost of ownership does not only consider the purchasing price of a product. Moreover, all direct and indirect costs involved in

buying and using a product over its life time are counted in to help buyers and owners decide on different alternatives. [4]
- Circularity: The renovation packages to be developed in the project should be based on the principles of circular economy and optimized for low embodied energy. Circularity describes the sustainability of a product considering its whole life cycle. Circular building concepts and Cradle-to-Cradle frameworks imply radical changes for the construction sector and must be considered. [5] [6]
- Effectiveness: Effectiveness describes the effort to make a good insulation panel with integrated technology like heating and ventilation. Characteristics like thermal insulation or thermal bridges, sensitivity to humidity, deformation or delamination must be considered. The possibility for upscaling automation the production process is also considered.

In a first step, the characteristics of the four structures about costs and circularity were discussed, taking the timber frame structure as the fixed starting point. The results were set on a two-dimensional coordinate system (see figure 1). Next, the characteristics of the four structures regarding costs and effectiveness were assessed. The results again were set on a two-dimensional coordinate system (see figure 2). To finalize the assessment, the results were discussed in the peer group to aggregate the findings in a joint figure.

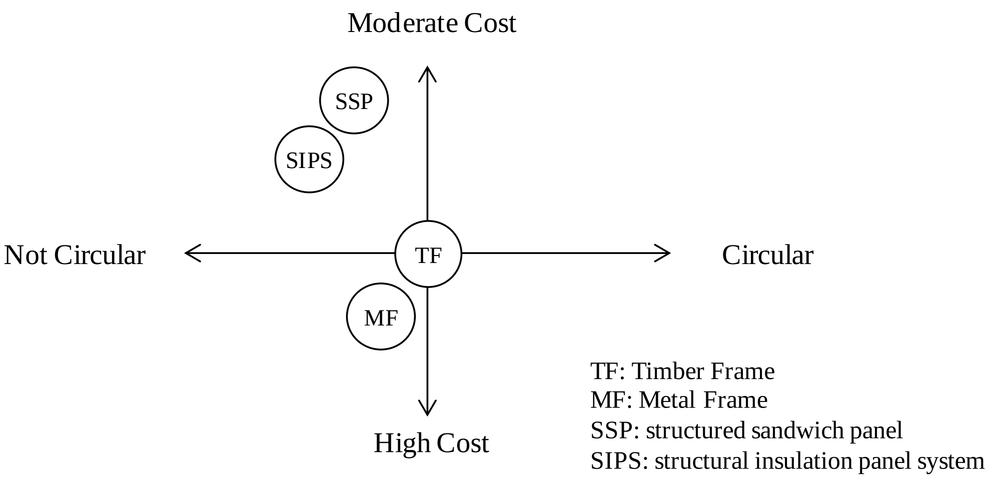

Figure 1. Assessment of structures – Circularity and Costs

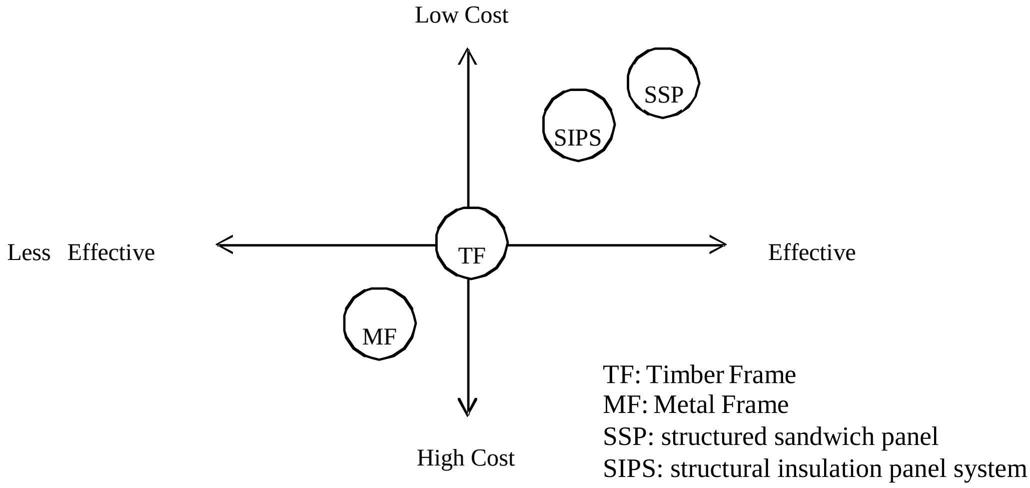

Figure 2. Assessment of structures – Effectiveness and Costs

The positioning of the four structures in the coordinate system was a long and controversial process. Different points of views had to be balanced. To give a short overview, main arguments for each structure are depicted in the next section.

Background information of main criteria for decision-making

All structures and their advantages and disadvantages had to be evaluated and compared. Therefore, not only the as-is-situation has to be considered. Also, potential future developments had to be discussed.

Timber frame structure (TF):
Circularity: A timber frame wall consists of different materials each with its own circularity. Main materials of the wall elements are: Timber frame, glass- or mineral wool insulation, oriented strand board (OSB), expanded polystyrene foam (EPS) insulation, damp barrier foils and the cladding. In theory each component could be separated and recycled on its own. However, actual wood frame constructions are difficult to disassemble as there is contamination due to adding spray foam in corners, added