MASTER THESIS REPORT

The Influence of Upcoming Global Warming Potential Requirements and Deviation from the Danish Prescriptive Fire Design Solutions

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Synopsis:

This report is completed under the main subjects of building component design, fire safety requirements, and CO_2 emissions. The study is centred around a parameter variation that is used to generate five million building components that are evaluated for load-bearing capacity, moisture performance, transmission loss, and fire safety measures. The fire safety evaluation is based on the Danish prescriptive fire design solutions.

By use of life cycle assessments, the CO_2 emissions are calculated for all components. All generated components are grouped based on the structural material to assess how each structure type performs regarding CO_2 emissions. The components are filtered for the current and future requirements to the global warming potential from the Danish building regulations. It was found that biogenic materials and frame constructions are most fit for future requirements, while mineral solid structures are not. The main reasons for this are sequestration of biogenic carbon and the amount of material used in the components.

The impact of adopting less strict prescriptive fire design solutions is assessed by grouping the generated building components into the ones that fulfil the Danish requirements and the ones that include three specified deviations. The study showed that adopting less strict prescriptive fire safety design solutions creates a potential for lowering the CO_2 emissions for biogenic components and for components with frame structures.

Resumé

Denne rapport omhandler design af bygningskomponenter, brandsikkerhed i byggeri og CO_2 emissioner i forbindelse med materialeforbrug. Rapporten er bygget op omkring en undersøgelse af, hvor stor en indflydelse de nuværende krav til brandsikkerhed og CO_2-emissioner har på design af bygningskomponenter. Undersøgelsen indeholder en parametervariation, hvor fem millioner bygningskomponenter er blevet genereret og evalueret på baggrund af deres bæreevne, fugtegenskaber, varmetab, brandsikkerhed og CO_2-emissioner. Evalueringen af brandsikkerhed for bygningskomponenter er udført på baggrund af de præaccepterede løsninger i det danske bygningsreglement.

Rapporten indeholder en undersøgelse af CO_2 emissioner i forbindelse med de forskellige typer af genererede bygningskomponenter. Denne undersøgelse indebar en gruppering af komponenter i forhold til det strukturelle materiale og bygningsprincip. De grupperede komponenter er sorteret på baggrund af de nuværende og fremtidige krav til bygningers CO_2 emissioner fra det danske bygningsreglement. Undersøgelsen viste, at biogene konstruktioner samt rammekonstruktioner klare sig bedst hvad angår de fremtidige krav, mens tunge mineralske materialer vil opleve begrænsninger i de kommende to til fire år.

De præaccepterede løsninger i Danmark og andre europæiske lande er blevet kortlagt, hvilket har ført til udvælgelse af tre aspekter fra det danske bygningsreglement, som ønskes undersøgt nærmere. Dette er dele af de præaccepterede løsninger, hvor det pågældende krav er mindre strengt eller ikke eksisterer i andre lande end Danmark. De udvalgte aspekter blev dertil valgt på baggrund af et potentiale for at skabe bygningskomponenter med lavere CO_2 emissioner, da alle udvalgte aspekter begrænser brugen af biobaserede materialer. Aspekterne omhandler klassificeringen af brandbeskyttelsesevne for beklædninger, reaktion på brand for indvendige overflader og reaktion på brand for isoleringsmateriale i bygningskomponenter med brandbar bærende konstruktion.

De genererede bygningskomponenter blev opdelt i dem, der overholder de danske præaccepterede løsninger og dem der indeholder de afvigelser, der er inkluderet i de udvalgte aspekter. Det viste sig, at de komponenter der afvigende fra de præaccepterede løsninger kunne opnå lavere CO_2-emissioner end dem der opfyldte reglementet. Indflydelsen var stor for de biogene konstruktioner og rammekonstruktioner, mens der ingen indflydelse var på de tunge mineralske konstruktioner.

Preface

This report is the result of a master thesis project completed during the 3rd and 4th semester of the Master's programme in Indoor Environmental and Energy Engineering at Aalborg University. The thesis was carried out in the time period of September 1st 2022 to June 9th 2023.

The main topics of the thesis are building component design and fire safety regulations, which have led to an assessment of the impacts associated with selected aspects of the prescriptive design solutions from the Danish building regulations. The thesis also covers the structural properties, moisture performance, and thermal performance of building components, as well as a comparison with the current and future requirements for building material emissions in Denmark. The base of the assessments is an extensive generation and evaluation of building components.

Special thanks to Anders Dragsted and the Danish Institute of Fire Safety, DBI for guidance regarding fire safety in buildings and inspiration for the thesis topic. Thanks should also be granted to Artelia and Rambøll for providing data for the thesis.

Reading Guide

The thesis report consists of a main report and an appendix report. The main report covers essential methodology and findings from the thesis, while additional information is included in the appendixes.

Chapters 1-3 in the main report introduce the thesis and the addressed problem. Chapters 4-9 cover findings in four assessments based on the work performed in the thesis. The findings that are deemed most relevant are included in the first result chapter, after which the following chapters elaborate the subject and describes other relevant findings. Chapter 4 is written as a journal article meaning that the layout of this chapter is different from the remaining report. The article is not dependent on the content of the other chapters.

The methodology used in the thesis is described within Chapter 4, of the article, and covers the method used in the entire thesis.

Chapters in the main report are numbered, and appendices are numbered with letters. The appendices are divided into five sections, as listed below.

- Appendix A: Regulative background
- Appendix B, and C: Data and results
- Appendix D, E, F, and G: Data collection
- Appendix H, I, J, K, and L: Calculation methods
- Appendix M: Micro Component overview

Abbreviations

LCA	Life cycle assessment
RSL	Reference service life
GWP	Total global warming potential
GWP_{fossil}	Global warming potential fossil fuels
GWP_{bio}	Global warming potential biogenic
GWP_{LULUC}	Global warming potential land use and land use change
ADPe	Abiotic depletion potential for non-fossil resources
ADPf	Abiotic depletion potential for fossil resources
PERT	Total use of renewable primary energy resources
PENRT	Total use of non-renewable primary energy resources
EPD	Environmental product declaration
IC	Interior cladding
IL	Installation layer
S	Structure
INS	Insulation
WP	Wind protection
EC	Exterior cladding
VB	Vapour barrier
SFH	Single-family house
AB	Apartment building
BF	Frame construction of a biogenic material
MF	Frame construction of a mineral material
BS	Solid construction of a biogenic material
MS	Solid construction of a mineral material
BF-BF	Frame construction of a biogenic material with an exterior rainscreen
MF-BF	Frame construction of a mineral material with an exterior rainscreen
BS-BF	Solid construction of a biogenic material with an exterior rainscreen
MS-BF	Solid construction of a mineral material with an exterior rainscreen
BF-MS	Frame construction of a biogenic material with a mineral solid front wall
MF-MS	Frame construction of a mineral material with a mineral solid front wall
BS-MS	Solid construction of a biogenic material with a mineral solid front wall
MS-MS	Solid construction of a mineral material with a mineral solid front wall
F0	Compliance with the prescriptive solutions
F1	Compliance with the prescriptive solutions except for the fire protection ability
F2	Compliance with the prescriptive solutions except for the reaction to fire for interior cladding
F3	Compliance with the prescriptive solutions except for reaction to fire for insulation
GLT	Glued laminated timber
CLT	Cross laminated timber
LVL	Laminated veneer lumber
OSB	Oriented stand board
R	Load bearing capacity, fire event
EI	Insulation and integrity

Contents

1 Introduction

In recent years, there has been an increased focus on CO_2 emissions from the building and construction industry, as it contributes to more than one-third of the CO_2 emission globally [United Nations Environment Programme, 2021]. The Danish government has collected goals for sustainable development of the building industry in a report from The Ministry of the Interior and Housing [2021], *National Strategy for Sustainable Construction*. The main goals in the report are covered by five focus areas: more climate-friendly buildings and construction, durable and long-lasting buildings, resource-efficient buildings, energy-efficient and healthy buildings, and digitally-supported construction. The plan for sustainable development is a cross-disciplinary plan ensuring that sustainability is considered in a wide perspective, and not only CO_2 emission [The Ministry of the Interior and Housing, 2021].

One of the initiatives described in the report is the implementation of a limit on greenhouse gas emissions from buildings. A requirement has been added to the Danish building regulations in January 2023 and future reductions of the limit are proclaimed [BR18, 2022] [The Ministry of the Interior and Housing, 2021]. The implemented requirement states that a life cycle assessment must be performed for all new buildings and that the resulting global warming potential from the assessment must not exceed $12\,\mathrm{kg}\ CO_2/\mathrm{m}^2$ per year for buildings with a heated floor area greater than $1000\,\mathrm{m}^2$ [BR18, 2022]. During the next years, these requirements will intensify, and also be applied to buildings with a gross area below $1000\,\mathrm{m}^2$. The specific requirements are shown in figure 1.1.

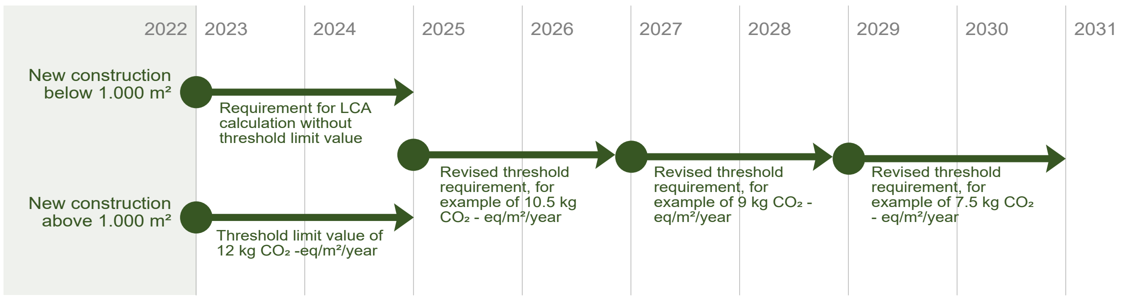

Figure 1.1. The LCA requirements today and in the future [The Ministry of the Interior and Housing, 2021].

To meet the future requirements for CO_2 emissions, building materials with lower CO_2 emissions are desired. Wooden materials and other biogenic materials are considered as materials with lower emission, as biogenic carbon is accounted for within the life cycle assessment, resulting in a lower CO_2 emission in the production stage of the building life cycle [Pittau et al., 2019] [Selman et al., 2021].

In Denmark, wooden products are not used as much as in other Nordic countries, especially when it comes to multi-storey buildings [Rasmussen et al., 2020]. The Danish building sector is more familiar with mineral products like concrete and steel than it is with biogenic materials. The lack of knowledge about biogenic materials compose challenges with moisture and fire safety [Rasmussen et al., 2020] [Selman et al., 2021]. Compared to mineral materials, biogenic materials are more combustible. Combustible materials act as fuel to buildings, which makes the development of fire faster. This can lead to premature failure of the building [Meacham and Mcnamee, 2020]. These challenges are taken into account in the Danish fire safety regulations, where the use of combustible materials is more restricted than non-flammable materials [BR18, 2022]. Increased use of biogenic materials in the building industry can help meet future requirements for building emissions. As more information becomes available on the performance of biogenic materials and building components, it may be necessary to expand fire safety regulations towards the use of materials with lower CO_2 emissions.

2 Literature Review

This literature review covers biogenic materials, LCA, and fireproofing of biogenic construction relevant to the Danish context. In Denmark, there is a tradition to construct buildings with materials such as concrete and bricks. These materials are often associated with relatively high CO_2 emissions, compared to biogenic materials such as wood. The increasingly stringent requirements for CO_2 emissions in the Danish building sector necessitate a change in the way we build buildings. One of the explored initiatives is increasing the use of materials with lower emissions in construction.

Biogenic materials are usually materials with lower CO_2 emissions than mineral materials. This is because production is usually associated with a relatively low amount of greenhouse gas emissions. Denmark has a tradition of using mineral building materials in the building sector. Meanwhile, other Nordic countries have a greater history of using wood as a building material. The report *Anvendelse af trae i byggeriet* by Rasmussen et al. [2020] summarises how widespread wooden buildings are in Denmark, Finland, Sweden, and Norway. The share of single-family houses made out of wood is 80-$90\,\%$ for Nordic countries other than Denmark. For multi-storey buildings, the number is much lower. In Denmark, about $8\,\%$ of all construction works are made of wood [Rasmussen et al., 2020] [Lind and Damsgaard, 2021]. A survey by Rasmussen et al. [2020] showed that the primary demand for wooden constructions is expected to exist for buildings with one to five storeys, which is estimated to account for more than $99\,\%$ of buildings constructed in Denmark from the year 2009 to 2019. The participants of the survey also estimated that the greatest demand for wooden buildings exists within single-family housing, terrace housing, multi-story housing, and daycare typologies.

Wood is emphasised as an interesting building material as it has the potential to contribute to the sequestration and storage of atmospheric carbon, and substitute carbon emissions associated with the use of materials with a higher emission during production [Rasmussen et al., 2020] [Churkina et al., 2020]. Other biogenic building materials also have these benefits. Pittau et al. [2019] has assessed the CO_2 emissions of exterior wall constructions utilising biogenic building materials, such as hemp, wood, reed, and straw. The research showed that biogenic materials are associated with lower emissions and that fast-growing materials have the largest potential for short-term carbon storage due to the short rotation period [Pittau et al., 2019]. Here, straw as an insulation material is highlighted as having significant potential for short-term storage. However, a literature review by Arehart et al. [2021] indicates that current estimates for the carbon storage potential of wooden products are small relative to the current total fossil emissions.

The short-term carbon storage potential of biogenic materials is affected by the method used to account for biogenic carbon. In the journal article *Biogenic carbon in buildings: a critical overview of LCA methods* [Hoxha et al., 2020], a 0/0 approach, a -1/+1 approach, and a dynamic approach was compared in a case study on a timber building. The -1/+1 approach, which is used in DS/EN 15978 [2012], is a static approach that accounts for biogenic carbon removal in the production stage and biogenic carbon emission at the end-of-life stage. The latter includes oxidation or degradation as well as transfers to subsequent systems. The 0/0 approach is a static approach that utilises the fact that the amount of carbon sequestrated in the production stage is equal to the biogenic carbon emission to the air at the end-of-life stage. It accounts for the biogenic carbon by setting the amount entering and leaving the system equal to zero. The dynamic approach examined in the case study accounts for the temporal variations in relation to biogenic carbon uptake. The study showed identical results for the two static approaches and a greater CO_2 emission for the dynamic approach which was deemed more reliable and transparent [Hoxha et al., 2020]. The current method used for LCAs on buildings in Denmark is the -1/+1 approach [DS/EN 15978, 2012].

In a survey by Selman et al. [2021], directed towards actors in the Danish building industry, the participants were asked about challenges experienced when using wood as a load-bearing structure. The results indicated a knowledge gap among designers on the topic of fireproofing wooden load-bearing structures. Challenges relating to fireproofing are also indicated for wood used for exterior cladding. The survey also finds that a risk of moisture problems is experienced for wooden load-bearing structures. Another survey on the topic of wood as a construction material has been made by Rasmussen et al. [2020]. The participants of the survey were part of the value chain of the Danish building sector, primarily engineers, construction managers, and architects. This survey identifies a lack of knowledge on how to construct wooden multi-storey buildings and a general lack of knowledge and experience on how to use wood as a building material. Additionally, fire-proofing challenges were established as some of the main perceived barriers to the use of wood in buildings in relation to the idea and project design. The survey also asked the participants about building regulations, prescriptive design solutions, and requirements for documentation. The results show that there is a perceived limitation from the Danish building regulations regarding the use of wood in buildings. Documentation and requirements relating to fireproofing are perceived as being unrealistic, excessive, and imprecise [Rasmussen et al., 2020]. Respondents encourage the development of prescriptive solutions for wooden buildings and wooden load-bearing structures, including solutions utilising mineral wool insulation material as well as biogenic insulation material. Also, alternative methods for securing against fire spread and development are requested. Respondents also note that conventional building traditions in Denmark of using non-combustible building materials contribute to perceived safety concerns on the use of wood in buildings [Rasmussen et al., 2020].

Wood generally has good structural properties during fire events, as the outer layer of the wood protects the inner part after it is charred, and the structural properties of the uncharred wood are kept throughout the fire event. This is reflected in the Eurocodes.

The use of biogenic insulation materials is associated with additional concerns regarding fire safety, as the organic insulation materials compose challenges with fire growth rate and smoke production, as well as a faster spread of fire and smoke to other buildings and building sections [Meacham and Mcnamee, 2020]. Additionally, organic insulation materials are relatively new in the building industry, and knowledge about fire safety properties is lacking [Meacham and Mcnamee, 2020]. Information on the fire behaviour of biogenic materials used in construction is gathered through fire tests when the products are developed and ready to be tested in combination with other building materials. Due to the novelty of, and lack of experience with some of these biogenic materials in a Danish context, it may take some time for the materials to be established in the Danish building sector.

In the publication *the national strategy for sustainable constructions* by the The Ministry of the Interior and Housing [2021], initiatives directed toward increasing the use of wood in buildings are announced. These initiatives include the development of prescriptive solutions for load-bearing structures in combustible materials up to five storeys, and the development of examples on how to construct and document the safety level for five-storey buildings. Also for multi-story buildings, generic solutions for constructions with wooden load-bearing structures, taking acoustics into account, are to be defined. These initiatives can increase the amount and accessibility of information on the use of biogenic constructions in a Danish context [The Ministry of the Interior and Housing, 2021].

Some projects have been initiated relating to these topics. One project, Wood:UpHigh, is a collaboration between several Danish building actors, including the Danish Housing and Planning Authority. Here 10 full-scale fire tests on biogenic building components for multi-story buildings along with 30-40 smaller fire tests will be performed [Realdania, 2022] [The Danish Institute of Fire and Security Technology, 2022]. The project will provide more knowledge of the fire behaviour of wooden constructions and may aid in the development of prescriptive solutions for combustible load-bearing structures in multi-storey construction [Realdania, 2022]. In the end, catalogues containing generic solutions for building components are to be made publicly available. One such catalogue has been released for horizontal divisions, where related greenhouse gas emissions, fire safety considerations, and acoustic performance are covered. The horizontal divisions in the catalogue are approved by fire consultants certified to fire class 4 [ARTELIA et al., 2023]. Four biogenic constructions were transformed from fire class 4 to fire class 2 resulting in an increase in the carbon footprint of 3-22 %. The prescriptive solutions are also in focus in a similar project by [The Danish Institute of Fire and Security Technology, 2023] called *BioFacades:UpHigh*. This project covers 10 full-scale facade fire tests which are performed to investigate how to design biogenic facades in multi-storey buildings while satisfying the required level of fire safety. The project seeks to gather information that can be used to create prescriptive solutions for unprotected wood and other biogenic materials on facades [The Danish Institute of Fire and Security Technology, 2023].

Information on the application of biogenic building materials for building typologies up to five storeys in a Danish context is currently in demand. Applications that comply with fire safety requirements are investigated with the purpose of introducing generic design solutions into the prescriptive design solutions that allow for the use of biogenic materials. Such generic design solutions can reduce the complexity involved with documenting fire safety compliance and increase the use of biogenic building materials. This will affect both the accessibility of the design space of building components and potential CO_2 emissions associated with potentially new component solutions.

3 Problem Description

Based on the literature on biogenic structures and the Danish fire safety regulations of buildings, research questions are stated. The research questions are listed below.

Research Questions

- How do current and potential future requirements for the global warming potential of buildings impact the availability of design solutions for building components?
- What are the impacts of adopting prescriptive fire design solutions inspired from other European countries?
    - What is the impact on the building component design space?
    - What are the available savings for the global warming potential on a component level?

To answer the research questions, a parameter variation is used to generate a large number of building component assemblies. The components are evaluated on several parameters and used to assess the impacts of fire safety requirements on the global warming potential and the consequences for the diversity of building designs.

The impact of the fire safety requirements is assessed by adopting less strict prescriptive fire design solutions. A comparison of the fire safety regulations in Denmark and nine other European countries has been conducted to determine areas where deviations from the prescriptive solutions are of interest, see appendix A. The comparison was performed on one-storey single-family housing and four-storey apartment buildings. Overall the comparison showed that the Danish fire safety requirements are quite strict. Some places where this is evident are with the interior cladding and exterior cladding for exterior walls.

The requirement for the interior cladding can be divided into requirements for walls and requirements for ceilings. For walls, five of the investigated countries had requirements for the reaction to fire which were similar to the Danish requirements. Four countries had requirements lower than the Danish requirements. For ceilings, four countries had similar requirements while one country had lower requirements compared to the Danish requirements. One country had more strict requirements for the reaction to fire of the ceiling material.

The Danish prescriptive solutions also specify requirements for the fire protection ability of interior wall cladding, ceiling cladding and exterior wall cladding. Here the sheathing must be of at least class K_1 10 for both single-family houses and four-storey apartment buildings. In most of the other examined countries, no such requirements were found. Only Sweden has a similar requirement was found relating to the use of insulation material with a reaction to fire on D-s2,d0 or worse. Here, the insulation material should be protected by a K_2 10 / B-s2,d0 material.

Concerning insulation material, the Danish requirement for the reaction to fire is B-s1,d0. Other materials may be used for specified scenarios. Two of the countries included in the investigation had similar requirements to the reaction to fire of insulation materials. One country had a more strict requirement, while six had a lower requirement.

Based on these comparisons, the following deviations from three specific design requirements are defined in the following section.

Deviations from Prescriptive Design Solutions

Three aspects of the prescriptive solutions are selected based on a mapping of the Danish fire regulations, see appendix A. This section covers the aspects relevant to four-storey buildings. The aspects cover interior and exterior cladding and insulation material in biogenic structures.

For interior cladding, the reaction to fire requirement for surface materials is selected. The requirement from the Danish building regulations is paraphrased below along with an English translation.

> Danish: *Overflader på væg eller loft bør udføres mindst som beklædning klasse K_1 10 / B-s1,d0 [klasse 1 beklædning].* [BR18, 2022]
>
> English translation: *Surfaces on walls or ceilings should be at least class K_1 10 / B-s1,d0.*

The required reaction to fire of interior cladding is described by the class "B-s1,d0". The less strict requirements are adopted by introducing wooden cladding with reaction to fire of D-s2,d0, see figure 3.1.

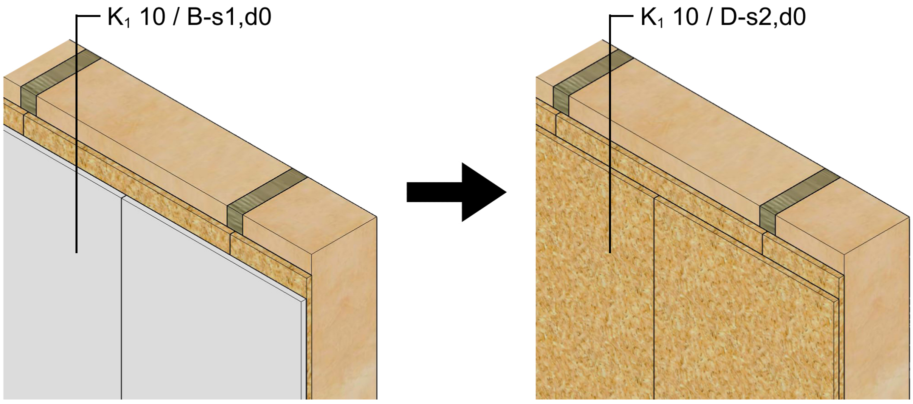

Figure 3.1. The less strict requirement for reaction to fire of interior cladding surface.

The next selected aspect is the fire protection ability of interior cladding and exterior wall cladding. In the above, it is stated that an interior surface must be classified at least as K_1 10, which refers to the fire protection ability. The requirement for exterior wall cladding is shown below, and the exterior cladding must be K_1 10 too. If a component includes a ventilated rainscreen, the requirement refers to wind protection or a solid wall located behind the rainscreen.

> Danish: *Den udvendige overflade, hvorpå regnskærm monteres, skal være mindst beklædning klasse K_1 10 / B-s1,d0 [klasse 1 beklædning].* [BR18, 2022]
>
> English translation: *The exterior surface, on which a rainscreen is mounted, must be at least class K_1 10 / B-s1,d0.*

A K_1 10 classification requires that the cladding is mounted on any material with a density of at least $300\,\text{kg/m}^3$ [DS/EN 13501-2, 2016]. For frame structures, this means that at least two material layers are required in the cladding. However, another class called K_2 10 exist. This class is not used in Denmark, but it has the same test requirements as K_1 10. A K_2 10 material may be used on any substrate material, and this allows a covering to be used on frame structures without the additional layer [DS/EN 14135, 2004]. To assess the impacts on the global warming potential from using K_2 10 instead of K_1 10, the less strict requirement is adopted by introducing K_1 10 cladding without the substrate layer, see figure 3.2.

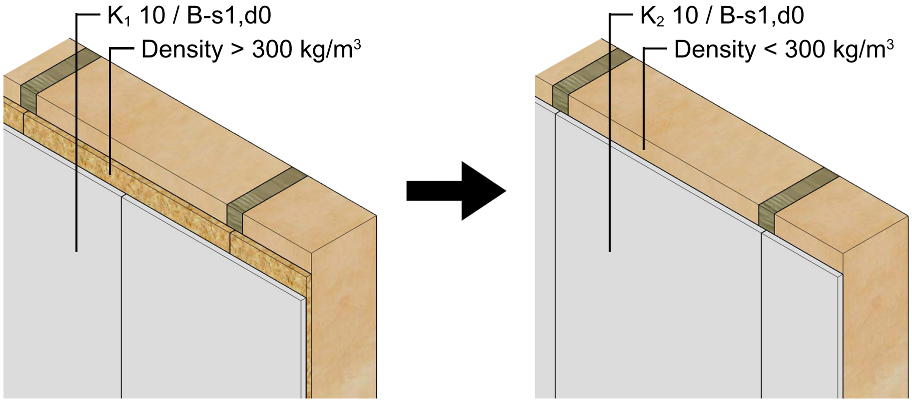

Figure 3.2. The less strict requirement for fire protection ability of interior cladding and exterior wall cladding.

The last selected aspect of the prescriptive solutions covers the reaction to fire for insulation materials assembled with structural components of combustible material. The requirement from the building regulations is paraphrased below.

> Danish: *Hvor de bærende bygningsdele ikke udføres i materialer, som er mindst klasse A2-s1,d0 [Ubrændbart materiale], må der ikke anvendes isoleringsmaterialer, der er ringere end materialeklasse B-s1,d0 [Klasse 1 materiale] i forbindelse med disse bærende bygningsdele.* [BR18, 2022]
>
> English translation: *Where structural components are not at least class A2-s1,d0, it is prohibited to use insulation materials worse than class B-s1,d0 in combination with these structural components.*

To fulfil the requirement to class B-s1,d0 or better, mineral wool insulation can be used. The less strict requirement is adopted by introducing biogenic insulation materials worse than class B-s1,d0, such as cellulose insulation and wood fibre insulation, see figure 3.3.

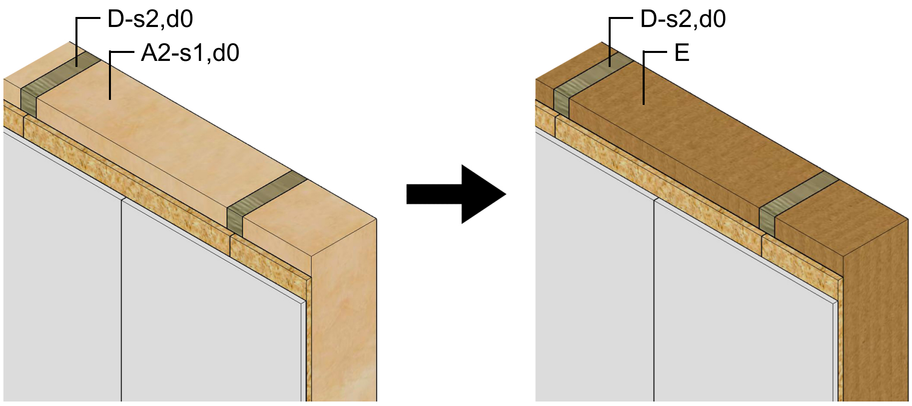

Figure 3.3. The less strict requirement for reaction to fire of insulation material in combination with a combustible structural component material.

4 Journal Article

Investigation of the Impact on CO_2 Emissions of Building Components when Adopting Less Strict Prescriptive Fire Solutions in a Four-Storey Building Typology

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A R T I C L E I N F O

Keywords:
Building component design
Fire safety strategies
Environmental impact
Parameter variation
LCA

A B S T R A C T

This article covers the potential for lowering the GWP for building components when adopting less strict prescriptive fire safety solutions in Denmark. Using a parameter variation, a large number of components are generated and used to assess how the components perform regarding the current and future GWP requirements in Denmark. The study applies the LCA method to calculate the GWP of building components. The study showed a potential for lowering the GWP on a component level when adopting two out of three investigated aspects of the prescriptive solutions. These aspects were the fire protection ability of cladding and the reaction to fire of insulation materials.

4.1 Introduction

In the building industry, there has been an increased focus on CO_2 emissions in recent years, as the industry contributes to more than one-third of the CO_2 emission globally [United Nations Environment Programme, 2021]. In 2023, requirements regarding greenhouse gas emissions were added to the Danish building regulations [BR18, 2022]. The requirements include a limit for the CO_2 emissions of buildings with a gross area greater than $1000\,\text{m}^2$. This limit is expected to be lowered every two years and apply to all new buildings in 2025 [The Ministry of the Interior and Housing, 2021].

The new requirements have created a demand for low-emission materials and technologies, including more extensive use of biogenic materials. Materials with a high biogenic carbon content are in focus as sequestration of biogenic carbon is accounted for in the LCA, reducing the CO_2 emissions in the production stage [Pittau et al., 2019] [Selman et al., 2021]. However, biogenic materials are more flammable than conventional Danish building materials such as concrete and clay bricks. The use of flammable materials is restricted in the fire safety regulations, and this compose a challenge as the actors in the industry have little experience with fireproofing construction in wood and other biogenic materials, especially in multi-storey buildings [Rasmussen et al., 2020] [Selman et al., 2021].

To assess the impact of these more strict fire design requirements on the CO_2 emission of buildings, an LCA study on building components is performed for a four-storey building case. The assessment is made by investigating the effects of adopting three less strict requirements into the Danish prescriptive solutions on a component level.

4.2 Methodology

The process of the present project is shown in figure 4.1, where the process is divided into steps.

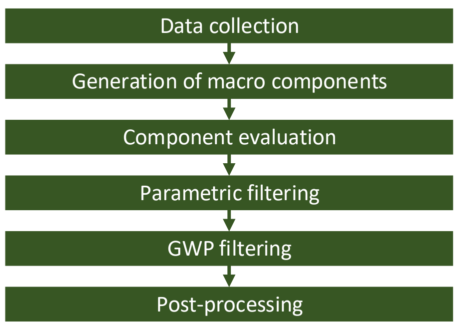


Figure 4.1. Steps in the project methodology.

The method is centred around a building component generation based on components found in Danish buildings. Parameters and properties for the generated components are evaluated. Using parametric filtering, the set of components is reduced to a more realistic set. The remaining building components are evaluated against current and expected future requirements for the global warming potential of buildings. Each step in the method is described in the following sections.

4.2.1 Generation of Building Components

A total of 43,100 exterior walls, 31,600 roofs, 1,600 interior walls, and 1,400 horizontal divisions were generated for the purpose of this study. These building components, in this study called macro components, were generated based on a factorial assembly of predefined sets of building component sub-systems, in this study called micro components. These micro components are split into various types that serve one or more purposes in the assembled macro component. For instance, this can be a structural component, insulation, cladding, vapour retarder, or an installation layer. To account for realistic combinations of micro components, some are defined as having limited compatibility with other micro components. Only compatible assemblies of micro components are saved, resulting in the previously specified amount of macro components.

The micro components used in the present study, are based on building components from existing buildings. These building components are separated into subsystems corresponding to the different micro components. The collected micro components are defined and stored in micro component databases. A separate material database is created to store information about materials used in the micro components.

The data collection and database setup are described in appendix E. A complete overview of the micro components and their associated properties is available in appendix M. The method for the generation of macro components covers components for four-storey buildings and single-family houses, but in this article, only results from the four-storey building case are presented.

Properties and performance parameters for the macro components are calculated using the information in the micro component databases and the material database. The procedure for generating and evaluating macro components is shown in figure 4.2, where the workflow is divided into two steps: generation of macro components and evaluation of macro components.

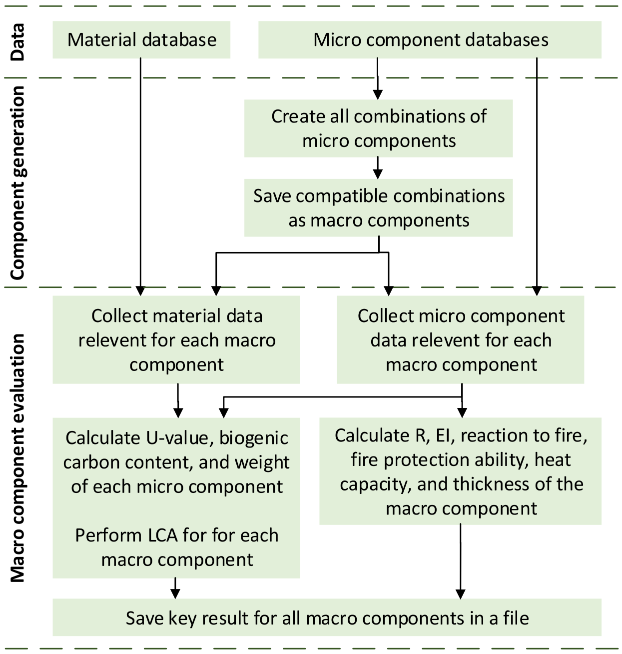


Figure 4.2. Procedure for macro component generation, performance evaluation, and filtering.

4.2.2 Component Evaluation

For all generated macro components, several properties are evaluated depending on the purpose of the component. An overview of the properties evaluated for each macro component type is given in table 4.1.

In the LCA, the components are assessed for the following environmental impact indicators and parameters describing resource use: GWP_{fossil}, $GWP_{biogenic}$, GWP_{LULUC}, ADPe, ADPf, PERT, and PENRT. These indicators and parameters are chosen to cover three areas: climate change, resource consumption, and energy consumption. The impacts and resource use parameters are calculated using the LCA method described in DS/EN 15978 [2012].

Generic datasets from Ökobaudat are used for the LCA. This data is established as the generic data to use for building LCAs according to the Danish building regulations. Environmental data stored in the material database and the material amounts stored in the micro component databases are used in the LCA. The information modules included in the LCA are A1-A3, B4,

Table 4.1. Parameters evaluated for each macro component type.

Component type	Evaluated component parameters							
	LCA	FTC	EI	R_{warm}	R_{cold}	U	HC	Bio
Exterior walls - one-storey	●	●	●	●	●	●	●	●
Exterior walls - four-storey	●	●	●	●	●	●	●	●
Roofs	●	●	●	●	●	●	●	●
Bearing interior walls	●	●	●	●	●		●	●
Interior partition walls	●	●	●				●	●
Horizontal divisions	●	●	●	●	●		●	●

LCA: Selected environmental impact indicators and parameters describing resource use
FTC: Fire technical classification including reaction to fire and fire protection ability
EI: Insulation and integrity in fire scenario
R_{warm}: Load bearing capacity in fire scenario
R_{cold}: Load bearing capacity
U: U-value
HC: Effective heat capacity
Bio: Biogenic carbon mass content

and C3-C4. For some materials used, the environmental datasets include packaging in the production stage A1-A3 and disposal of packaging in module A5. If the disposal of packaging is not accounted for, the datasets with biogenic packaging may be falsely discounted, as the net $GWP_{biogenic}$ amount across the system boundary of the LCA does not equate to zero. To account for this, information from module A5, presented in the environmental dataset of the materials, is included in the LCA.

An assessment of the fire technical classification is performed on all macro component types. The reaction to fire of a macro component is defined as the reaction to fire of the most flammable material in the component. Reaction to fire and fire protection ability of surface cladding are included in the micro component specification. The load-bearing capacity of load-bearing components is determined in cold and warm scenarios. The load-bearing capacities, insulation and integrity during fire exposure are determined in accordance with relevant Eurocodes. The approach for determining the fire-related properties is described in appendix H.

Based on information in the micro component specification, the macro component U-value and effective heat capacity for the macro component are determined. The U-value is calculated following DS 418 [2011] and the effective heat capacity is calculated following DS 418-2 [2014]. A description of the methods and assumptions used to calculate the thermal properties are described in appendix J.

The biogenic carbon mass content of materials is calculated from the biogenic carbon content in the environmental dataset using the method described in DS/EN 16449 [2014]. The calculation and an overview of the biogenic content of the addressed materials are shown in appendix I.

4.2.3 Parametric Filtering

To narrow down the initial set of generated macro components, four performance-related filters are created for the present study: a filter for the load-bearing capacity, a filter for moisture performance, a filter for thermal insulation, and a filter for fire-related restrictions. The filters are specified in appendix D. The filter for load-bearing capacity, removes macro components with an insufficient load-bearing capacity in the cold and warm scenarios, based on predefined loads and spans from a reference building, see appendix L. The filter for moisture-related performance removes components with a moisture-related performance that is deemed insufficient based on numerical evaluations of selected component assemblies, see appendix K. The filter for thermal insulation removes components with a U-value above $0.13\,\mathrm{W/m^2\,K}$ for roofs and $0.20\,\mathrm{W/m^2\,K}$ for exterior walls. The thresholds are based on the requirements and the correction for thermal bridges described in the Danish building regulations. The filter for fire-related restrictions removes macro components, that do not fulfil the requirements in the Danish prescriptive design solutions. A comparison of the fire safety regulations in Denmark and nine other European countries has been made, see appendix A. This comparison showed that the requirements in Denmark are rather strict. To investigate the impact of adopting three less strict requirements from the other countries, the fire filter is divided into three sub-filters: F1) a filter for fire protection ability, F2) a filter for reaction to fire of interior cladding, and F3) a filter for reaction to fire of insulation material.

F1) This part of the fire filter relates to a requirement that states, that the interior and exterior cladding have a fire protection ability of K_1 10 or better. All fire protection ability ratings used in the present study are K_1 10 and assumed to be classified for substrates with a density of at least $300\,\mathrm{kg/m^3}$ DS/EN 13501-2 [2016]. The filter removes macro components, that do not have a cladding with a K_1 10 classification. Mineral solid structures are assumed to correspond to at least a K_1 10 cladding, even though the material is unclassified.

F2) This part of the fire filter relates to a requirement that states, that the reaction to fire of the interior cladding on walls and ceilings in buildings must be B-s1,d0 or better. The filter removes macro components, that have interior cladding with a reaction to fire worse than B-s1,d0.

F3) This part of the fire filter relates to a requirement that states, that insulation material with a reaction to fire worse than B-s1,d0 must be used in conjunction with load-bearing structure of materials with a reaction to fire of at least A2-s1,d0. The filter removes macro components, that have an insulation material worse than B-s1,d0 in conjunction with a load-bearing structural material worse than A2-s1,d0.

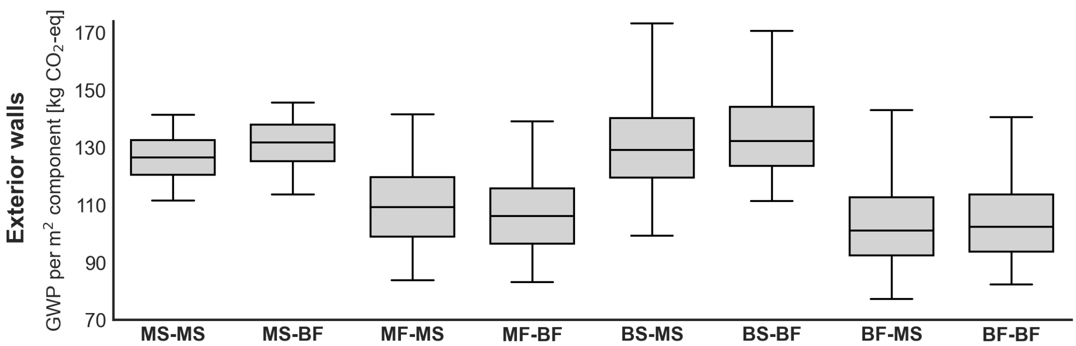
By separating the fire filter into these three aspects, it is possible to remove one or more filters. Micro components that do not fulfil these three requirements are included in the study. This allows for the examination of solutions where one or more requirements in the Danish prescriptive solutions are deviated from. In practice, this allows changing the required fire protection ability from at least K_1 10 to K_2 10, changing the reaction to fire of interior claddings from at least B-s1,d0 to D-s2,d2, and changing the reaction to fire of insulation material in conjunction with combustible structural components from A_2-s1,d0 to E.

4.3 Results

The results cover the GWP of the components, future requirements, and the impacts of adopting less strict prescriptive solutions. To group the components in relation to the anticipated biogenic content and structure type, four main groups are created. The groups are based on the main structural principle and the material type used in the structural part of the component. The four groups are listed below.

- BF: Biogenic frame structures
- MF: Mineral frame structures
- BS: Biogenic solid structures
- MS: Mineral solid structures

Typical components in the four groups are construction wood or GLT frame structures (BF), steel frame structures (MF), CLT elements (BS), and concrete or masonry structures (MS).



MS-MS:	Mineral solid structure and exterior wall	MS-BF:	Mineral solid structure with rainscreen
MF-MS:	Mineral frame structure and solid exterior wall	MF-BF:	Mineral frame structure with rainscreen
BS-MS:	Biogenic solid structure and solid exterior wall	BS-BF:	Biogenic solid structure with rainscreen
BF-MS:	Biogenic frame structure and solid exterior wall	BF-BF:	Biogenic frame structure with rainscreen

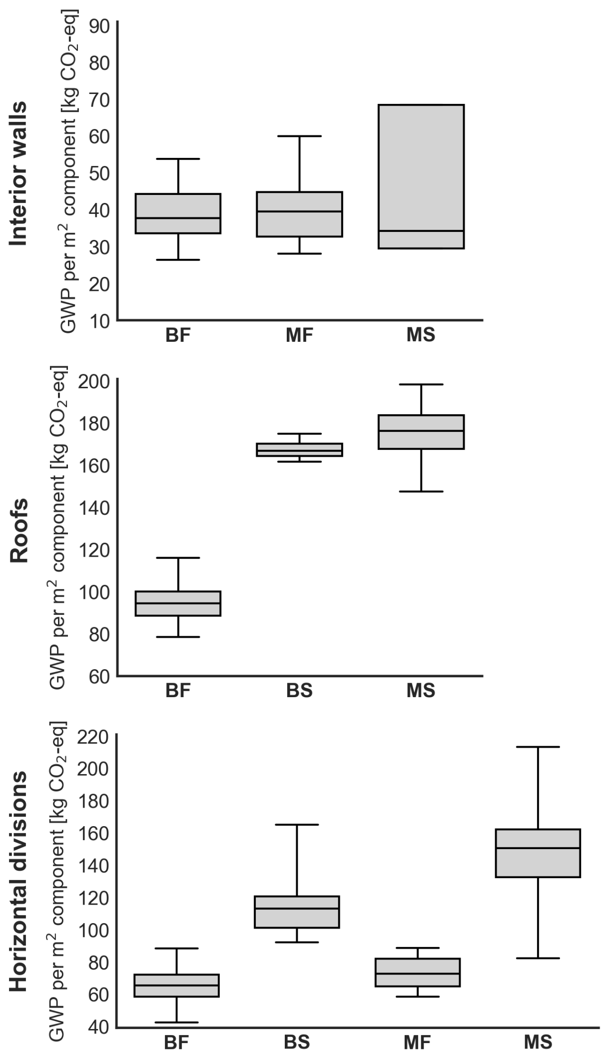
Figure 4.3. Distribution of GWP for exterior wall components after filtering.

