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Geert De Schutter

Nele De Belie

Arnold Janssens

Nathan Van Den Bossche

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# Influence of life span prediction on building component's LCA performance

SIE Marion<sup>1,a</sup>, SUSCA Tiziana<sup>2,b</sup>, WILLIAMS PORTAL Natalie<sup>3,c</sup>, DURING Otto<sup>4,d</sup>, FONTANA Patrick<sup>2,e</sup>, SJOSTROM Christer<sup>5,f</sup> and PAYET Jérôme<sup>1,g</sup>

<sup>1</sup>Cycleco, 18 avenue Roger Salengro, 01500 Ambérieu-en-Bugey, France

<sup>2</sup>Bundesanstalt für Materialforschung und –prüfung (BAM), Division 7.1 - Building Materials, Unter den Eichen 87, 12205 Berlin, Germany

<sup>3</sup>CBI Swedish Cement and Concrete Research Institute, c/o SP, Box 857, 501 15 Borås, Sweden

<sup>4</sup>CBI Swedish Cement and Concrete Research Institute, Drottning Kristinas väg 26, 100 44 Stockholm, Sweden

<sup>5</sup>Svenska Aerogel AB, Strömmavägen 2, SE-80309, Gävle, Sweden

<sup>a</sup>marion.sie@cycleco.eu, <sup>b</sup>tiziana.susca@bam.de, <sup>c</sup>natalie.williamsportal@cbi.se,

<sup>d</sup>otto.during@cbi.se, <sup>e</sup>patrick.fontana@bam.de, <sup>f</sup>christer.sjostrom@aerogel.se,

<sup>g</sup>jerome.payet@cycleco.eu

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**Abstract.** The life span of a building product is a key parameter when it comes to Life Cycle Assessment (LCA) performance. Nevertheless, many uncertainties affect this parameter due to a lack of long-term performance data. The sensitivity of the LCA outcomes to this parameter has been studied within the framework of the FP7 project H-House (Healthier Life with Eco-innovative Components for Housing Constructions) funded by the European Commission. The paper features two comparative studies conducted within the scope of this project: one for new construction and another for renovation. An innovative precast sandwich panel made of Textile Reinforced Concrete (TRC) and Foamed Concrete (FC), used for external walls in new construction, is compared with a steel reinforced concrete (SRC) wall of the same thermal resistance. For renovation, a novel half-sandwich panel made of Ultra-High-Performance-Concrete (UHPC) and Autoclaved Aerated Concrete (AAC) is compared with cladding having the same thermal performance. The evaluation was conducted using a multi-criteria basis according to the LCA methodology (ISO 14040-44). In each case, an identical life span for both scenarios leads to the fact that H-House components have a better environmental performance. The ISO 15686 and its relevant parts have been considered for the estimation of the service life span. The sensitivity analysis shows the link between the impact savings of the innovative walls and the life span of the walls and their components. In particular, it was found that since both scenarios need to fulfil the same service during an identical reference period, and since some maintenance and replacement of materials are necessary over time for standard solutions compared to the innovative ones, the chosen life span of the components plays a role of utmost importance. The sensitivity analysis discloses the effect of the assumptions on these aspects.

## Abbreviations

AAC: Autoclaved Aerated Concrete  
LCA: Life Cycle Assessment  
LCI: Life Cycle Inventory  
LCIA: Life Cycle Impact Assessment  
FC: Foamed Concrete  
RSP: Reference Study Period  
SRC: Steel Reinforced Concrete  
TRC: Textile Reinforced Concrete

## Introduction

The H-House (Healthier Life with Eco-innovative Components for Housing Constructions) project, funded by the European Commission, aims to develop numerous new building systems suited for a society where both environmental awareness and a high degree of living comfort are required [1]. One of the objectives of the project is to develop innovative panels for external walls with a longer service life than conventional panels, for use in both new and retrofitted buildings. The service life of H-House components is enhanced through the use of innovative concrete and insulation materials.