glue between panels or (chemically) treated materials to make them resilient. Although timber frame has a potential for a good circularity this treatment has a big negative impact on the recyclability of the used materials. Timber has a low carbon footprint and is renewable. Softwood species are fast growing, and some are grown widely across (northern) Europe. Untreated softwood can be down cycled in wood-based products or as fuel.

Effectiveness: Wood has relatively good thermal insulation values compared to other building materials. As the frame is self-supporting, the choice of insulation can be tailored to the environmental situation. Softwood when exposed to humidity can deform and create air gaps. Thus, frame and insulation need to be kept dry and ventilated to prevent sagging. Looking at the production process it is important to note that timber frames can also be prefabricated into panels or modules.

Cost: Timber is relatively expensive per volume. However, softwood is cheaper than hardwood, even when it is FSC certified.

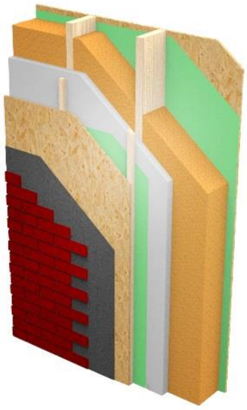

Figure 3. Timber frame construction

Metal frame structure (MF):
Circularity: A metal frame wall consists of several different materials with their own circularity. Main materials of the wall elements are: Steel frame, glass- or mineral wool insulation, chipboard (OSB), EPS insulation, damp barrier foils and the cladding. Like wood frame constructions, these are difficult to disassemble due to the addition of spray foam or glue. Raw materials are non-renewable. The production of steel has a high carbon footprint. It requires a lot of energy and material and releases CO^2 during the process. Still, steel is quite easy to recycle. Steel frames even have a possibility to be re-used.

Effectiveness: Because of the 'c shape' of the metal frame, insulation is held in place very well and hardly any sagging occurs. As the frame is self-supporting, the choice of insulation can be tailored to the environmental situation. However, there is a big risk of air gaps where the insulation does not fill up the frame correctly. Metal itself has very bad thermal insulation values. There is a very high chance for thermal bridges. Thus, an additional layer of insulation is needed to dampen this effect.

Cost: Metal frames themselves are quite expensive to produce.

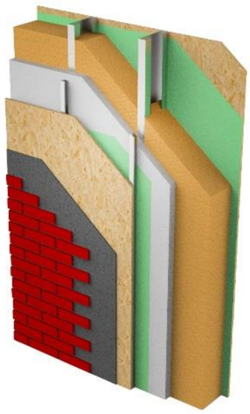

Figure 4. Metal frame construction

Sandwich panels (SSP):
Circularity: As the structured sandwich panel (SSP) and the structural insulation panel system (SIPS) are sandwich composed panels, an end-of-life recycling and reuse is difficult. Although some components might be easy to reuse, most components are glued together. Thus, separating materials is difficult and labour intensive.