4.3.1 GWP Distributions of Components

This section considers the GWP of each component group without the deviations in the fire filter. All results from the filtering process are described for the different component types in appendix C. The appendix also includes data for each material type, for instance, construction wood and GLT frames in separate groups.

Exterior Wall Components

The distribution of the total GWP for each group of exterior wall components is shown in figure 4.3. Here, the exterior wall components are divided according to both the structural and exterior parts of the components. The exterior cladding group consists of rainscreens (BF) and mineral solid front walls (MS).



BF: Biogenic frame structure
BS: Biogenic solid structure
MF: Mineral frame structure
MS: Mineral solid structure

Figure 4.4. GWP for components after filtering.

The component groups with frame load-bearing structures have a lower median GWP when compared to the solid structures groups, regardless of the material being mineral or biogenic. This is the case for both components with rainscreens and solid front walls.

Components with biogenic solid structures reach similar median GWP as components with mineral solid structures, but the dispersion is greater for the BS groups. The emissions of steel frame structures are similar to those of biogenic frame structures although steel as a material is associated with greater emissions than wood. The low emission for steel frames is caused by a low amount of steel necessary in exterior wall components.

Interior Wall Components

In the macro component generation, the interior walls are divided into bearing walls and partition walls. As the results from the bearing walls and partition walls are similar, the results for these component types are presented together. The distribution of GWP for interior walls is shown in the uppermost graph in figure 4.4.

The biogenic frame structures have a slightly lower GWP than the steel frame structures. The mineral solid structures result in the lowest median GWP, but also the highest total GWP. This is because most of the solid walls are made of of aerated concrete, which performs well regarding emissions. The highest value in the MS group is masonry walls. However, the solid structures consists of only 14 components.

Roof Components

The graph in the middle of figure 4.4 illustrate the distribution of GWP for the roof components. The biogenic frame structures perform significantly better than the solid structures regarding GWP. This is partly caused by the solid structures being insulated with a rigid insulation material, which results in higher GWP per m^3 material compared to the flexible insulation batts used in the frame structures. For the roofs, the biogenic solid structures perform better than the mineral structures, which was not the case for the exterior walls.

Horizontal Division Components

The GWP distribution for horizontal divisions is shown in the lower graph in figure 4.4. This data show that the biogenic frame structures result in the lowest emissions, while the mineral solid structures result in the highest emissions. Compared to the roof components, the difference between the frame structures and solid structures is significantly lower, as no horizontal divisions include rigid insulation. The steel frame structures do not result in as low emissions as the biogenic frame structures, which were the case for exterior walls and interior walls. This is caused by a greater amount of steel in the structural components of the horizontal divisions compared to the wall components.

4.3.2 Future Component Design Space

This section deals with the GWP requirements stated in the Danish building regulations, as well as the potential future requirements.

GWP Limits for components

To investigate which component types are fit to use when the future GWP requirements become effective, a GWP filtration for all macro components is performed. The GWP filters contain limits for the GWP of the different macro component types. The limits are determined based on existing buildings that comply with the future requirements, see appendix D. The GWP filtration is performed for all component types and the results are shown in appendix C. The components exposed to the largest share of components being discarded in the GWP filtering are mineral solid structures. For most of the macro component types, only biogenic frame structures are passing the GWP 2029 filter.

Removing the Fire Filter

A large number of the generated components do not comply with the Danish prescriptive fire safety solutions. These components are generated to assess the impact that the prescriptive solutions have on the number of solutions passing the GWP filters. The following two scenarios are set up:

- F: All filters active
- nF: All filters active except for the fire filter

Figure 4.5 illustrate the number of macro components remaining after filtering in the two scenarios. The figure includes components in the groups BF and MS, as these groups see the highest and lowest impact from removing the fire filter, respectively. The exterior walls also include components in the MS-BF group, which covers a mix of components with biogenic frame structures and a solid either front or back wall.

It is evident that removing the fire filter result in a significantly larger number of biogenic frame components passing the GWP filters for all component types. Especially for the exterior wall components, the number of solutions is increased significantly by removing the fire filter. In the MS-BF group, there is an increased amount of solutions when removing the fire filter, but this is not as significant as for the biogenic frame structures.

The number of solutions passing the GWP filters is not changed for the mineral solid structures, as most of these components comply with all three aspects of the fire filter as they are. Thereby, the potential for lowering the GWP by adopting less strict prescriptive fire regulations is mostly relevant for the frame structures. This was expected as the aspects of the fire filter adopt less strict requirements for the cladding reaction to fire, cladding fire protection ability, and reaction to fire of insulation in conjunction with wooden structures.

Limitations of Removing the Fire Filter

Removing the fire filter means that all three aspects of the prescriptive solutions are disregarded at the same time. This is not realistic, as a component differs significantly from the prescriptive solutions if none of the three aspects is obtained. Instead, the more realistic approach is to remove one aspect at a time to determine which aspect has the greatest influence on the GWP and the distribution of the GWP of components.

4.3.3 Deviating from Prescriptive Solutions

The impact on the distribution of GWP for components is assessed for each aspect of the fire filter. This is done for the group with the greatest potential for lowering the GWP, group BF. To be able to assess the impact of the emissions, the components are divided into the four groups listed below:

- F0: Components fulfilling requirements to all aspects of the prescriptive solutions
- F1: Components that adopt less strict requirements for the fire protection ability of the interior and/or exterior cladding
- F2: Components that adopt less strict requirements for the reaction to fire of the interior surface material
- F3: Components that adopt less strict requirements for the reaction to fire of insulation material in conjunction with wooden structures

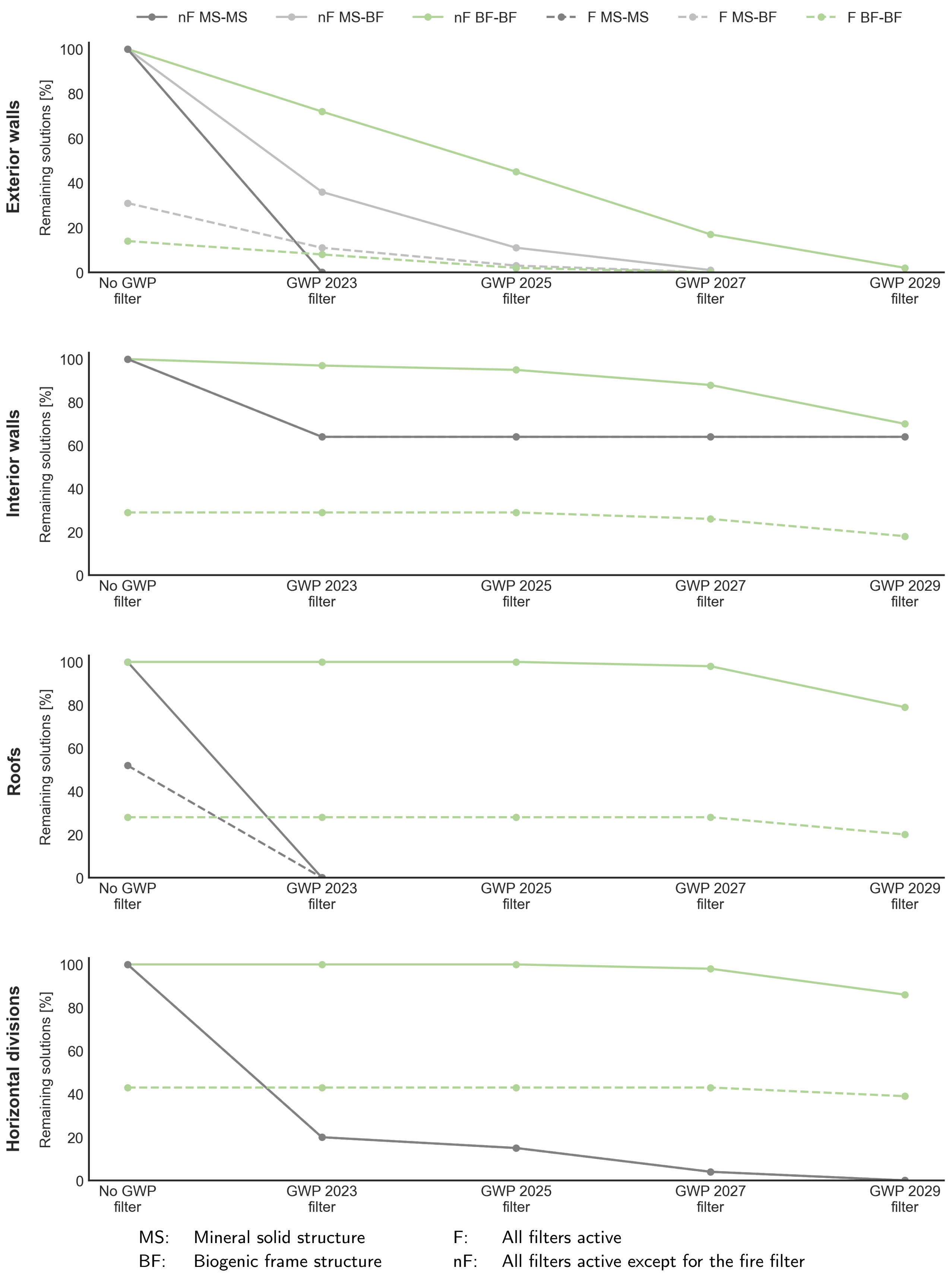


Figure 4.5. Comparison of the GWP filtering for component group BF, MS, and MS-BF in a scenario including all filters and a scenario including all filters except for the fire filter.

All components comply with the requirements to REI for buildings with a height to floor on the top floor of 5.1 to 12 metres. Thereby it is assumed that the components to some extent are buildable concerning fire safety. The regulations state that all load-bearing components must be R60 as well as all horizontal divisions and fire-separating walls must be EI60 in the selected building case.

Fire Protection Ability

The distribution of the GWP in each fire safety group is shown in figure 4.6. Using the F0 group as a baseline, the distributions show that the F1 group results in a lower GWP for all examined components. Adopting less strict requirements for the fire protection ability makes the components differ from F0 by using less cladding material and thereby lowering the GWP of the components. The median of the components in this group is 6-21 % lower than the median in F0.

Reaction to Fire of Interior Cladding

The median GWP for the components in group F2 is similar to or higher than components in group F0. However, group F2 has a greater dispersion than F0, which covers solutions with both higher and lower GWP. This is caused by the increased ability to use wood as cladding, and the fact that the datasets used for wooden interior cladding result in both higher and lower GWP compared to the plasterboard datasets. This means that changing the reaction to fire requirement of the interior cladding opens up for solutions with lower GWP, but does not change the median GWP for the dataset.

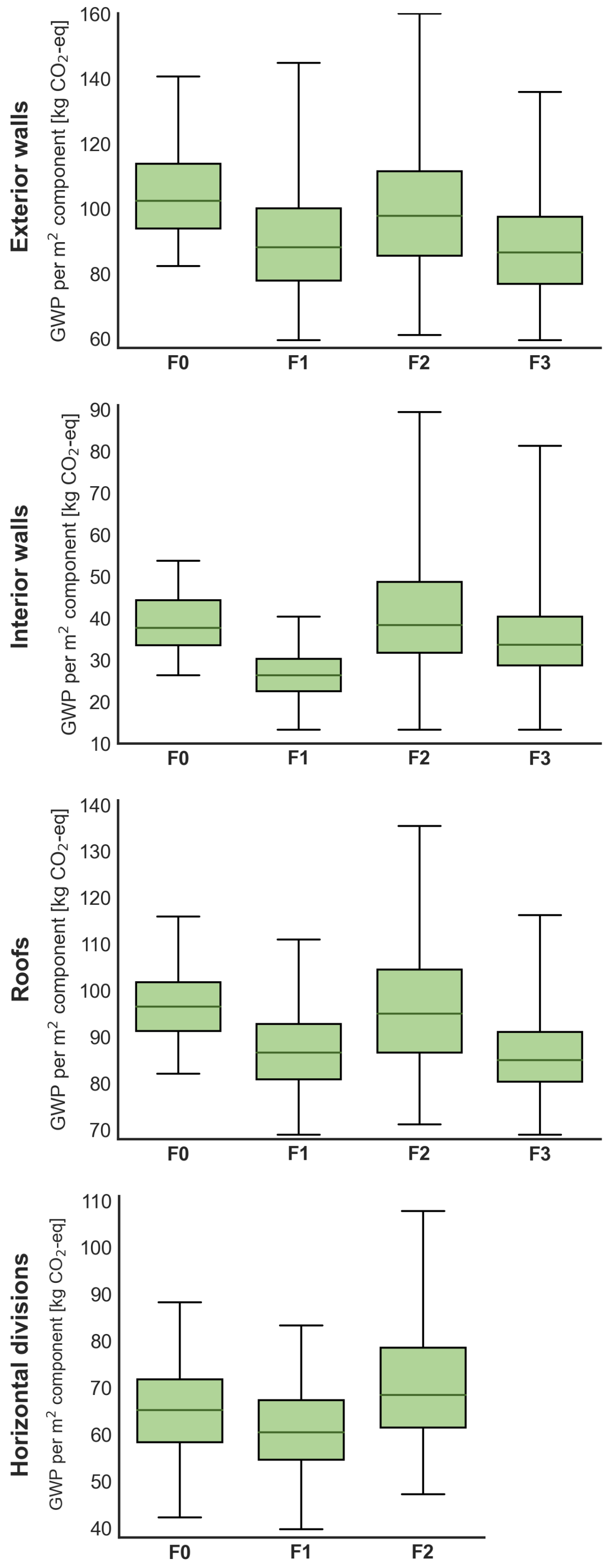
Reaction to Fire of Insulation Material

The components in the F3 group result in a reduction in GWP when compared to F0. The median of the components in F3 is 5-20 % lower than the median in F0. The difference between the components in the two groups lies in the insulation material type.

In the BF group, no horizontal division components including biogenic insulation passed the REI60 requirement, and therefore no solutions exist in F3.

Deviations from the Prescriptive Solutions

Deviation from the prescriptive solutions is an integrated part of the Danish fire regulations, allowing buildings to be constructed in other ways than described in the prescriptive solutions, as long as the level of fire safety is not reduced. To justify a deviation, the level of fire safety



F0: Prescriptive solutions
F1: Less strict requirements for fire protection ability
F2: Less strict requirements for cladding Reaction to fire
F3: Less strict requirements for insulation reaction to fire

Figure 4.6. GWP for biogenic components filtered in different fire safety groups.

must be documented and compensatory initiatives can be necessary. Thereby, the aspects of adopting less strict requirements for the prescriptive solutions presented in this study may not be possible to integrate without other fire technical considerations.

When buildings include only a few deviations from the prescriptive solutions, comparative analyses are often used to document the level of fire safety. For deviations regarding ignition and spread of fire, a widely used compensatory initiative is sprinkling. If sprinkling is not desired, the component can be tested to document that the fire technical properties are fulfilling the prescriptive solutions. This is a method for verifying that the fire protection ability of a single cladding board can obtain a K_1 10 classification when mounted on the specific insulation material. For the remaining aspects of the fire filter, fire tests may not be satisfactory to document fire safety.

4.4 Discussion

The Parameter Variation Method

The assessment in this study covers a wide range of structural principles and building materials. The parameter variation used to generate macro components results in a large design space being covered in the component analysis. The wide range of components results in more robust conclusions, but the parameter variation method is bounded by the input and can result in a large number of non-realistic components. To ensure that the generated components are realistic, a comprehensive filtering process is included in the generation process.

The micro component database is constructed based on existing buildings built in 2007-2023. The addressed buildings and the available generic environmental data limit the number of innovative low-emission materials, which means that it may be possible to construct components with significantly lower GWP.

Environmental Data and GWP Limits

The environmental data used to determine the GWP for the generated components is generic data from Ökobaudat. This is a data type often used in the early design stage when a specific product is not chosen, which is the case for the generated components. However, emissions calculated using generic data deviate from the product-specific data available in Denmark. The research group behind the Danish LCA software, LCAByg, published a report covering the impact of using product-specific data instead of generic data in three different exterior wall types. The report found that the GWP for wooden frame structures were approximately $50\,\%$ higher when using generic data compared to when using environmental product declarations [Harpa Birgisdottir et al., 2021]. A similar assessment has been performed for biogenic horizontal divisions, where the product-specific data result in 27-$63\,\%$ lower emissions compared to generic data [ARTELIA et al., 2023]. The components evaluated in the present study may also have a significantly lower GWP if the generic datasets are substituted with Danish product-specific datasets. This means that more components will pass the defined GWP filters.

The GWP filters in the present study consist of limits for the GWP of each component type. The limits are determined based on 17 existing buildings, that obtain the 2023 requirement by using a combination of generic and product-specific data. The limits are highly bounded by these buildings. The data used in the existing buildings may result in non-representative limits for the generated components, as the components are bounded by generic data.

Fire Technical Analysis

In this study, it has not been possible to perform a comprehensive comparative analysis for all generated components, ensuring that the level of fire safety is sufficient. Instead, the REI parameters are used as an indicator of the components being acceptable, and this is not sufficient according to Danish regulations. However, the assessment gives an insight into the potential of changing the aspects of the prescriptive solutions in the future, even though the components may not obtain an acceptable level of fire safety according to the current regulations.

The aspect of using cladding that is not classified with a K_1 10 fire protection ability is considered as a potential for a future change in the regulations, as the previous Danish fire regulations did not include a requirement for the fire protection ability. In the previous regulations, the requirement was a *Class 2 cladding*, which can be fulfilled by the use of a $9\,$mm board of gypsum, plywood, or OSB [TRÆ 78, 2022]. However, this will not be possible when the previous Danish regulations are omitted.

In this study, the requirement for the reaction to fire for interior surface materials in four-storey buildings is defined as B - s1,d0, which is challenged by adopting a less strict requirement of D - s2,d2 material. However, the prescriptive solutions for apartment buildings and office buildings in fire class 2 it is allowed to use class D - s2,d2 surface materials if the building is divided into small fire sections.

The aspect of the prescriptive solutions obstructing wooden frame structures in four-storey buildings with insulation material worse than class B - s1,d0 is included in the study because of a large expected potential for lowering the material emissions, which was also the case. Most components include a large amount of insulation material. Therefore, it may significantly influence the fire safety if the insulation material is substituted with one with a worse reaction to fire.

4.5 Conclusion

An LCA has been performed on 77,700 four-storey building components distributed across exterior walls, interior walls, roofs, and horizontal divisions. The components were generated based on a factorial assembly of sub-components followed by a filtration for load-bearing capacity, moisture performance, thermal insulation, and fire safety design. Three deviations from the Danish prescriptive fire design solutions allowing for an increased use of combustible materials are defined. Using these deviations, new sets of building components are generated. The global warming potential of the building components has been evaluated using the LCA method with generic environmental datasets from Ökobaudat. The environmental performance of the components are evaluated against current and future Danish limits on the global warming potential. The study found that loosening all three requirements simultaneously has no effect on mineral structures, but significantly increased the estimated future design space (2023-2029) for biogenic frame components. For biogenic frame components, almost all individual deviations increase the number of component solutions with a lower GWP for all examined component types.

Changing the required fire protection ability or lowering the required reaction to fire of insulation material decreased the median GWP of the biogenic frame components by 5-$21\,\%$. Wall and roof components showed the greatest potential for reductions in GWP. Changing the required reaction to fire of interior cladding however, did not change the median GWP of the generated biogenic frame components in any particular direction, but increased the spread of the GWP. Any potential reductions found in this study are based on large sets of components. Therefore, the reductions in GWP are related to sets of components.

The resulting GWP of the LCA is affected by the use of generic environmental data. Especially the GWP of biogenic building products seem to be overestimated by generic datasets from Ökobuadat in a Danish context. The reliability of the results from this study can be increased for a specific region by using industrial EPD's as environmental input data.

In order to estimate concrete saving potential for any component or component type, a comparative study of a particular component assembly with the variations defined in the present study must be performed. This should then be applied to a building case where appropriate compensatory fire safety initiatives are introduced and included in the LCA.

5 Comparison of Design Space for Building Typologies

In this project, an extensive mapping of the Danish fire safety regulations has been performed for two building cases: single-family houses in one-storey and four-storey buildings with a height to the floor on the top floor no more than 12 metres. The fire regulations are described in appendix A. The fire safety requirements are more strict for building components in the taller building case. To assess the difference in how great an impact the regulations have on the GWP of the components, the study on the four-storey case described in chapter 4 is performed for the single-family house case as well.

In this chapter, generated macro components from the two building cases are compared in regard to the component filtering process and the current and future requirements for GWP. The method used for the generation, evaluation and filtering of the macro components is described in chapter 4, and the input data is described in appendix E.

5.1 Number of Generated Macro Components

The number of components created in the study for each building case is shown in table 5.1. The amount of components is the same in both building cases for roofs and interior walls, as similar design parameters are used in both cases. For horizontal divisions, no components are relevant in the single-family house case, as this case is in one storey. Exterior walls in single-family houses differ significantly from those in four-storey buildings, and therefore two separate macro component generations are performed for the exterior walls. An overview of the micro components used in the generation of the macro components is shown in appendix M.

Table 5.1. Number of macro components in the study on single-family houses and four-storey buildings respectively.

Macro component type	Number of components generated	
	Single-family house	Four-storey building
Exterior walls	$4.3 \cdot 10^5$	$4.3 \cdot 10^4$
Roofs	$3.2 \cdot 10^4$	$3.2 \cdot 10^4$
Bearing interior walls	$4.0 \cdot 10^2$	$4.0 \cdot 10^2$
Interior partition walls	$1.2 \cdot 10^3$	$1.2 \cdot 10^3$
Horizontal divisions	0	$1.4 \cdot 10^3$

5.2 Filtering of Generated Macro Components

In both building cases, the evaluation and filtration of components are performed using the same method. The filtering principle for load-bearing capacity, moisture performance and fire safety is described in appendix D, along with the limits for U-value and GWP. The results from the filtering process are described for both the single-family house case and the four-storey building case in appendix C. As this chapter deals with the difference between how components perform in the two building cases, only components included in both building cases are described in this section.

5.2.1 Load-bearing Capacity, Moisture Performance and U-value

The distributions after filtering for load-bearing capacity, moisture performance, and U-value are similar for the two building cases. For the load-bearing capacity, the component types are exposed to different loads, but most components have an acceptable load-bearing capacity, meaning that few components are discarded.

The moisture performance evaluation for roofs covers both building cases, as the same roof components are used. For exterior walls, the moisture performance evaluation covers both building cases with the variations in component assemblies that exist between the cases. Therefore the filtering exceptions are similar for both cases. The limits for the U-value cover both building cases, which result in similar filtering results for roofs. As the generated exterior walls are not the same in both cases, a small variation is present for exterior walls.

5.2.2 Fire Safety

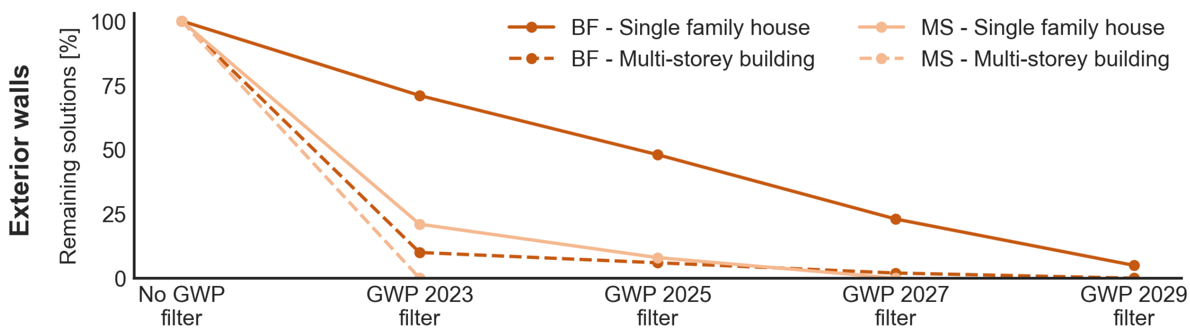
Significantly more components are discarded in the fire safety filter for the four-storey building case. This is caused by the regulations being more strict, and the fact that micro components are created to investigate the possibility of adopting less strict requirements in the prescriptive solutions in the four-storey case. For all component types, it is the biogenic structures and frame structures which are exposed to the largest share of components being discarded in the fire filtering.

5.2.3 GWP of Components

The GWP filters discard more exterior wall and roof components for the single-family house case than for the four-storey case. For the interior walls, the amount of discarded components is approximately the same. The limits are determined based on existing buildings. In these buildings, the envelope components of the single-family house category had a lower GWP. This is caused by one-storey buildings having a greater envelope area relative to the gross floor area, while the requirement for the GWP on building level is the same in both cases.

5.3 Comparison of Future Design Space for Building Typologies

To compare the building cases in regard to the current and future requirements for GWP, all filters are applied to the components. In appendix C, data for each component and structural type is shown. For both biogenic and mineral structures, a larger share of the solutions passes each GWP filter for the single-family house case. The amount of MF and MS solutions passing GWP filters are shown in figure 5.1 for exterior walls in the two building cases.



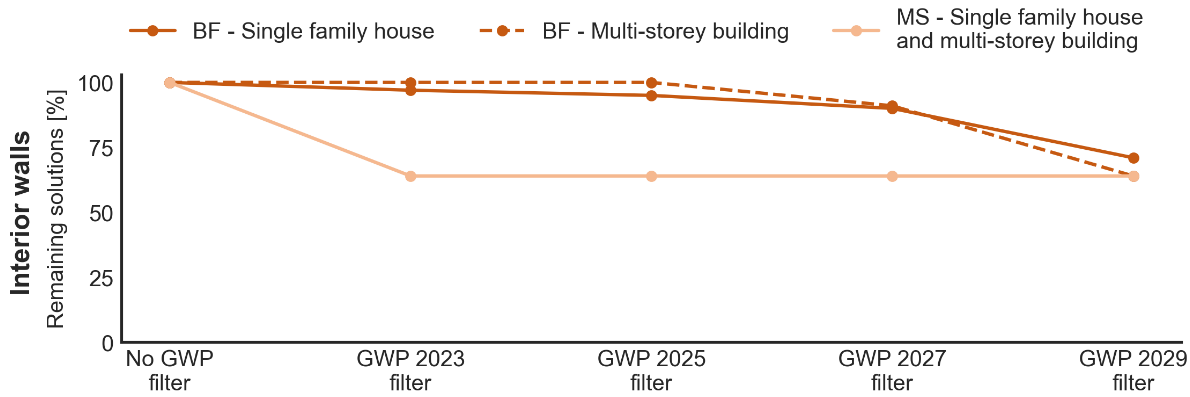
Initial number of components	BF	MS
Single-family house	84,516	178
Four-storey building	7,872	40

MS: Mineral solid structure
BF: Biogenic frame structure

Figure 5.1. Amount of components remaining after the GWP filtering of exterior walls for groups BF and MS in each building case. The amounts are normalised to the number of initial components before the application of GWP filters.

For the exterior walls, the decrease is greater for the biogenic frame components of the four-storey building case compared to the single-family house. This is because many biogenic frame structures with low emissions are removed by the stricter fire filter for the four-storey case. The components in group BF are construction wood or GLT frame structures. Component group MS covers mineral solid structures such as concrete, aerated concrete, and masonry.

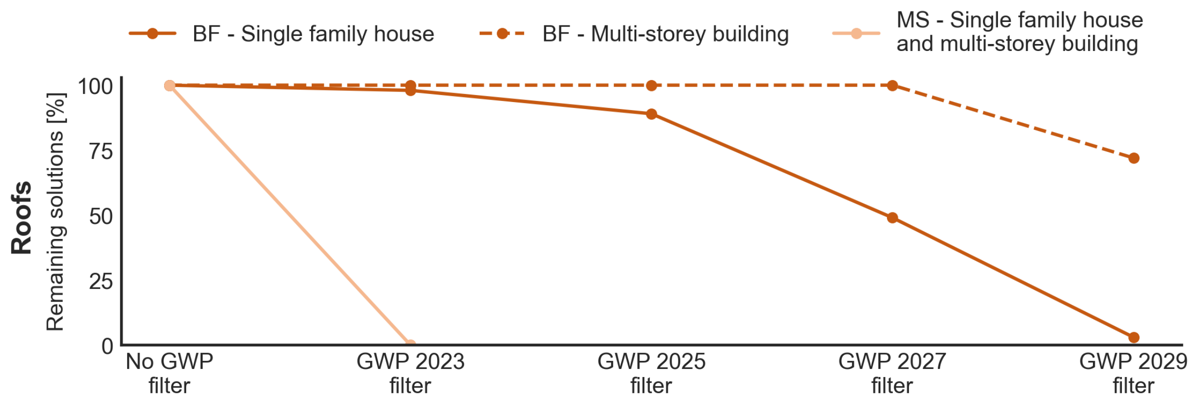
The comparison of the two building cases is performed for interior walls, and the data is shown in figure 5.2. The components in the MS group perform similarly in both building cases and are plotted together. The aerated concrete structures in group MS are performing well regarding the future GWP requirements and remain after the 2029 filter. The components in group BF are performing similarly in the two building cases, even though the fire filter is more extensive in the four-storey case. This can be due to the low amount of solutions discarded by the GWP filter, which is a result of loose GWP limits.



Initial number of components	BF	MS
Single-family house	690	14
Four-storey building	228	14

MS: Mineral solid structure
BF: Biogenic frame structure

Figure 5.2. Amount of components remaining after GWP filtering of interior walls for groups BF and MS in each case. The amounts are normalised to the number of components before the application of GWP filters.



Initial number of components	BF	MS
Single-family house	1628	900
Four-storey building	672	660

MS: Mineral solid structure
BF: Biogenic frame structure

Figure 5.3. Amount of components remaining after GWP filtering of roofs for the groups BF and MS in each case. The amounts are normalised to the number of components before the application of GWP filters.

Figure 5.3 illustrate the number of components in the groups for roof components. The roofs in group MS perform equally in both building cases, while a significant difference occurs for the components in group BF. The components in the four-storey case perform better than the single-family house case regarding the future requirements, which is caused by less strict GWP limits for components.

When comparing the performance of components in relation to the GWP filters, the performance varies with respect to the addressed component type. Compared to the single-family house case, the amount of generated solutions fit for the future requirements in the four-storey building case is lower for exterior walls, equal for interior walls, and greater for roofs. This variation is caused by the geometric differences between the two building cases. The taller the building, the less impact the roof has on the total GWP of the building. Therefore, the GWP limits for the roofs are less strict in the four-storey case compared to the single-family house case. The impact from exterior walls is not dependent on the number of storeys, but this component type is highly influenced by the fire filter. This causes many frame solutions with a low GWP to be discarded. The interior walls are similar in the two cases, as the GWP limits are not as strict compared to roofs and exterior walls.

The main reasons for these differences are the fire safety filter and the GWP filter, as the components perform similarly regarding load-bearing capacity, moisture performance, and U-value. From the filtering, it is evident, that the GWP filters had the greatest influence in the single-family house case and the fire filter had the greatest impact in the four-storey case. This means that the less strict fire safety requirements do not necessarily result in easier design of solutions for the single-family house case, as the stricter GWP limits counteract the fire safety advantage. This effect may increase as the GWP limits are lowered.

6 Impact of Current and Future GWP Requirements on Structural Materials

This chapter includes an examination of how the filtration for the estimated future GWP requirements in the Danish building regulations affects the examined design space.The examination covers the effect on the components with different structural materials for the different component types and the biogenic content of exterior wall components.

6.1 One-at-a-Time Filtering of Components

The factorial parameter variation generates a total of 5,953,000 macro components. The generation of macro components includes an elimination of incompatible components, which narrows the number of solutions down to 511,000. To reduce this new set of compatible macro components to a more realistic set of solutions, parametric filtering is applied. In appendix C, results from this filtering of the generated macro components are shown for the single-family house and four-storey building case. To describe the influence on the design space for each filter, this section composes an overview of the amount of discarded components in a one-at-the-time filtering approach.

Figure 6.1 shows the percentage of discarded components by each filter for the component types in the study. As this is one-at-a-time filtering, there is an overlap of components discarded in the filters.

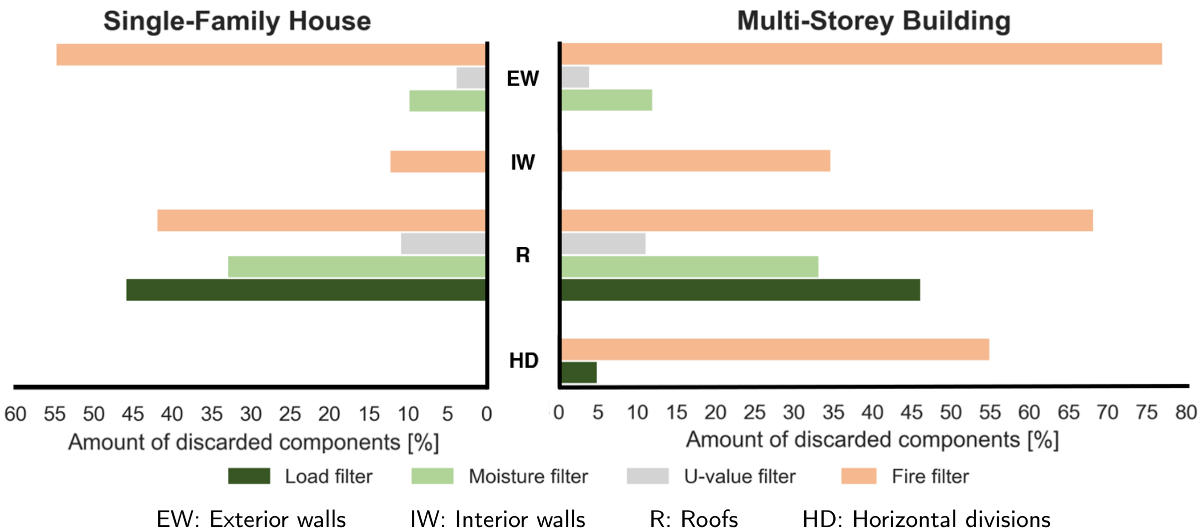


Figure 6.1. Amount of components discarded by each filter for each component type in the one-at-a-time filtering.

The exterior walls and roof components are filtered for load-bearing capacity, moisture performance, U-value, and fire safety measures. In the filtering of exterior wall components, no components were discarded due to insufficient load-bearing capacities. In the U-value filtering, $4\,\%$ of the components were discarded which were mainly steel frame structures with a low amount of insulation. $11\,\%$ of the components were discarded due to the moisture performance. These were only components with a solid veneer wall which is slightly ventilated. The fire filter discarded components from all component groups except for the ones with both a mineral solid front and back wall. A total of $55\,\%$ and $77\,\%$ of the components were discarded in the fire filter for the single-family house case and four-storey building case respectively.

For roofs, the load-bearing capacity filter and the U-value filter discarded $46\,\%$ and $33\,\%$ respectively, which were only frame structures. $11\,\%$ of the components were discarded in the moisture filter, consisting of only solid non-ventilated structures. The fire filter discarded $42\,\%$ components in the single-family house case and $68\,\%$ of components in the four-storey building case.

All interior walls and horizontal divisions are filtered for fire safety measures, and the bearing components are filtered for load-bearing capacity. No interior wall components were discarded due to the load-bearing capacity and $13\,\%$ and $39\,\%$ of the wall components were discarded in the fire safety filter for the single-family house case and four-storey building case respectively.

In the filtration of horizontal divisions, $5\,\%$ of the components were discarded due to the load-bearing capacity, mostly steel frame structures. For fire safety measures, $55\,\%$ of the components were discarded, only consisting of biogenic structures.

6.2 Structural Materials and Future GWP Requirements

To assess how the included structural materials are performing regarding the current and future GWP requirements, all filters are applied simultaneously. The components are coloured according to the most strict GWP limit that the component group is able to attain, see table 6.1. An empty space in the table indicates that no components exist with this particular structural material. Construction wood, GLT, steel, and aerated concrete pass the strictest GWP filters. Meanwhile, no masonry, CLT, or concrete components pass the GWP 2027 filter. Except for aerated concrete, all components with frame structures perform better than components with solid structures.

Table 6.1. GWP filter passed by selected structural types for the components included in the study.

Structural material	Component type						
	Single-family house			Four-storey building			
	EW	R	IW	EW	R	IW	HD
Construction wood	2029	2027	2029	2027	2029	2029	2029
GLT	2029	2027		2027	2029	2029	2029
CLT	2025	none		none	none		2025
Steel			2029	2025		2029	2029
Concrete	2025	none	2025	none	none	2025	2025
Masonry	2023		none			none	
Aerated concrete	2029		2029			2029	

- 2029: Components passing GWP 2029 filter
- 2027: Components passing GWP 2027 filter
- 2025: Components passing GWP 2025 filter
- 2023: Components passing GWP 2023 filter
- none: Components not passing any GWP filter

EW: Exterior wall
R: Roof
IW: Interior wall
HD: Horizontal division

To investigate the tendency of frame structures performing better than solid structures regarding the GWP requirements, all components are grouped into the following categories: frame structures, solid structures, and a mix of those. As the GWP is dependent on the material amount, the component thickness and plane weight are assessed to see if these parameters correlate with the GWP of each component category. The mean GWP, wall thickness, and plane weight for the three categories are shown in figure 6.2. The data covers exterior wall components in the four-storey building case.

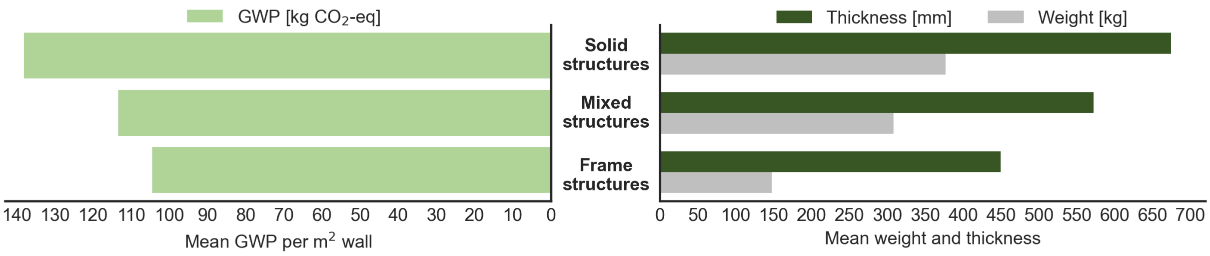


Figure 6.2. Mean GWP, mean thickness, and mean weight per m^2 wall for a four story building components with a frame structure, solid structure, and components with a mix of those.

The frame structures generally attain a lower material use, as indicated by the mean component thickness and the mean plane weight. The lower material use seems to correlate with the GWP. This is also indicated by the solid structures, that attain the highest value in all three parameters.

6.3 Biogenic Content and Future GWP Requirements

Grouping the macro components in regard to the GWP requirements did not result in any clear tendencies for biogenic structural materials being more beneficial than mineral materials. In appendix B, the GWP for all generated components is graphed as a function of the biogenic content. The data shown in the appendix reveals a general tendency of low biogenic content leading to high GWP values, but also high biogenic content leading to high GWP values. The method used for calculation of the biogenic carbon mass percent is shown in appendix I along with an overview of the biogenic carbon content of the addressed materials.

Exterior wall components are grouped according to their total mass percent of biogenic carbon to assess the impact of the GWP filtering on the biogenic carbon content in the design space. The amount of components passing the GWP filters in each group is shown in figure 6.3, where the percentage values of remaining solutions are calculated based on the number of solutions before GWP filtering. Only exterior wall components from the single-family house case are included in this examination. This case is chosen, as this component type holds the greatest component diversity with the most biogenic solutions. Additionally, the exterior wall component type has the greatest amount of solutions available after the GWP filtering.

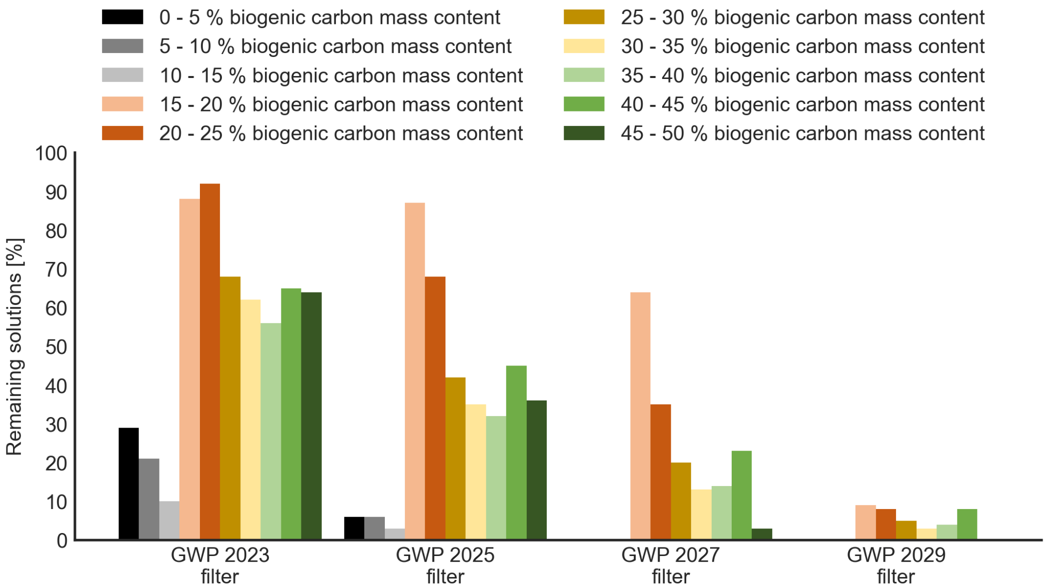


Figure 6.3. Amount of wall four story building components that passes GWP filters grouped according to the biogenic mass content.

The components passing the GWP 2023 filter include all types of structural material. In 2025, the masonry structures are discarded, and in 2027, the CLT and concrete structures are discarded. As shown, the components with a biogenic content below $15\,\%$ perform significantly worse regarding the future GWP requirements, compared to the components with a biogenic content above $15\,\%$. The components with a biogenic content of 15-$25\,\%$ perform the best against the GWP limits in 2023 to 2027. In 2029 the components with 40-$45\,\%$ biogenic content perform as good as the ones with 15-$25\,\%$.

Components with a low biogenic content result in high GWP because components in this group mainly consist of mineral solid structures and mineral wool insulation. For the components with a biogenic carbon content above $45\,\%$, the high GWP is a result of excessive use of wooden materials, as the study includes wooden cladding micro components with greater material amounts than for plasterboard cladding. Components with CLT structures contain a large amount of wood mass and are grouped in the 40-$45\,\%$ and 45-$50\,\%$ group. The 45-$50\,\%$ group decrease significantly when components with the structural component are discarded by the GWP 2027 filter.

Wall components with a biogenic mass content of 15-$25\,\%$ perform well regarding the GWP limits, as the benefit of using biogenic materials is utilised without extensive use of material. It should be noted that by choosing components from the single-family house case, components with a significantly higher biogenic content exist as opposed to the four-storey case where the fire regulations are more strict.

6.4 Consequences of Future GWP Requirements

The current and future requirements to GWP may result in some building materials becoming more difficult to incorporate into buildings when using generic datasets. In this project, it was found beneficial to use more biogenic materials, but only to some extent. Additionally, it was found very beneficial to use frame structures with a lower material use as opposed to solid structures.