LCA as described in the ISO standards [2, 3] is an appropriate tool to assess and compare the environmental performance of building products for it allows to consider all life cycle stages, hence preventing transfer of pollution from one stage to another [4]. The LCA method particularly allows the comparison of building solutions while taking into account their difference in terms of service life [5]. The present study assesses the benefits of H-House components' durability, and compares them with conventional solutions, as regards to the contribution to climate change and non-renewable energetic resource depletion. The goal is to particularly check whether H-House components' high service life causes impacts savings compared to conventional solutions.

Although the service lifetime of a building and its components is a very decisive parameter when conducting an LCA [5, 6, 7], there is no commonly accepted method for how to determine building products' life span [8, 9]. ISO 15686 and its relevant parts [11, 12, 13] provide a significant step towards the harmonization of practices related to defining the service life of building products. The latter is determined using the so-called factor method: service life is derived from the theoretical service life of building components out of their context of use – the “reference service life” – and seven adjustment factors reflecting the quality of the building component itself and of the work execution as well as the in-use conditions (environment, maintenance, etc.). Two additional aspects to consider are proposed in [7]: the related components and the trends, i.e. the choices people make based on the appearance of the product or spatial use. In practice, as summarized by [8] “Actual service lifetimes, based on experience, are generally favored over potential or maximum technical lifetimes” in LCA, and, in order to check the sensitivity of the conclusion on this parameter, the assessment is conducted several times for distinct service lives as in [5, 6, 10].

## Goal definition

Two assessments are performed, one for new constructions (i.e. assessment n°1) and another for retrofitted buildings (i.e. assessment n°2). Each assessment focuses on the comparison of external walls, one which is innovative and another one which is conventional. In assessment n°1, an innovative precast sandwich panel made of TRC and FC, used for external walls in new constructions, is compared with a SRC wall of the same thermal resistance. For retrofitted buildings, a novel half-sandwich panel made of UHPC and AAC is compared with cladding with the same thermal performance.

The evaluation is conducted using a multi-criteria basis as according to the LCA methodology [2, 3]. It is performed at the same time that the innovative components are developed. The objective is to check the environmental performance of the components being developed according to their service life.

## Scope definition

**Functional unit.** The functional unit, i.e. the basis for comparison, is defined as follows: one square meter of façade to be installed in a new construction (assessment n°1) / a refurbished building (assessment n°2) in Berlin (Germany). The facade fulfills the following functions during a given RSP:

- o Separation of exterior from interior,

- o Self-supporting capacity,
- o Load-bearing (assessment n°1) / non-load-bearing capacity (assessment n°2),
- o Thermal transmittance U-value: 0.15 W/(m<sup>2</sup>.K)

For both assessments, the reference flow is the square meter of the wall. The functional equivalence between scenarios is set by the functions listed above. Additional aspects and functions such as fire resistance, aesthetical aspects, etc. are disregarded in this analysis. The RSP is defined in [14] as the time period for which the time-dependent characteristics of the object under assessment are analyzed. It is to say that the RSP determines the use phase of the assessed product. Within the present study, the RSP is set as the service life of the most long-lasting removable component amongst the ones involved in the scenarios being compared. The number of replacements of the other components during the RSP is thus determined by their service life.

**Description of scenarios.** Scenarios are described in Table 1 and 2 for assessments n° 1 and 2 respectively.

Table 1. Description of scenarios being compared in assessment n°1.

Scenarios	Layer	Thickness [mm]	Materials	Material density [kg/m <sup>3</sup> ]	Amount in 1 m <sup>2</sup> prototype [kg]	Manufacturing mode
Conventional wall: SRC + insulation	1.	15	Lime cement plaster (finishing render)	1800.00	27.00	In situ
	2.	0.5	Glass fiber mesh (reinforcement layer)	330.00	0.17	
	3.	220	Rock wool	260.00	57.20	
	4.	200	SRC C25/30, 2 M.-% reinforcement	2400.00	384.00	
H-House composite element: TRC-FC-TRC	1.	30	TRC with self-cleaning properties (outer layer)	2365.50	70.97	Precast. Pin and plate connectors are included for the layers to be fixed together
	2.	150	FC	230.98	34.65	
	3.	50	TRC (inner layer)	2365.50	118.28	

Table 2. Description of scenarios being compared in assessment n°2.