The virgin raw materials to produce OSB have a low carbon footprint. FSB certified OSB is available. Raw materials can contain recycled woods like chipped construction wood. However, OSB needs high heat and pressure to be produced, just like plywood, particleboard and MDF. The reuse of OSB is difficult due to its relatively low durability. Recycling of OSB is difficult as well. OSB waste is usually incinerated and used for energy. Moreover, there are limited possibilities for downcycling (e.g. downcycled boards).

Effectiveness: The main advantage of SSP modules compared to SIPS modules is the size and thus the handling possibilities. SSP walls and roofs usually consist of one or two large panels (up to 15m). This minimises the mounting effort and thus the construction time at the construction site. Moreover, this lessens joints which reduces air penetration. Because of the EPS foam which is an integral part of the wall (less gaps) the insulation core and raw insulation values are good. As SSP panels have very few internal structures, the insulation value is very homogenous and thermal bridges are eliminated. The production process can easily be automated due to the structure of the panels.

Cost: OSB, used in both sandwich structures, is less expensive than plywood and similar fibre/composite boards.

Figure 5. Sandwich panel construction

Structural Insulation Panel Systems (SIPS):
Effectiveness: SIPS walls and roofs usually consist of multiple smaller standard size panels. Linking these requires the mounting of timber beams in the wall which is an additional time-consuming process at the construction site. Moreover, this diminishes the R value locally. One particular weakness of these SIPS panels is air penetration at joints or penetrations. Still, due to the hard foam insulation core, raw insulation values tend to be good.

Cost: OSB, used in both sandwich structures, is less expensive than plywood and similar fibre/composite boards. Looking at the insulation core of the SIPS module, costs for EPS are low. Other materials like extruded polystyrene foam (XPS) or polyisocyanurate foam (PIR) or polyurethane foam (PUR) are more expensive. The production process can be automated.

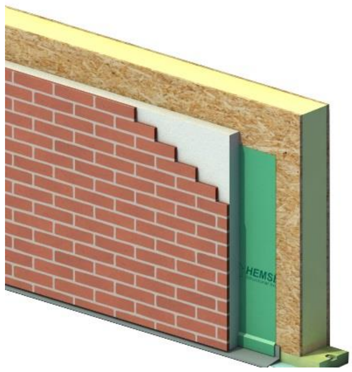

Figure 6. Structural insulated panel construction

The process after Bodø meeting - further examinations needed

After the consortium meeting in Bodø the conclusion was that further examination of two of the solutions Sandwich panel and Timber frame panel was needed. Along two traces more knowledge was need before decisions were made:

- Typology of houses used as retrofit objects
- LCA consideration of the two chosen alternatives: Sandwich panels and Timber frame panels

To do this two groups were established: Christian Struck, Gerard Salemink and Bram Bruins from the Saxion university of Applied Science gathered information from all project partners and presented the results in the report "Dwelling stock that is suitable" and Marijke Steeman and Yanaika Delcorte from the University from Belgium of Ghent together with Per Svänsson from Building Future Institute in Sweden prepared a "Preliminary LCA analysis sandwich panel versus timber frame panel" which was presented in an internal webinar.

Typology of houses used as retrofit objects

The report "Presentation of archetypes and local case study buildings in NL" takes part of departure in building typologies in the Netherlands. These are expected to be generalisable as typologies for the other partner countries with in INDU-ZERO.

This report proposes three dwelling types from the period 1965-1974 to be used as cases for the INDU-ZERO project. The selection has been made based on two criteria:

1. Degree of representativeness for the building stock in the North-Sea region; and
2. Feasibility for large scale production.

The selected dwelling types are semi-detached, terraced dwellings and apartments. Detached dwellings, maisonettes and miscellaneous flats have not been considered as these types of dwellings are not consistent with respect to floor area and overall design which makes it more difficult to design pre-fabricated renovation concepts.