In appendix G, a study on building materials in existing newly constructed buildings is performed. The study showed that mineral materials are used significantly more than wooden materials. This means that the building industry must make mineral materials more competitive regarding GWP if the building traditions should continue and the diversity of building component design should not be affected.

Poor building diversity can carry issues regarding resource use in the building industry. Based on the LCAs of macro components, the components with the highest ADPe are components using plastic vapour barriers and mineral materials such as concrete and clay brick, see appendix C. If the GWP requirements push the material use towards exclusively wooden products, this will increase the consumption of wood and affect the land use from this industry in the future.

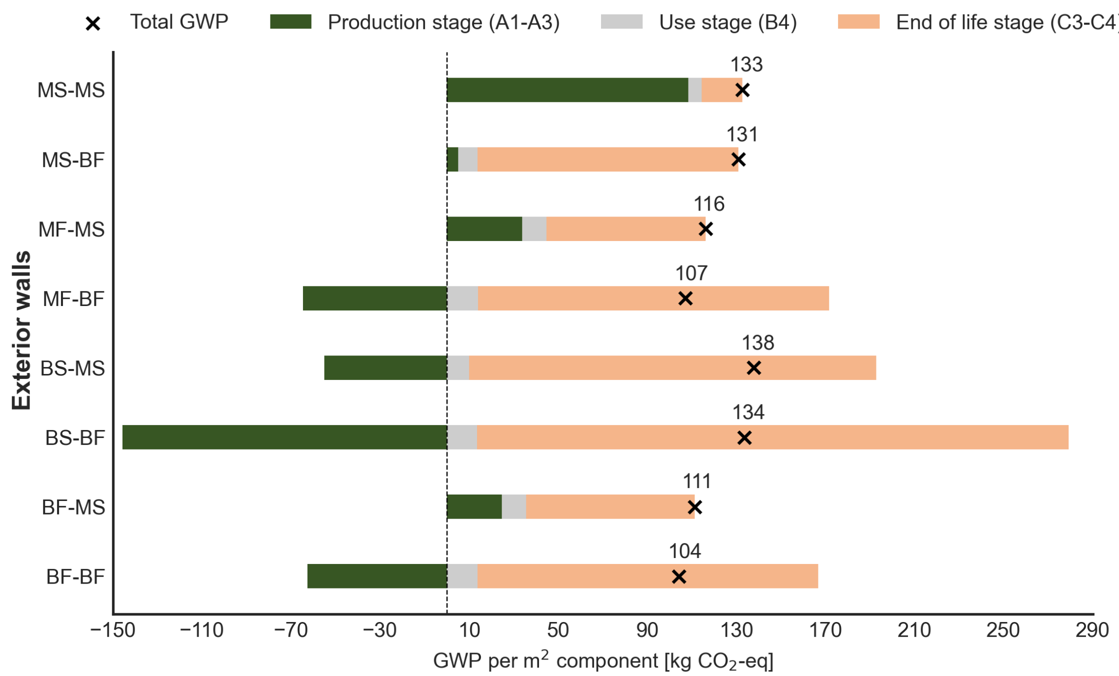
Potential development to prevent affecting the diversity of building design can consist of a decrease of emissions in material production, development of new construction principles that use less material, or increased use of recycled building materials. If further development within traditional building products is not sufficient to meet future GWP requirements, an increased demand for the development of new building materials will occur. Today, several innovative low-emission materials are being developed, but these are not covered by the study in this project.

7 Assessment of LCA Stages on Component Level

From the previous chapters, it is evident that some component types are discarded due to the increasingly strict requirements on the GWP of buildings. In this chapter, the different groups will be assessed further to see how the stages in the LCA contribute to the total GWP of the components. Therefore, the allocation of the GWP in the LCA stages is determined for the different groups. In the stages, mean values are used for the macro components that are featured in the different groups and filtered for load-bearing capacity, U-value, moisture performance, and fire safety. In the assessment, the -1/+1 approach is used in the illustrations to account for biogenic carbon storage.

7.1 Exterior Walls

The exterior walls are split into eight groups, that describe the type of macro component. In figure 7.1, the allocation of the mean GWP for each component group is shown for the production stage, use stage, and end-of-life stage, along with the total GWP for each group.



MS-MS:	Mineral solid structure and exterior wall	MS-BF:	Mineral solid structure with rainscreen
MF-MS:	Mineral frame structure and solid exterior wall	MF-BF:	Mineral frame structure with rainscreen
BS-MS:	Biogenic solid structure and solid exterior wall	BS-BF:	Biogenic solid structure with rainscreen
BF-MS:	Biogenic frame structure and solid exterior wall	BF-BF:	Biogenic frame structure with rainscreen

Figure 7.1. Allocation of GWP to the included life cycle stages for exterior wall components for a four story building.

Biogenic materials usually have a negative GWP in the production stage. This is due to the fact that biogenic materials, such as wood, absorb atmospheric CO_2 while growing. This effect is indicated in figure 7.1, where the groups with the greatest content of biogenic material have the largest negative GWP in the production stage. The BS-BF group has the lowest GWP in the production stage, which is caused by this group containing the most amount of biogenic material. The group covers CLT back walls and a rainscreen mounted on wooden studs. However, it is not necessarily better with regard to GWP to simply have a large amount of wood in the component, as the BS categories result in some of the highest mean GWP per m^2 wall.

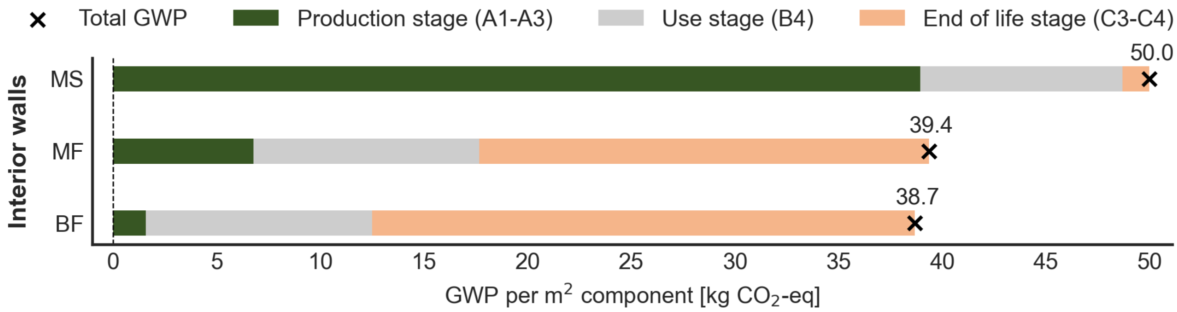
Groups MS-BF and BF-MS also contain wood, but here the mean value of the GWP in the production stage is positive. This is because other materials in the component have a large GWP in the production stage which surpasses the negative GWP.

The mineral frame structures are quite similar to the biogenic frame structures. Results from the mineral and biogenic frame structures are similar in case of both mineral veneer walls and rainscreens. The difference between MF-BF and BF-BF is only 3 kg CO_2-eq, while it is 5 kg CO_2-eq between the MF-MS and BF-MS. The mineral structures have a smaller end-of-life stage than the biogenic components but result in greater total GWP because of higher emissions in the production stage.

As shown in figure 7.1, the BF-BF group is the one with the lowest total mean GWP at 104 kg CO_2-eq, while BS-MS has the highest mean GWP at 134 kg CO_2-eq. Extensive use of wood in the buildings is not necessarily better regarding GWP, because of more wood being combusted at the end-of-life stage.

7.2 Interior Walls

The interior walls consist of three different groups. The distribution of GWP in the building life cycle stages can be seen in figure 7.2. Here, the component groups refer to the structural part of the walls, which consist of wooden frame structures, steel frame structures and mineral solid structures.



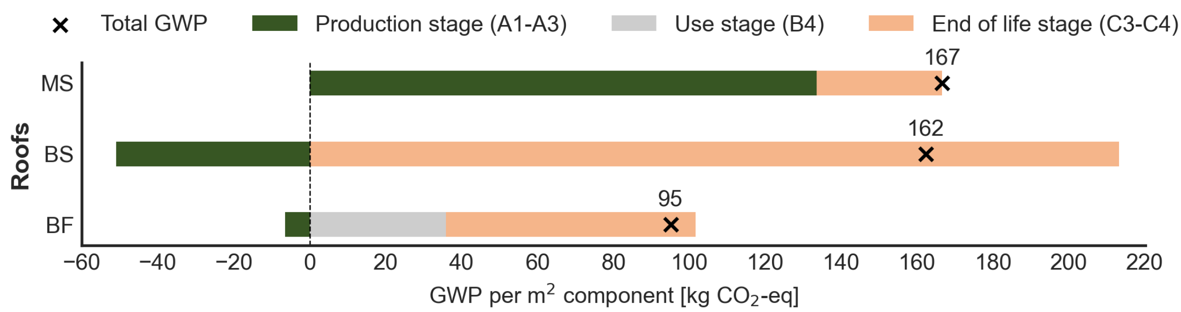
MS: Mineral solid structure MF: Mineral frame structure BF: Biogenic frame structure

Figure 7.2. Allocation of GWP to the included life cycle stages in interior wall components a four story building.

As for the exterior walls, the mineral frame and the biogenic frame structures are similar in impact. The BF category results in less than 1 kg CO_2-eq less than the MF category. The biogenic frame structures do not have a negative net mean GWP in the production stage, which may be due to the cladding and insulation material neutralising the negative effects of the wooden products. The production stage in mineral solid structures contributes to the greatest GWP for all components, while the end-of-life stage is smaller than for the other categories. This distribution is similar to the MS-MS category for exterior wall components.

7.3 Roofs

For roof components, three different groups are examined, see figure 7.3. The impact stages are shown for the component groups. The groups refer to the structural part of the roof components. The mineral solid structures and the biogenic solid structures are similar in regard to the total mean GWP. As concluded for wall components, the production stage for mineral solid structures is high, while the end-of-life stage is relatively low. For the biogenic solid structures, it is the opposite, where the production stage is negative, and then the end-of-life stage has high CO_2 emissions.



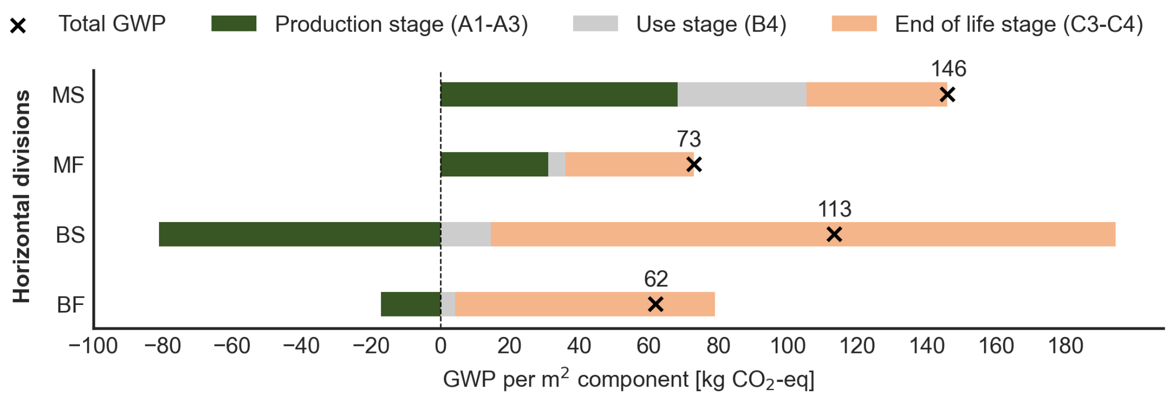
MS: Mineral solid structure BS: Biogenic solid structure BF: Biogenic frame structure

Figure 7.3. Allocation of GWP to the included life cycle stages in roof components a four story building.

The biogenic frame group results in significantly lower total GWP compared to the other groups. For roofs, the biogenic structures result in a small negative GWP in the production stage and a relatively high GWP in the end-of-life stage.

7.4 Horizontal Divisions

The horizontal divisions are split into four groups based on the structural part of the components. The distribution of GWP in the different stages are shown in figure 7.4.



MS: Mineral solid structure MF: Mineral frame structure
BS: Biogenic solid structure BF: Biogenic frame structure

Figure 7.4. Allocation of GWP to the included life cycle stages in horizontal divisions a four story building.

Mineral solid horizontal divisions have the highest total mean GWP. The mean GWP for mineral solid structures has a relatively even distribution across the LCA stages. The use stage contributes to greater emissions compared to MS groups in the other component types. This may be caused by the fact that the mineral solid structures only have four different interior cladding, where three of which are rigid insulation panels. These panels contribute to high emissions, because of the environmental data and a reference service life of 30 years, which results in one replacement during the building's lifetime. If a larger number of cladding and more diverse cladding were used, the mean GWP in the use stage might have been smaller.

The mineral frame structures in this case consist of components with load-bearing steel beams. To make sure that the steel beam can bear the load, a large cross-section of the beams is needed. Steel has a large GWP in the production stage and a low GWP in the end-of-life stage. This is caused by steel being a recyclable material, and only a small part is wasted in the recycling process. Approximately 35 kg CO_2-eq is attributed to the end-of-life stage, and a large share of the emission may be caused by the cladding and insulation material.

The biogenic solid structures consist of CLT elements. For this category, the production stage is approximately -80 kg CO_2-eq, which is mostly caused by the big amount of wood used in these CLT elements.

7.5 Comparison of the Impact of LCA Stages

In the previous chapter, the mineral groups did not perform well regarding the future GWP requirements. In this chapter, it is shown that mineral materials' end-of-life stages are quite small. This is because part parts of these materials are reused, and emissions from these are not attributed to the end-of-life stage. On the other hand, the production stage contributes to high CO_2 emissions. Lowering the CO_2 emissions in the production stage could contribute to mineral building materials fulfilling the stricter CO_2 requirements of the future.

The solid biogenic structures have a large negative GWP in the production stage because of the large wood content. At the end-of-life stage, this type of component emits a lot of CO_2, which is caused by the combustion process for wooden products. The high CO_2 emissions cause the solid biogenic structures to have a high total GWP. This is the reason why CLT elements are discarded in the GWP filters in the previous chapters.

The components with biogenic frame structure are the ones with the lowest GWP per m^2. This is the reason why not all biogenic frame structures were discarded by the GWP filters in the previous chapters.

The mineral frame structures behave almost equally to the biogenic frame structures in terms of total mean GWP. This is because a small amount of steel is necessary for steel structures to withstand the loads as opposed to wooden structures, where a greater amount of wood is needed to withstand the same loads. Other than this, steel is assumed reused at the end-of-life stage of the environmental datasets.

8 Discussion

In this chapter, the method used in this project is discussed to address the influence of choices and assumptions made in the process of generating, evaluating, and filtering macro components. The discussion covers the collection of data for the micro component database, the generic input data, the parameter variation method and the chosen component evaluation parameters.

8.1 Data Collection Procedure

The contents of the micro component databases are based on technical information from existing buildings build in the years 2007-2023. In the data collection process, it was only possible to cover a small number of buildings with low emissions, as these types of buildings compose a small share of the current building stock in Denmark. This means that the study does not cover novel low-emission materials and components.

When collecting data for the micro component databases and material database, it was difficult to sustain coherent data quality, as not all necessary information was available from the same source. No single database including environmental data and material properties for structural, thermal, moisture and fire safety analysis was found during this project. Therefore, material properties were assembled from different sources, resulting in a lower data quality, as the material properties vary with respect to the specific product. This was evident in the mapping of thermal properties for insulation materials, see appendix J, where the thermal conductivity was determined based on market products with varying densities.

8.2 Influence of Environmental Data Type

For the LCAs in this study, data exclusively from Ökobaudat have been used. The single source of data makes the origin of the data more transparent. However, the environmental data is not based on industrial data but is calculated based on assumed production and end-of-life processes for Germany [Federal Institute for Research on Building, Urban Affairs and Spatial Development, 2020].

The impact of replacing the generic data with product-specific data has been assessed in studies, concluding that the biogenic materials perform significantly better regarding GWP when using EPDs as opposed to generic datasets from Ökobaudat [Harpa Birgisdottir et al., 2021] [ARTELIA et al., 2023]. The studies showed a minor benefit or no benefit of switching to product-specific datasets for mineral building materials. To investigate to what degree the use of generic environmental data has affected the conclusions in this project, selected materials are chosen for a comparison study. The study includes data from all available environmental product declarations in the database from EPD Danmark that are relevant to the materials. In figure 8.1, the difference EPDs and generic data are visualised. Table 8.1 show information on the EPDs included in the study.

For the biogenic materials, CLT and construction wood, the study showed that the GWP from generic datasets is significantly higher compared to product-specific data. The overshoot from generic data is $67\,\%$ and $83\,\%$ respectively, which would have changed the number of components being discarded in the GWP filters significantly. Especially for CLT, the conclusions may have changed significantly as all CLT structures were discarded by the GWP 2025 filter. For the mineral solid components, the masonry walls performed poorly regarding GWP, while the aerated concrete walls performed unexpectedly well. As shown in figure 8.1 this can be caused by an overshoot for bricks and a significant undershoot for aerated concrete. Thereby, the conclusions for mineral structures may have changed significantly if product-specific data were used.

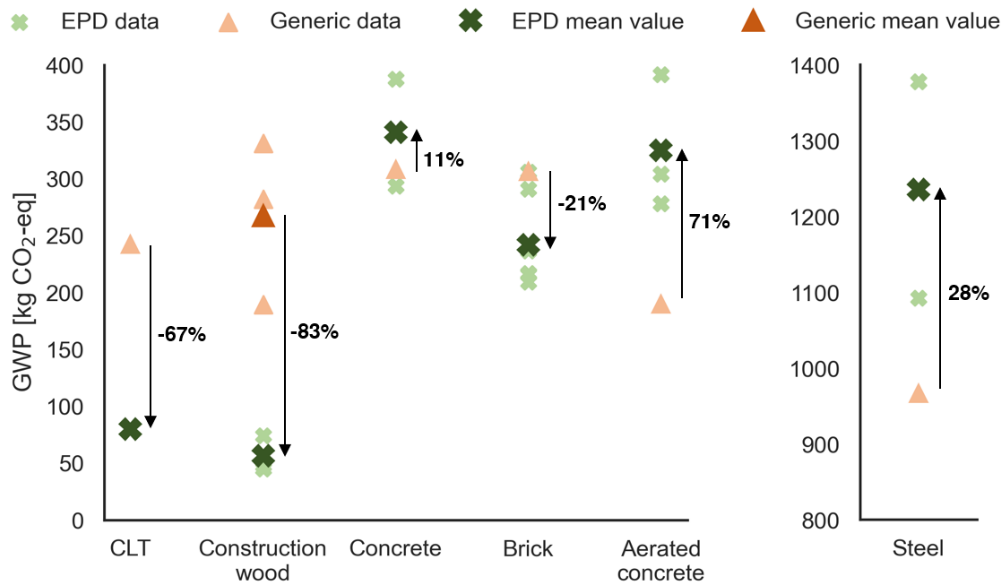


Figure 8.1. Distribution of GWP for EPDs and generic data for selected structural materials along with the deviation of the EPD data from the generic data.

Table 8.1. Overview of environmental data for selected materials used in the EPD study [EPD Danmark, 2023].

Structural material	Number of EPDs	Functional unit	Name of EPDs
CLT	1	m^3	MD-20007-EN_rev1
Construction wood	5	m^3	MD-20002-EN, MD-20004-EN_rev1, MD-20001-EN, MD-20003-EN, MD-22076-DA
Concrete	2	m^3	MD-20012-DA_rev1,MD-22074-DA
Steel	2	ton	MD-20040-EN, MD-20042-EN_rev1, MD-21007-EN
Brick	7	ton	MD-21047-EN, MD-20030-EN, MD-21042-EN MD-18015-EN, MD-20044-EN MD-21058-EN, MD-22004-EN
Aerated concrete	3	m^3	MD-20016-DA_rev1, MD-22103-DA, MD-22012-DA

The steel frame structures in this project have been performing similarly to the wooden frame structures. This may not only be caused by the significant overshoot on construction wood but also an undershoot on the steel material. In this project, the use of generic datasets composes a challenge when comparing the macro components with the GWP limits determined for the GWP filters. The GWP limits are determined based on LCA documentation from 17 existing low-emission buildings, where all cases use product-specific data to some extent. Meanwhile, the GWP of the macro components is determined using generic data. Based on the deviations presented in figure 8.1, the comparison of the GWP limits and the generated macro components may not be compatible.

8.3 The Parameter Variation Method

The parameter variation used in this project covers a wide range of structures and building materials. Thereby, a large design space is covered in the component analysis. This forms the basis for more robust conclusions compared to studies including a low amount of components. However, a parameter variation method is highly influenced by the input data and can result in a large number of non-realistic components, and therefore a comprehensive filtering process is included in the macro component generation. The filtering process sorts out unrealistic components such as a rainscreen mounted directly on flexible insulation batts without a frame structure.

8.4 Parameters Included for Parametric Filtering

The parameters used in the filtering of macro components are specified based on a mapping of significant component properties. Due to time limitations, it was not possible to include all component properties in the study. Component parameters that were deemed significant, but were not included in the project are economy and acoustic performance. In a study on horizontal divisions, the sound reduction and economy were taken into account for 28 components, including both concrete, construction wood and CLT structures [ARTELIA et al., 2023]. The study found that the biogenic structures were more difficult to soundproof and the wooden components were significantly more expensive to construct [ARTELIA et al., 2023]. These properties may have had an impact on the number of biogenic components passing the filtering process.

The time scope of the project also limited the quality of the calculations used to filter macro components for some of the filters. The focus has been on the fire safety measures, the moisture properties, and the GWP. The remaining filters are based on simple calculations, which may cause the results to differ from reality.

The experience of the authors relating to fire safety in buildings limits the project to an examination of prescriptive solutions without compensatory initiatives. Conclusions made in this project should not be considered as stand-alone results but as a part of an evaluation where additional aspects of fire safety should be considered. Environmental benefits from deviating from a prescriptive design solution should be considered alongside compensatory initiatives which may in turn cause greater emissions. The necessary compensatory initiatives are case-specific and can be determined by a certified fire safety consultant.

8.5 Drawbacks for Biogenic Structures

Adopting less strict prescriptive fire safety solutions did show potential for biogenic structures and frame structures. However, the study on future building diversity showed that the biogenic frame structures can be used under the future GWP requirements, which was not the case for mineral solid structures.

Enhancing the use of buildings with biogenic materials is beneficial regarding GWP, but mineral solid structures include benefits for several other component parameters. One parameter is the lifetime of the mineral products that are not affected by the climate to the same extent as wooden products. This benefit is not considered in this project, as the reference study period is 50 years in the LCA calculations.

The density and heat capacity of the mineral materials also results in a benefit regarding the effective heat capacity, which was included in the macro component evaluation. The heat capacity of concrete structures is approximately ten times bigger than for frame structures with plasterboard cladding. A high heat capacity is beneficial regarding the stability of the thermal indoor environment and the energy consumption in buildings, as the component can store excessive heat.

9 Conclusion

A total of 511,000 single-family house and four-story building components were generated in the present study about the effect of GWP limits on building component assemblies. The components are distributed across exterior walls, interior walls, roofs, and horizontal divisions. The components are the result of a factorial component generation and subsequent compatibility check and parametric filtering. The filtering process include filtering for load-bearing capacity, moisture performance, thermal insulation, and fire safety design. A wide variety of properties and performance parameters including the GWP of the building components are determined. The components are evaluated against current and expected future limits on the GWP of buildings in Denmark. The GWP is evaluated using generic environmental datasets from Ökobaudat.

The study showed a lower resource use and lower GWP for building components utilising a frame structure for both the single-family house and multi-storey building typology. This increases the future prospects of frame structure components, which in the study is estimated to be able to comply with future GWP requirements for 2027 and 2029. Meanwhile, no components mineral structural components, except for aerated concrete, are estimated to be able to comply with the expected 2025 requirements. This is also the case for CLT structures. Components able to meet the 2029 requirements made up $5\,\%$ of the initial components. These were components with a biogenic carbon mass content of 15-$45\,\%$. The use of biogenic materials is more restricted for multi-story buildings compared to one story buildings due to fire safety requirements.

In order to increase the future design space, three deviations from the Danish prescriptive fire design solutions allowing for an increased use of combustible materials are defined. The influence of these deviations are assessed by generating components that utilise the deviations. For biogenic frame components, almost all individual deviations increase the number of biogenic frame solutions with a lower GWP for all examined building component types. Two of the deviations reduced the median GWP of the investigated sets by up to $21\,\%$ each. Wall and roof components showed the greatest potential for reductions in GWP.

All assessments in this study are based on large sets of components. Therefore, the reductions in GWP are related to sets of components. In order to estimate concrete saving potential for any component or component type, a comparative study of a particular component assembly with the variations defined in the present study must be performed. This should then be applied to a building case where appropriate compensatory fire safety initiatives are introduced and included in the LCA.

The resulting GWP of the LCA is affected by the use of generic environmental data. Especially the GWP of biogenic building products seem to be overestimated by generic datasets from Ökobuadat in a Danish context. The reliability of the results from this study can be increased for a specific region by using industrial EPD's as environmental input data.

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Appendix

A Fire Safety Regulations in Denmark and Other European Countries

This chapter is a study on fire safety strategies. All countries in Europe follow a European standard with a description of how to classify materials and components regarding fire. This chapter includes a description of the material-specific content of this standard, after which the fire safety strategies in Denmark and other European countries are covered. Since the fire safety regulations are dependent on the building evaluated, two different building typologies are used in this chapter to describe and compare the fire safety regulations. The selected building typologies are single-family houses in one-storey and four-storey buildings.

A.1 European Standards

To standardise the procedure for classifying construction products, regarding fire safety performance, a European standard has been made. This standard is called "EN 13501 - Fire classification of construction products and building elements", and it is split into 6 parts. The name of the parts and the current versions are listed below:

- **DS/EN 13501-1:2018** - Classification using data from reaction to fire tests
- **DS/EN 13501-2:2016** - Classification using data from fire resistance tests, excluding ventilation services
- **DS/EN 13501-3+A1:2009** - Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers
- **DS/EN 13501-4:2016** - Classification using data from fire resistance tests on components of smoke control systems
- **DS/EN 13501-5:2016** - Classification using data from external fire exposure to roofs tests
- **DS/EN 13501-6:2018** - Classification using data from reaction to fire tests on power, control, and communication cables

Since this project mainly focuses on building parts and materials, the focus will be on parts 1, 2, and 3.

A.1.1 Classification of Materials and Building Parts

The classification of building materials and building parts regarding their fire technical properties take the following things into account:

- Reaction to fire
- Fire resistance ability

Reaction to Fire

When classifying materials in regards to their reaction to fire, the standard operates with 7 primary classes, which are listed below [DS/EN 13501-1, 2018]:

- A1
- A2
- B
- C
- D
- E
- F

Floors and roofs are classified in a different way than other surfaces. The floors are marked with the reaction to fire class followed by "fl", and the roof will instead be marked with "roof". The roof class is combined with its testing method and is indicated by t1, t2, t3, or t4 [DS/EN 13501-1, 2018].

A material in class A1 is considered non-inflammable, while class E and F are considered highly flammable. Class A2 to D are combined with an additional class describing smoke and droplets [DS/EN 13501-1, 2018]. Smoke will form when a material is burning, but the amount of smoke generated will depend on the material and the efficiency of the combustion. The additional class describing the smoke is indicated by the letter s and a number. The smoke class is described in DS/EN 13501-1 [2018] and consists of:

- s1 - Very limited smoke development
- s2 - Limited smoke development
- s3 - No requirement for smoke development

The materials in classes A2 to D are also evaluated for the release of burning droplets and particles, which can result in fire dispersion. The additional class describing droplets are indicated by the letter d and a number. The classes are shown hereunder and described in DS/EN 13501-1 [2018]:

- d0 - No burning droplets or particles
- d1 - Burning droplets or particles to a limited extend
- d2 - No requirements to the number of burning droplets or particles

A material's reaction to fire could be, A2-s1,d0.

Fire Resistance Ability

The classification of a building section's fire resistance ability indicates the period that a building part can maintain its fire resistance. The resistance to fire can be described from the following parameters [DS/EN 13501-2, 2016]:

- R - Load-bearing capacity
- E - Integrity
- I - Insulation
- S - Smoke control
- W - Radiation
- M - Mechanical action
- C - Self-closing
- S - Smoke leakage
- K - Fire protection ability

An example of using this classification of fire resistance ability could be REI30. This describes that the load-bearing capacity, the integrity, and the insulation are kept through 30 minutes of fire exposure[DS/EN 13501-2, 2016].

The time spans that are normally used in this classification are 15, 30, 60 and 120 minutes.

Fire Protection Ability

Some materials can protect underlying materials against fire and limit critical heating of building parts. A fire protection material can be a cladding or a fire protection system [DS/EN 13501-2, 2016].

The fire protection ability of cladding is classified as K_1 10, K_2 10, K_2 30, or K_2 60. Here the K_1/K2_2 describes the application limits, and "10/30/60" describes the amount of time that the cladding can hold its fire protection abilities [DS/EN 13501-2, 2016].

A.2 The Danish Fire Safety Regulations

The Danish regulations concerning fire safety are described in Chapter 5 §82 - §158 of the Danish building regulations. The regulations are made up of requirements and a guideline describing the requirements and ways to fulfil each requirement [BR18, 2022].

This section contains relevant information on how to document fire safety strategies in buildings, how buildings are classified, and relevant fire safety regulations.

A.2.1 Documentation of Fire Technology

BR18 §506 states that the documentation of fire safety in buildings should demonstrate that the building's fire safety strategies comply with the requirements from the building regulations [BR18, 2022]. There are different methods to document fire safety in a building, and these are listed below. The methods are described in table A.1.

- Prescriptive solutions
- Fire technical assessment
- Comparative analysis
- Fire technical design
- Fire testing
- A combination of the above-mentioned

Table A.1. Methods for documenting fire safety in buildings [BR18, 2022].

Method	Description
Prescriptive solutions	Using the prescriptive solutions that are included in the appendices of the Danish building regulations, is one way to demonstrate that the building has been constructed correctly in terms of fire safety
Fire technical assessment	Describing how the proposed strategy has the same or better fire safety rating as the prescriptive solutions
Comparative analysis	Based on general solutions or a specific prescriptive solution. Here an assessment, fire technical design or fire testing will be used to prove that the proposed solution has the same fire safety level as the prescriptive solutions.
Fire technical design	Fire technology is documented by fire technical design. Here calculations are used to document proper fire safety.
Fire testing	Fire testing is used to document the fire technology of a building. Here fire technology solutions are tested to show that the solutions are safe to use in the building
A combination of the above-mentioned	Fire safety is documented with a combination of the before-mentioned methods.
Performance-based design	Fire safety is documented in other ways than described in the above methods.

A.2.2 Classification of Buildings

The Danish building regulations state that a building should be divided into one or more building sections with similar fire risk and that a use category and a risk class must be assigned for each of these building sections [BR18, 2022].

Use Category
There are six distinct use categories, which are chosen based on the purpose of the building. The category depends on the following statements:

- If there are sleeping arrangements in the building
- The people's knowledge of fire escapes
- If people can help themselves out of the building
- The maximum number of people in the building

Risk Class
Four distinct risk classes are available. It is chosen based on the following:

- Use category
- Fire load
- Building/building section height
- Number of people in the building section

Fire Class
A building is also given a fire class. The fire class is chosen based on the risk class and the chosen method for documentation. The fire class is determined using table A.2.

Table A.2. Division into fire class on basis of risk class and documentation method [BR18, 2022].

	Method for documentation				
Risk class	**Prescriptive solutions**	**Fire technical assessment**	**Comparative analysis**	**Fire technical design**	**Fire class**
1	×				1
2 3	× ×				2
1-3	×	×	×	×	3
1-4	×	×	×	×	4

A.3 Prescriptive Fire Safety Solutions in Denmark

The prescriptive solutions of the Danish building regulations are complex and depend on how a building is constructed. Therefore two case-building typologies are used to map the Danish fire safety regulations. The two building cases are based on a one-storey single-family house and a four-storey apartment building. A section with taller buildings is also made to describe the stricter parts of the fire regulations concerning the use of biogenic materials.

A.3.1 One-storey Building

Most one-storey buildings are placed in the lowest fire class consisting of the least strict requirements to fire safety measures. The requirements relevant to one-storey buildings in fire class 1 are covered in this section.

A building in fire class 1 has a height to the floor on the top floor of a maximum of 5.1 metres, and thereby the requirements listed in this section can cover buildings in more than one storey. However, the building must comply with the remaining requirements to fire class 1.

Load-bearing Construction

The requirement for the fire resistance is shown in table A.3. In a one-storey building, all constructions must be assigned R30 [BR18, 2022]. A stricter requirement is only relevant if the building includes a basement.

Table A.3. Requirements for fire resistance of the constructions in one-storey buildings [BR18, 2022].

Construction	Requirement
Horizontal division above basement & basement constructions	R60 / A2-s1,d0
Remaining constructions	R30

Interior Cladding

The prescriptive solutions include requirements for all interior surfaces. Requirements are set for walls, floors, and ceilings and cover the material reaction to fire and the fire protection ability of wall and ceiling cladding. The requirements are listed in table A.4.

Table A.4. Requirements for interior cladding in one-storey buildings [BR18, 2022].

Surface	Requirement
Wall and ceiling surfaces	K_1 10 / D-s2,d2
Floor surfaces	No requirements

Exterior Cladding

Requirements for the external cladding materials in one-storey buildings are listed in table A.5. The external cladding includes the roofing and the exterior walls. In wall constructions including a rainscreen, the requirement is divided between the rainscreen material and the underlying material, for instance, the wind protection [BR18, 2022].

Table A.5. Requirements for exterior cladding in one-storey buildings [BR18, 2022].

Surface	Requirement
Exterior sheathing	K_1 10 / D-s2,d2
External rainscreen	D-s2,d2
Roof	B_{roof}(t2)
Windows, exterior doors, ventilation grills and similar	No requirements

Insulation Materials

The requirements for the use of different reactions to fire for the insulation material are shown in table A.6.

Table A.6. Requirements regarding insulation materials in building components for one-storey buildings [BR18, 2022].

Insulation material	Requirement	
Better than B-s1,d0	No limitations	
Better than D-s2,d2	Can be used if other materials keep their requirements	
Worse than D-s2,d2	Horizontal divisions	It can be used on the horizontal division that is at least REI 60 / A2–s1,d0, and the floor is at least D_{fl}–s1
	Walls and ceilings	The insulation should be covered by at least (R)EI / A2–s1,d0 on both side
	Floor in top floor is no more than 12 m above terrain	The insulation should be covered by at least K_1 10 / B–s1,d0 on both sides
		The insulation should be covered by at least EI30 on both side
	Floor in top floor is no more than 9.6 m above terrain	The insulation can be used in roofs if the construction part below the insulation is EI30, and the roofing is of at least Broof (t2)

A.3.2 Four-storey Buildings

In this section, the fire regulations will be walked through for buildings with four storeys, and then the deviations from the building typologies will be shown in the section *"Building typology deviations"*.

Regarding the building fire class, a four-storey building is assumed to have a height to the floor on the top floor between 5.1 metres and 12 metres.

Load-bearing Construction

The requirements for load-bearing constructions depend on the construction type and the location of the component. The requirements are shown in table A.7.

Table A.7. Requirements for fire resistance of the building construction in four-storey buildings [BR18, 2022].

<table>
<tr><th>Construction</th><th>Requirement</th></tr>
<tr><td>Top floor</td><td>R30</td></tr>
<tr><td>Horizontal division above basement</td><td>R60 / A2-s1,d0</td></tr>
<tr><td>Remaining constructions</td><td>R60 / A2-s1,d0
R60 / D-s2,d2, but the whole building is sprinkled
R60 / D-s2,d2, but:
The fire-exposed surface of the load-bearing construction is less than 20 % of the wall and ceiling surface within the first 60 minutes of the standard fire. If this is not the case:
A fire-protection system is added with at least class K_2 60 / A2-s1,d0
Or, a fire-protection cladding is added with at least cladding class A2–s1,d0, and it is ensured that charring of wood does not occur during the first 60 minutes</td></tr>
</table>

It is stated in the prescriptive solutions that if the load-bearing construction is constructed of a material worse than class A2-s1,d0, then an insulation material worse than B-s1,d0 must not be used [BR18, 2022].

Interior Cladding

The regulations include requirements for the interior cladding in buildings, more specifically for the floors, walls, and ceilings. The requirements can be seen in table A.8.

Table A.8. Requirements for interior cladding in four-storey buildings [BR18, 2022].

Surface	Requirement
Wall and ceiling surfaces	K_1 10 / B-s1,d0
Floor surfaces	USe category 1, 2, 4 & 5 : No requirements Use category 3 & 6 : D_{fl} - s1 in escape route
Suspended ceilings	Should be at least B-s1,d0, and the ceiling and walls above should be at least K_1 10 / B-s1,d0

Exterior Cladding

The requirements for the exterior cladding are shown in table A.9. The requirements cover the roof and external wall surface.

Table A.9. Requirements for exterior cladding in four-storey buildings [BR18, 2022].

Surface	Requirement
Exterior sheathing	K_1 10 / B-s1,d0
External rainscreen	B-s1,d0
Roof	B_{roof}(t2)
Windows, exterior doors, ventilation grills and similar	No requirements

Insulation Materials

There are different requirements for a building depending on what kind of insulation is used. The different limitations there are in the use of insulation materials can be seen in table A.10.

Table A.10. Requirements regarding insulation materials in building components [BR18, 2022].

Insulation	Requirement	
Better than A2-s1,d0	No limitations	
Worse than A2-s1,d0	B-s2,d0 insulation materials can be used on the top of the roof constructions where the underlying construction is at least REI60 / A2-s1,d0	
Better than B-s1,d0	Use category 1-5: No limitations Use category 6: Not possible to use B-s1,d0, and worse if the building is more than two storeys	
Worse than B-s1,d0	The load-bearing construction must be of A2-s1,d0 or better	
Better than D-s2,d2	Can be used if other materials keep their requirements, e.g., the requirement that states that the load-bearing construction must be A2–s1,d0 or better	
Worse than D-s2,d2	Horizontal divisions	It can be used on the horizontal division that is at least REI 60 / A2–s1,d0, and the floor is at least D_{fl}–s1
	Walls and ceilings	The insulations should be covered at least (R)EI / A2–s1,d0 on both side
	Floor in top floor is no more than 12 m above terrain	The insulation should be covered by at least K_1 10 / B–s1,d0 on both sides The insulation should be covered by at least EI30 on both side
	Floor in top floor is no more than 9.6 m above terrain	The insulation can be used in roofs if the construction part below the insulation is EI30, and the roofing is of at least Broof (t2)

Building Typology Deviations

The building regulations hold guidelines that describe the prescriptive solutions for specific building typologies. These follow the above-mentioned requirements, but for some building typologies, some relaxations of the requirements are introduced. For multi-storey buildings, apartment and office buildings are some of the building typologies that are built the most. The deviations for these types will be described below:

Apartment buildings
All the requirements except one follow the above-mentioned prescriptive solutions. The only deviation is that the interior cladding on the walls can be of class K_1 10 / D-s2,d2.

Office buildings
In the office building typology, only one deviation was found as well. This was that in fire cells smaller than 150 m^2 it is allowed to use an interior cladding on the walls of class K_1 10 / D-s2,d2.

A.3.3 Comparison for Typologies

The requirements for four-storey buildings are more strict than the requirements for one-storey buildings in all categories. The main differences in each category are listed in table A.11.

Table A.11. Diviation in fire safety requirements for one-storey and four-storey buildings [BR18, 2022].

Classification	One-storey requirement	Four-storey requirement
General fire resistance	R30	R60
General interior cladding classification	K_1 10 / D-s2,d2	K_1 10 / B-s1,d0
General exterior cladding classification	D-s2,d2	B-s1,d0
Insulation classification if the load-bearing construction is worse than A2-s1,d0	No requirements	B-s1,d0

The requirements shown in table A.11 are the ones that will be in focus in the fire safety evaluation performed in this project. The deviation in the regulations for the two building types entails that fewer construction solutions are possible to use in the four-storey scenario. The solutions that are not possible to use will to a high degree consist of components with a highly biogenic content, as biogenic materials are often classified as flammable materials.

A.3.4 Taller Buildings

The higher the building gets, the stricter the fire safety requirements are. This section covers selected requirements for buildings with a height to the floor at the top floor of more than 12 metres.

Load-bearing Construction

The fire resistance of load-bearing constructions must be R120 except for the top floor, which must be R60. This requirement is stricter than for four-storey buildings, where the requirement was R30 for the top floor and R60 for the remaining floors.

In buildings taller than 12 metres, the load-bearing constructions must always be constructed of materials with reaction to fire of A2-s1,d0 or better.

Interior Cladding

The requirements for the interior surfaces in four-storey buildings are also valid for taller buildings. The requirements are shown in table A.8.

Exterior Cladding

In taller buildings with a height to the floor on the top floor of 12 to 22 metres, the requirement is the same as for four-storey buildings. In buildings taller than 22 metres to the floor on the top floor, the exterior material must be class A2-s1,d0 or better. This limits the use of biogenic materials further.

Insulation Materials

The requirements for reaction to fire of insulation materials in four-storey buildings are valid for buildings up to 22 metres to floor on the top floor, see table A.10. For buildings taller than 22 metres, the insulation material cannot be worse than B-s1,d0. This requirement limits the use of biogenic-based insulation materials.

A.4 Fire Safety Regulations in Other Countries

To investigate if the Danish requirements are more strict than those in other countries, a study on regulations in other European countries has been made.

To compare the Danish fire safety regulations to the regulations in other countries the two building cases are considered, a one-storey single-family house and an apartment building on four storeys.

The countries addressed in the study are illustrated with a red colour in figure A.1.

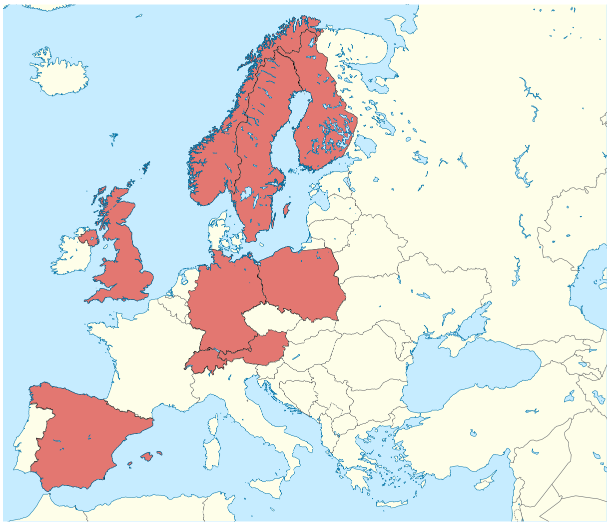


Figure A.1. The countries for which the fire safety regulations are investigated.

A.4.1 Fire Safety Regulations in Austria

In Austria, the building regulations are governed by the federal states[Austrian Institute of Construction Engineering, 2019]. To unify the regulations these states changed their building regulations in 2008. This unification is what is gathered in the OIB guidelines. OIB stands for "Österreichisches Institut für Bautechnik", which means Austrian Institute for Building Technology[Austrian Institute of Construction Engineering, 2019]. Overall there are six OIB guidelines, where the OIB 2 guidelines are used to describe the fire safety regulations. There are different OIB 2 - guidelines, and these are:

- OIB 2 - guideline: Fire protection
- OIB 2 - guideline, manual: Deviations in fire protection and fire protection concepts
- OIB 2.1 - guideline: Fire protection in industrial buildings
- OIB 2.2 - guideline: Fire protection in garages, covered parking spaces, and parking decks
- OIB 2.3 - guideline: Fire protection in buildings with an escape level in a height of more than 22 metres.