Scenarios	Layer	Thickness [mm]	Materials	Material density [kg/m <sup>3</sup> ]	Amount in 1 m <sup>2</sup> prototype [kg]	Manufacturing mode
Conventional wall: Cladding	1.	60	SRC C25/30, 2 M.-% reinforcement	2400.00	144.00	Precast. Insulation fasteners are included for the layers to be fixed together
	2.	50	Air	0	0	
	3.	220	Rock wool	260.00	57.20	
H-House composite element: UHPC-AAC	1.	35	UHPC with self-cleaning properties (outer layer)	2400.00	110.80	Precast. The AAC is inserted into a UHPC "box". Cementitious glue ensures the connection of both layers.
	2.	345	AAC	95.00	33.20	

**Service life definition.** As explained in the introduction, common practice on service life definition in LCA involves the use of expert judgement on actual service lives as a source of values [8]. [15] proposes a database of service lives based on seven publications on building components' service lives currently observed. Table 3 shows service life intervals for materials involved in the conventional walls scenario according to [15].

Table 3. Service life interval for materials involved in conventional wall scenarios [15].

Materials	Service life intervals [years]
Lime cement plaster + glass fiber reinforcement	20 – 50
Rock wool	30 – 60
SRC	40 – 100
Cladding (SRC + rock wool)	30 – 60

Since service life prediction tools are limited within the context of innovative building materials, the service life of the H-House wall elements is based on the durability potential observed through individual long-term material tests. It has been observed in [16] and [17] that TRC has a promising long-term durability. In case of UHPC, the increased density, i.e. the very low porosity particularly in the interfacial transition zone between cement paste matrix and aggregates, is in general associated with a significantly lower water and gas permeability and increased resistance to chloride ion diffusion and carbonation compared to ordinary concrete (cf. [18] and [19]). In regard to the current findings, H-House partners consider that H-House innovative walls can last as long as the building itself, even considering the weak points (joints and connections). The service life of innovative components is therefore based on the service life of the building in this study. It should be noted that large-scale durability experiments, including cyclic temperature and moisture boundary conditions, will be performed to further evaluate the level of durability of the H-House composite elements.

Assumption 1:

- H-House composite element's service life = Building's service life (Assessment n°1)
- H-House composite element's service life = Existing building's remaining service life (Assessment n°2)

In [7] experts from the Netherlands were asked about their opinion on the lifespan of new residential buildings. Answers vary from 55 to 500 years and differ according to the expert's background:

- Building associations: 80 years,
- Building consultants: 146 years,
- Research institutes: 162 years,
- Project developers: 288 years.

In the present study we consider these survey's results valid for the German context. Assessment n°1 compares the environmental performance of building components for these four service life values. The lowest value, 80 years, reflects a pessimistic scenario in which the innovative composite elements are demolished before the end of their technical service life. The highest value, 288 years, reflects an optimistic scenario in which the innovative composite elements have a technical service life equal or over 288 years. Moreover, assessment n°2 deals with retrofitted buildings. Without knowledge on given existing buildings' remaining service life, the minimum value provided in [7] (i.e. 55 years) is considered and the maximum values (i.e. 162 and 288 years) are discarded.

For each assessment and for each of the options listed above, the H-House composite elements are the most long-lasting removable component among the one included in the scenarios of interest. In accordance with the RSP definition reported in the previous paragraph, the service life of the H-House component corresponds to the RSP.

Assumption 2: RSP = H-House composite element's service life

Assumptions 1 and 2 lead to the fact that the RSP also corresponds to the building's service life for assessment n°1, and to the building's remaining service life for assessment n°2.