Figure 7. Terraced house archetype

Figure 8. Semi-detached house archetype

Figure 9. Appartement building archetype

LCA consideration of the two chosen alternatives: Sandwich and Timber frame

The work to calculate the LCA cost of alternatives Sandwich and timber frame in more detail is necessary as we need to qualify the precondition made at consortium meeting referred to above. Tool to calculate LCA is made in the database TOTEM. TOTEM takes part of departure in the following prerequisite:

1. Generic materials are used, no EPD's (Environmental Product Declaration)
2. Material data is based on the Eco invent database (Swiss database), translated to the Belgian context (e.g. transport distances, energy mix, end of life scenarios)
3. The tool considers the whole life cycle (cradle to grave): from raw material extraction, materials processing, manufacturing, transport, use, maintenance, replacement, end of life scenarios is included

The TOTEM methodology Combines the impact of material that is the embedded energy in building materials. The impact of energy use during operational phase concerning transmission losses but not the heat balance. This includes:

- Thermal transmission coefficient (U value).
- Simplified calculation using the degree days method.
- Average efficiency of the heating installation (condensing gas boiler)

Furthermore, the CLA analysis only consider the prefab element itself and does not include: The existing structure, the connection mechanism and the. inside finishing layer. To levels of U level are compared U ≤ 0,24 W/m² and the level of passive house standard and U = 0,15 W/m²K

With these condition in mind the comparing of sandwich panel versus the timber frame alternatives shows the following result.

- We don't find any significant comparing environmental cost between: Sandwich panel RC panel at U = 0,21 and U = 0,15. From an environmental point of view, lowering the U value has a limited impact on the overall impact. Material impact increases but impact of energy use during operational phase reduces.
- Sandwich RC panel U=0,22W/m²K have environmental cost of 13,02 €/m² (material cost 7,67 €/m² and energy 5,35 €/m²) versus Timber-frame panel U=0,22 W/m²K have environmental cost of 16,62 €/m² (material 11,33 €/m² and energy 5,29 €/m²)
- Under these conditions there are there is a significant difference of environmental cost between the two prefab panels

However, if we change some variable of timber panels and glues the stone strips to a hard rock wool panel instead of using a ventilated facade, the environmental cost decreases 18% (due to less material use) and environmental cost is reduced to 13,67€/m². Thus, the impact of a timber frame panel without a ventilated facade is comparable with the impact of a sandwich panel. The environmental impact of the timber frame panel is strongly related with the materials that are used e.g. cement fibre board, wooden substructure to create a ventilated facade (from 8 €/m² to 31€/m²). Furthermore the impact of the sandwich panel is underestimated because only one glue layer is taken into account. This should be investigated more in detail in the future. But during our group discussions in Bodö it was discussed that even if it is interesting to develop a light weight wood-fiber insulated panel there is doubt about moisture and organic material in this solutions. One finds a lot of bad examples with non-ventilated organic constructions in a Swedish wood panels.

The sandwich panel will be used both as wall and roof construction. When reflecting roof construction we however have to be aware that sandwich panels are light weight and could therefore have strength issues. We therefore need to be aware of this and if necessary develop a timber frame roof construction as well if we can't overcome the issues. .

Conclusion

The description made in this report of the decisions process to select renovation packages we have concluded:

- the sandwich structures result to be more promising when developing a smart factory with the aim of reducing the cost of retrofitting houses on a large scale and taking into account circularity as well.

The assessment of the effectiveness shows that the SSP modules even outmatch the SIPS modules.

- First, SSP is cheapest due to the use of EPS and OSB, both cheaper than other components in the SIPS module.
- Second, the SSP production process is less complex as less components and materials must be handled. This results in a reduced construction time and costs.
- Third argument it is the possible to size the SSP modules which can lead to a minimised mounting effort and thus a reduced construction time at the construction site.

The assessment of circularity has been analysed according to a LCA analysis. This shows that

- We don't find any significant difference between the sandwich panels and timber frame panels.

Our main conclusion at current state is that we find the most promising potential in using sandwich panel both as wall and roof constructions and will focus our efforts on re-designing this panel to suit our needs and requirements.

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