As seen in the titles of the guidelines, some separate guidelines are made for garages, Industrial buildings and buildings with a height of the escape route higher than 22 metres.

Classification of Buildings

In the OIB guidelines, five different building classes classify buildings based on the number of floors, height to the escape route on the top floor, the number of units, and gross floor area on the floors above the terrain[Austrian Institute of Construction Engineering, 2019]. The classes are called "Building Class 1-5".

There are different requirements for the building classes. Furthermore, some building typologies differ a bit from these requirements, and these are:

- Educational buildings
- Farmer and forestry houses

- Boutiques
- Retirement homes
- Nursing homes
- Hospitals
- Local halls
- Accommodation facilities, dormitory
- Shelter in extreme places

Most of the deviations do not concern the building constructions, and therefore these deviations will not be looked further into in this study.

Case Study - Single-family House

A single-family house will usually be placed in building class 1. The requirements for the load-bearing construction, interior cladding, exterior cladding, and insulation material can be seen in table A.12.

Table A.12. Requirements for Austrian single-family houses[Austrian Institute of Construction Engineering, 2019].

Construction	Requirement
Load-bearing construction:	
Walls:	R30 / E
Roof:	E
Basement:	R60
Exterior cladding:	
Roof:	B_{roof} (t1)
Other constructions:	E
Interior cladding:	
All constructions:	E
Insulation material:	
All constructions:	E

Case Study - Four-storey Building

A four-storey apartment building is assumed to be in building class 4. The Austrian requirements for a building in building class 4 can be seen in table A.13.

Table A.13. Requirements for Austrian four-storey buildings[Austrian Institute of Construction Engineering, 2019].

Construction	Requirement
Load-bearing construction:	
Top floor:	R30
Other floors:	R60
Basement:	R90 / A2
Roof:	R30 / B
Load-bearing & separating constructions:	
Top floor:	REI30
Other floors:	REI60
Basement:	REI90
Exterior cladding:	
Roof:	B_{roof} (t1)
Other constructions:	A2-d1$^{(1)}$
Interior cladding:	
All constructions:	A2-d1$^{(1)}$
Insulation material:	
All constructions:	B

(1): Can be B-d1 or a wood-based D material if the insulation material i A2.

A.4.2 Fire Safety Regulations in Finland

The Finnish fire safety regulations can be found in "The National Building Code of Finland", where the regulations regarding fire safety can be found in a document called the "Decree of the Ministry of the Environment on the Fire Safety of Buildings"[The Finnish Ministry of the Environment, 2017]. This Decree was put into use in January 2018.

Classification of Buildings

There are four different fire classes for buildings in Finland, these are P0, P1, P2, and P3[The Finnish Ministry of the Environment, 2017]. P0 is used for performance-based design. P1 has the most strict fire safety requirements, while P3 has the least strict requirements. The class is chosen based on the size of the building and the number of occupants.

Other than this, a fire load class also has to be determined for buildings in building class P0 or P1 if there are more than four fire compartments[The Finnish Ministry of the Environment, 2017]. Here there are three different classes, "Fire load class 1-3".

Case Study - Single-family House

A single-family house in one storey would usually be placed in fire class P3. The requirements for buildings in fire class P3 are shown in table A.14.

Table A.14. Requirements for Finnish single-family houses[The Finnish Ministry of the Environment, 2017].

Construction	Requirement
Load-bearing construction:	
Basement storey below the uppermost basement:	R60 / A2-s1,d0
In general:	None
Exterior cladding:	
Roof:	B_{roof}(t2)
Walls:	D-s2,d2
Interior cladding:	
All constructions:	D-s2,d2
Insulation material:	
All constructions:	None

Case Study - Four-storey Building

A four-storey apartment building will usually be placed in fire class P2. The requirements for multi-storey buildings are more strict, the requirements for this type of building can be seen in figure A.15.

Table A.15. Requirements for Finnish four-storey apartment buildings[The Finnish Ministry of the Environment, 2017].

Construction	Requirement
Load-bearing construction:	
Uppermost basement storey:	R60 / A2 - s1,d0 $^{(1)}$
In general:	R60 $^{(1)}$ $^{(2)}$ $^{(3)}$ $^{(4)}$
Exterior cladding:	
Roof:	B_{roof} (t2)
Walls:	D-s2,d2
Interior cladding:	
All constructions:	D-s2,d2
Insulation material:	
All constructions:	None

(1): A fire-extinguishing system must be added.

(2): Insulation materials should be at least A2-s1,d0.

(3): All other requirements in this table have to be fulfilled.

(4): If the fireload is between 600 - 1,200 MJ/m^2.

A.4.3 Fire Safety Regulations in Germany

The German fire safety requirements are governed by the federal states in Germany but are all guided by the "Musterbauordnung"(National model building code)[Der Bauministerkonferenz, 2022].

Classification of Buildings

The German regulations have five different building classes, "Building class 1-5". The building class is determined using the building type, height and area[Der Bauministerkonferenz, 2022].

The German requirements are set up slightly different than in the other countries. The fire safety regulations describe how fire-safe different components should be in different building classes, by the terms: fire retardant, not highly fire retardant, highly fire retardant, not fire resistant and fire resistant[Der Bauministerkonferenz, 2022]. Then these words have a class and load-bearing capacity connected to them.

Case Study - Single-family House

A German single-family house is a building class 1 building. The specific requirements for buildings in this class can be seen in table A.16.

Table A.16. Requirements for German single-family houses[Der Bauministerkonferenz, 2022].

Construction	Requirement
Load-bearing construction:	
Basement:	R60 / A2
Exterior cladding:	
Roof:	Hard roof

Case Study - Four-storey Building

A four-storey apartment building will be placed in building class 4. The requirements for buildings in this class can be seen in table A.17.

Table A.17. Requirements for German four-storey apartment buildings[Der Bauministerkonferenz, 2022].

Construction	Requirement
Load-bearing construction:	
Basement:	R90 / A2
In general:	R60 / A2
Exterior cladding:	
Roof:	Hard roof
In general:	C-s2,d2
Interior cladding:	
All constructions:	C-s2,d2
Insulation material:	
All constructions:	C-s2,d2

A.4.4 Fire Safety Regulations in Norway

The fire safety regulations are managed by "Direktoratet for Byggkvalitet" (The directorate for building quality)[Direktoratet for byggkvalitet, 2023]. The Norwegian building regulations can be found in TEK17, which are the building technical norms in Norway that describe the minimum requirements for buildings. The requirements regarding fire safety can be found in chapter 11 of TEK17[Direktoratet for byggkvalitet, 2023].

Classification of Buildings

In Norway, buildings are split into different risk classes and fire classes[Direktoratet for byggkvalitet, 2023]. The risk classes describe how big of a threat a fire is to life and health. The risk class is determined by how the building users use the building if they know the building if they sleep in the building and if the users induce the risk of a fire starting.

The fire class is determined using the risk class and the height of the building[Direktoratet for byggkvalitet, 2023]. The regulation does not provide any prescriptive solutions for buildings in fire class 4[Direktoratet for byggkvalitet, 2023].

Case Study - Single-family House

A Norwegian single-family house would be placed in risk class 4 and fire class 1. The requirements that Norway has for building materials and components can be seen in table A.18.

Table A.18. Requirements for Norwegian single-family houses[Direktoratet for byggkvalitet, 2023].

Construction	Requirement
Load-bearing construction:	
Basement storey below the uppermost basement:	R60 / A2-s1,d0
In general:	R30
Exterior cladding:	
Roof:	B_{roof} (t2)
Walls:	D-s3,d0
Interior cladding:	
All constructions:	D-s2,d0
Insulation material:	
Roof:	A2-s1,d0 (1)
All constructions:	None

(1): Compensatory measures have to be taken into account, if other than A2-s1,d0 is used.

Case Study - Four-storey Building

A four-storey apartment building would be placed in risk class 4 and fire class 2. The requirements can be seen in table A.19.

Table A.19. Requirements for Norwegian four-storey apartment buildings[Direktoratet for byggkvalitet, 2023].

Construction	Requirement
Load-bearing construction:	
Basement storey below the uppermost basement:	R90 / A2-s1,d0
In general:	R60
Exterior cladding:	
Roof:	B_{roof} (t2)
Walls:	B-s3,d0
Interior cladding:	
Floor:	D_{fl}-s1
All constructions:	D-s2,d0 (1)
Insulation material:	
All constructions:	A2-s1,d0 (2)

(1): If the fire cell is more than 200 m^2 then the interior cladding should be of B-s1,d0.
(2): In some cases insulation of a worse class can be used.

A.4.5 Fire Safety Regulations in Poland

The Polish fire safety requirements are found in "DZIENNIK USTAW - RZECZYPOSPOLITEJ POLSKIEJ Poz. 1225"(Polish Republic Journal of Law - item/number 1225)[MINISTRA ROZWOJU I TECHNOLOGII, 2022]. Section 6 of the act holds the fire safety requirements.

Classification of Buildings

In Poland, risk classes are used. There are five different risk classes, and they are based on the use of the building. The risk class is denoted with "ZL I - V". They also differentiate between the height of the building, and there are 4 different classes; Short (N), Medium tall (SW), tall (W) and very tall(WW)[MINISTRA ROZWOJU I TECHNOLOGII, 2022].

Case Study - Single-family House

A single-family house would be placed in ZL IV. The single-family house typology is considered to be categorised as short. The requirements for Polish single-family houses are shown in table A.20.

Table A.20. Requirements for Polish single-family houses[MINISTRA ROZWOJU I TECHNOLOGII, 2022].

Construction	Requirement
Load-bearing construction:	
Roof	No requirements
Interior walls	No requirements
In general:	REI30
Exterior cladding:	
Roof:	B_{roof}(t1)
Interior cladding:	
Ceiling	B-s3,d0
Floor	A2-s2
All constructions:	D-s2,d0

Case Study - Four-storey Building

A four-storey apartment building is also placed in ZL IV and is considered short (N). The requirements for this building typology are shown in table A.21.

Table A.21. Requirements for Polish four-storey apartment buildings[MINISTRA ROZWOJU I TECHNOLOGII, 2022].

Construction	Requirement
Load-bearing construction:	
Roof	No requirements
Interior walls	No requirements
In general:	REI30
Exterior cladding:	
Roof:	B_{roof}(t1)
Interior cladding:	
Ceiling	B-s3,d0
Floor	A2-s2

A.4.6 Fire Safety Regulations in Spain

The Spanish fire safety requirements can be found in "Docomento Basico - Seguridad en caso de incendio (DB-SI)" (Basic document - Security in case of fire)[Ministerio de Fomento, 2019].

Classification of Buildings

In Spain, they operate with building typologies and building heights instead of building classes[Ministerio de Fomento, 2019]. Some requirements in the Spanish regulations are valid for all building typologies and building heights. Others depend on the building typology or height.

Case Study - Single-family House

As a single-family house is below 10 metres, the fire technical requirements are as shown in table A.22.

Table A.22. Requirements for Spanish single-family houses[Ministerio de Fomento, 2019].

Construction	Requirement
Load-bearing construction:	
In general:	R30
Exterior cladding:	
Roof:	$B_{roof}(t1)$
In general	D-s3,d0
Interior cladding:	
Floor	E_{fl}
In general	C-s2,d0
Insulation:	
In general	D-s3,d0

Case Study - Four-storey Building

A four-storey apartment building is normally below 18 metres in height, therefore the requirements will be as shown in table A.23.

Table A.23. Requirements for Spanish four-storey apartment buildings[Ministerio de Fomento, 2019].

Construction	Requirement
Load-bearing construction:	
Basement	R120
In general:	R60
Exterior cladding:	
Roof:	$B_{roof}(t1)$
In general	C-s3,d0
Interior cladding:	
Floor	E_{fl}
In general	C-s2,d0
Insulation:	
In general	B-s3,d0

A.4.7 Fire Safety Regulations in Sweden

The Swedish fire safety regulations can be found in "Boverkets byggregler" in BBR, and EKS[Boverket, 2017][Boverket, 2022]. BBR is the Swedish building regulation, which holds general recommendations and mandatory provisions. EKS holds all the mandatory provisions and the general recommendations there are on the application of the Eurocodes.

Classification of Buildings

In the Swedish fire safety regulations, three different classifications of buildings exist. These are the use class, building class, and fire class.

The use class is determined by the use of the building. For instance, residential buildings and office buildings are not in the same use class. The building class is found in a building's need for fire protection. The fire class is found using the building class and is dependent on the addressed part of the building. Thereby, two different constructions in one building can have different fire classes[Boverket, 2017][Boverket, 2022].

Case Study - Single-family House

A one-storey single-family house is located in use class 3A, and building class 2. The main part of the load-bearing system is located in fire class 3, while the basement storey below the uppermost basement storey is located in fire class 5. Requirements for the single-family house typology are shown in table A.24.

Table A.24. Requirements for Swedish single-family houses[Boverket, 2017][Boverket, 2022].

Construction	Requirement
Load-bearing construction:	
Basement storey below the uppermost basement:	For fire load ≤ 800 MJ/m^2: R90 For fire load ≤ 1600 MJ/m^2: R160 For fire load >1600 MJ/m^2: R240
In general:	R30
Exterior cladding:	
Roof:	C-s2,d0 + A2-s1,d0 material underneath or C-s2,d0 + $K_2$10 / B-s2,d0 material underneath
In general	D-s2,d2
Interior cladding:	
In general	D-s2,d0
Insulation:	
In general	Better than D-s2,d0, or if D-s2,d0 or worse then the insulation should be protected by a K_2 10 / B-s2,d0 material

Case Study - Four-storey Building

A four-storey apartment building will be located in use class 3A, and building class 1. The main part of the load-bearing constructions is placed in fire class 4, and the basement storey below the uppermost basement is placed in fire class 5. The requirements for a Swedish four-storey apartment building can be seen in table A.25.

Table A.25. Requirements for Swedish four-storey apartment buildings[Boverket, 2017][Boverket, 2022].

Construction	Requirement
Load-bearing construction:	
Basement storey below the uppermost basement:	For fire load ≤ 800 MJ/m^2: R90 For fire load ≤ 1600 MJ/m^2: R160 For fire load >1600 MJ/m^2: R240
In general:	For fire load ≤ 800 MJ/m^2: R60 For fire load ≤ 1600 MJ/m^2: R120 For fire load >1600 MJ/m^2: R180
Exterior cladding:	
Roof:	B-s1,d0 + A2-s1,d0 material underneath or B-s1,d0 + $K_2$10 / B-s2,d0 material underneath
In general	A2-s1,d0 or D-s2,d2 + Sprinkling + A2-s1,d0 on the ground floor
Interior cladding:	
In general	C-s2,d0
Insulation:	
In general	Better than D-s2,d0, or if D-s2,d0 or worse then the insulation should be protected by a K_2 10 / B-s2,d0 material

A.4.8 Fire Safety Regulations in Switzerland

Switzerland is split into 26 different federal states called cantons. The fire safety regulations are managed by the "Interkantonalen Organ Technische Handelshemmnisse (IOTH)" (The inter-cantonal Institution of Technical Barriers to Trade), where the individual canton can deviate from these requirements[Interkantonale Organ Technische Handelshemmnisse, 2023].

Classification of Buildings

In Switzerland, buildings are classified by the use of the building and how tall the building is[Interkantonale Organ Technische Handelshemmnisse, 2023]. There are four different classes for the building height, which are:

- Small buildings: Max 2 storeys + max floor area on $600\,\mathrm{m}^2$ + no sleeping in the building
- Low buildings: below 11 metres in height
- Medium high buildings: Below 30 metres in height
- High-rise buildings: More than 30 metres in height

In Switzerland, they also keep the requirements, for buildings that are sprinkled and buildings that are not, apart[Interkantonale Organ Technische Handelshemmnisse, 2023]. This section is only considering the requirements for buildings that are not sprinkled.

Case Study - Single-family House

A single-family house is a low building, and the requirements are shown in table A.26.

Table A.26. Requirements for Swiss single-family houses[Interkantonale Organ Technische Handelshemmnisse, 2023].

Construction	Requirement
Load-bearing construction:	
In general:	R30 / D-s2,d1
Exterior cladding:	
Roof:	D_{roof} (t4)
In general	E-d2
Interior cladding:	
Floor	C_{fl}-s2
Ceiling	A2-s1,d0
In general	D-s2,d1
Insulation:	
Roof	D-s2,d1
In general	A2-s1,d0

Case Study - Four-storey Building

A four-storey building is a medium-height building. The requirements for a Swiss four-storey building are shown in table A.27.

Table A.27. Requirements for Swiss four-storey building[Interkantonale Organ Technische Handelshemmnisse, 2023].

Construction	Requirement
Load-bearing construction:	
In general:	R60 / D-s2,d1
Exterior cladding:	
Roof:	D_{roof} (t4)
In general	C-s2,d1
Interior cladding:	
Floor	C_{fl}-s2
Ceiling	A2-s1,d0
In general	D-s2,d1
Insulation:	
Roof	D-s2,d1
In general	A2-s1,d0

A.4.9 Fire Safety Regulations in the United Kingdom

The British fire safety requirements can be found on the United Kingdom government's website[HM Government, 2022]. In the United Kingdom, they operate with "Approved Documents" which is holding the building regulations. There are 15 different "Approved documents", and the one describing fire safety requirements is Approved Document B[HM Government, 2022].

Classification of Buildings

The United Kingdom differentiates between the requirements by looking at the building use and the height of the building. The fire safety requirements do not use any building classes[HM Government, 2022].

Case Study - Single-family House

The requirements for single-family houses in the United Kingdom can be seen in table A.28.

Table A.28. Requirements for British single-family houses[HM Government, 2022].

Construction	Requirement
Load-bearing construction:	
In general:	R30
Exterior cladding:	
Roof:	B_{roof} (t4) if less than 6 m to another building E_{roof} (t4) if less than 20 m to another building F_{roof} (t4) if more than 20 m to another building
In general	B-s3,d0
Interior cladding:	
Ceiling	C-s3,d2
In general	C-s3,d2

Case Study - Four-storey Building

The requirements for four-storey apartment buildings can be seen in figure A.29.

Table A.29. Requirements for British four-storey apartment buildings[HM Government, 2022].

Construction	Requirement
Load-bearing construction:	
In general:	R60
Exterior cladding:	
Roof:	B_{roof}(t4) if less than 6 m to another building E_{roof}(t4) if less than 20 m to another building F_{roof}(t4) if more than 20 m to another building
In general	A2-s1,d0
Interior cladding:	
In common areas:	B-s3,d2
In the apartments:	C-s3,d2

A.5 Comparison of Requirements

To compare the requirements in the addressed countries, the requirements are here combined for the different building cases.

A.5.1 Single-family House

Table A.30 shows the different requirements for load-bearing capacity in the part of a building that is above ground level. Table A.31 compares the requirements for the load-bearing capacity in the building part below ground level. Table A.32 shows the different countries' requirements for exterior cladding. Table A.33 show the requirements for the interior cladding. In table A.34, the requirements there are shown for the insulation materials in buildings.

Table A.30. Requirements to load-bearing structures in the addressed countries.

Country	Roof	Exterior walls	Interior walls
Denmark	R30	R30	R30
Austria	R30 / E	R30 / E	R30 / E
Finland	None	None	None
Germany	None	None	None
Norway	R30	R30	R30
Poland	R30	None	None
Spain	R30	R30	R30
Sweden	R30	R30	R30
Switzerland	R30 / D-s2,d1	R30 / D-s2,d1	R30 / D-s2,d1
United Kingdom	R30	R30	R30

Table A.31. Requirements to load-bearing capacity for basement constructions and the constructions in the storeys below the uppermost basement storey for the addressed countries.

Country	Basement	Below uppermost basement
Denmark	R60 / A2-s1,d0	R60 / A2-s1,d0
Austria	R60	R60
Finland	None	R60
Germany	R60 / A2	R60 / A2
Norway	R30	R60 / A2-s1,d0
Poland	R30	R30
Spain	R30	R30
Sweden	R30	R160$^{(1)}$
Switzerland	R30 / D-s2,d1	R30 / D-s2,d1
United Kingdom	R30	R30

(1): R160 if the fire load is between 800 - 1600 MJ/m^2. At higher fire load: R240. At lower fire load: R90.

Table A.32. Requirements to exterior cladding in the addressed countries.

Country	Roof	Exterior Sheating	External rainscreen
Denmark	B_{ROOF}(t2)	K_1 10 / D-s2,d2	D-s2,d2
Austria	B_{ROOF}(t1)	E	E
Finland	B_{ROOF}(t2)	B-s2,d2	B-s2,d2
Germany	Hard roof	None	None
Norway	B_{ROOF}(t2)	D-s3,d0	D-s3,d0
Poland	B_{ROOF}(t1)	None	None
Spain	B_{ROOF}(t1)	D-s3,d0	D-s3,d0
Sweden	C-s2,d0 (1)	D-s2,d2	D-s2,d2
Switzerland	D_{ROOF}(t4)	E-d2	E-d2
United Kingdom	E_{ROOF}(t4) (2)	B-s3,d0	B-s3,d0

(1) A material of A2-s1,d0 or K_2 10 / B-s2,d0 should be placed underneath the roofing.
(2): For constructions with a distance to another building between 6-20 m. If above 20 m: F_{ROOF}(t4). If below 6m: B_{ROOF}(t4).

Table A.33. Requirements to interior cladding in the addressed countries.

Country	Ceiling	Wall	Flooring
Denmark	K_1 10 / D-s2,d2	K_1 10 / D-s2,d2	None
Austria	E	E	E
Finland	D-s2,d2	D-s2,d2	D-s2,d2
Germany	None	None	None
Norway	D-s2,d2	D-s2,d0	D-s2,d0
Poland	B-s3,d0	D-s2,d0	$A2_{fl}$-s2
Spain	D-s2,d0	C-s2,d0	E_{fl}
Sweden	D-s2,d0	D-s2,d0	None
Switzerland	A2-s1,d0	D-s2,d0	C_{fl}-s2
United Kingdom	C-s3,d2	C-s3,d2	None

Table A.34. Requirements to insulation material in the addressed countries.

Country	Roof	Walls
Denmark	D-s2,d2	D-s2,d2
Austria	E	E
Finland	None	None
Germany	None	None
Norway	A2 (1)	None
Poland	None	None
Spain	D-s3,d0	D-s3,d0
Sweden	D-s2,d0 (2)	D-s2,d0 (2)
Switzerland	D-s2,d1	A2-s1,d0
United Kingdom	None	None

(1): Insulation with a worse reaction to fire can be used, but then some compensatory measures have to be added.
(2): A worse insulation material can be used if the insulation material is protected by K_2 10 / B-s2,d0.

A.5.2 Four-storey Apartment Building

Table A.35 shows the requirements for load-bearing capacity of the building parts above ground level. Table A.36 holds the requirements for the load-bearing capacity of the building parts below ground level. In table A.37 the requirements for exterior cladding are shown. Table A.38 shows the interior cladding requirements. Table A.39 shows the requirements for insulation materials.

Table A.35. Requirements to load-bearing structures in the addressed countries.

Country	Roof	Top floor	Exterior walls	Interior walls
Denmark	R30	R30	R60 / A2-s1,d0 (1)	R60 / A2-s1,d0 (1)
Austria	R30 / B	R30	R60	R60
Finland	R60	R60	R60	R60
Germany	R60 / A2	R60 / A2	R60 / A2	R60 / A2
Norway	R60	R60	R60	R60
Poland	None	R30	R30	None
Spain	R60	R60	R60	R60
Sweden	R120(2)	R120(2)	R120(2)	R120(2)
Switzerland	R60 / D-s2,d1	R60 / D-s2,d1	R60 / D-s2,d1	R60 / D-s2,d1
United Kingdom	R60	R60	R60	R60

(1): D-s2,d2 can also be used if the building is either sprinkled or if the fire-exposed surface of the load-bearing construction makes up less than $20\,\%$ of the wall and ceiling area within the first 60 minutes of the standard fire.
(2): The requirement on R120 is only valid if the fire load is between 800 - 1600 MJ/m^2. If the fire load is above 1600 MJ/m^2: R180. If the fire load is below 800 MJ/m^2: R60.

Table A.36. Requirements to load-bearing capacity for basement constructions and the constructions in the storeys below the uppermost basement storey for the addressed countries.

Country	Basement	Below uppermost basement
Denmark	R60 / A2-s1,d0	R60 / A2-s1,d0
Austria	R90 / A2	R90 / A2
Finland	R60 / A2-s1,d0 (1)	R60 / A2-s1,d0 (1)
Germany	R90 / A2	R90 / A2
Norway	R60	R90 / A2-s1,d0
Poland	R30	R30
Spain	R120	R120
Sweden	R120 (2)	R160 (3)
Switzerland	R60 / D-s2,d1	R60 / D-s2,d1
United Kingdom	R60	R60

(1): A Fire extinguishing system must be added to the basement storeys.
(2): The requirement on R120 is only valid if the fire load is between 800 - 1600 MJ/m^2. If the fire load is above 1600 MJ/m^2: R180. If the fire load is below 800 MJ/m^2: R60.
(3): The requirement on R160 is only valid if the fire load is between 800 - 1600 MJ/m^2. If the fire load is above 1600 MJ/m^2: R240. If the fire load is below 800 MJ/m^2: R90.

Table A.37. Requirements to exterior cladding in the addressed countries.

Country	Roof	Exterior Sheating	External rainscreen
Denmark	B_{ROOF}(t2)	K_1 10 / B-s1,d0	B-s1,d0
Austria	B_{ROOF}(t1)	A2-d1	A2-d1
Finland	B_{ROOF}(t2)	D-s2,d2	D-s2,d2
Germany	Hard roof	C-s2,s2	C-s2,s2
Norway	B_{ROOF}(t2)	B-s3,d0	B-s3,d0
Poland	B_{ROOF}(t1)	None	None
Spain	B_{ROOF}(t1)	C-s3,d0	C-s3,d0
Sweden	B-s1,d0 (1)	A2-s1,d0 (3)	A2-s1,d0 (3)
Switzerland	D_{ROOF}(t4)	C-s2,d1	C-s2,d1
United Kingdom	E_{ROOF}(t4) (2)	A2-s1,d0	A2-s1,d0

(1): A material of A2-s1,d0 or K_2 10 / b-s2,d0 should be placed underneath the roofing.
(2): For constructions with a distance to another building between 6 - 20 metres. If above 20 metres: F_{ROOF}(t4). If below 6 metres: B_{ROOF}(t4).
(3): D-s2,d2 can also be used if the building is sprinkled and if the cladding on the ground floor is A2-s1,d0.

Table A.38. Requirements to interior cladding in the addressed countries.

Country	Ceiling	Wall	Flooring
Denmark	K_1 10 / B-s1,d0	K_1 10 / D-s2,d2	None
Austria	A2-d1	A2-d1	None
Finland	D-s2,d2	D-s2,d2	None
Germany	C-s2,d2	C-s2,d2	None
Norway	D-s2,d0	D-s2,d0	D_{fl}-s1
Poland	B-s3,d0	D-s2,d0	$A2_{fl}$-s2
Spain	C-s2,d0	C-s2,d0	E_{fl}
Sweden	C-s2,d0	C-s2,d0	None
Switzerland	A2-s1,d0	D-s1,d1	C_{fl}-s2
United Kingdom	C-s3,d2 (1)	C-s3,d2 (1)	None

(1): C-s3,s2 should be used in the apartments, while B-s3,s2 should be used in the buildings common areas.

Table A.39. Requirements to insulation in the addressed countries.

Country	Roof	Walls
Denmark	B-s1,d0 (1)	B-s1,d0 (1)
Austria	B	B
Finland	None	None
Germany	C-s2,d2	C-s2,d2
Norway	A2-s1,d0	A2-s1,d0
Poland	None	None
Spain	B-s3,d0	B-s3,d0
Sweden	D-s2,d0 (2)	D-s2,d0 (2)
Switzerland	D-s2,d1	A2-s1,d0
United Kingdom	None	None

(1): Insulation of worse class can be used, but some compensatory things have to be done. This is further described in table A.10
(2): An insulation material worse than can be used if the insulation material is protected by K_2 10 / B-s2,d0.

B Number of Micro Components and Macro Component Distributions

This appendix cover information on the number of micro components used in the generation of each macro component type, as well as illustrations showing how the different macro components are placed regarding GWP and the amount of biogenic carbon.

Exterior Walls - Single-family Houses

For the exterior walls in one-storey buildings, the different types of micro components and the number of micro components are listed in table B.1. The GWP per m^2 wall for all generated components are plotted in figure B.4, B.5, and B.6 as against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.1. Number of micro components used in the generation of exterior walls in single-family houses.

Micro component	Number of components
Interior cladding (IC)	28
Installation layer (IL)	4
Vapour barrier (VB)	5
Structural part (S)	30
Insulation material (INS)	4
Wind protection (WP)	7
Exterior cladding (EC)	11

Exterior Walls - Four-storey Buildings

For the exterior walls in four-storey buildings, the different types of micro components and the number of micro components are listed in table B.2. The GWP per m^2 wall for all generated components are plotted in figure B.1, B.2, and B.3 against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.2. Number of micro components used in the generation of exterior walls in four-storey buildings.

Micro component	Number of components
Interior cladding (IC)	16
Installation layer (IL)	5
Vapour barrier (VB)	5
Structural part (S)	18
Insulation material (INS)	4
Wind protection (WP)	3
Exterior cladding (EC)	6

Roof Constructions

For the roof constructions, the different types of micro components and the number of micro components are listed in table B.3. The GWP per m^2 construction for all generated components are plotted in figure B.7, B.8, and B.9 against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.3. Number of micro components used in the generation of roof constructions.

Micro component	Number of components
Interior cladding (IC)	21
Installation layer (IL)	5
Vapour barrier (VB)	5
Structural part (S)	23
Insulation material (INS)	4
Exterior cladding (EC)	5

Horizontal Divisions

For the horizontal divisions, the number of micro components is listed in table B.4. The GWP per m^2 construction for all generated components are plotted in figure B.10, B.11, and B.12 against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.4. Number of micro components used in the generation of horizontal divisions.

Micro component	Number of components
Ceiling cladding (IC)*	21
Installation layer (IL)	5
Structural part (S)	13
Insulation material (INS)	4
Floor cladding (EC)**	3

Bearing Interior Walls

For the bearing interior walls, the number of micro components is listed in table B.5. The GWP per m^2 wall for all generated components are plotted in figure B.13, B.14, and B.15 against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.5. Number of micro components used in the generation of bearing interior walls.

Micro component	Number of components
Interior cladding (IC)	38
Structural part (S)	5
Insulation material (INS)	4

Interior Partition Walls

For the partition walls, the number of micro components is listed in table B.6. The GWP per m^2 wall for all generated components are plotted in figure B.16, B.17, and B.18 against biogenic mass percent, biogenic amount and biogenic volume percent respectively.

Table B.6. Number of micro components used in the generation of interior partition walls.

Micro component	Number of components
Interior cladding (IC)	38
Structural part (S)	12
Insulation material (INS)	4

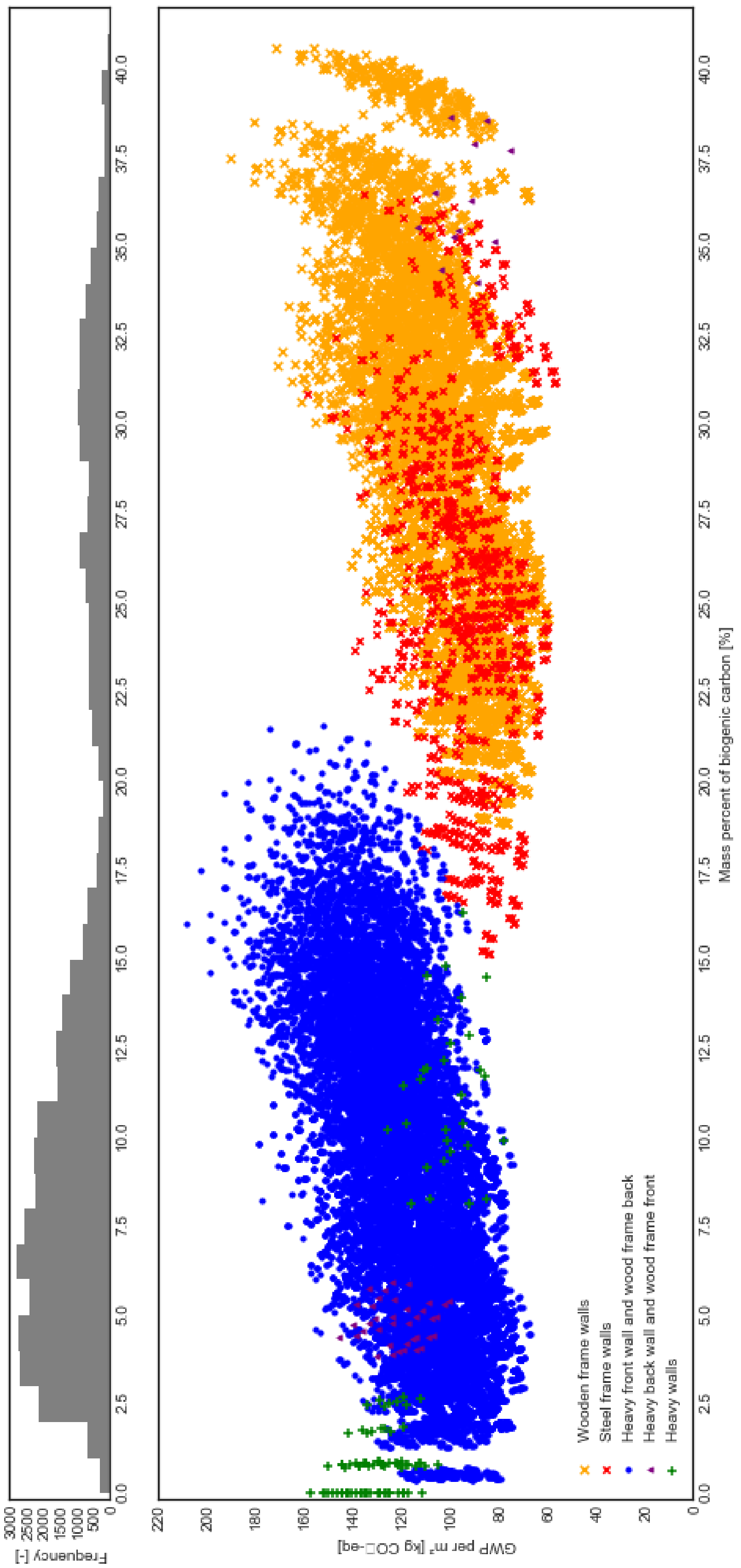


Figure B.1. Distribution of generated exterior wall components in the multi-storey building case against the mass percent of biogenic carbon in the constructions.

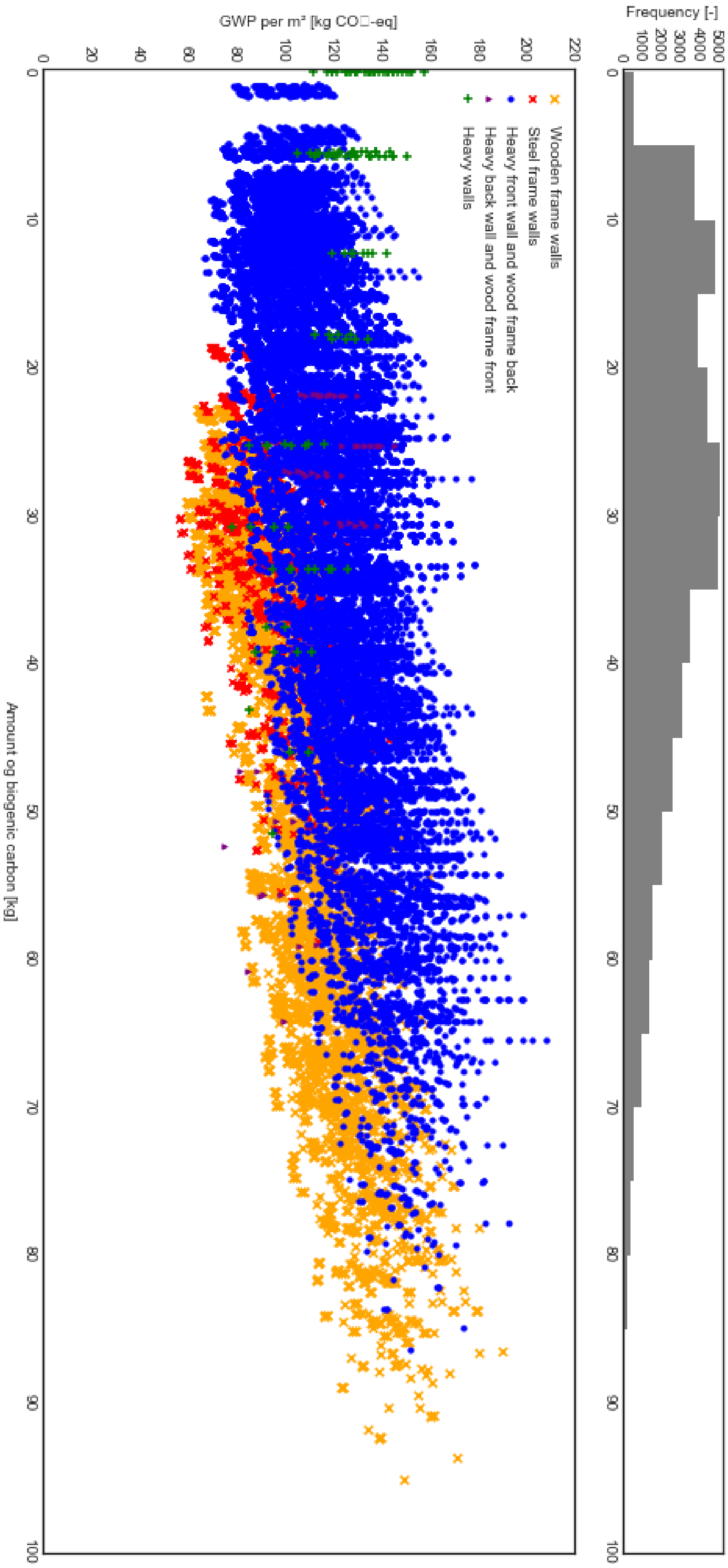


Figure B.2. Distribution of generated exterior wall components in the multi-storey building case against the amount of biogenic carbon in the constructions.

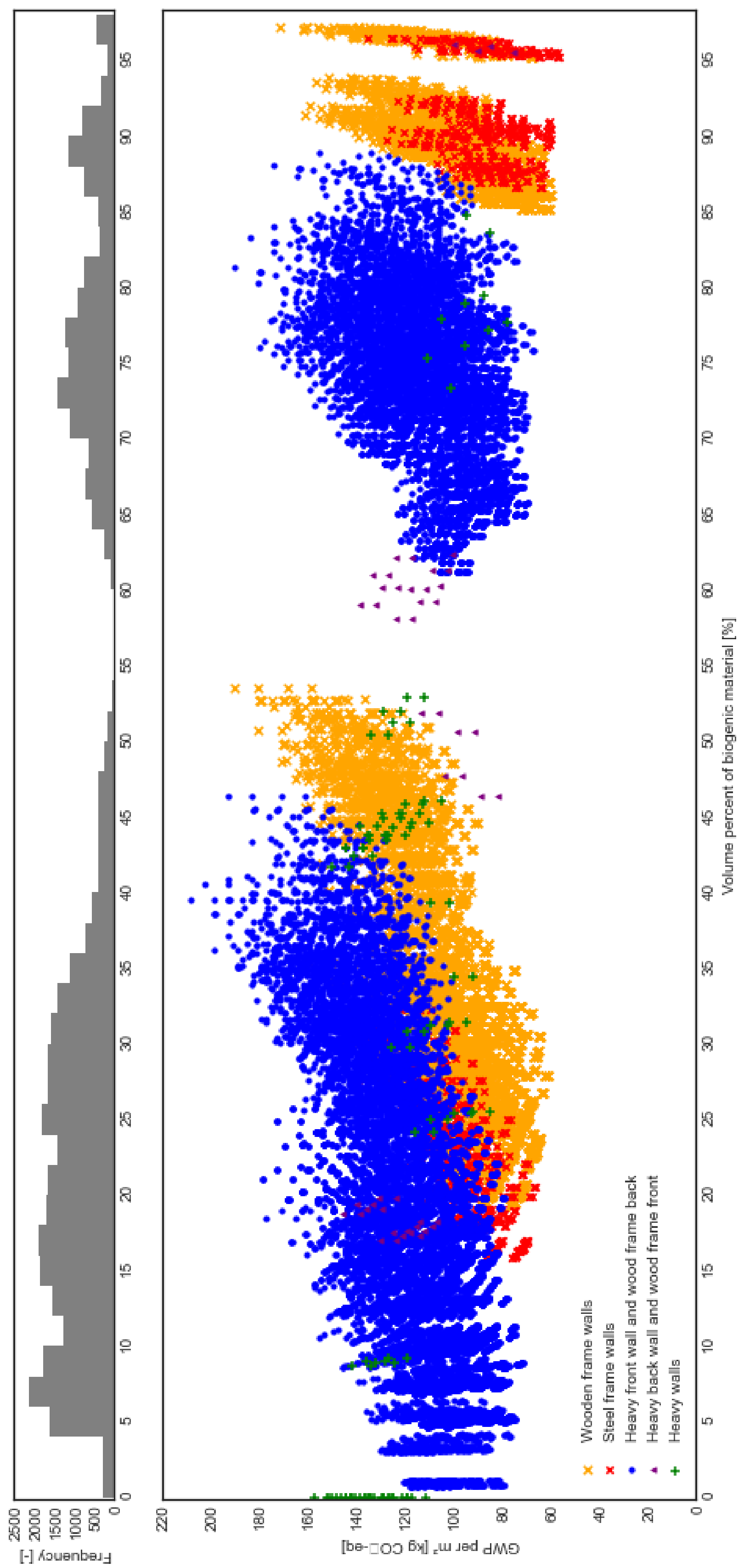


Figure B.3. Distribution of generated exterior wall components in the multi-storey building case against the volume percent of biogenic carbon in the constructions.