The number of replacements of the removable materials is the most influencing parameter in LCA, which, in turn, depends on their service life. The number of replacements of removable materials is reported in Table 4 and Table 5 for the RSP being studied in assessment n°1 and 2, respectively. As far as the materials for conventional walls are concerned, these numbers have been established based on the service life's intervals presented in Table 3 with the objective of reaching a round number of replacements. In some cases, the interval is wide and several numbers of replacements are possible. For instance, Table 3 states that the service life of SRC is between 40 and 100 years; which in consequence for a RSP of 162 years, could consist of either 1 replacement (i.e. service life of SRC = 81 years), 2 replacements (i.e. service life of SRC = 54 years) or 3 replacements (i.e. service life of SRC = 40,5 years). In such case, the number of replacements matching with the highest service life of the conventional materials is retained. As far as innovative components are concerned, the previously mentioned assumption has been adopted: the service life of innovative components is determined based on the service life of the building.

In both cases, optimistic service lives are used for both scenarios.

Table 4. Number of replacements for four RSP options in assessment n°1. The service life of the component matching with the number of replacements is indicated in brackets.

Components	RSP Options			
	80 years	146 years	162 years	288 years
Rock wool + lime cement plaster + glass fiber mesh (external layer)	1 (40 years)	2 (48.6 years)	3 (40.5 years)	5 (48 years)
SRC <sup>1</sup>	0 (80 years)	1 (73 years)	1 (81 years)	2 (96 years)
TRC-FC-TRC	0 (80 years)	0 (146 years)	0 (162 years)	0 (288 years)

<sup>1</sup>The replacement of the SRC involves the building's demolition and reconstruction

Table 5. Number of replacements for three RSP options in assessment n°2. The service life of the component matching with the number of replacements is indicated in brackets.

Components	RSP Options		
	55 years	80 years	146 years
Cladding	0 (55 years)	1 (40 years)	2 (48.6 years)
UHPC-FC	0 (55 years)	0 (80 years)	0 (146 years)

**System boundaries.** The study is cradle to grave, i.e. all life cycle stages (from primary material extraction to end of life components treatment) are accounted for.

### Life Cycle Inventory

A product's LCI is the list of emissions and consumptions of elementary flows into and from the environment caused by the product to fulfil the functional unit [3]. It inventories each and every flow emitted in different locations at different periods of time. Setting up each scenario's LCI requires a modelling of each scenario into LCA software which includes background data on elementary flows emissions and consumptions caused by standard processes as regards to the manufacturing of 1 kg Portland cement or landfill of 1 kg inert material. Specific wall data are linked to background datasets in the software which then proceeds to the matrix operations required to compile elementary flows

involved in each life cycle's stage. The background database used for this assessment is ecoinvent 3.3 [20] and the software is SimaPro [21]. Specific data pertaining to the walls studied are described in Table 6 and Table 7. Most of the specific data relating to the H-House composite elements have been retrieved from confidential H-House deliverables.

Table 6. Specific data of walls studied in assessment n°1.

Life cycle steps	Scenarios	
	SRC + insulation	TRC-FC-TRC
Production of materials	Ready-mix concrete is prepared in a plant located in Germany and transported wet in a truck mixer. On the contrary, the cover plaster is brought dry and water is added on site. Concrete's primary materials and other materials are those available on the European market (ecoinvent datasets representative for European market).	Manufacturing in Germany at 200 km distance from the place of use (assumption from H-House partners). Primary materials are those available on the European market (ecoinvent datasets representative for European market).
Transport to assembly location	Not Applicable (NA)	None. The materials are manufactured in the same plant as panels are casted. Nota Bene (NB): FC can be produced in mobile equipment
Manufacture of components	NA	Manufacturing in Germany, near the construction site location. The layers are poured into a mold and dried in atmospheric conditions. The layers are fixed on one another using connectors. Easy-to-clean surface functionalization through introduction of TiO <sub>2</sub> in the demolding agent.
Transport to the building's construction site	Transportation mode and distance according to ecoinvent assumptions [20]	200 km by lorry (assumption from H-House partners)
Assembly on to the building	Water and energy consumption for construction work according to [10, 20]	Energy consumption for the installation according to [10]. Anchoring systems for reinforced steel are also used.
Maintenance	Replacement of the insulation layer or the whole system according to Table 4. Cleaning every five years (likely a reasonable amount of time to ensure the maintenance of aesthetics according to [22] using cleaning agents and high-pressure water [23, 24])	No replacement, no cleaning due to self-cleaning surface properties.
Dismantling a/o demolition	Energy consumption and particulates emissions due to the demolition process according to [25]	Energy consumption and particulates emissions due to the demolition process according to [25]
Transport to end of life treatment plant	150 km by lorry for recycling and 100 km by lorry for landfill [25]	150 km by lorry for recycling and 100 km by lorry for landfill [25]
End of life treatment plant	H-House partners make the following assumptions: The SRC is crushed for down-cycling of concrete, the recovered reinforcement steel is recycled. The cover plaster plus rock wool insulation is landfilled.	H-House partners make the following assumptions: The panel is crushed for down-cycling of concretes. The recovered textile mesh is landfilled.

Table 7. Specific data of walls studied in assessment n°2.

Life cycle steps	Scenarios	
	Cladding	UHPC-AAC
Production of materials	Materials are those available on the European market (ecoinvent datasets representative for European market).	Manufacturing in Germany. Primary materials are those available on the European market (ecoinvent datasets representative for European market).
Transport to assembly location	Transportation mode and distance according to ecoinvent assumptions [20]	The UHPC is manufactured in the same plant as panels are casted. The AAC is produced in southern Germany and the panel is produced near Berlin. 600km by lorry is taken into account for transport of the AAC from material production plant gate to panel production plant gate.
Manufacturing of components	Manufacturing in Germany, near the construction site location, according to ecoinvent data on concrete block manufacturing. [20]	Manufacturing in Germany, near the construction site location. The layers are poured into a mold and dried in atmospheric conditions. The layers are fixed on one another using connectors. Easy-to-clean surface functionalization through introduction of TiO <sub>2</sub> in the UHPC binder.
Transport to the building's construction site	200 km by lorry, assumption from H-House partners	200 km by lorry, assumption from H-House partners
Assembly on to the building	Consummation of energy for the installation according to [10]. Anchoring system in reinforcing steel are also used (assumed identical to the one used for UHPC-AAC panel).	Some energy is consumed for the installation [9]. Anchoring system in reinforcing steel are also used.
Maintenance	Replacement of the whole cladding according to Table 5 Cleaning every five years (likely a reasonable amount of time to ensure the maintenance of aesthetics according to [22] using cleaning agent and pressurized water [23, 24])	No replacement, no cleaning due to self-cleaning surface properties.
Dismantling a/o demolition	Energy consumption and particulates emissions due to the demolition process according to [25]	Energy consumption and particulates emissions due to the demolition process according to [25]
Transport to end of life treatment plant	150 km by lorry for recycling and 100 km by lorry for landfill [25]	150 km by lorry for recycling [25]
End of life treatment plant	The H-House partners make the following assumptions: The SRC is crushed for down-cycling of concrete, the recovered reinforcement steel is recycled. The rock wool insulation is landfilled.	The H-House partners make the following assumptions: The panel is crushed for down-cycling of concretes.

The adopted modelling principle is attributional, i.e. the processes are described as they are likely to occur at the end of the H-House project, without taking into account rebound effects and experience curves. In the background system, the multi-functionalities are dealt with allocation at the point of substitution based on the “true value”. True value allocation is a modified form of revenue allocation that includes correction to the revenue deriving from the mass balance for the carbon that has a significant impact [20]. There are no cases of multi-functionalities in the foreground system, i.e. the

system specific to the present study, except at the end of life where recycling is performed. In this case, the system stops when materials reach the “end-of-waste status” and all benefits beyond the system boundaries are not included in the life cycle impact results [14].

## LCIA

Elementary flows are then converted into impact categories using characterization factors [3]. Both impact categories selected for the present LCA and the corresponding LCIA method are listed in Table 8. These impact categories were selected according to the H-House project’s priority which is life cycle impacts’ decrease induced by the use of H-house innovative components in place of conventional components.

Table 8. Impact categories and LCIA models.

Impact categories	Unit	LCIA models
Non-renewable primary energy consumption	MJ	CED ecoinvent [26]
Climate change	kg CO <sub>2</sub> eq	Intergovernmental Panel on Climate Change [27]

The scenarios’ life cycle impacts are displayed in Fig. 1 for assessment n°1 and in Fig. 2 for assessment n°2.