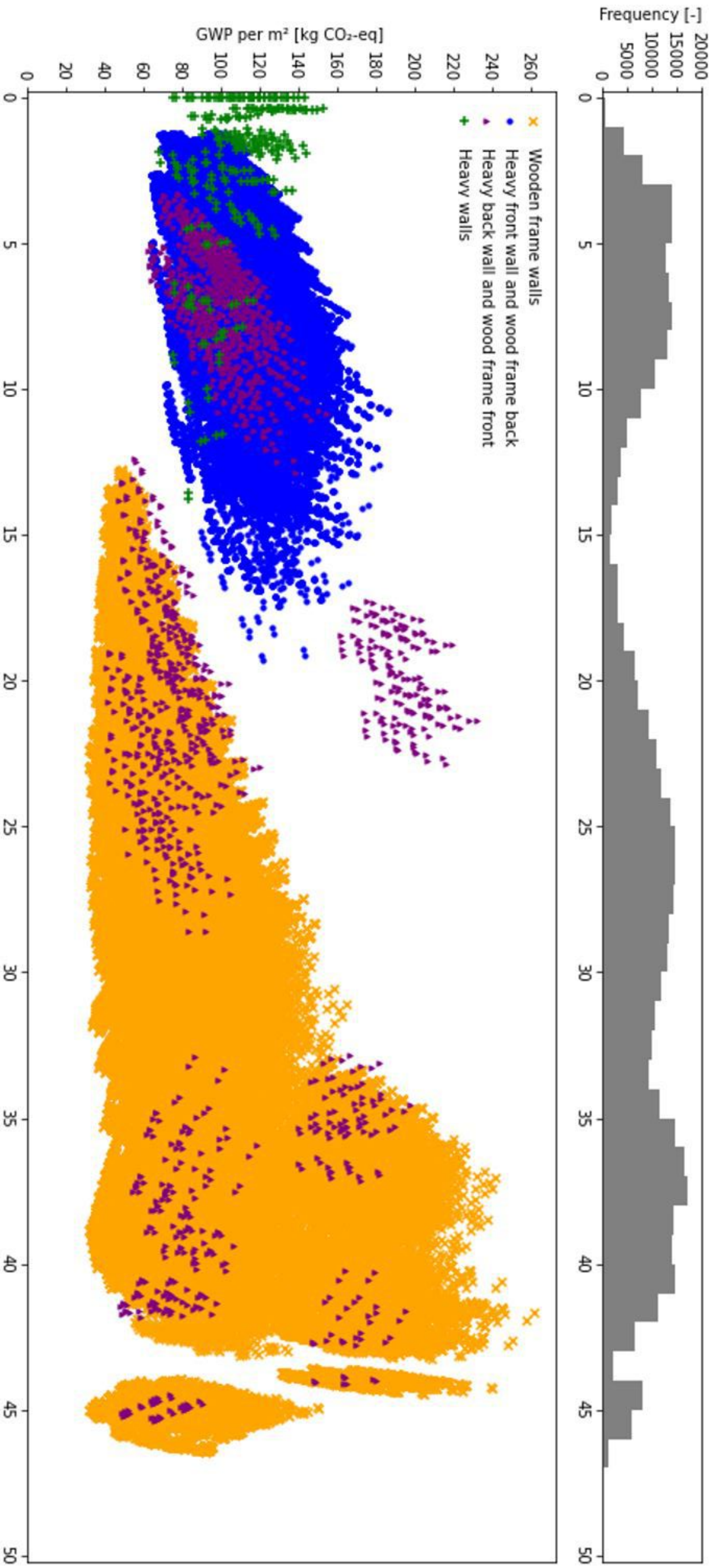


Figure B.4. Distribution of generated exterior wall components in the single-family house case against the mass percent of biogenic carbon in the constructions.

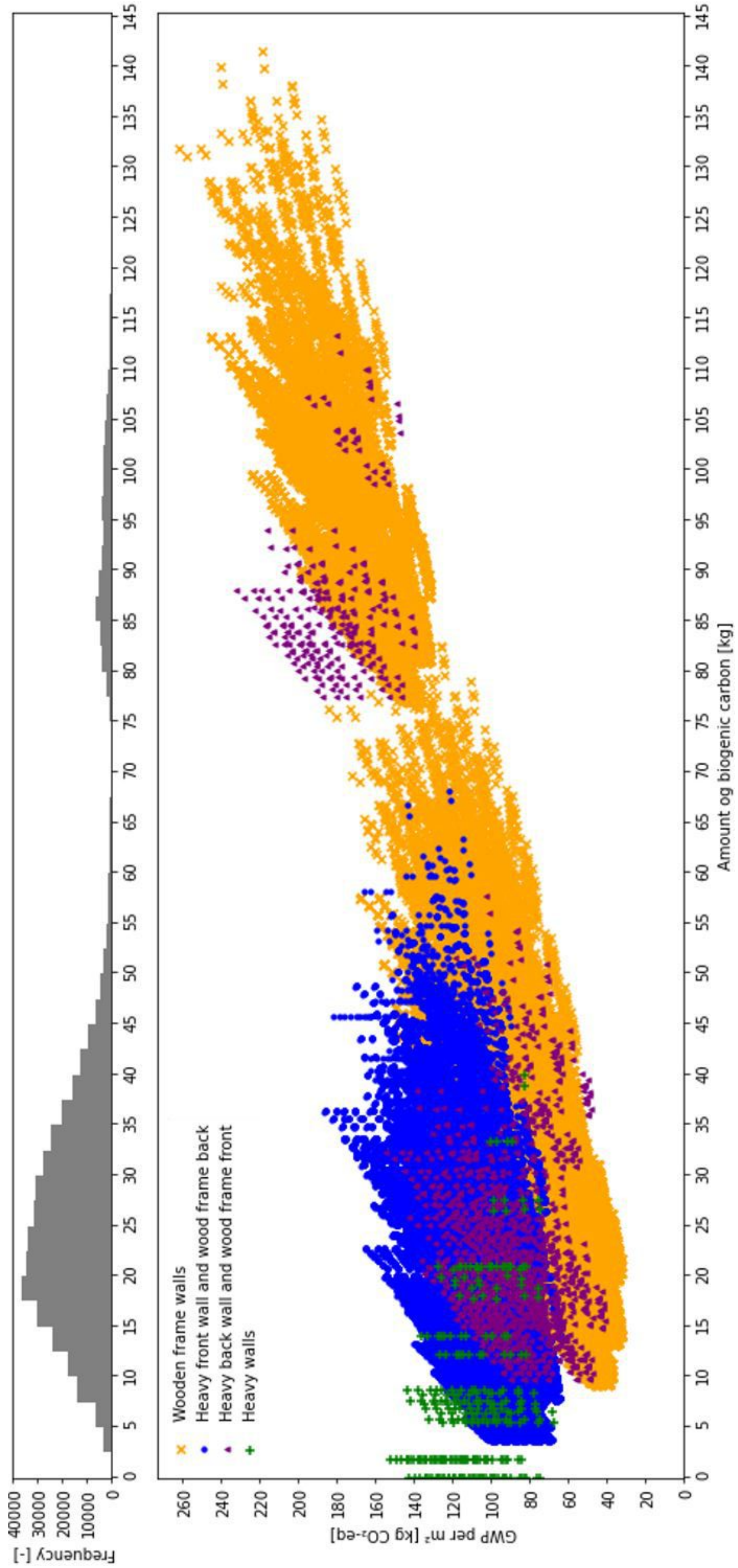


Figure B.5. Distribution of generated exterior wall components in the single-family house case against the amount of biogenic carbon in the constructions.

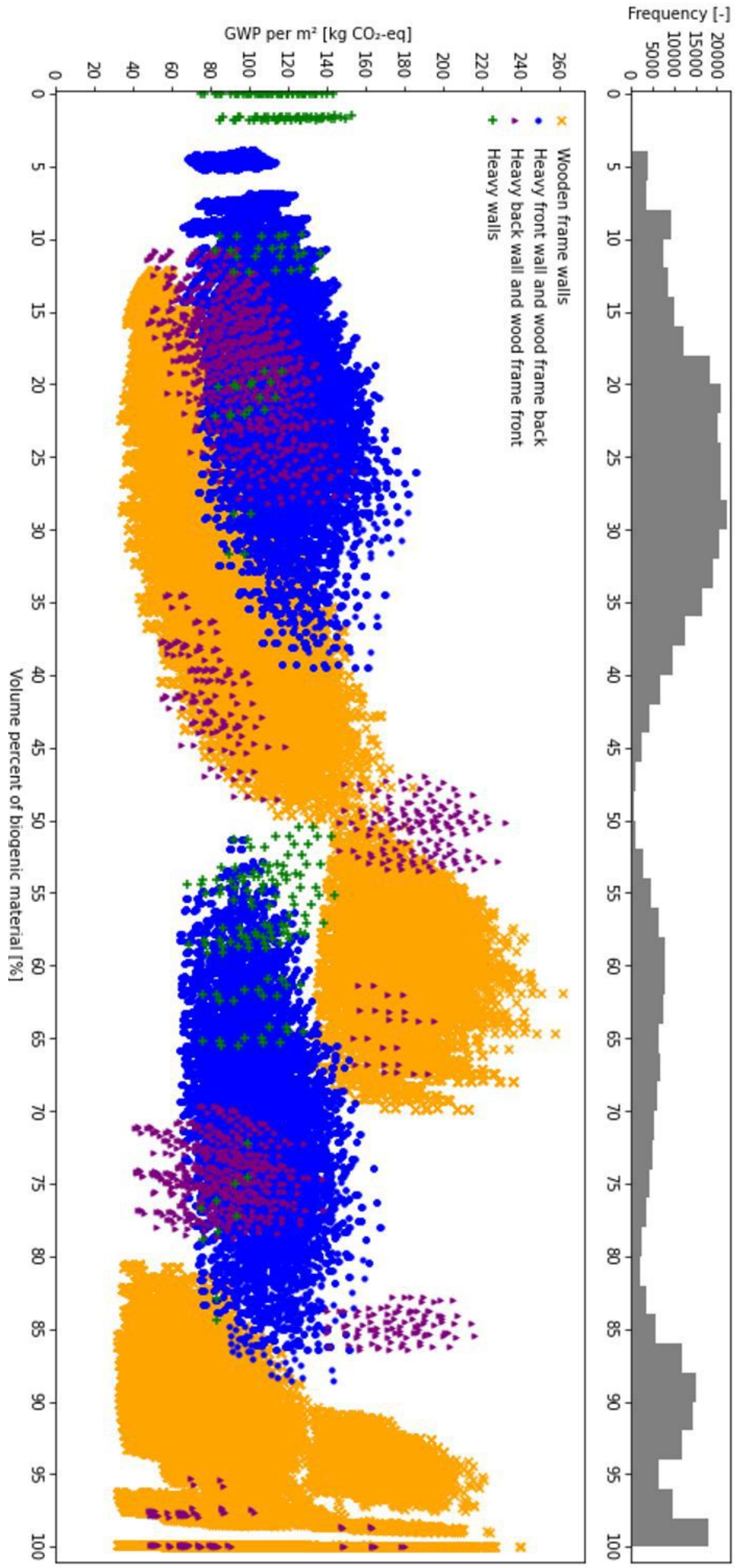


Figure B.6. Distribution of generated exterior wall components in the single-family house case against the volume percent of biogenic carbon in the constructions.

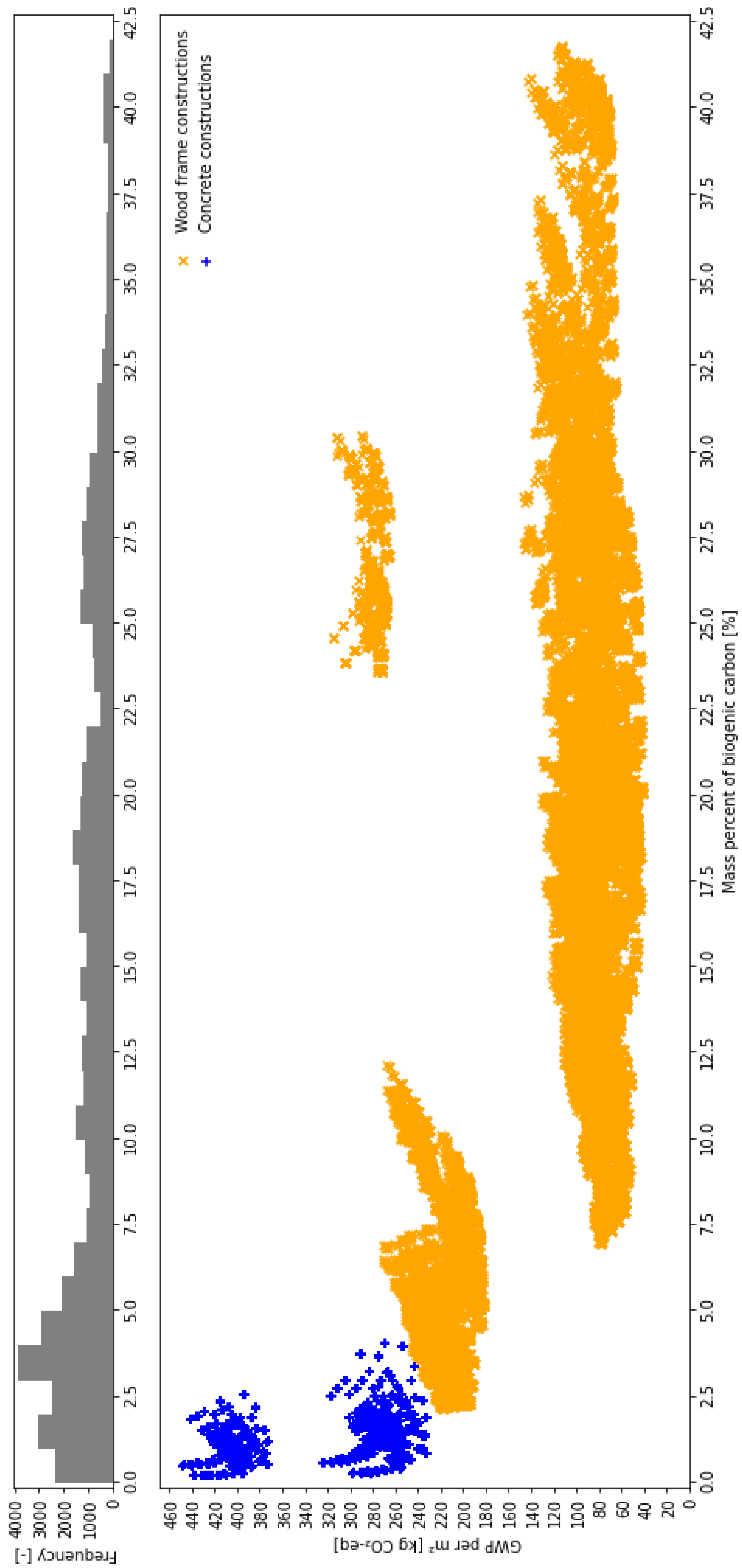


Figure B.7. Distribution of generated roof components against the mass percent of biogenic carbon in the constructions.

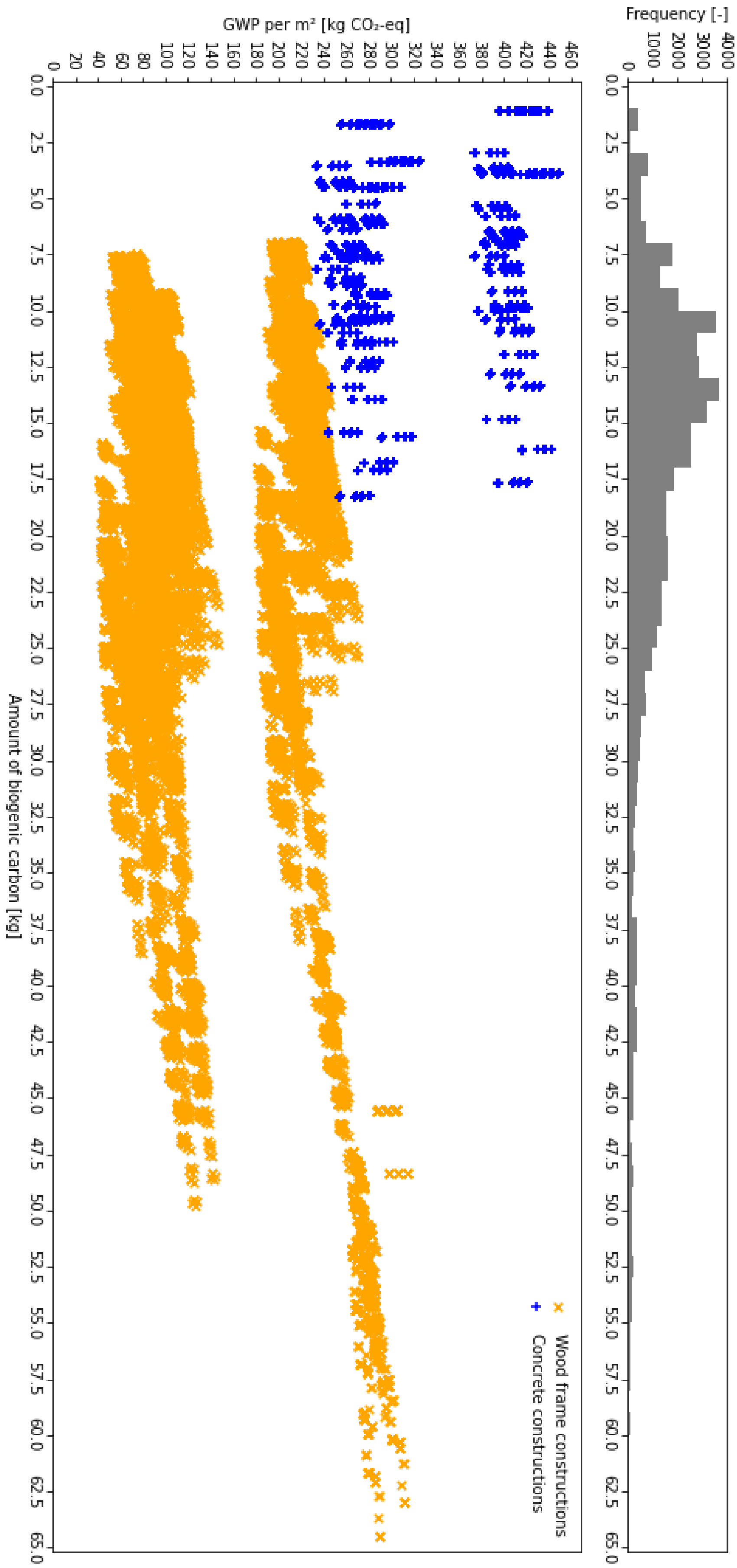


Figure B.8. Distribution of generated roof components against the amount of biogenic carbon in the constructions.

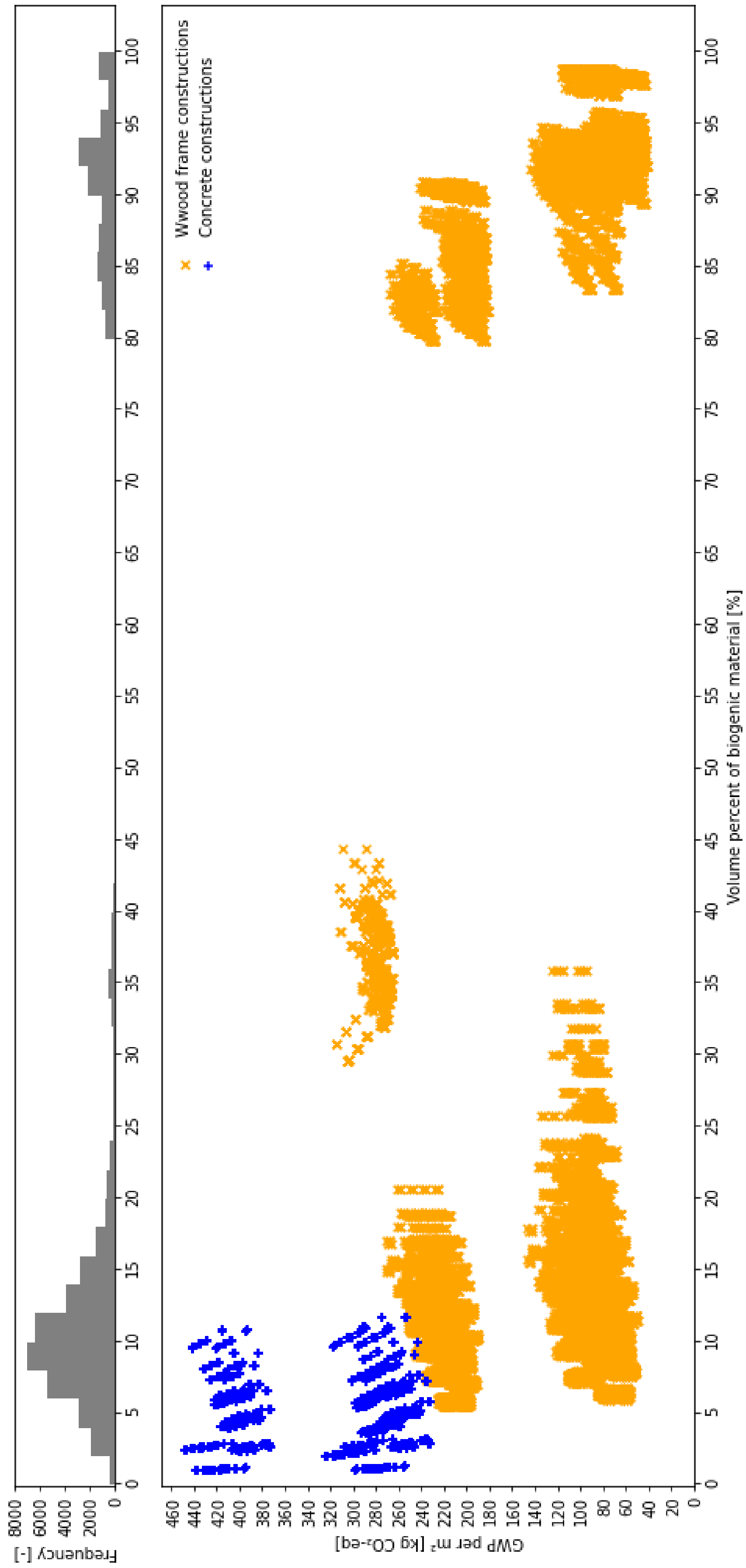


Figure B.9. Distribution of generated roof components against the volume percent of biogenic carbon in the constructions.

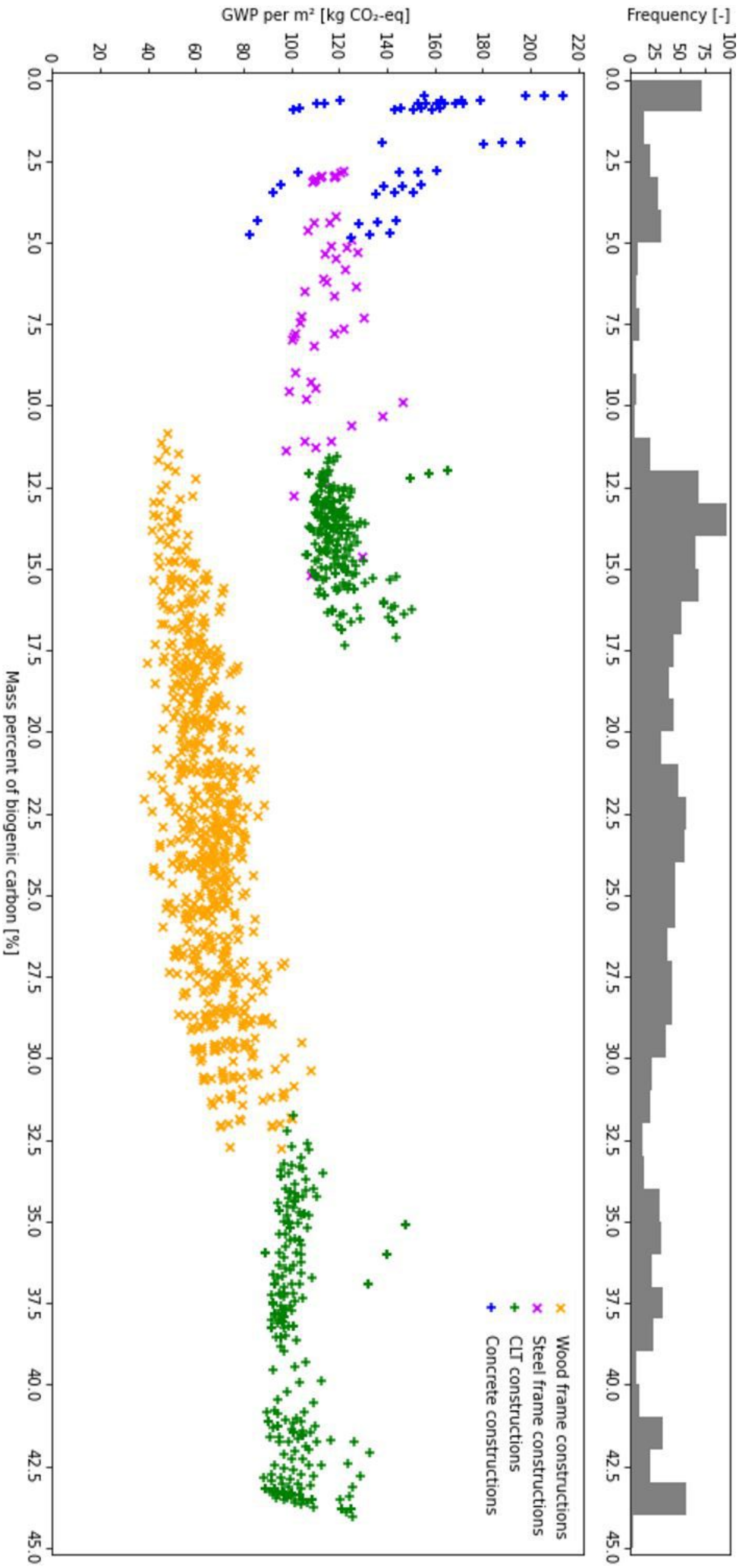


Figure B.10. Distribution of generated horizontal division components against the mass percent of biogenic carbon in the constructions.

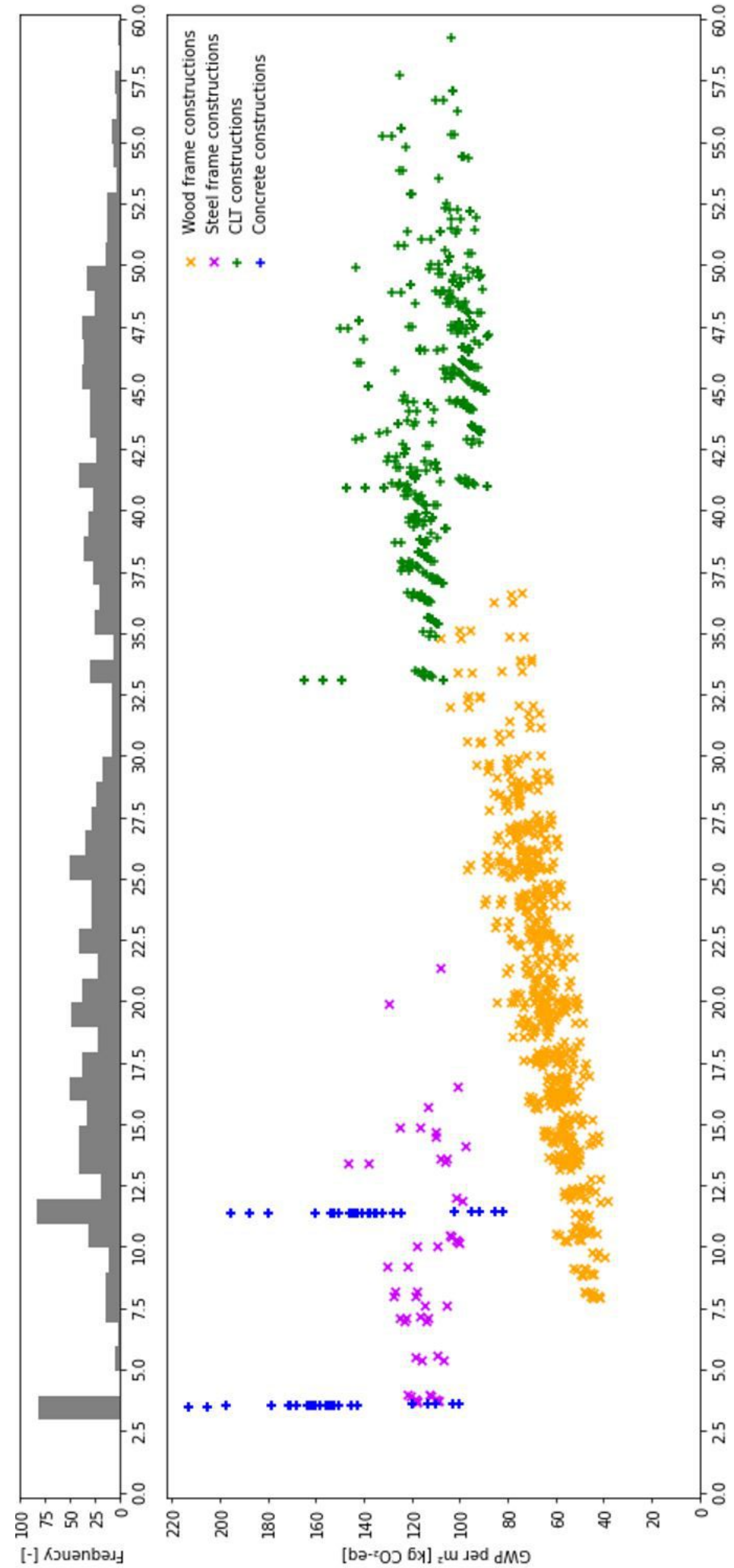


Figure B.11. Distribution of generated horizontal division components against the amount of biogenic carbon in the constructions.

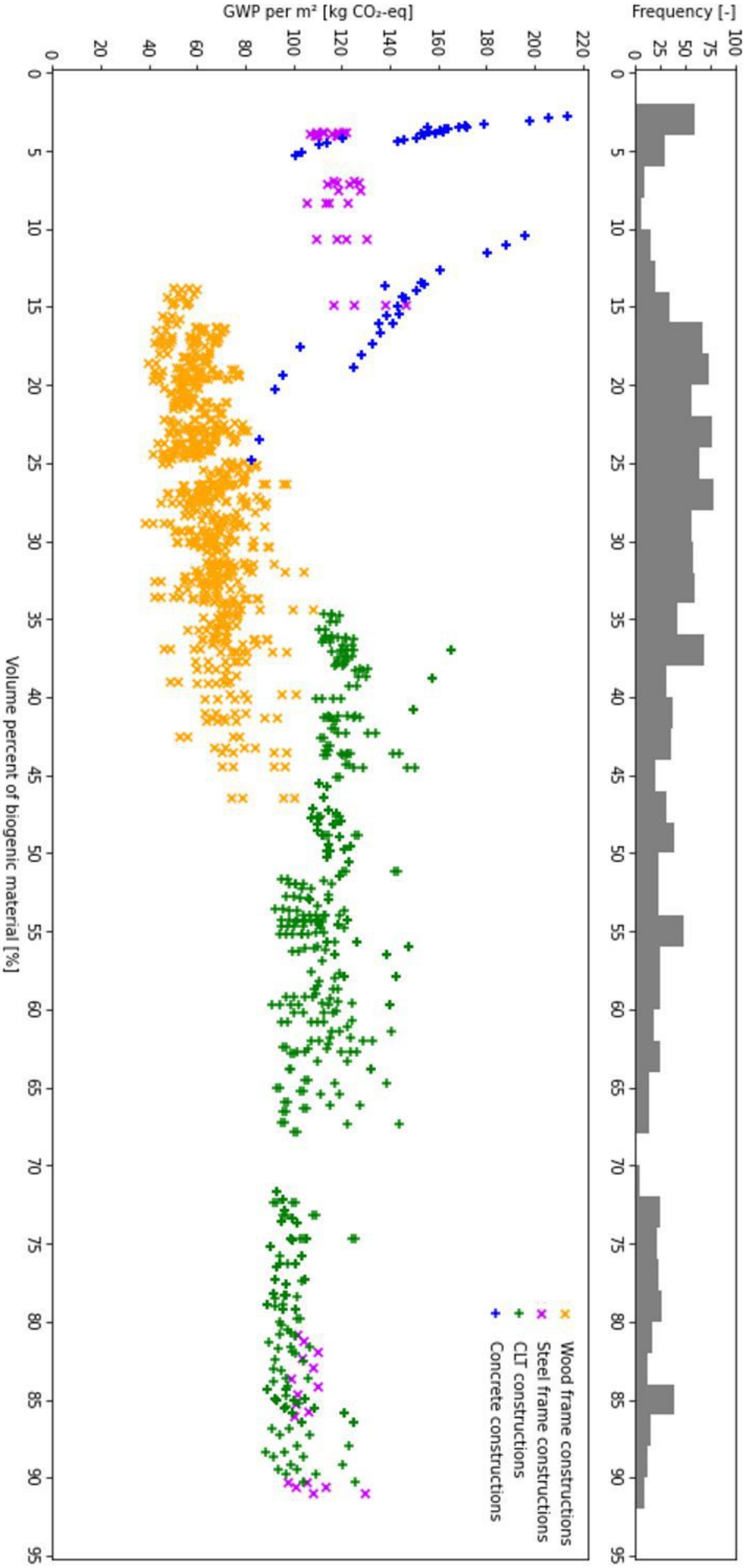


Figure B.12. Distribution of generated horizontal division components against the volume percent of biogenic carbon in the constructions.

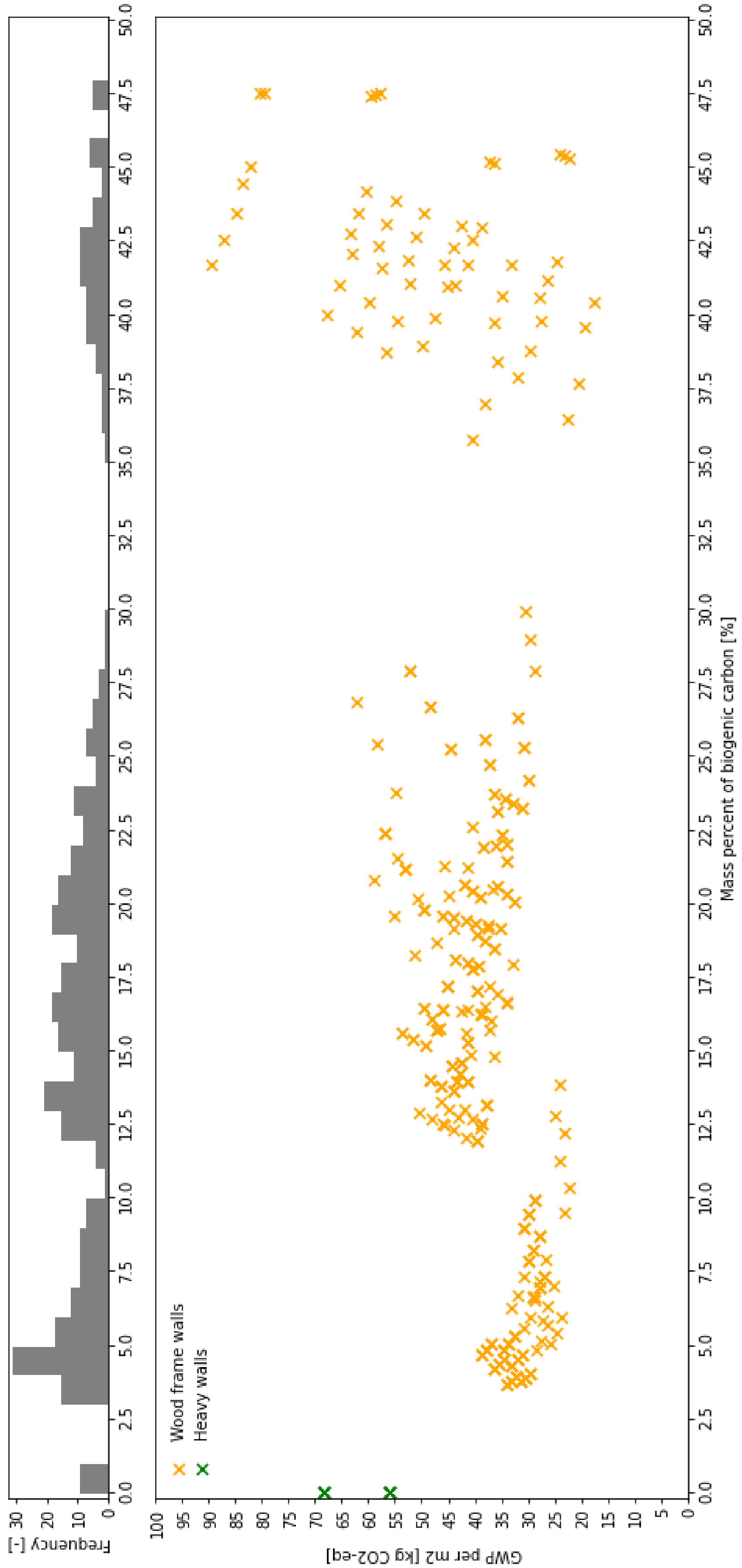


Figure B.13. Distribution of generated bearing interior wall components against the mass percent of biogenic carbon in the constructions.

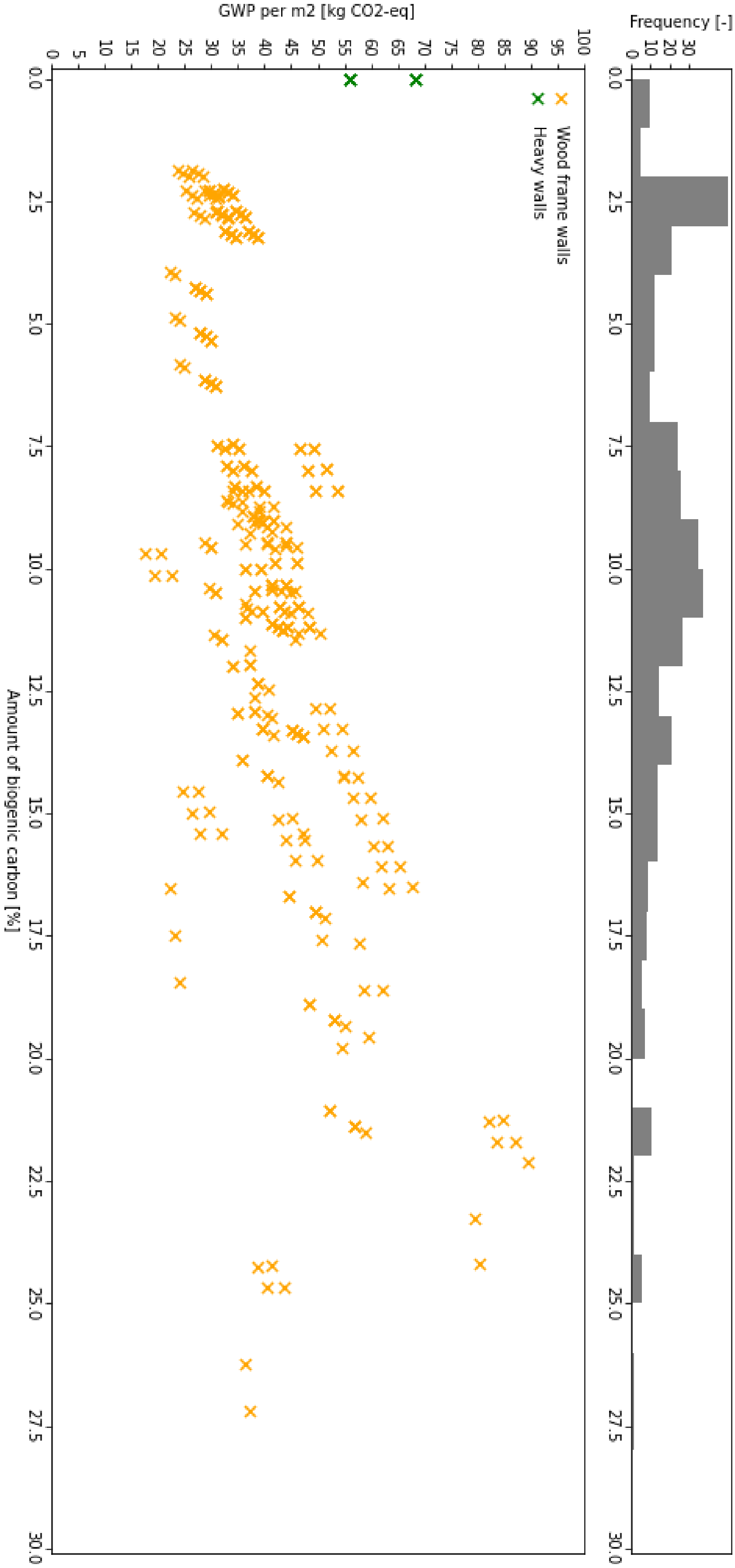


Figure B.14. Distribution of generated bearing interior wall components against the amount of biogenic carbon in the constructions.

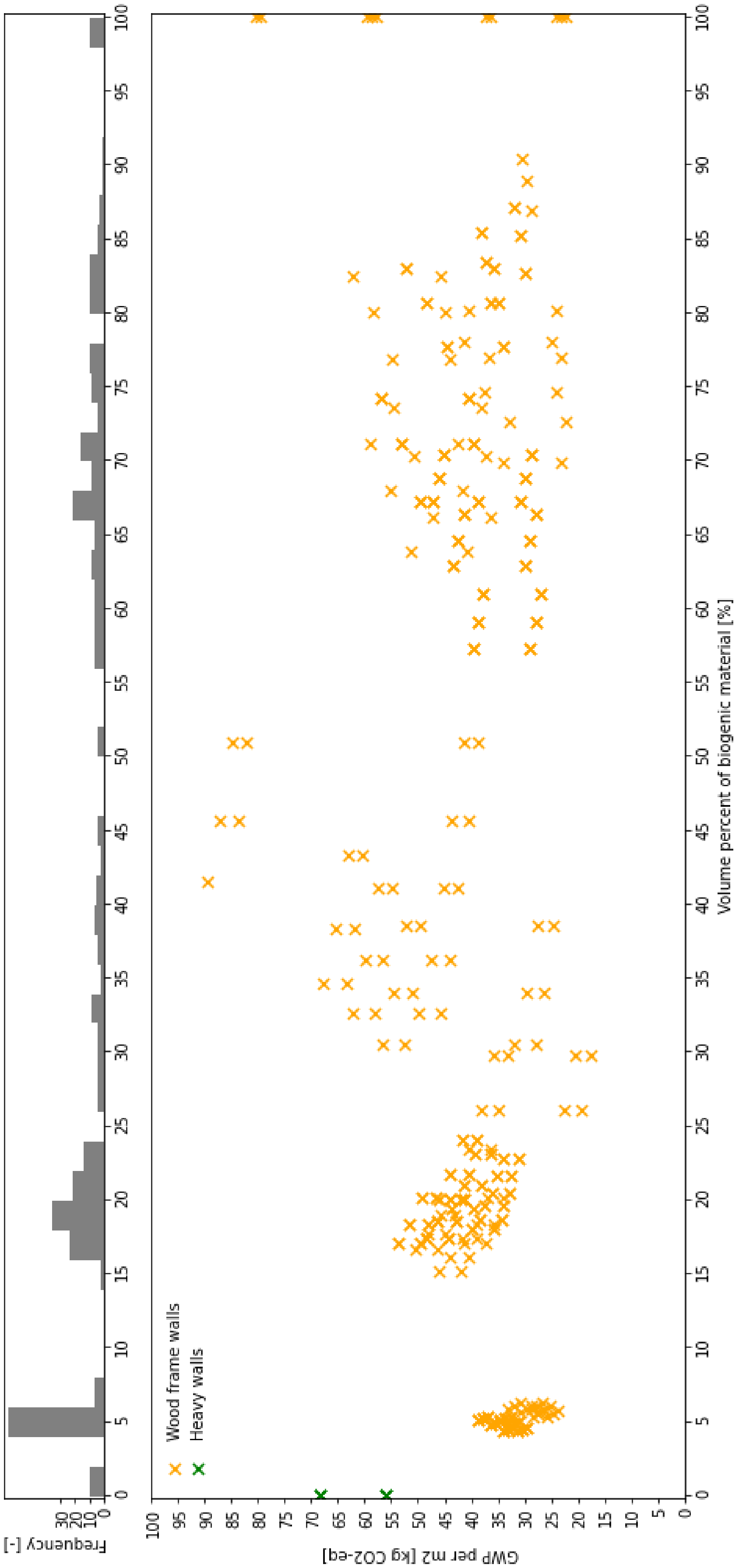


Figure B.15. Distribution of generated bearing interior wall components against the volume percent of biogenic carbon in the construction.