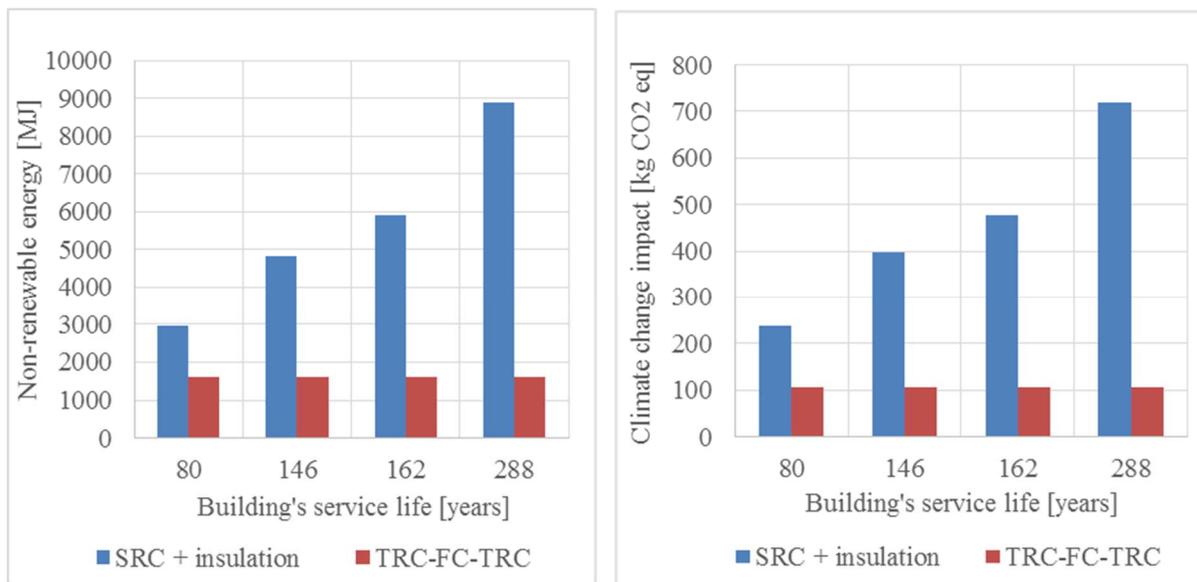


Figure 1. Comparison of external walls for new buildings on non-renewable energy and climate change impact categories (assessment n°1).