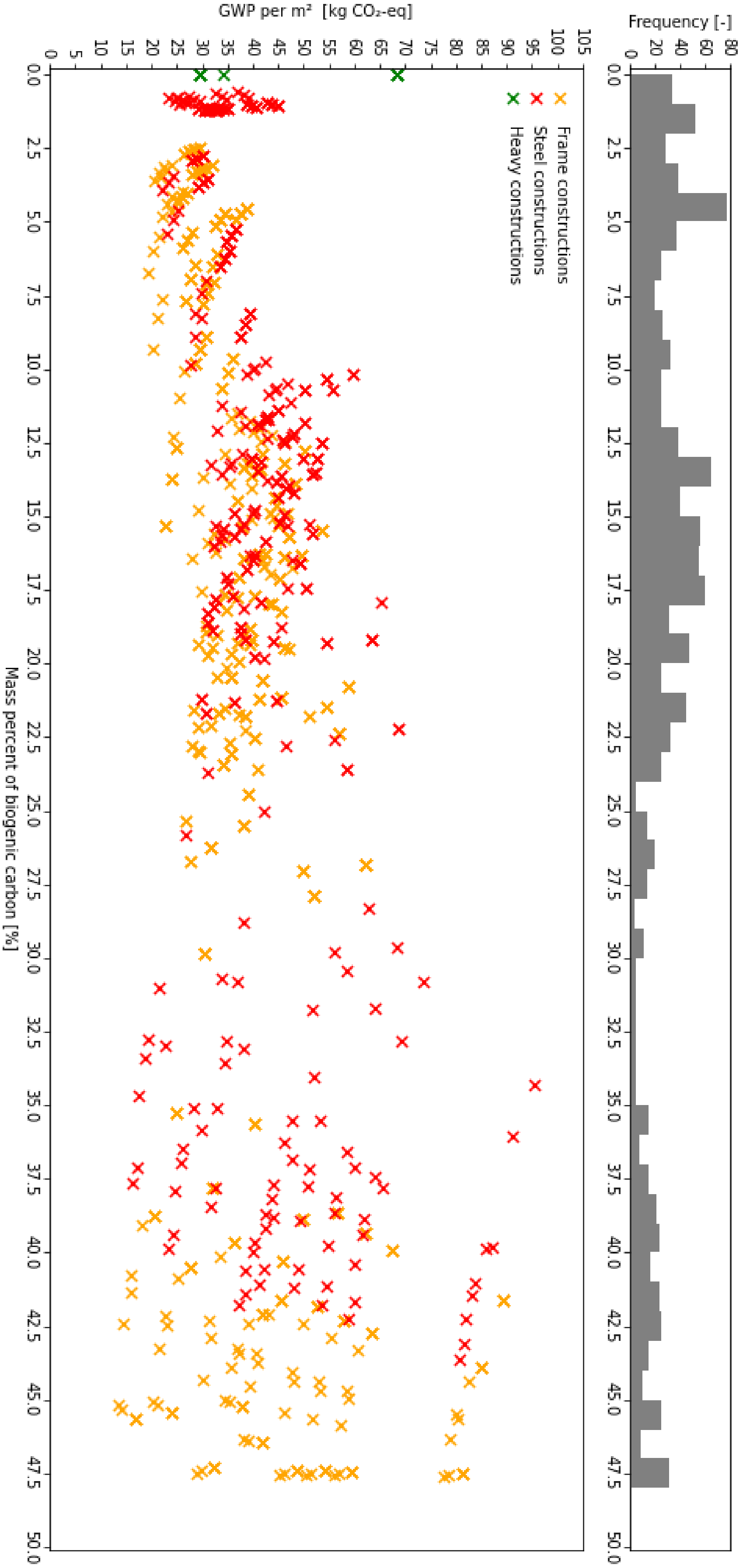


Figure B.16. Distribution of generated interior partition wall components against the mass percent of biogenic carbon in the constructions.

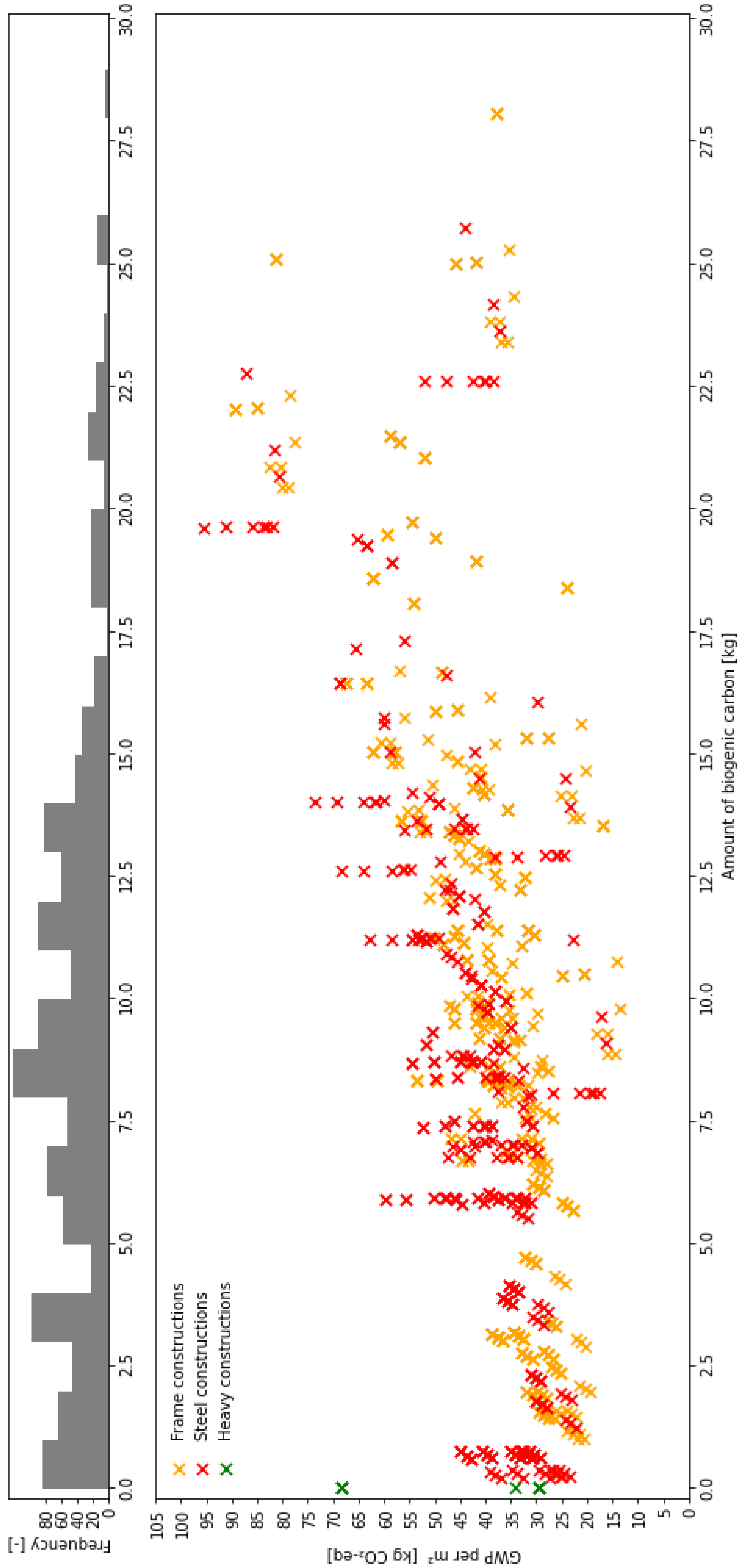


Figure B.17. Distribution of generated interior partition wall components against the amount of biogenic carbon in the constructions.

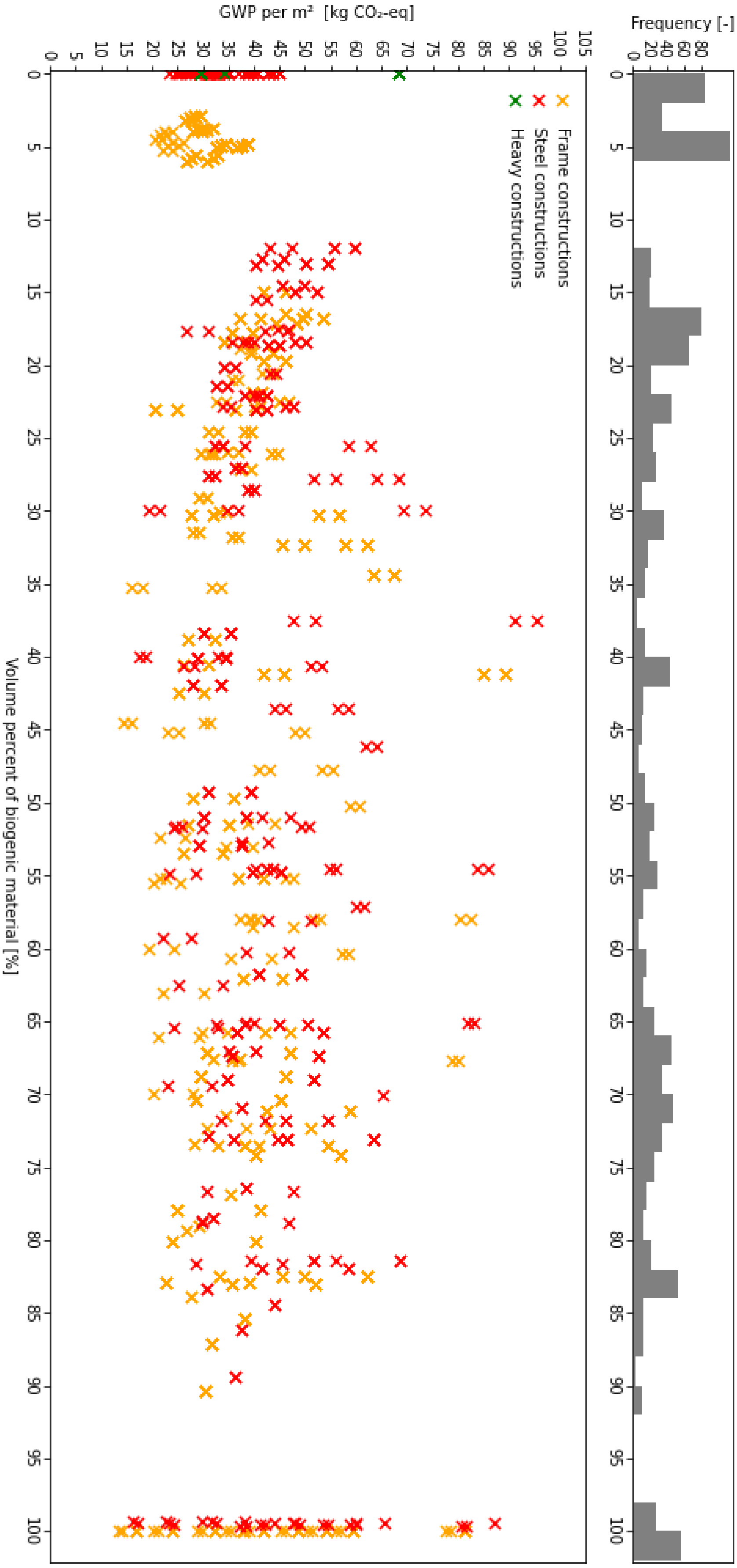


Figure B.18. Distribution of generated interior partition wall components against the volume percent of biogenic carbon in the constructions.

C Analysis on Parametric Filtering

In this appendix, results from the generated sets of macro components are visualised. The generation of macro components results in 433,000 solutions for exterior walls in the single-family house typology, 43,100 solutions for exterior walls in the four-story building typology, 31,600 solutions for roofs, 1,410 solutions for horizontal divisions, 373 solutions for bearing interior walls, and 1211 solutions for interior partition walls. The setup and method for the generation of macro components are described in appendix E. All micro components in the study can be found in appendix M. The number of micro components of each type and scatter plots showing the global warming potential plotted against biogenic carbon content for all macro components prior to filtering are available in appendix B.

The amount of generated macro components is highly dependent on the number of micro component types included in the generation, as well as the number of micro components defined for each micro component type. Therefore, more solutions exist for complex components such as exterior walls with a frame composition which consists of seven micro components, as opposed to more simple components such as interior walls which consist of three micro components. In order to approach a set of solutions which are realistic, a set of filters are applied to the initial set of solutions. These filters, described in appendix D, are listed below along with the appendices describing the evaluation method.

- Load-bearing capacity in the cold and warm scenario, see appendix L and H
- Fire safety requirements, see appendix A
- Moisture related performance, see appendix K
- U-value, see appendix D
- Estimated future impact limits on the global warming potential appropriated for building components, see appendix D

The filter may impose restrictions or in other ways alter the design space for building components. The initial set of generated solutions is considered the baseline for the investigation of the influence of different filters. Applying filters to this baseline may remove some of the solutions and alter the distribution of solutions. The influence of the filters on the baseline set will be affected by the contents of the baseline set. For example, if all macro components are well insulated, the effect of the U-value filter on the baseline set will be low. To accommodate the fact that all filters as defined in this project may not always be relevant to the design process of a particular building component, their influence on the generated set of solutions is investigated both separately and in succession.

C.1 One-at-a-Time-Filtering

This section includes an overview of which structural components are impacted the most by each filter when filtering the components using a one-at-a-time filtering approach. The results are divided into each addressed component type.

C.1.1 Exterior walls - Four-Storey buildings

For the four-storey building typology, 43.100 solutions for exterior walls are generated. The density of solutions in the baseline plotted against GWP per m^2 wall resembles a normal distribution. When applying each filter individually, the distribution changes as shown in figure C.1. It is apparent, that the load filter does not affect the distribution as no solutions are discarded. The solutions have a sufficient load-bearing capacity to manage the loads assumed in the filter. Application of the fire filter results in a shift in the density of solutions slightly toward a higher GWP. The moisture filtration removes some of the solutions that contain a front wall made of concrete and clay brick masonry. These solutions are associated with a higher GWP, and thus the removal of these solutions shifts the density slightly toward a lower GWP. Filtering for the U-value removes a few solutions with too high thermal transmission losses.

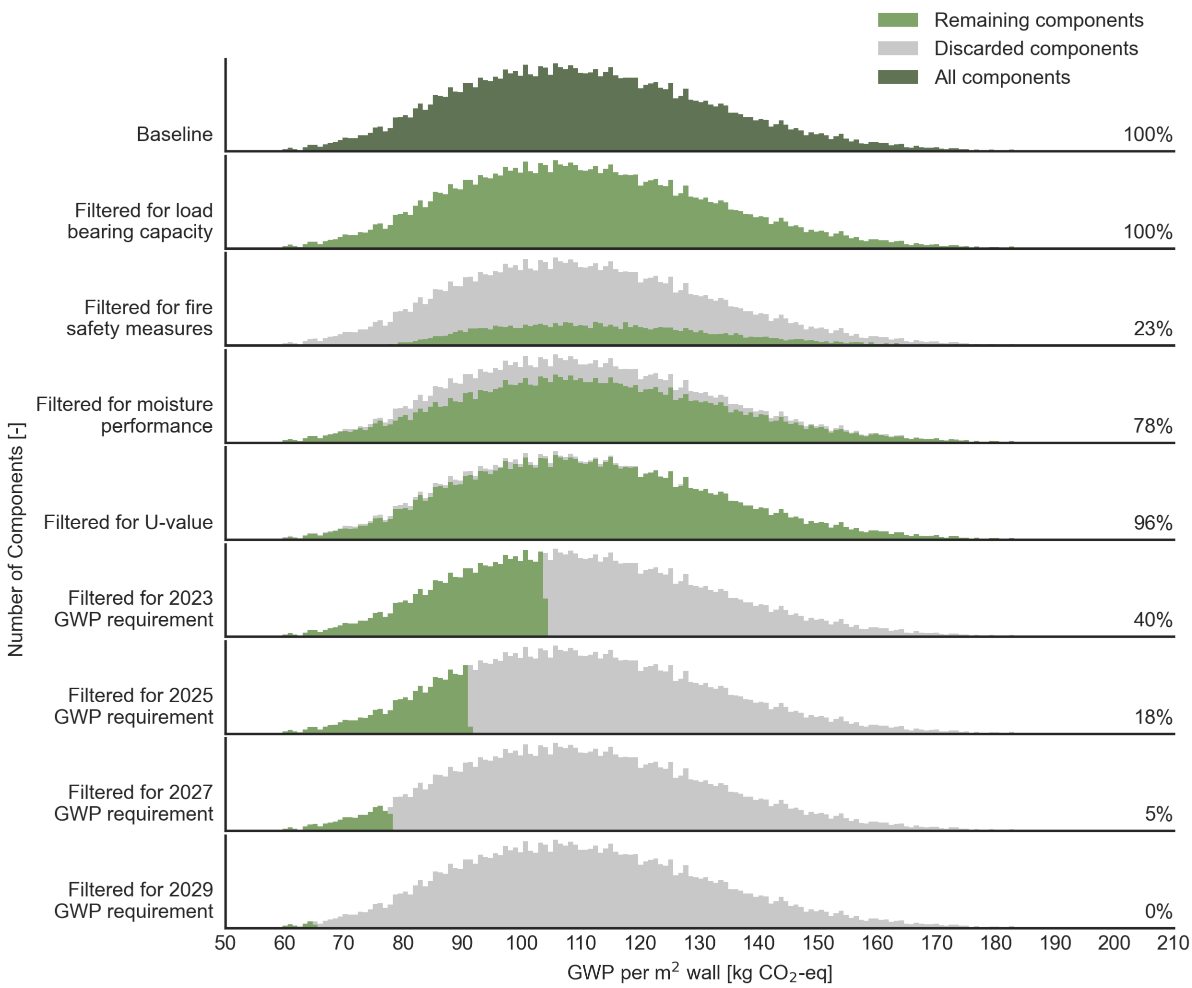


Figure C.1. Impact of one-at-a-time filtration on the distribution of GWP for exterior walls in the four-storey building typology.

To investigate the influence of the filter on different building components, the percentage of discarded component solutions from each filter is shown in figure C.2, where the solutions are divided into different materials and construction principles.

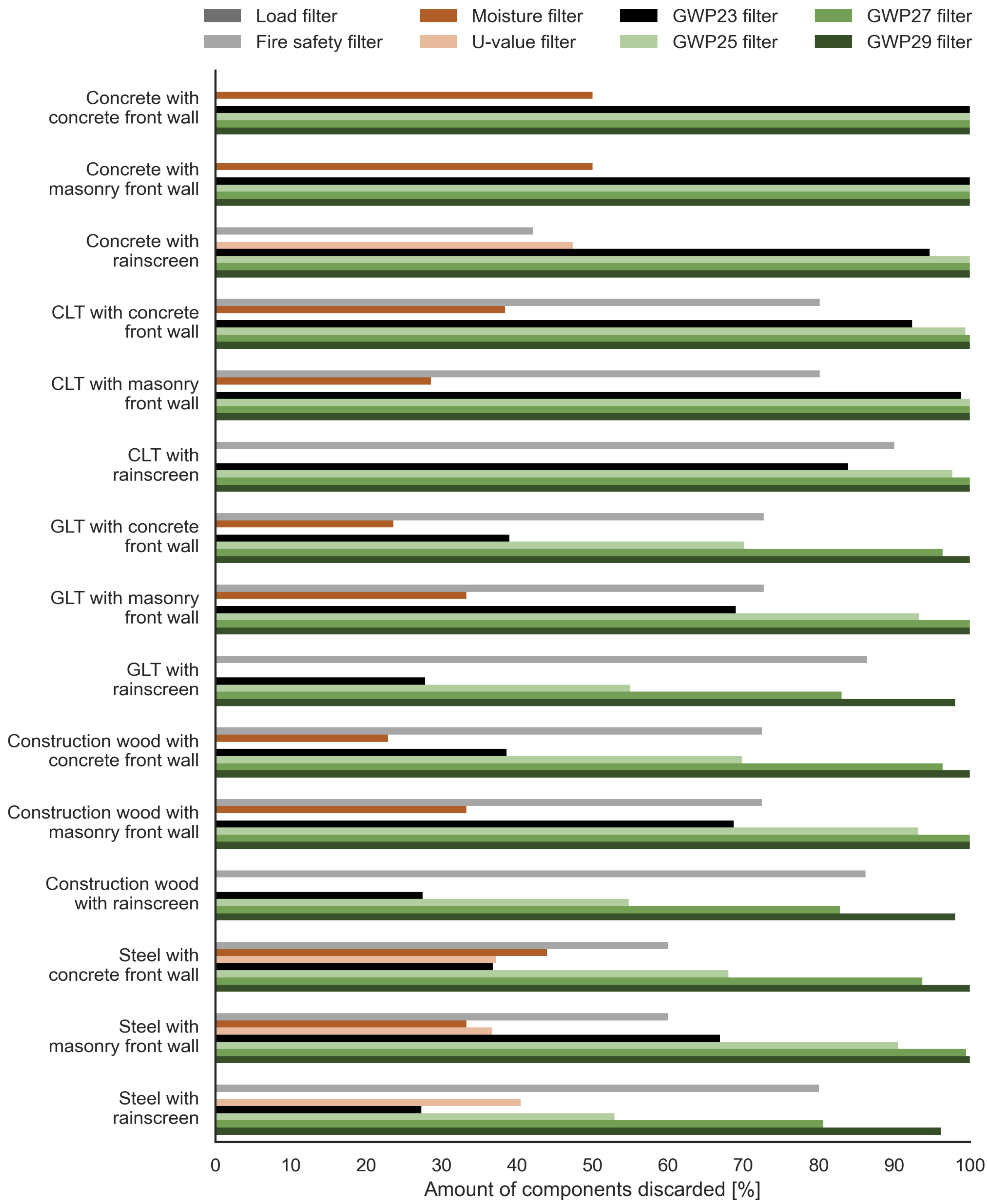


Figure C.2. Percentage of discarded components for each filter divided between component categories for exterior walls in the four-storey building typology.

The fire filter consists of three aspects selected from the prescriptive fire safety solutions applying to the four-storey building typology. The influence of the different aspects of the fire filter is illustrated in figure C.3 along with the total amount of discarded components, where the overlap from the three aspects is taken into account.

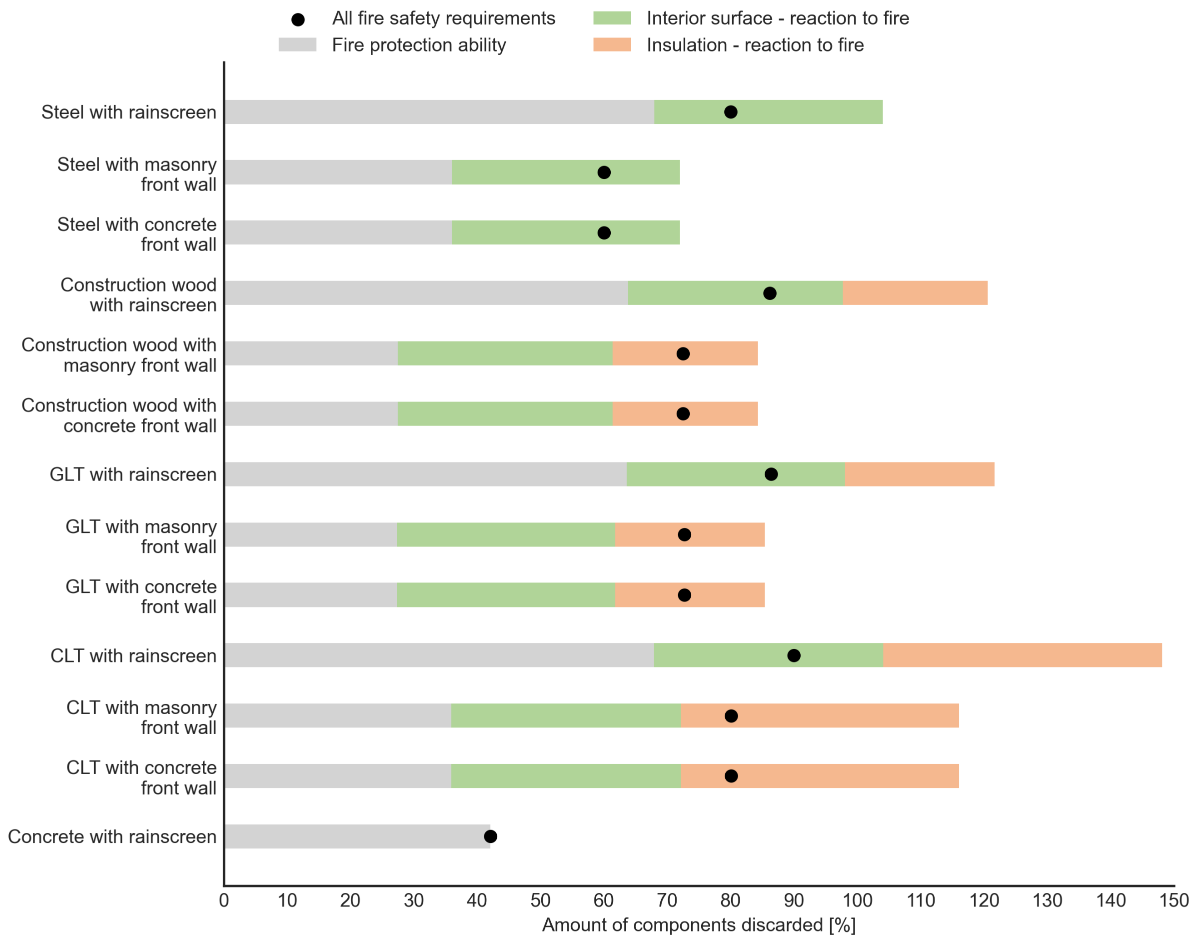


Figure C.3. Amount of exterior wall components discarded by each part of the fire safety filter and the total amount of discarded components when taking filter overlap into account.

C.1.2 Roof Constructions - Four-Storey Buildings

31.600 roof constructions are generated. The density of solutions in the baseline plotted against GWP per m^2 construction creates two clusters consisting of wooden frame structures and solid structures respectively. The distribution change when applying each filter individually, as shown in figure C.1. Application of the fire filters for load-bearing capacity, fire safety and U-value has a significant impact on the distribution of solutions.

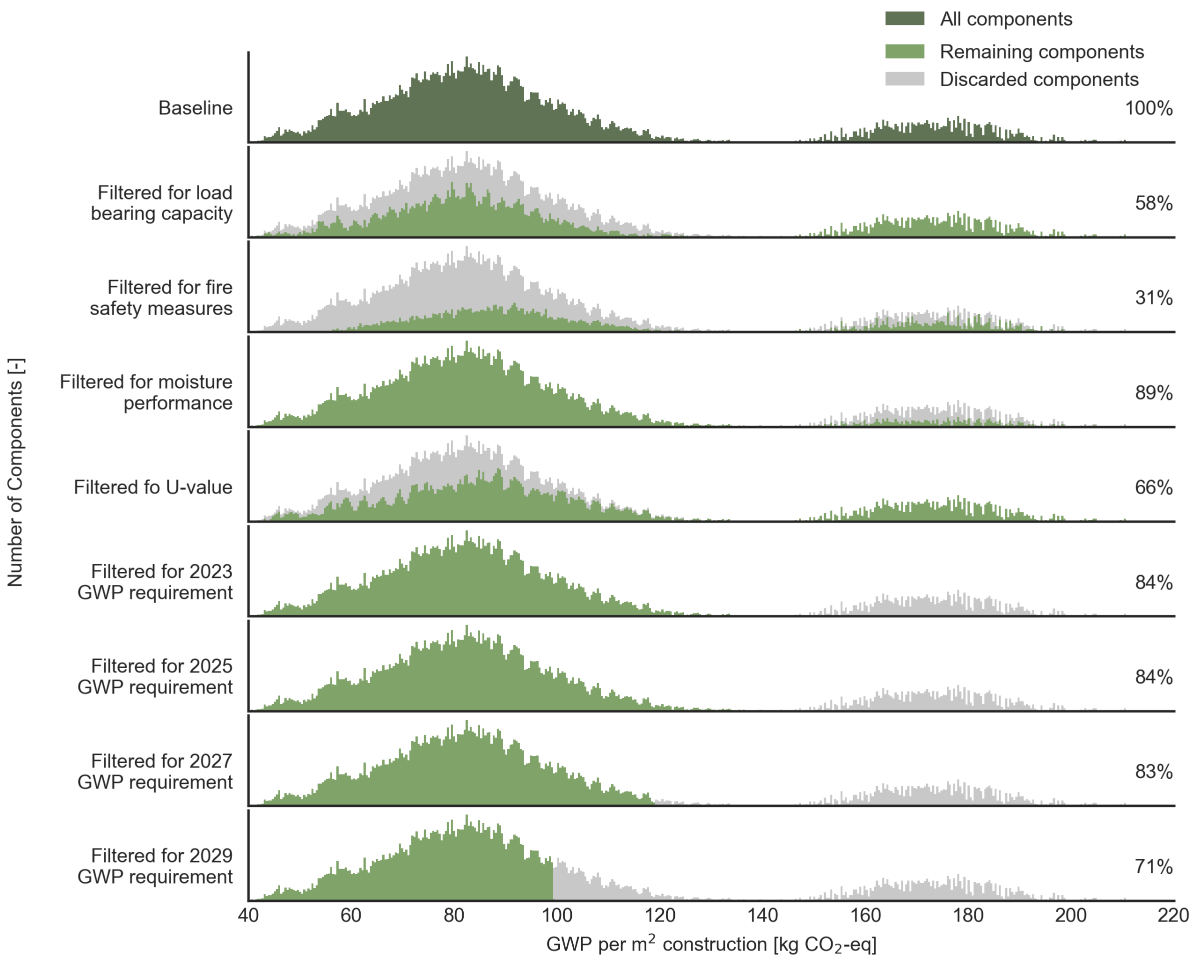


Figure C.4. Impact of one-at-a-time filtration on the distribution of GWP for roofs in the four-storey building typology.

The influence on the number of acceptable solutions for the different construction types from each filter is shown in figure C.19. This graph illustrates the percentage of discarded component solutions.

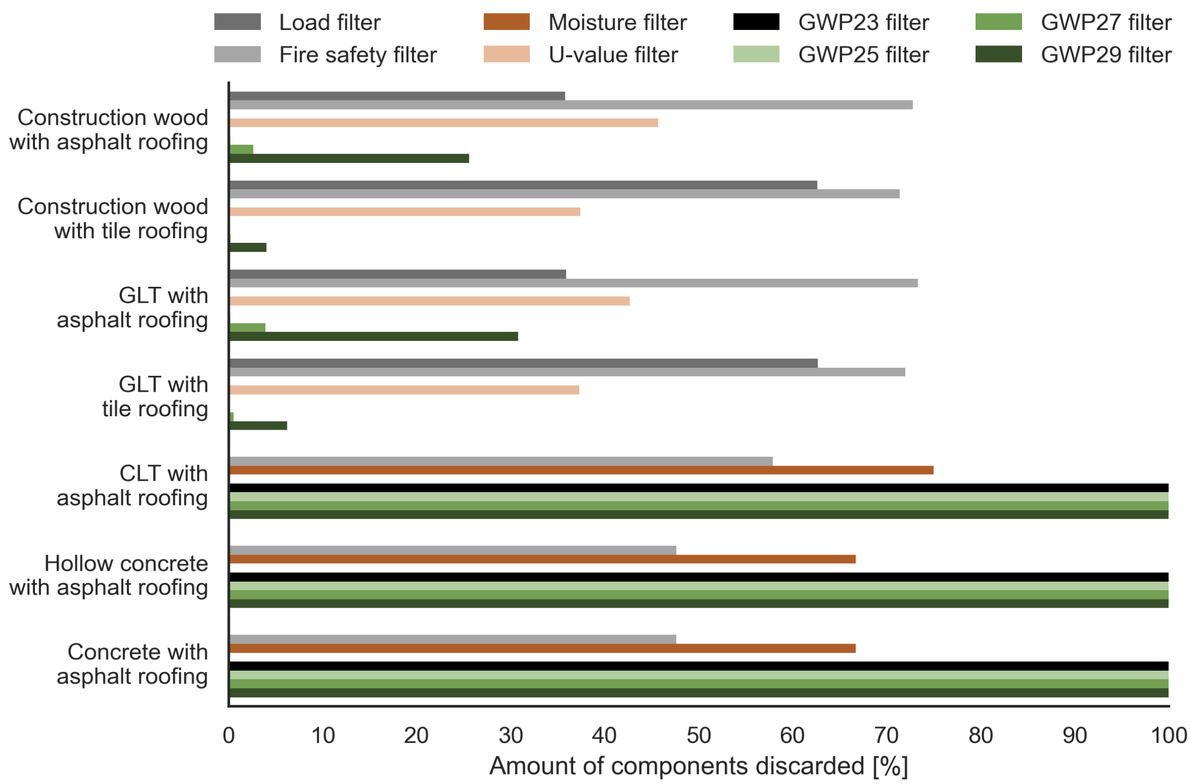


Figure C.5. Percentage of discarded components for each filter divided by component category for roofs in the four-storey building typology.

The three addressed aspects of the prescriptive solutions and their impact on the amount of roof solutions are shown in figure C.6. There is an overlap of components discarded by each aspect of the fire filter, and the total discarded components are added to the graph.

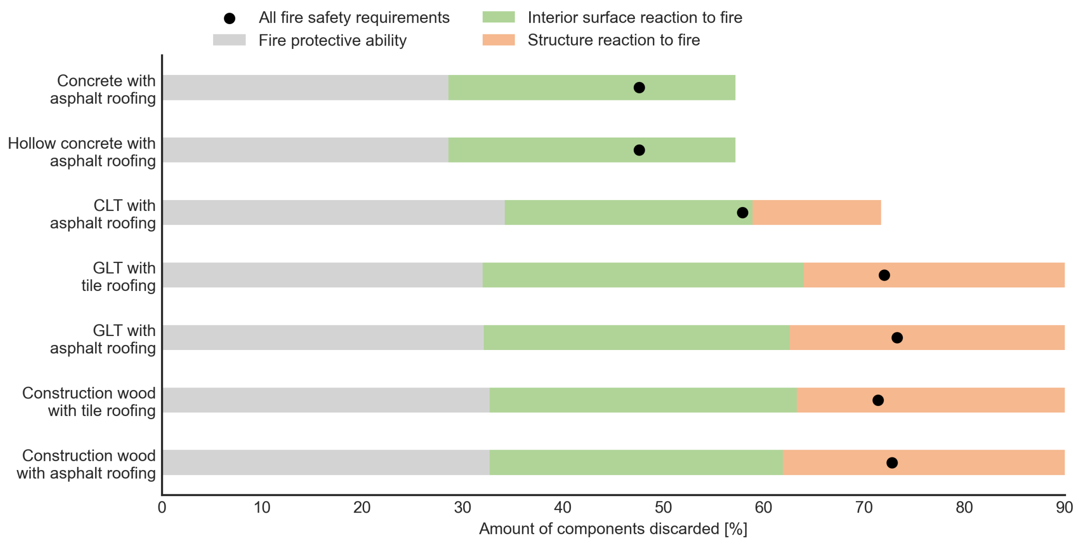


Figure C.6. Amount of roof components discarded by each part of the fire safety filter and the total amount of discarded components when taking filter overlap into account.

C.1.3 Horizontal Divisions - Four-Storey Buildings

For horizontal divisions, 1410 solutions for are created in the macro component generation. The density of solutions is shown in figure C.7 for the baseline and when applying relevant filters. Except for the GWP filters, only the fire filter is removing a significant amount of components in the one-at-a-time filtering approach.

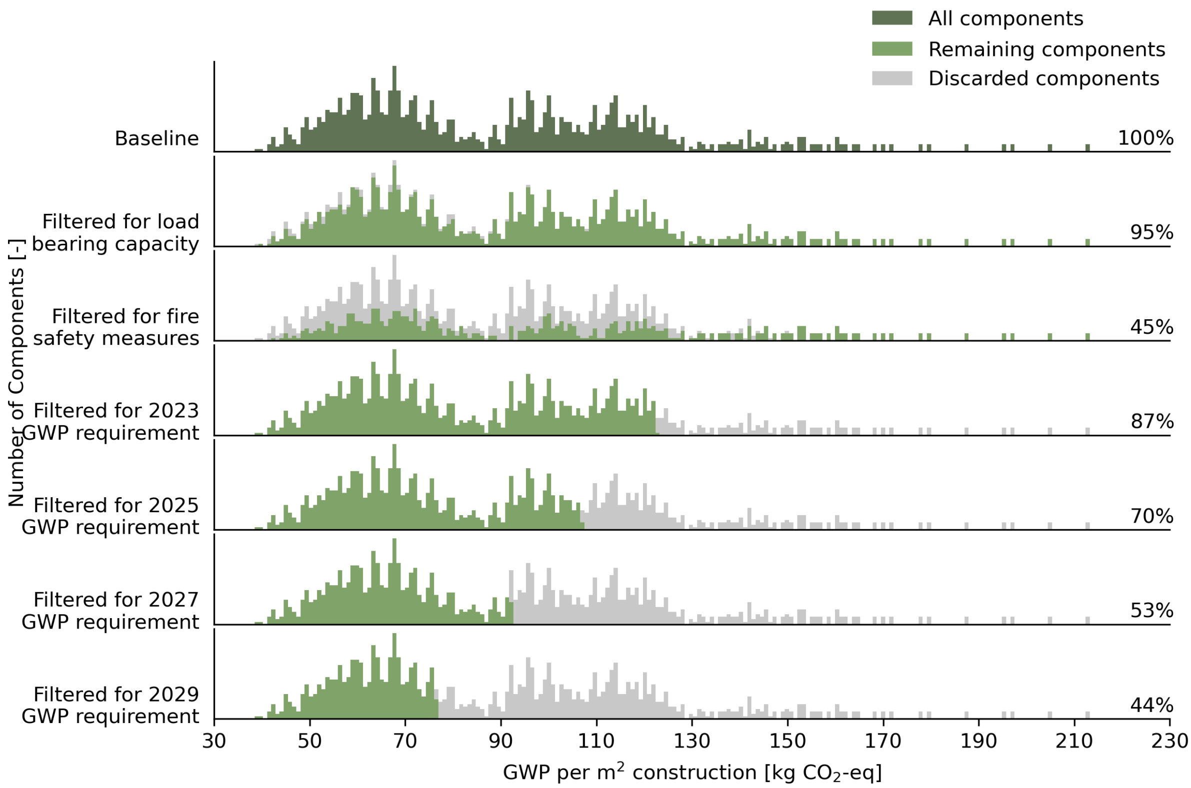


Figure C.7. Impact of one-at-a-time filtration on the distribution of GWP for horizontal divisions in the four-storey building typology.

The percentages of discarded components by each filter are shown in figure C.8, divided into construction categories. The GWP filters are impacting the solid constructions the most, while the fire filter impacts the biogenic constructions and frame constructions.

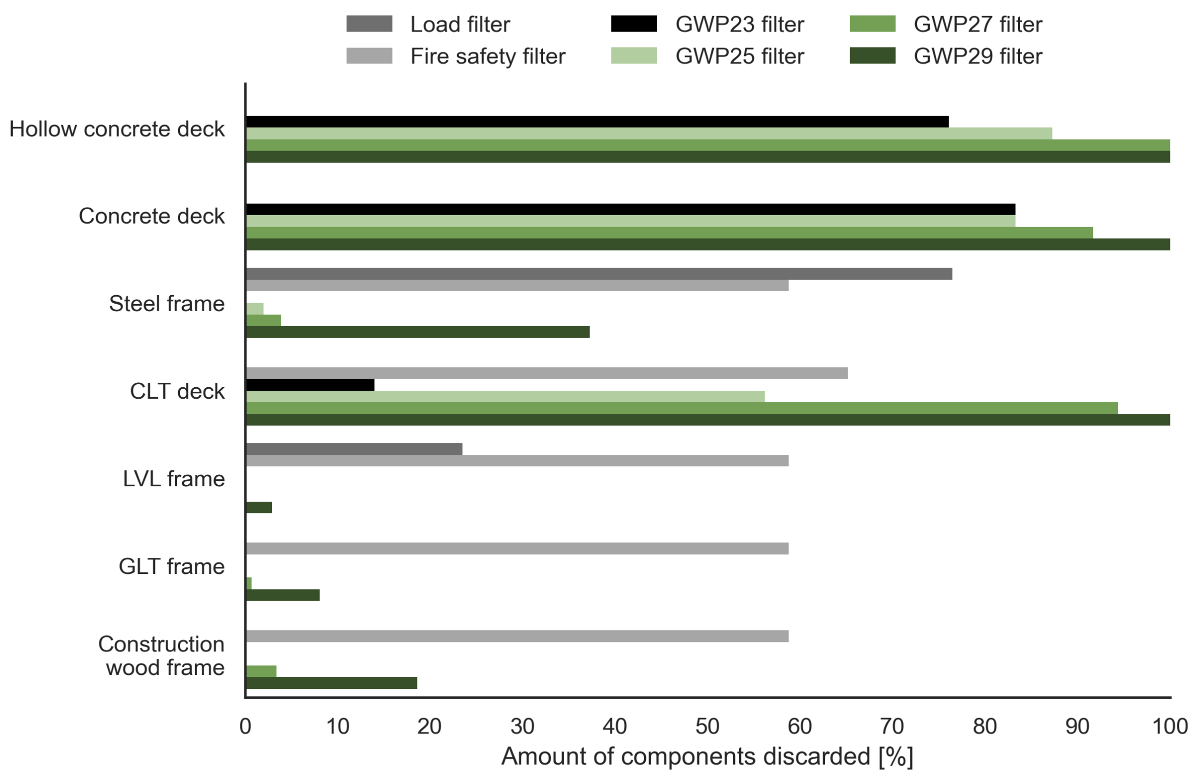


Figure C.8. Percentage of discarded components for each filter divided on the component category for horizontal divisions in the four-storey building typology.

The impact from each aspect of the fire filter is shown in figure C.9 along with the total amount of discarded components, where the overlap between aspects is taken into account. Only the CLT construction group is exposed to components being discarded by the insulation filter, as the remaining biogenic constructions do not include insulation.

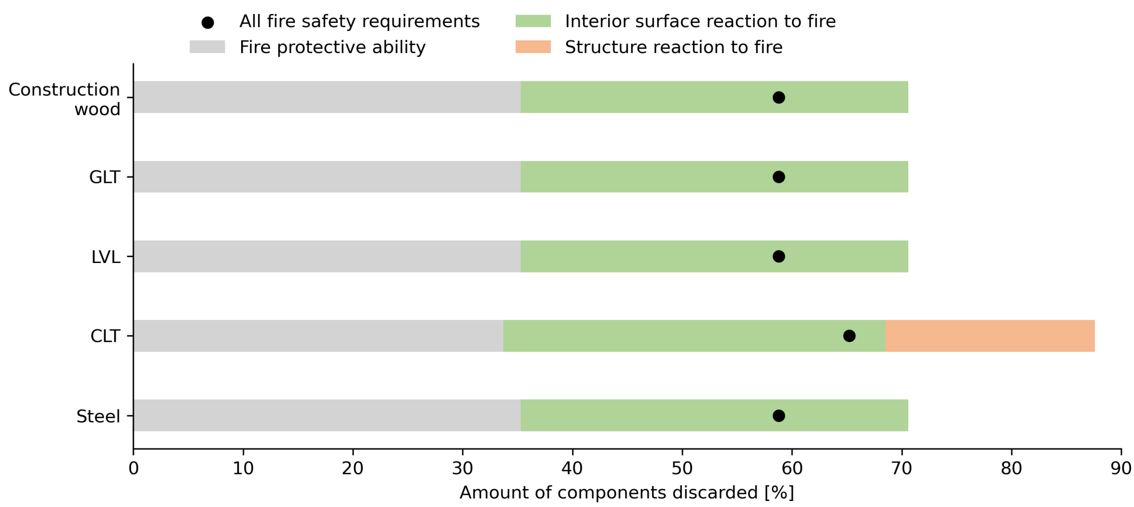


Figure C.9. Amount of horizontal divisions wall components discarded by each part of the fire safety filter and the total amount of discarded components when taking filter overlap into account.