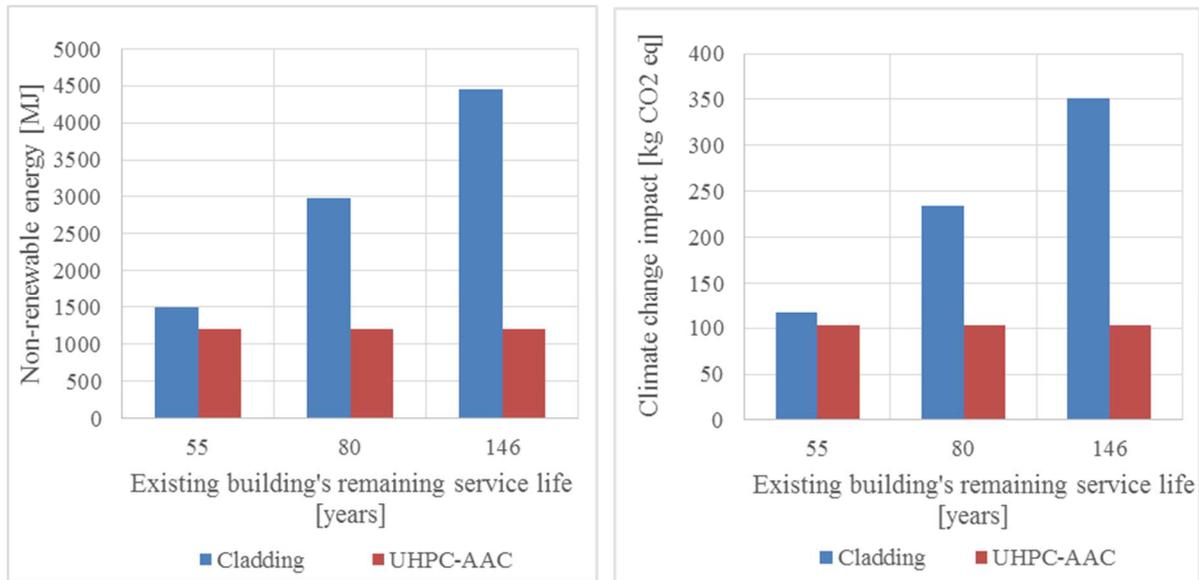


Figure 2. Comparison of external walls for retrofitted buildings on non-renewable energy and climate change impact categories (assessment n°2).

The H-House innovative panels have better environmental performance whatever the estimation of the building's service life is. This observation is true both for new construction and retrofitted building.

### Life cycle interpretation

For a better understanding of the results, the contribution of each life cycle's stage presented in Table 6 and Table 7 was investigated. Fig. 3 and Fig. 4 provide the comparison of scenarios for assessment n°1 and n°2 respectively, taking into account the shortest value among all RSP options (80 years for new constructions and 55 years for refurbished buildings).

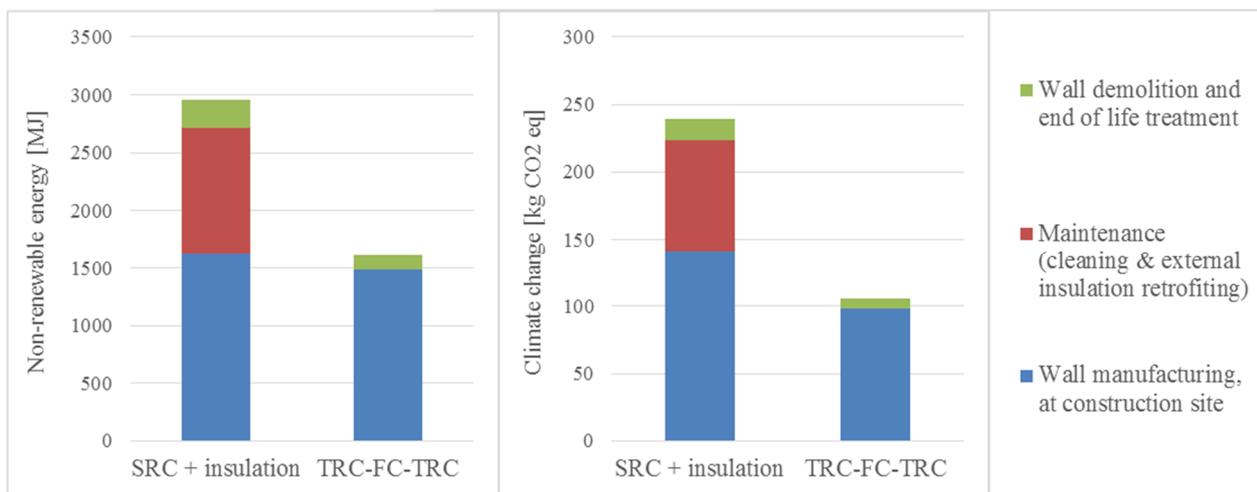


Figure 3. Comparison of external walls for new buildings on non-renewable energy and climate change impact categories (assessment n°1) for RSP=80 years, with details on the contribution of the life cycle steps to the impacts.