C.1.4 Bearing Interior Walls - Four-Storey Buildings

373 solutions are generated for bearing interior walls. The density of solutions is shown in figure C.10 for the baseline and when applying filters. Only the GWP 2029 filter and the fire filter are removing a significant amount of components in the one-at-a-time filtering approach.

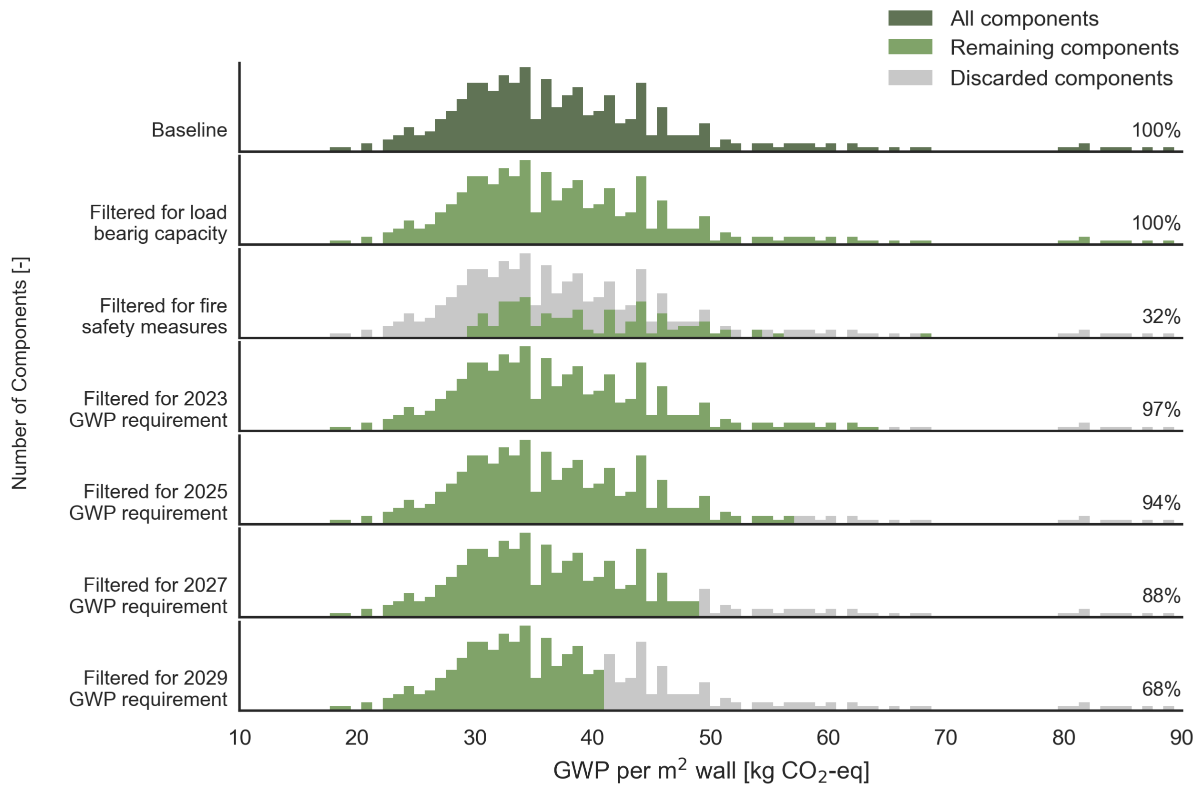


Figure C.10. Impact of one-at-a-time filtration on the distribution of GWP for bearing interior walls in the four-storey building typology.

The components discarded in each construction category are shown in figure C.11 for the bearing interior walls.

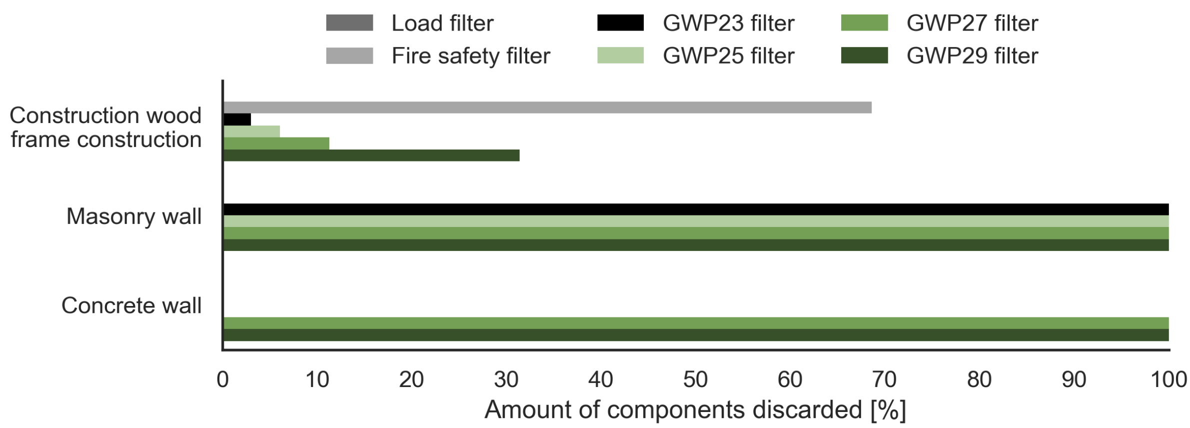


Figure C.11. Percentage of discarded components for each filter divided on the component category for bearing interior walls in the four-storey building typology.

The amount of discarded components in the three aspects of the fire filter is shown in figure C.12. The total amount of discarded components is also shown, where the overlap of constructions discarded for each aspect is considered.

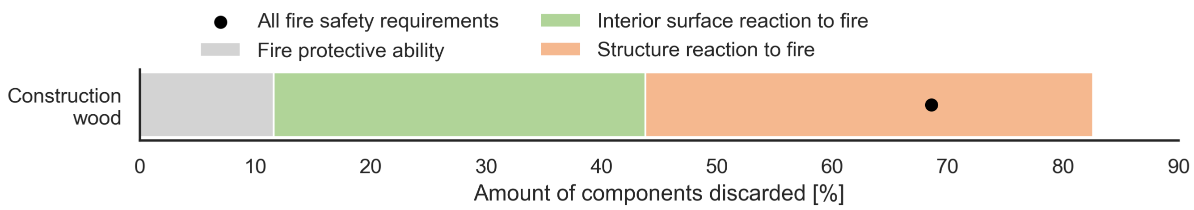


Figure C.12. Amount of bearing interior wall components discarded by each part of the fire safety filter and the total amount of discarded components when taking filter overlap into account.

C.1.5 Interior Partition Walls - Four-Storey Buildings

For partition walls, 1210 solutions are generated. The density of solutions is shown in figure C.13 for the baseline and when applying relevant filters one at a time.

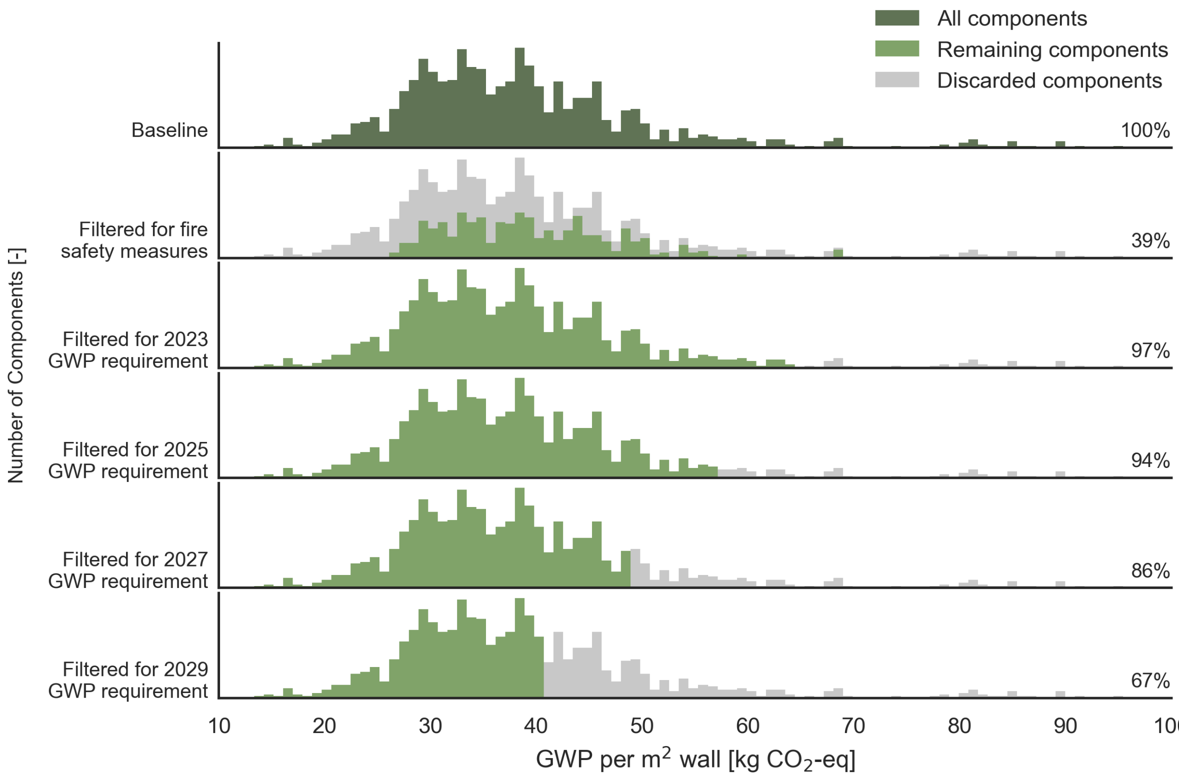


Figure C.13. Impact of one-at-a-time filtration on the distribution of GWP for interior partition walls in the four-storey building typology.

The components discarded in each construction category are shown in figure C.14 for the partition walls.

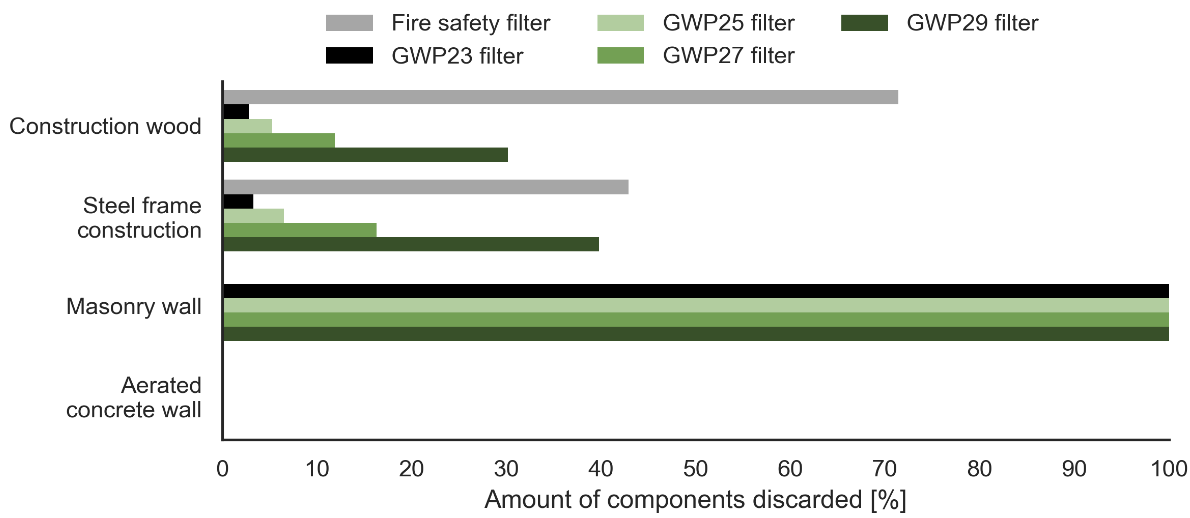


Figure C.14. Percentage of discarded components for each filter divided by component category for interior partition walls in the four-storey building typology.

The amount of discarded components in the three aspects of the fire filter is shown in figure C.15. The total amount of discarded components is also shown, where the overlap of constructions discarded for each aspect is considered.

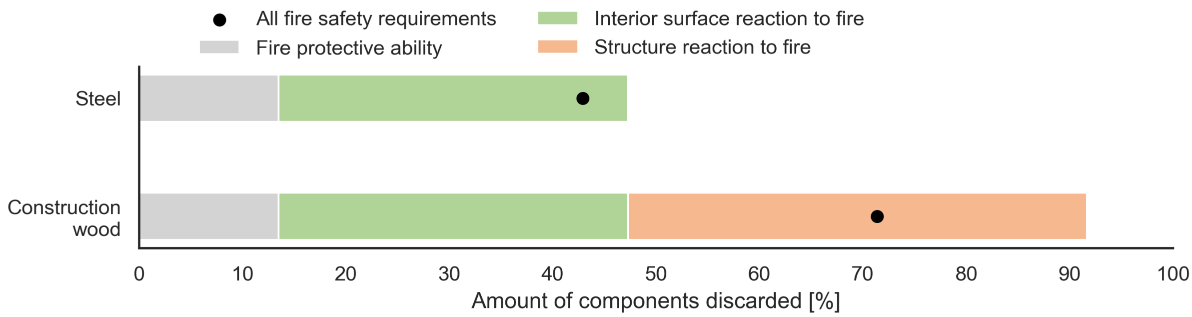


Figure C.15. Amount of interior partition wall components discarded by each part of the fire safety filter and the total amount of discarded components when taking filter overlap into account.

C.1.6 Exterior walls - Single-Family Houses

For the single-family house typology, 433.000 solutions for exterior walls are generated. The density of solutions in the baseline plotted against GWP per m^2 wall resembles a normal distribution. When applying each filter individually, the distribution changes as shown in figure C.16. It is apparent, that the load filter does not affect the distribution as no solutions are discarded. The solutions have a sufficient load-bearing capacity to manage the loads assumed in the filter. Application of the fire filter results in a shift in the density of solutions toward a higher GWP. The moisture filtration removes some of the solutions that contain a front wall made of concrete and clay brick masonry. These solutions are associated with a higher GWP, and thus the removal of these solutions shifts the density slightly toward a lower GWP. Filtering for the U-value removes solutions with too high thermal transmission losses. As the thermal insulation increases with material use, the solutions removed are found in the lower end of the GWP spectrum.

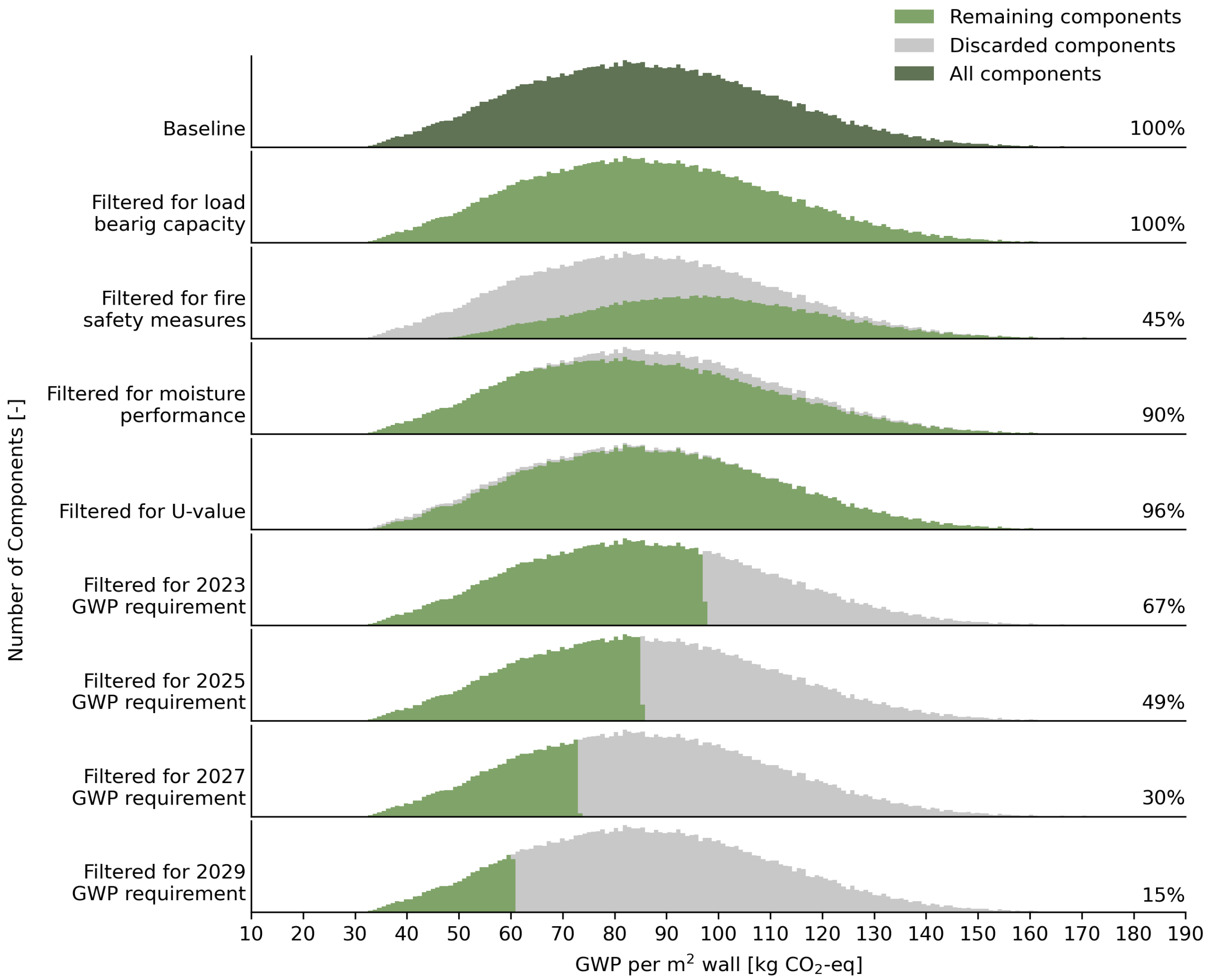


Figure C.16. Impact of one-at-a-time filtration on the distribution of GWP for exterior walls in the single-family house typology.

To investigate the influence of the filter on different building components, the percentage of discarded component solutions from each filter is shown in figure C.17, where the solutions are divided into different design categories.

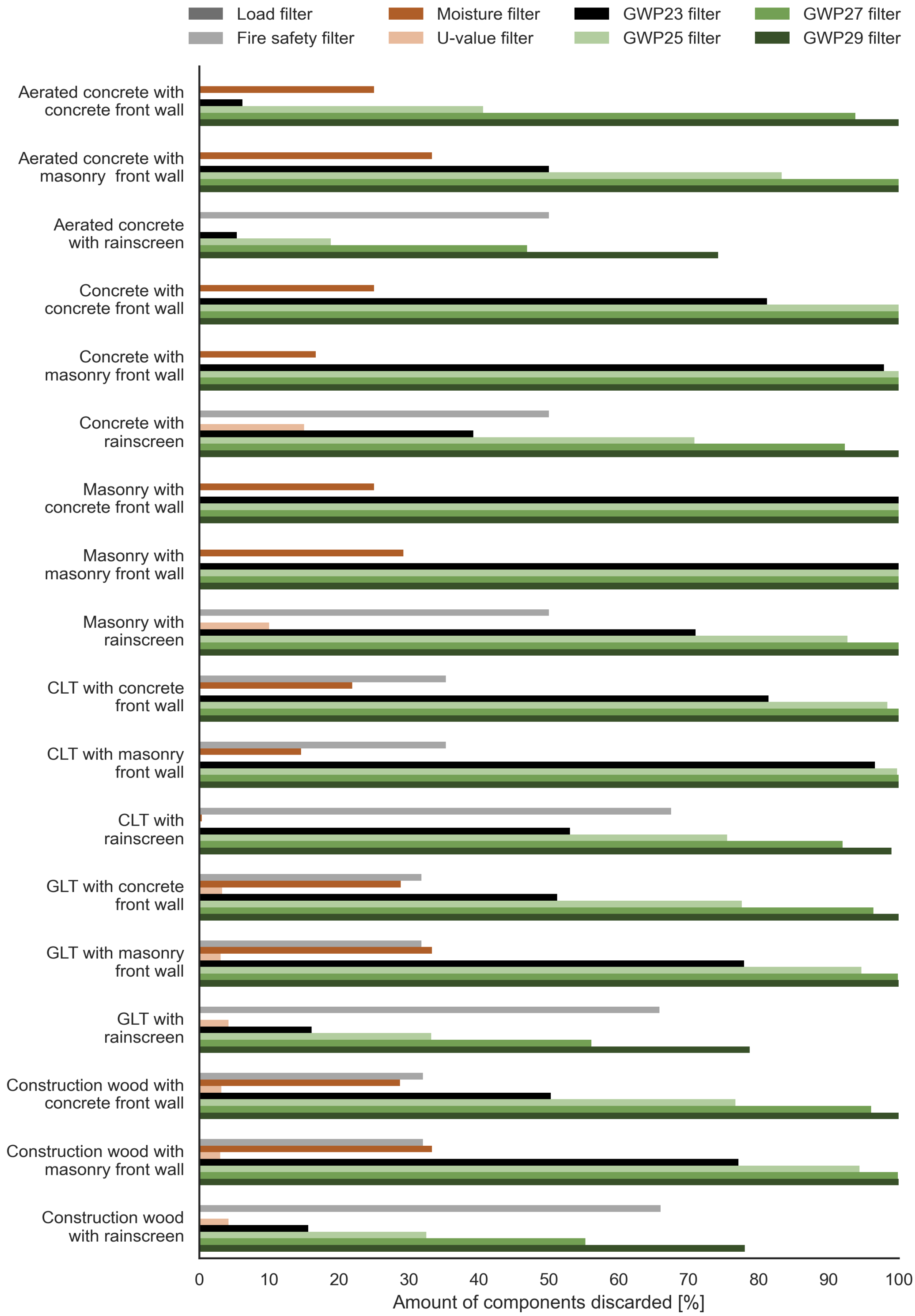


Figure C.17. Percentage of discarded components for each filter divided on the component category for exterior walls in the single-family house typology.

C.1.7 Roof Constructions - Single-Family Houses

In the generation of components, 31.600 solutions for roofs are created. In figure C.18, the density of solutions in the baseline is plotted against GWP per m^2 roof and shows two clusters. The large cluster contains the construction wood and GLT frame structures, while the small cluster contains concrete and CLT structures. When applying each filter individually, the distribution changes. The load filter reduces the number of solutions with wooden frames. Application of the fire filter results in a shift in the density of solutions toward a higher GWP. The moisture filtration removes the concrete and CLT solutions that do not have an adaptive vapour retarder. Filtering for the U-value removes solutions with too high thermal transmission losses. As the thermal insulation increases with material use, the solutions removed are found in the lower end of the GWP spectrum.

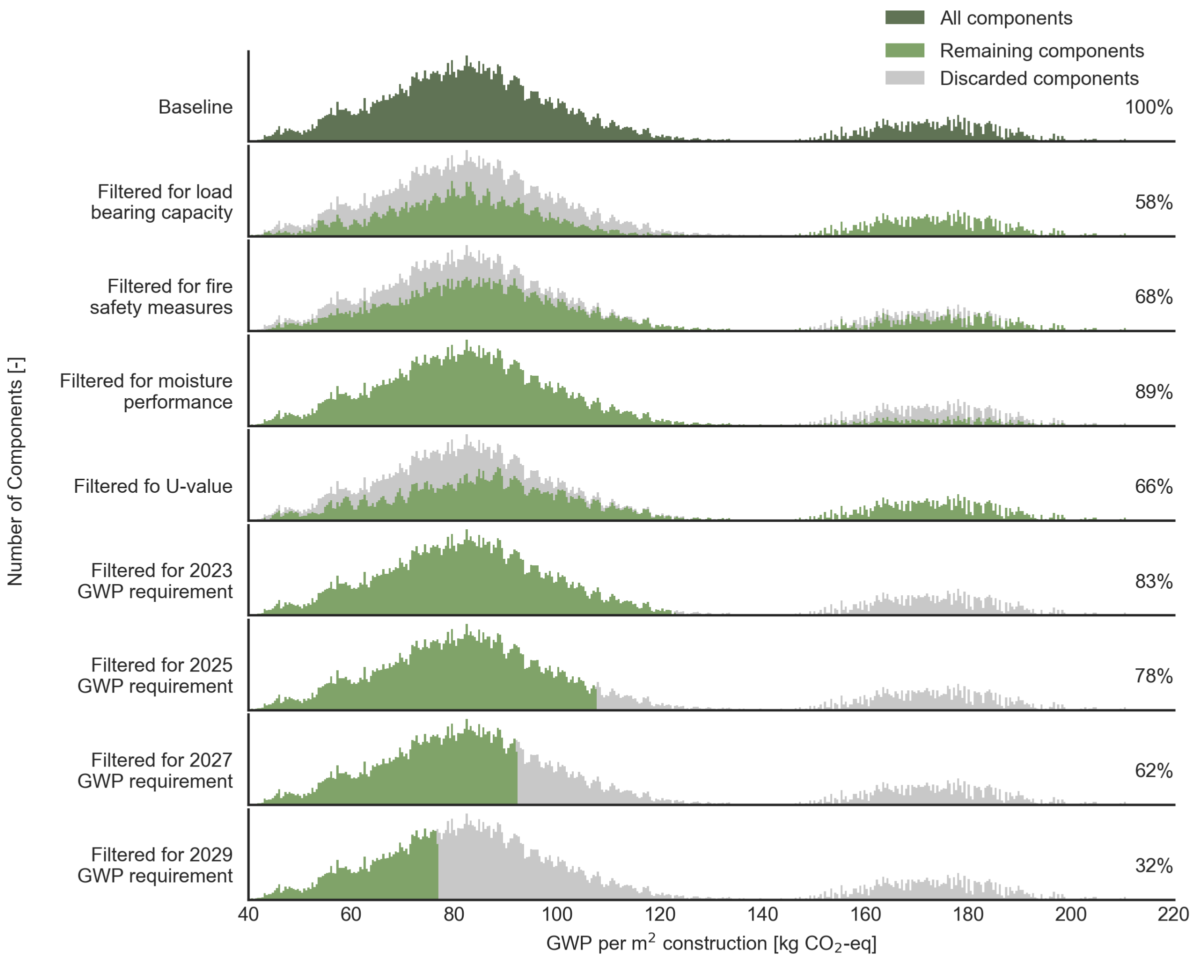


Figure C.18. Impact of one-at-a-time filtration on the distribution of GWP for the roof in the single-family house typology.

To investigate the influence of the filter on different building components, the percentage of discarded component solutions from each filter is shown in figure C.19, where the solutions are divided into different design categories.

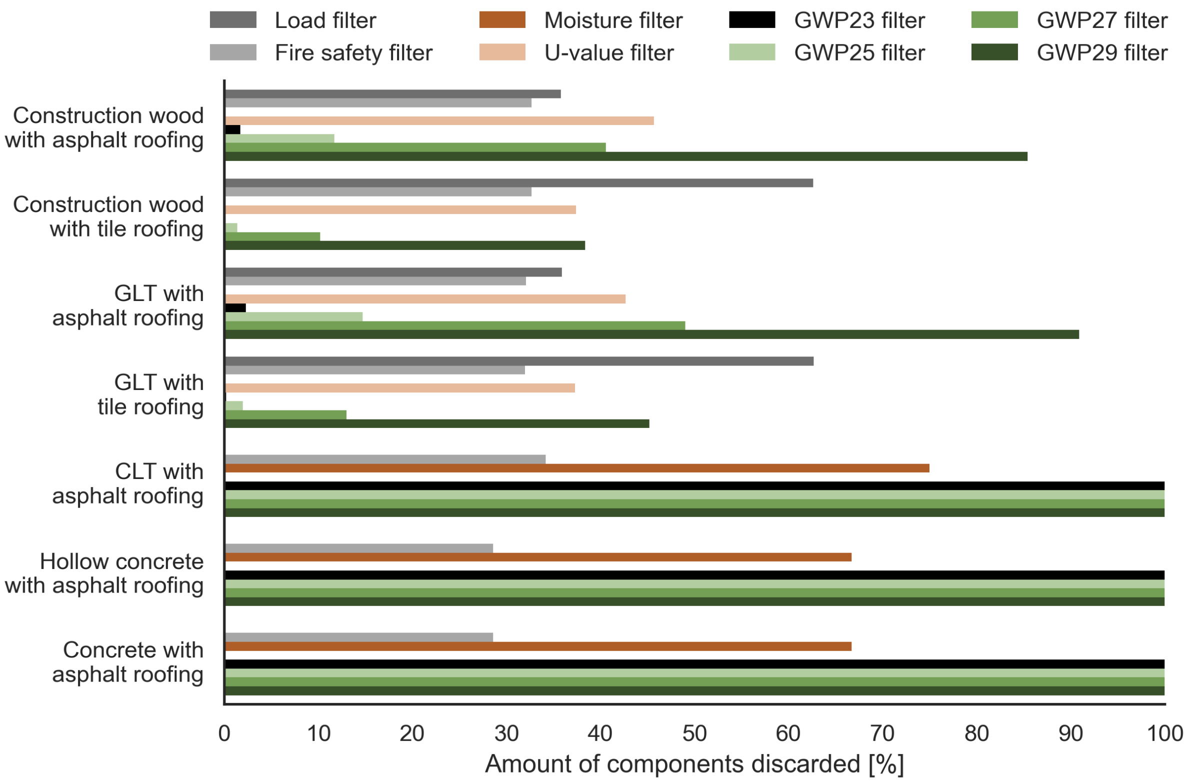


Figure C.19. Percentage of discarded components for each filter divided on the component category for roofs in the single-family house typology.

C.1.8 Bearing Interior Walls - Single-Family Houses

For bearing interior walls, 373 solutions are generated. The density of solutions is shown in figure C.20 for the baseline and when applying relevant filters.

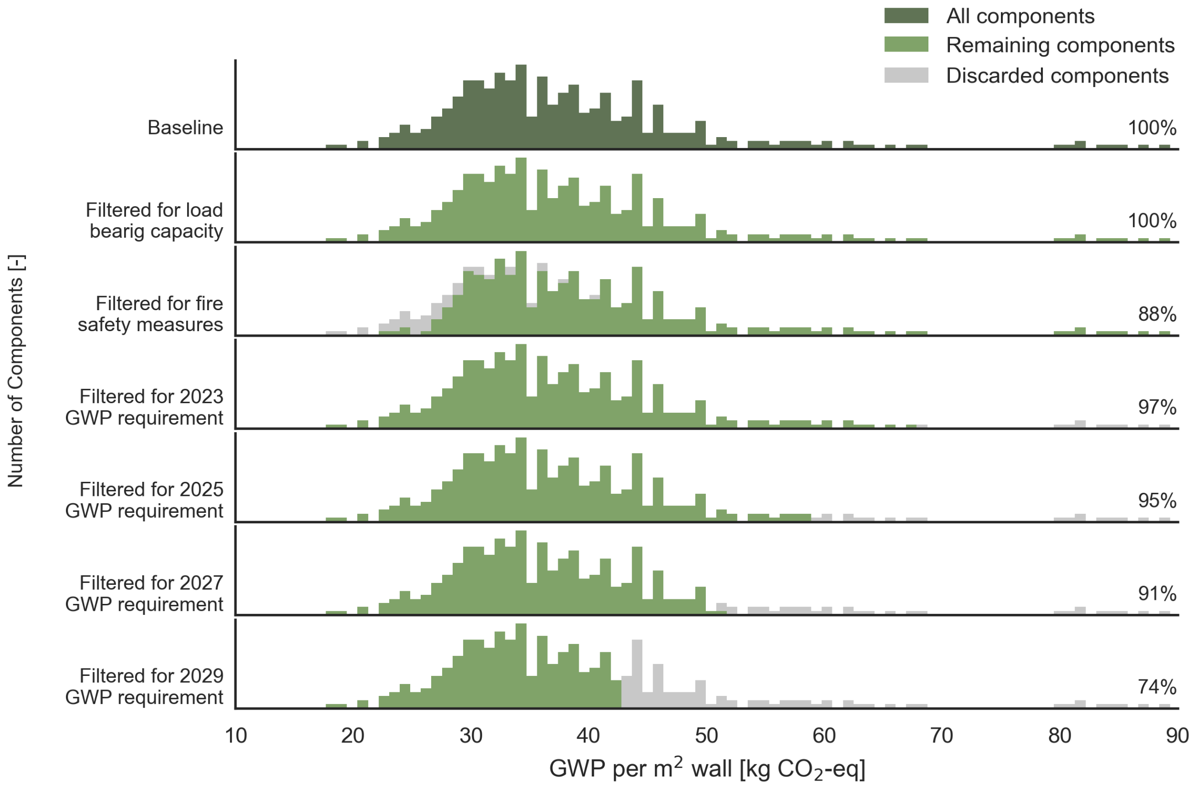


Figure C.20. Impact of one-at-a-time filtration on the distribution of GWP for bearing interior walls in the single-family house typology.

The components discarded in each construction category are shown in figure C.21 for the bearing interior walls.

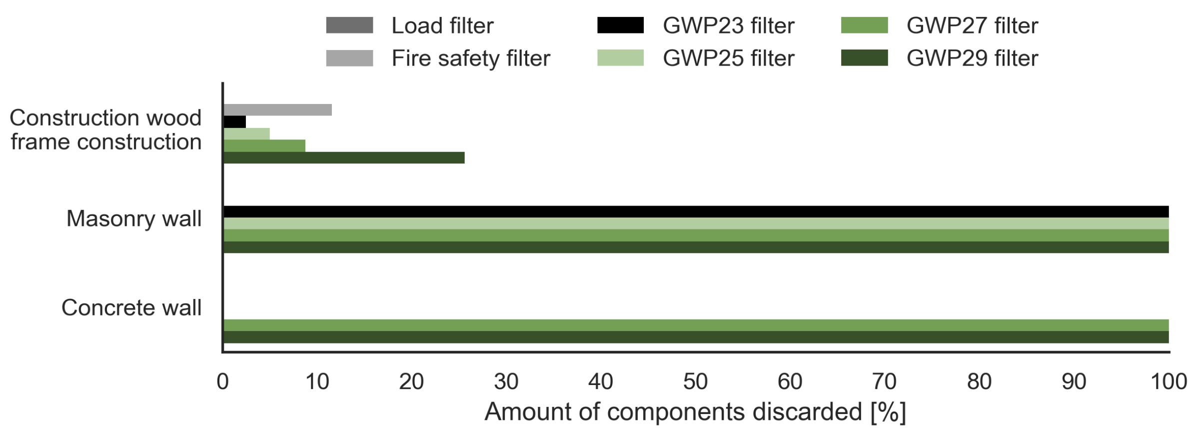


Figure C.21. Percentage of discarded components for each filter divided by component category for bearing interior walls in the single-family house typology.

C.1.9 Interior Partition Walls - Single-Family Houses

For partition walls, 1210 solutions are generated. The density of solutions is shown in figure C.22 for the baseline and when applying relevant filters.

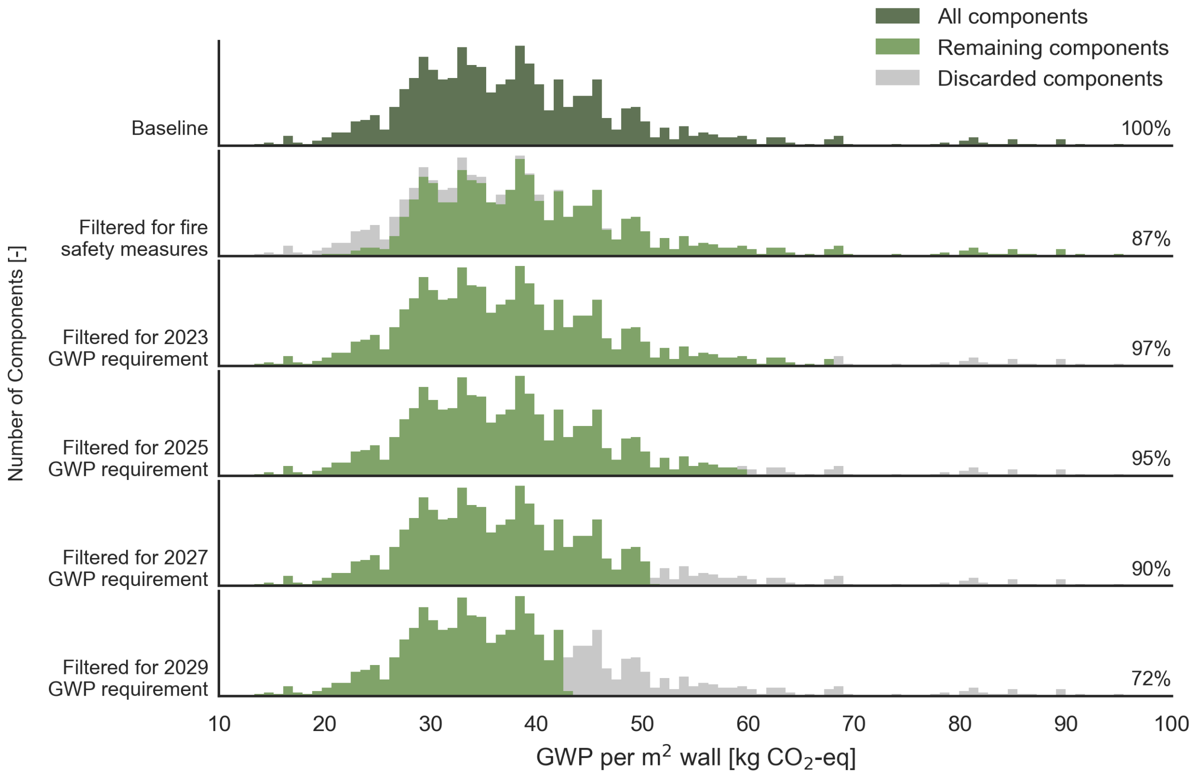


Figure C.22. Impact of one-at-a-time filtration on the distribution of GWP for interior partition walls in the single-family house typology.

The components discarded in each construction category are shown in figure C.23 for the partition interior walls.

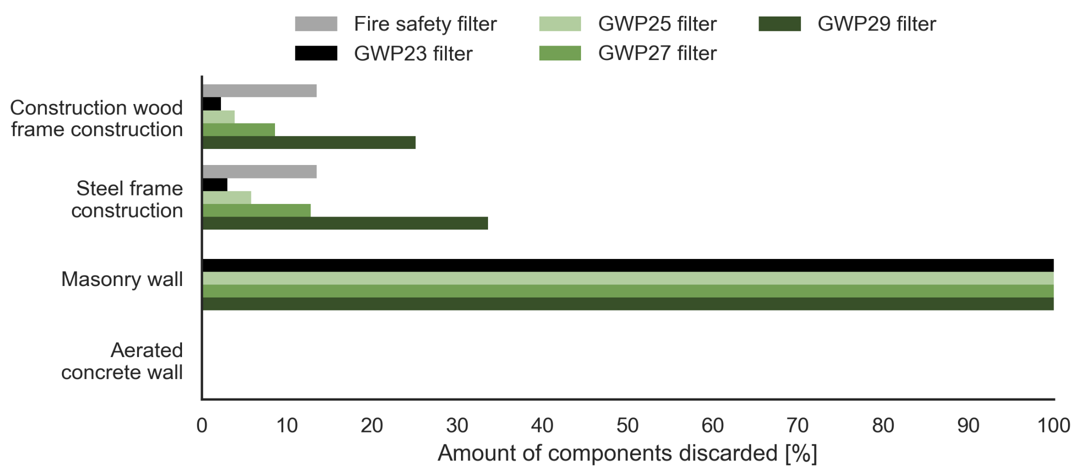


Figure C.23. Percentage of discarded components for each filter divided by component category for interior partition walls in the single-family house typology.

C.2 Cumulative Filtering

This section includes results from filtering the component groups using a cumulative filtering approach.

C.2.1 Exterior walls - Four-Storey buildings

When applying the filters in succession, the resulting amount of solutions is influenced by the degree to which the filters overlap. In figure C.24, the amount of solutions throughout the cumulative application of filters is illustrated for components with wooden frame constructions. The same is shown for non-wooden frame components in figure C.25. These two graphs are divided into two because of the significant difference between the number of solutions with a wood frame structure and solutions for other structures.

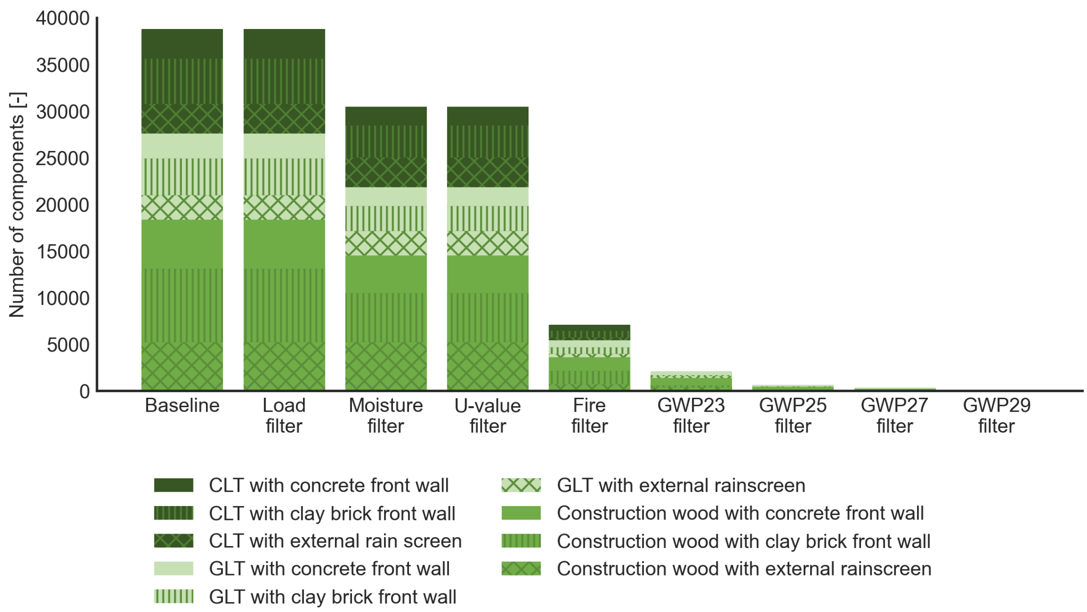


Figure C.24. Amount of solutions remaining after successive application of each filter for wooden frame exterior walls in the four-storey building typology.