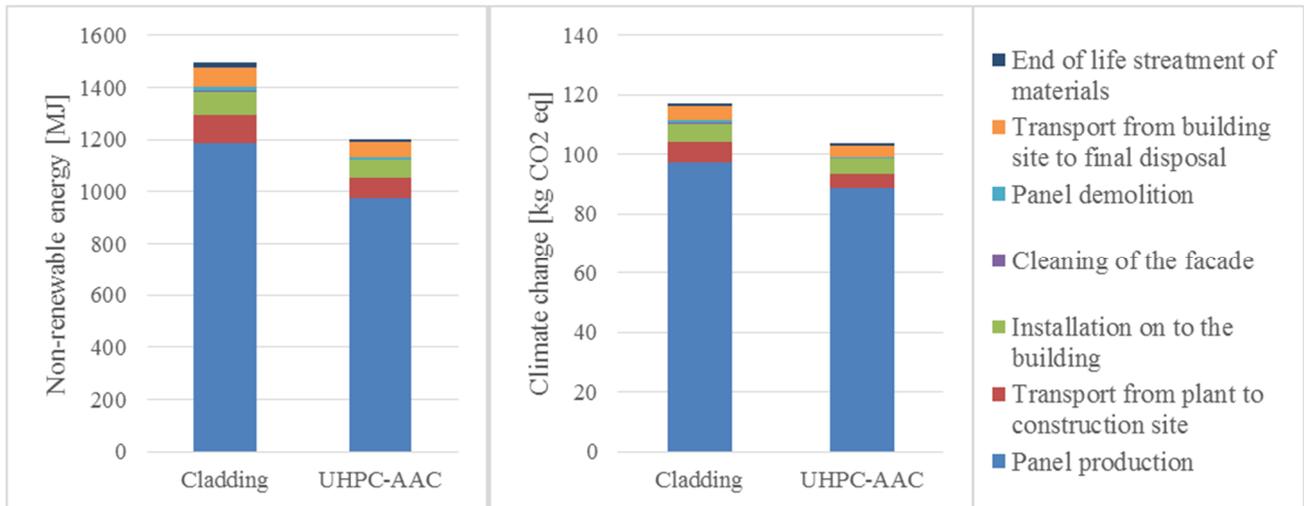


Figure 4. Comparison of external walls for retrofitted buildings on non-renewable energy and climate change impact categories (assessment n°2) for RSP=55 years, with details on the contribution of the life cycle steps to the impacts.

Fig. 3 gives for both scenarios of external walls for new buildings, the highest contributor which is the wall manufacturing stage (from primary materials extraction up to on-site construction work). The maintenance of SRC + insulation is particularly impacting as it includes the manufacturing of the mineral insulation. The wall demolition and end of life treatment account for no more than 8 %.

Fig. 4 gives for both scenarios of external walls for refurbished buildings, the highest contributor which is the panel production stage (from primary materials extraction up to panel manufacturing at the plant). The panel installation onto the building represents 5 to 6% of the total impacts. The transports before and after use represents 8 to 12%. All other contributors are below 2%.

It is important to note that the highest service life for conventional materials has been considered in the study, which disfavors the H-House panels. If the results would have shown that the conventional scenarios were better from an environmental point of view than the innovative panels, a sensitivity analysis would have been conducted accordingly. As it is not the case, such sensitivity analysis (to consider lower service life for conventional materials) would not modify the conclusions.

Finally, it can be observed that, regardless of the components' service life and associated replacement needs, H-House project's innovative composite panels are less impacting to manufacture than other conventional walls providing the same functions (see functional unit definition).

## Conclusions and limitations

The study intends to evaluate the environmental performance of innovative composite panels for use as external walls in buildings developed within the frame of the H-House project. The durability of H-House composite panels is higher than that of conventional panels. This is due to the use of innovative concrete and insulation materials. The study assesses the benefits of H-House components' durability, and compares them with conventional solutions, as regard to the contribution to climate change and non-renewable energetic resource depletion.

Although the service lifetime of a building and its components is a key decisive parameter when conducting an LCA, the actual service life of the H-House innovative panels has not been quantified. Consequently, the assessment was conducted several times for different service lives. In each assessment, external walls made of H-House composite elements have less impact on climate change and non-renewable energy consumption than conventional walls have. More importantly, the present study shows that, regardless of the components' service life and associated replacement needs, H-House's innovative composite panels are less impacting to manufacture than conventional walls providing the same functions (see functional unit definition).

The study's limitation is the reduced scope of the impact categories being investigated. It is recommended in the following steps of the H-House project to check the validity of the present conclusions on additional impacts categories as recommended in [28].

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