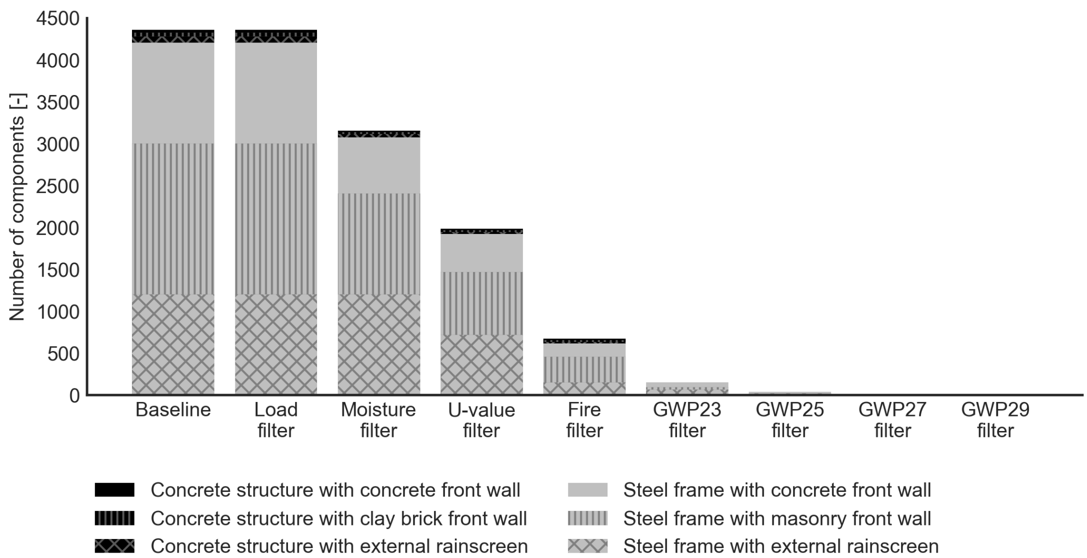


Figure C.25. Amount of solutions remaining after successive application of each filter for non-wooden exterior walls in the four-storey building typology.

To better illustrate how the GWP filters affect the different components categories, the remaining percentage of solutions is visualised in figure C.26, where the set of solutions after filtrating for load, fire, moisture, and U-value is used as the baseline.

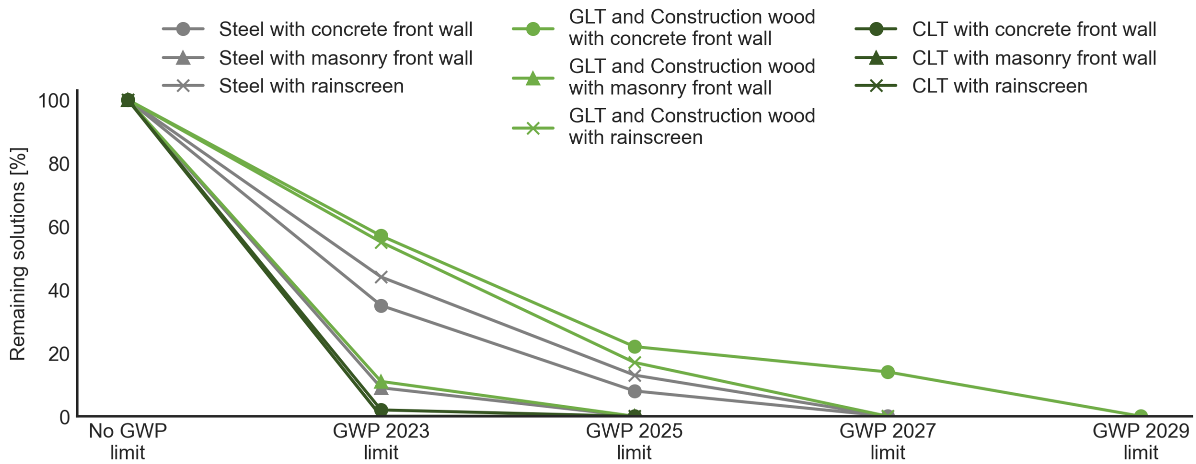


Figure C.26. Percentage of solutions remaining after application of each GWP filter for exterior walls in the four-storey building typology.

C.2.2 Roof Constructions - Four-Storey Buildings

The filters are added to the roof construction in succession to illustrate the total impact of the filters. The distribution of discarded components divided into material categories is shown in figure C.27 for the cumulative filter application.

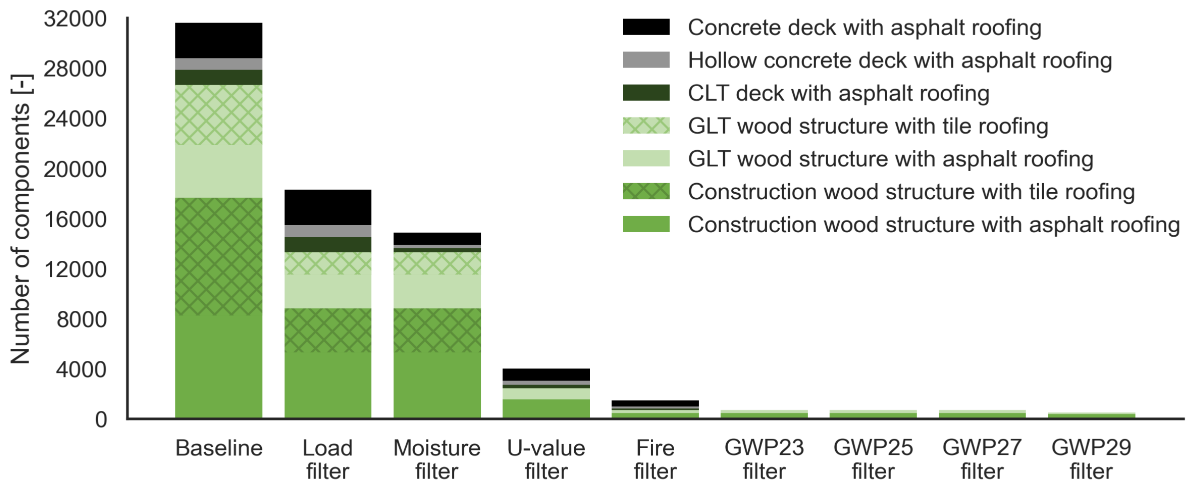


Figure C.27. Amount of solutions remaining after successive application of each filter for roofs in the four-storey building typology.

A percentage graph is used to illustrate the last five columns in the bar plot, and this is shown in figure C.39, where the set of solutions after filtrating for load, fire, moisture, and U-value is used as the baseline.

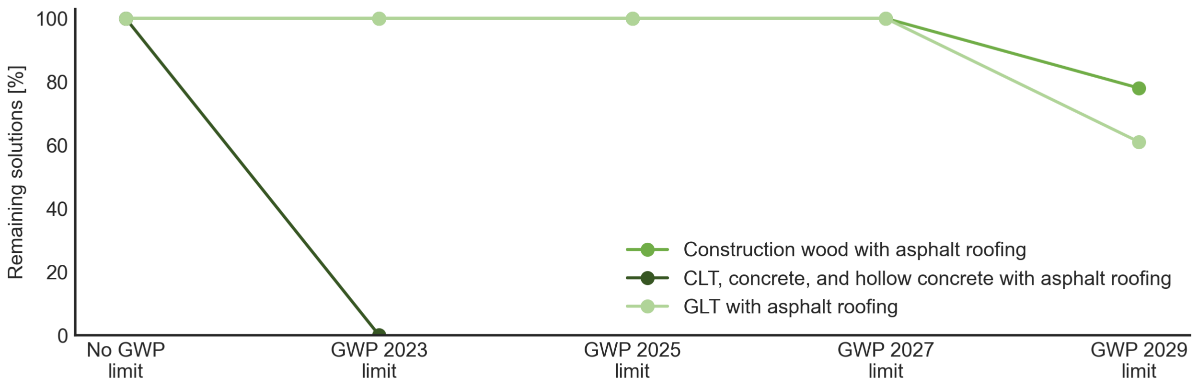


Figure C.28. Percentage of solutions remaining after application of each GWP filter for roofs in the four-storey building typology.

C.2.3 Horizontal Divisions - Four-Storey Buildings

The filters have been applied to the horizontal divisions in succession, and the number of components after each applied filter is shown in figure C.29.

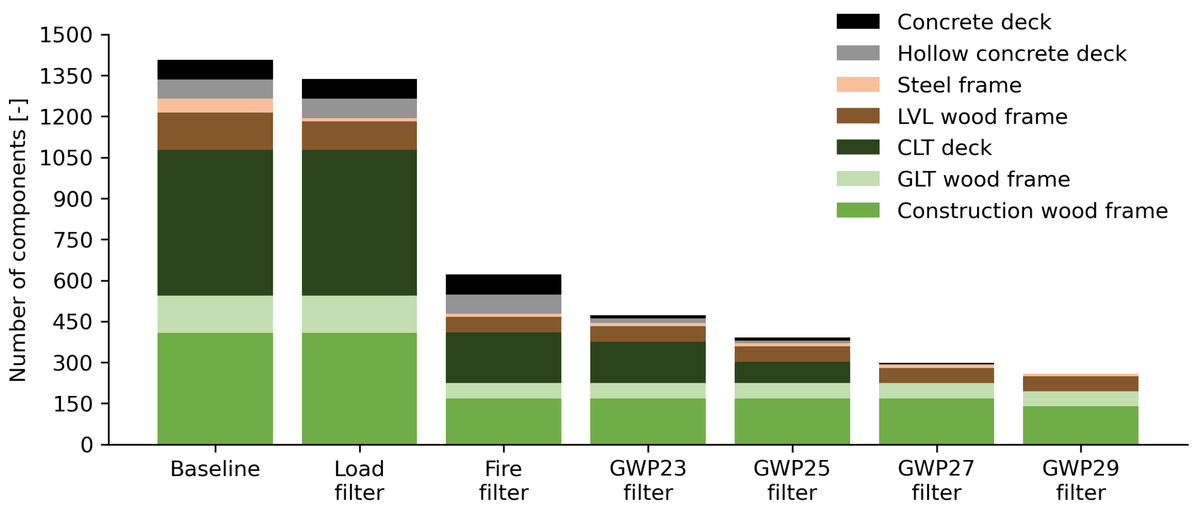


Figure C.29. Amount of solutions remaining after successive application of each filter for horizontal divisions in the four-storey building typology.

The amount of remaining components in the last five bars are illustrated in figure C.30 as a percentage value, using the set of solutions after filtrating for load, fire, moisture, and U-value as the baseline.

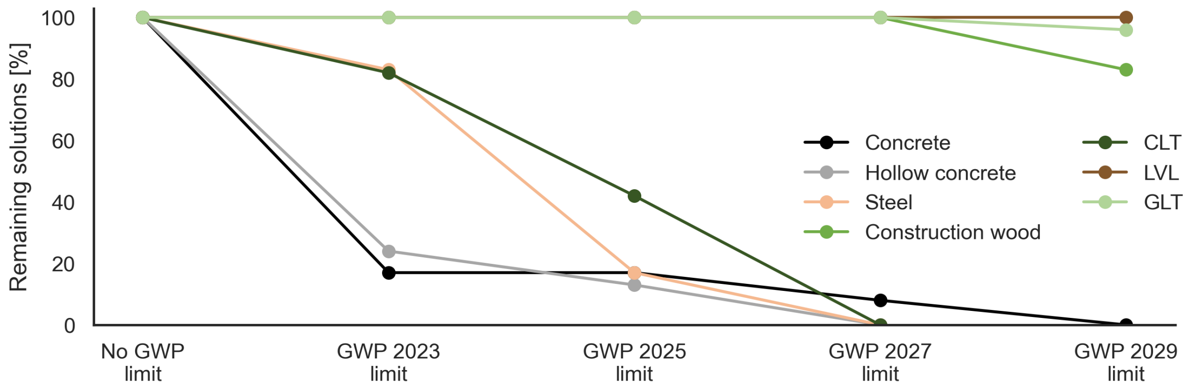


Figure C.30. Percentage of solutions remaining after application of each GWP filter for horizontal divisions in the four-storey building typology.

C.2.4 Bearing Interior Walls - Four-Storey Buildings

In figure C.31, the amount of remaining components in each construction category is illustrated when applying the filters in succession. The bearing interior walls are consisting of mainly wooden frame structures and only a few mineral solid constructions.

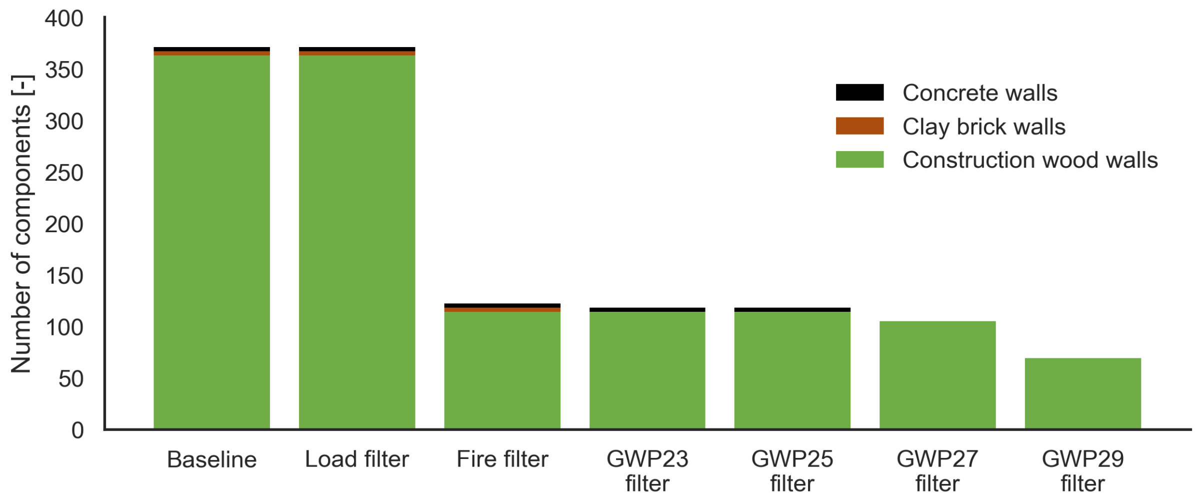


Figure C.31. Amount of solutions remaining after successive application of each filter for bearing interior walls in the four-storey building typology.

The amount of components remaining in the GWP filtering is illustrated as a percentage in figure C.32. The first point in the graph is the constructions passing the filters for load-bearing capacity and fire safety.

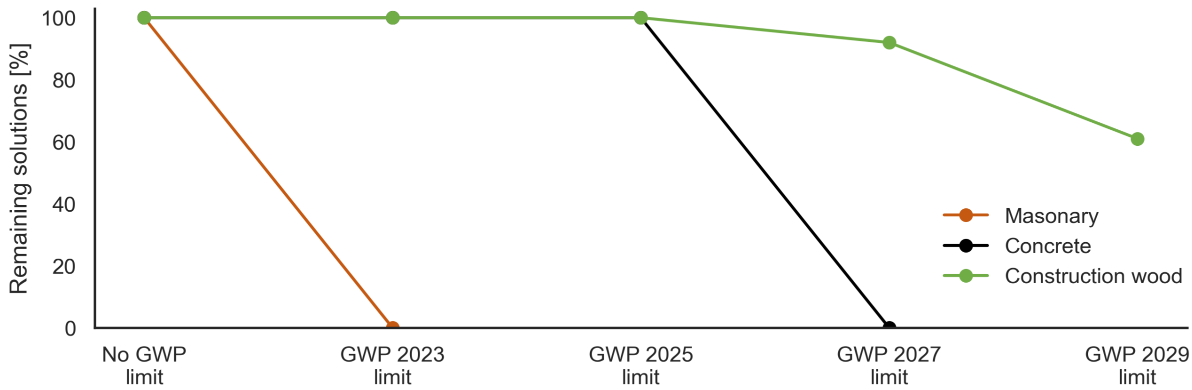


Figure C.32. Percentage of solutions remaining after application of each GWP filter for bearing interior walls in the four-storey building typology.

C.2.5 Interior Partition Walls - Four-Storey Buildings

In figure C.33, the amount of remaining components in each construction category is illustrated when applying the filters in succession. The partition walls are consisting of mainly frame structures and only a few mineral solid constructions.

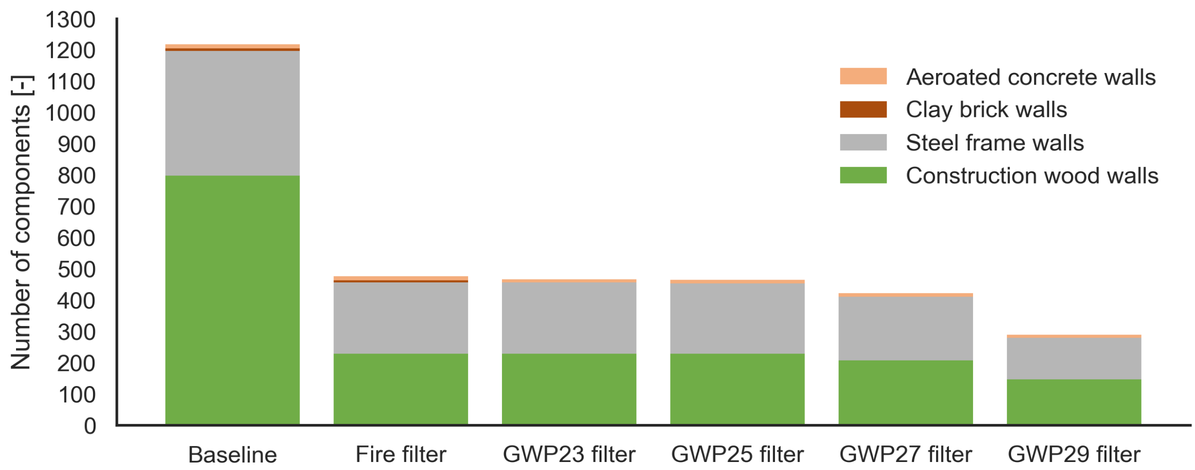


Figure C.33. Amount of solutions remaining after successive application of each filter for interior partition walls in the four-storey building typology.

The amount of components remaining in the GWP filtering is illustrated as a percentage in figure C.34. The first point in the graph is the constructions passing the filters for load-bearing capacity and fire safety.

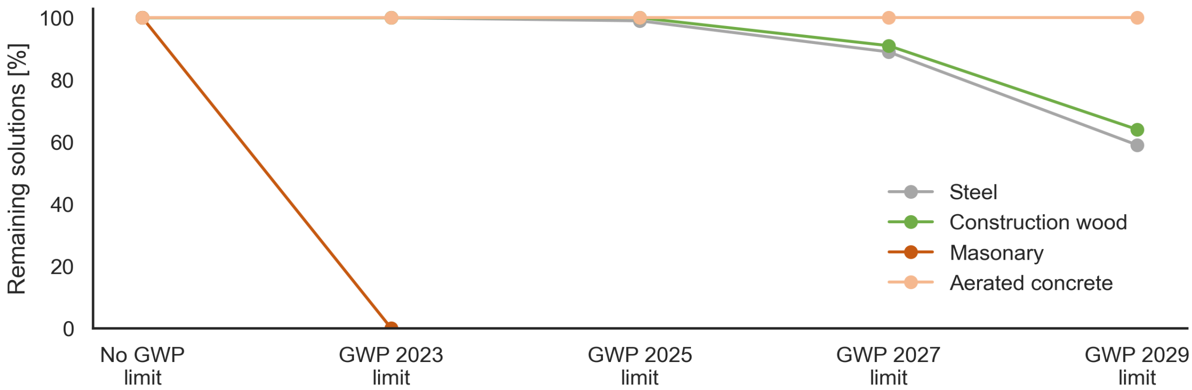


Figure C.34. Percentage of solutions remaining after application of each GWP filter for interior partition walls in the four-storey building typology.

C.2.6 Exterior walls - Single-Family Houses

When applying the filters in succession, the resulting amount of solutions is influenced by the degree to which the filters overlap. In figure C.35, the number of solutions throughout the cumulative application of filters on components with wooden frame constructions are illustrated. The same is shown for non-wooden frame components in figure C.36. These two graphs are divided into two because of the significant difference between the number of solutions with a wood frame structure and solutions without a wood frame structure.

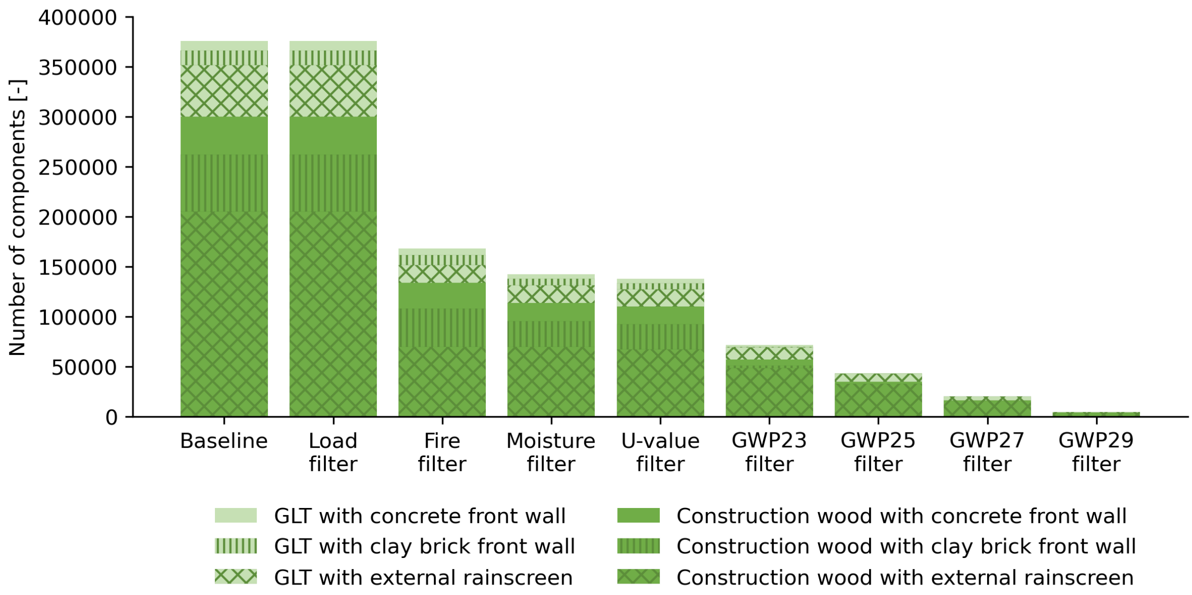


Figure C.35. Amount of solutions remaining after successive application of each filter for wooden frame exterior walls in the single-family house typology.

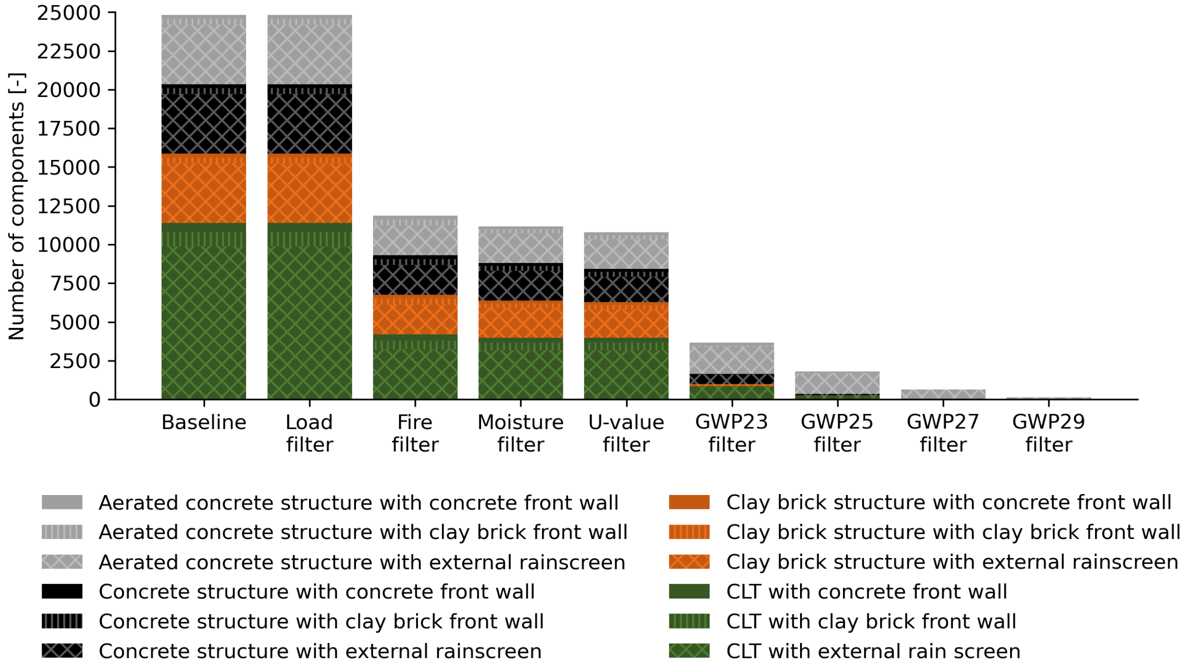


Figure C.36. Amount of solutions remaining after successive application of each filter for non-wooden frame exterior walls in the single-family house typology.

To better illustrate how the GWP filters affect the different components categories, the remaining percentage of solutions is visualised in figure C.37, where the set of solutions after filtrating for load, fire, moisture, and U-value is used as the baseline.

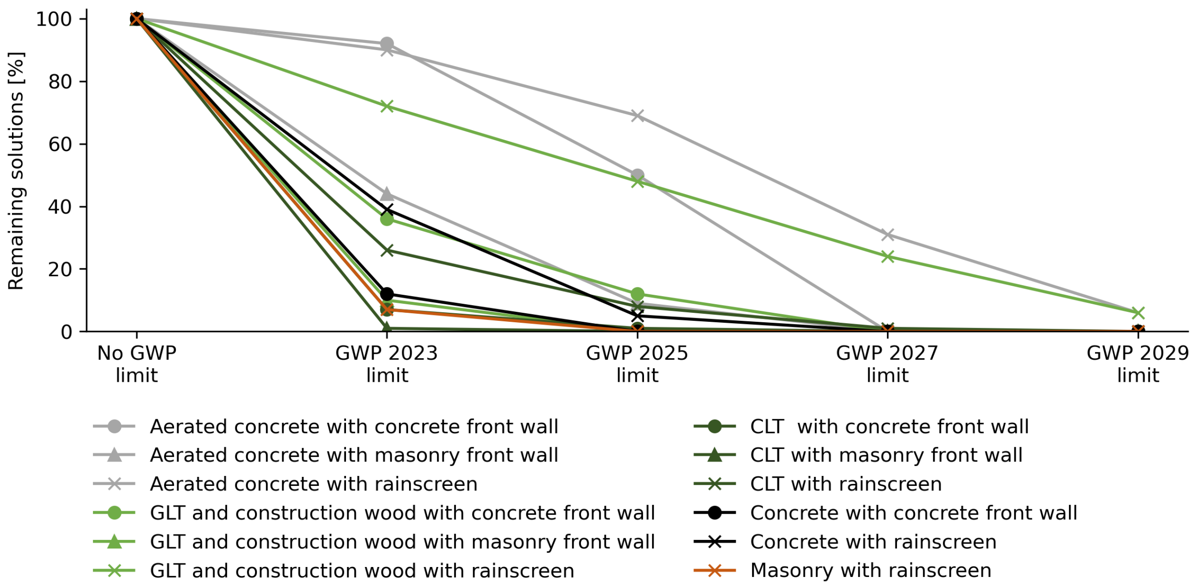


Figure C.37. Percentage of solutions remaining after application of each GWP filter for exterior walls in the single-family house typology.

C.2.7 Roof Constructions - Single-Family Houses

When applying the filters in succession, the resulting amount of solutions is influenced by the degree to which the filters overlap. In figure C.38, the amount of solutions throughout the cumulative application of filters is illustrated.

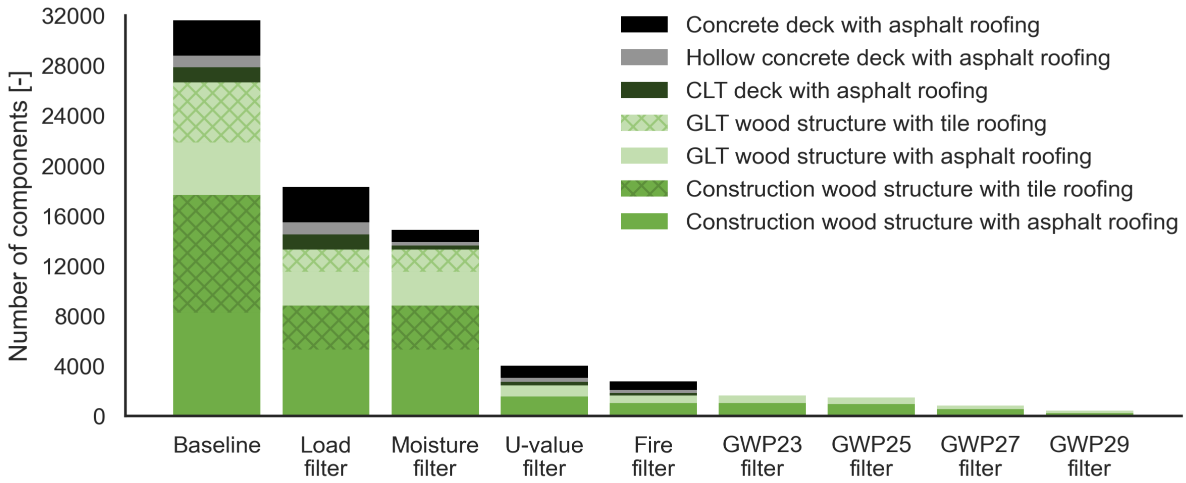


Figure C.38. Amount of solutions remaining after successive application of each filter for roofs in the single-family house typology.

To better illustrate how the GWP filters affect the different components categories, the percentage of remaining solutions is visualised in figure C.39, where the set of solutions after filtrating for load, fire, moisture, and U-value is used as the baseline.

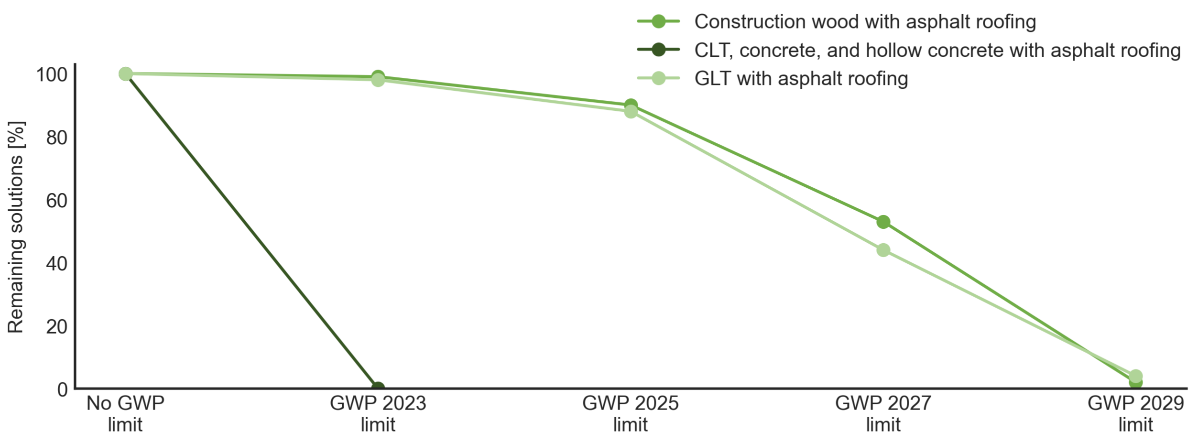


Figure C.39. Percentage of solutions remaining after application of each GWP filter for roofs in the single-family house typology.

C.2.8 Bearing Interior Walls - Single-Family Houses

In figure C.40, the amount of remaining components in each construction category is illustrated when applying the filters in succession. The bearing interior walls are consisting of mainly wooden frame structures and only a few mineral solid constructions.

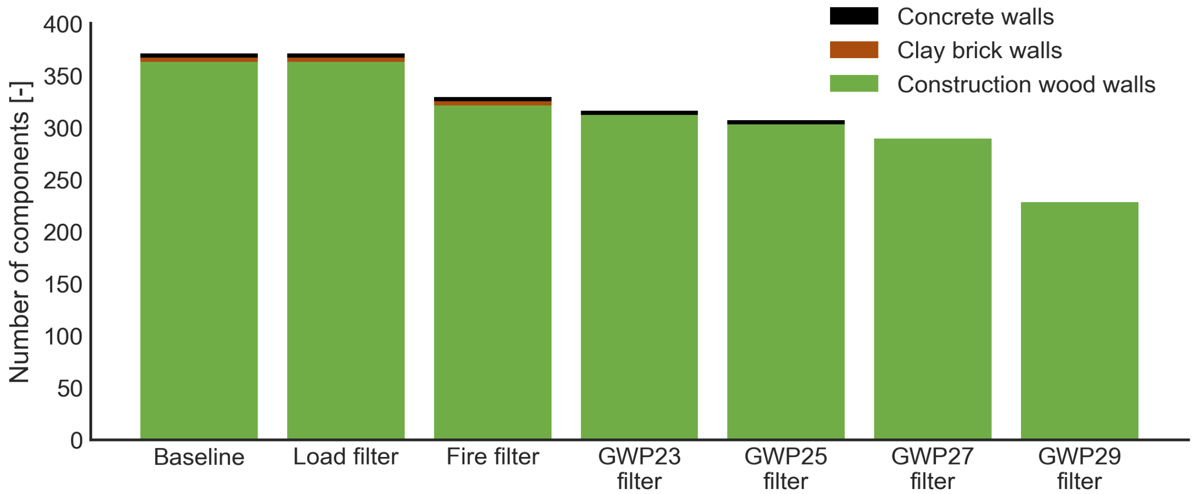


Figure C.40. Amount of solutions remaining after successive application of each filter for bearing interior walls in the single-family house typology.

The amount of components remaining in the GWP filtering is illustrated as a percentage in figure C.41. The first point in the graph is the constructions passing the filters for load-bearing capacity and fire safety.

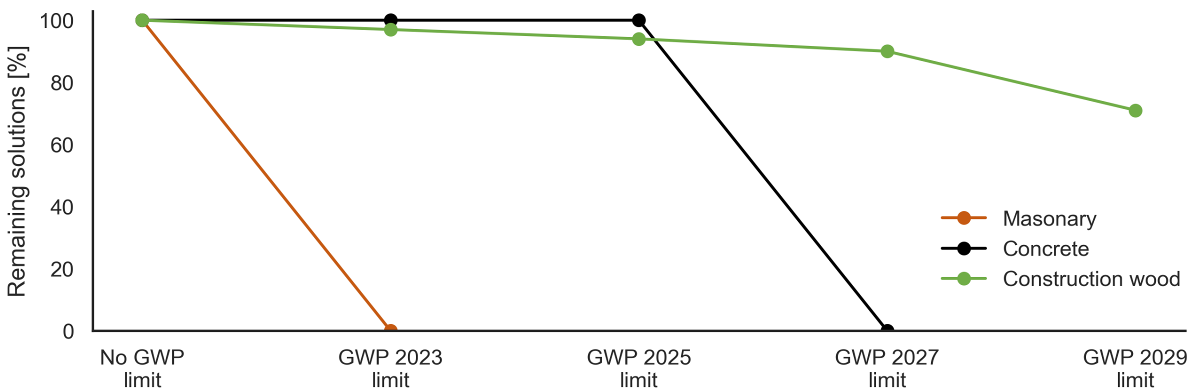


Figure C.41. Percentage of solutions remaining after application of each GWP filter for bearing interior walls in the single-family house typology.

C.2.9 Interior Partition Walls - Single-Family Houses

In figure C.42, the amount of remaining components in each construction category is illustrated when applying the filters in succession. The partition walls are consisting of mainly frame structures and only a few mineral solid constructions.

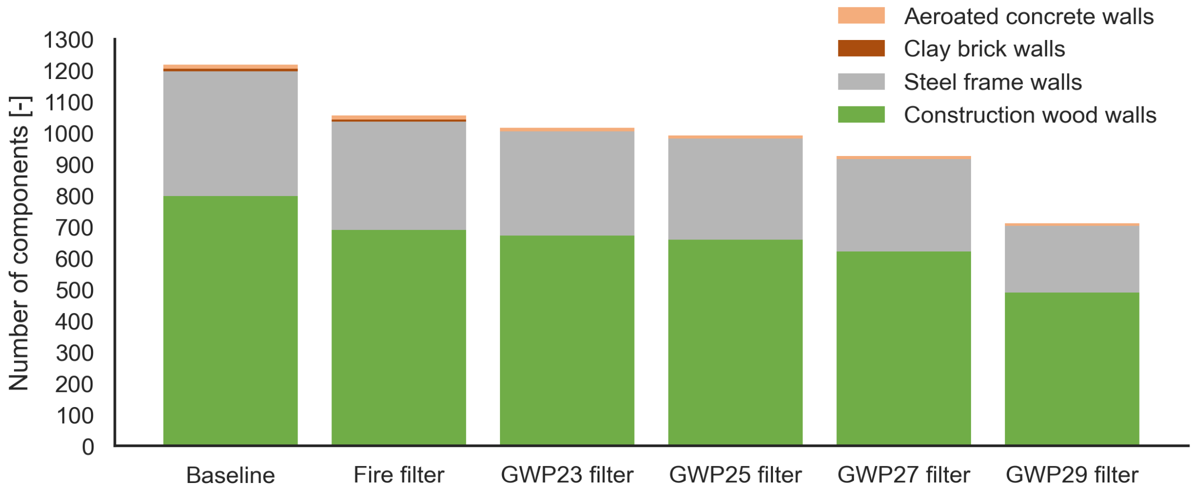


Figure C.42. Amount of solutions remaining after successive application of each filter for interior partition walls in the single-family house typology.

The amount of components remaining in the GWP filtering is illustrated as a percentage in figure C.43. The first point in the graph is the constructions passing the filters for load-bearing capacity and fire safety.

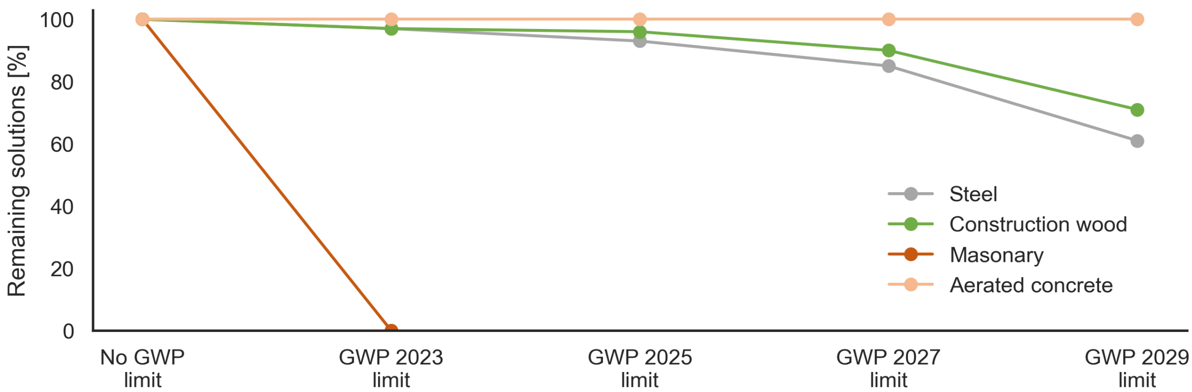


Figure C.43. Percentage of solutions remaining after application of each GWP filter for interior partition walls in the single-family house typology.

C.3 Environmental Impact Indicators in Cumulative Filtering

This section includes an overview of the other included LCA indicators in the cumulative filtering process for each building component. The overview covers mean values for components divided into the different structural material types.

C.3.1 Exterior walls - Four-Storey buildings

As the different filters are applied, the materials used in the remaining components will be more frequent in the remaining set of solutions. As the environmental data differ, the filtration may result in changes in the overall environmental impacts of the components. The mean value for each environmental impact and resource use parameter tracked in this project is shown for each component category in figure C.44. From this figure, the PENRT, PERT, ADP_f, and GWP seem to correlate.

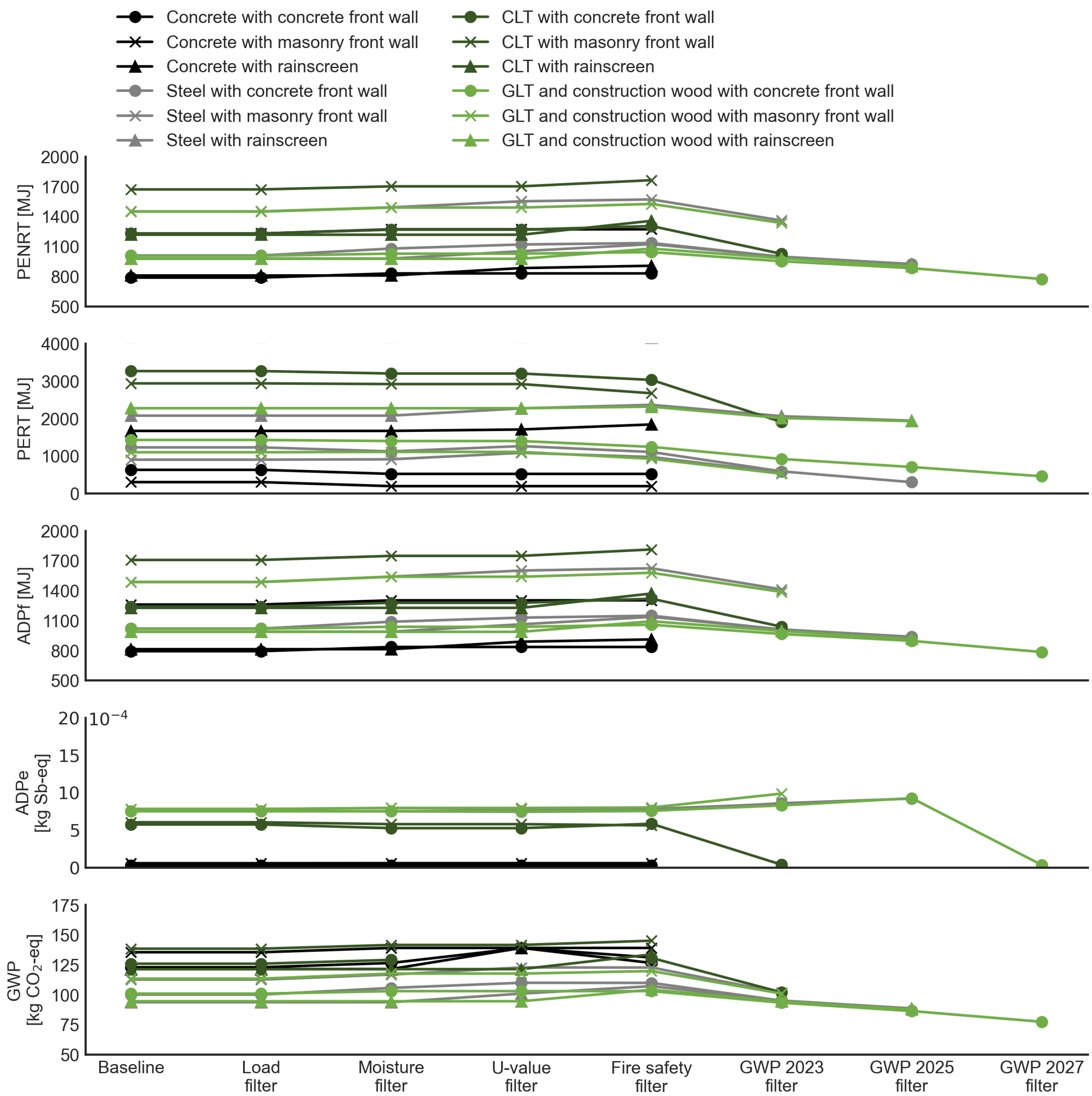


Figure C.44. Mean values for LCA indicators after successive application of filters for exterior walls in the four-Storey building typology.

C.3.2 Roof Constructions - Four-Storey Buildings

In this project, LCA indicators covering resource use and energy use are calculated along with the GWP. The influence of the filtering process on the mean value of each considered indicator is shown in figure C.45.

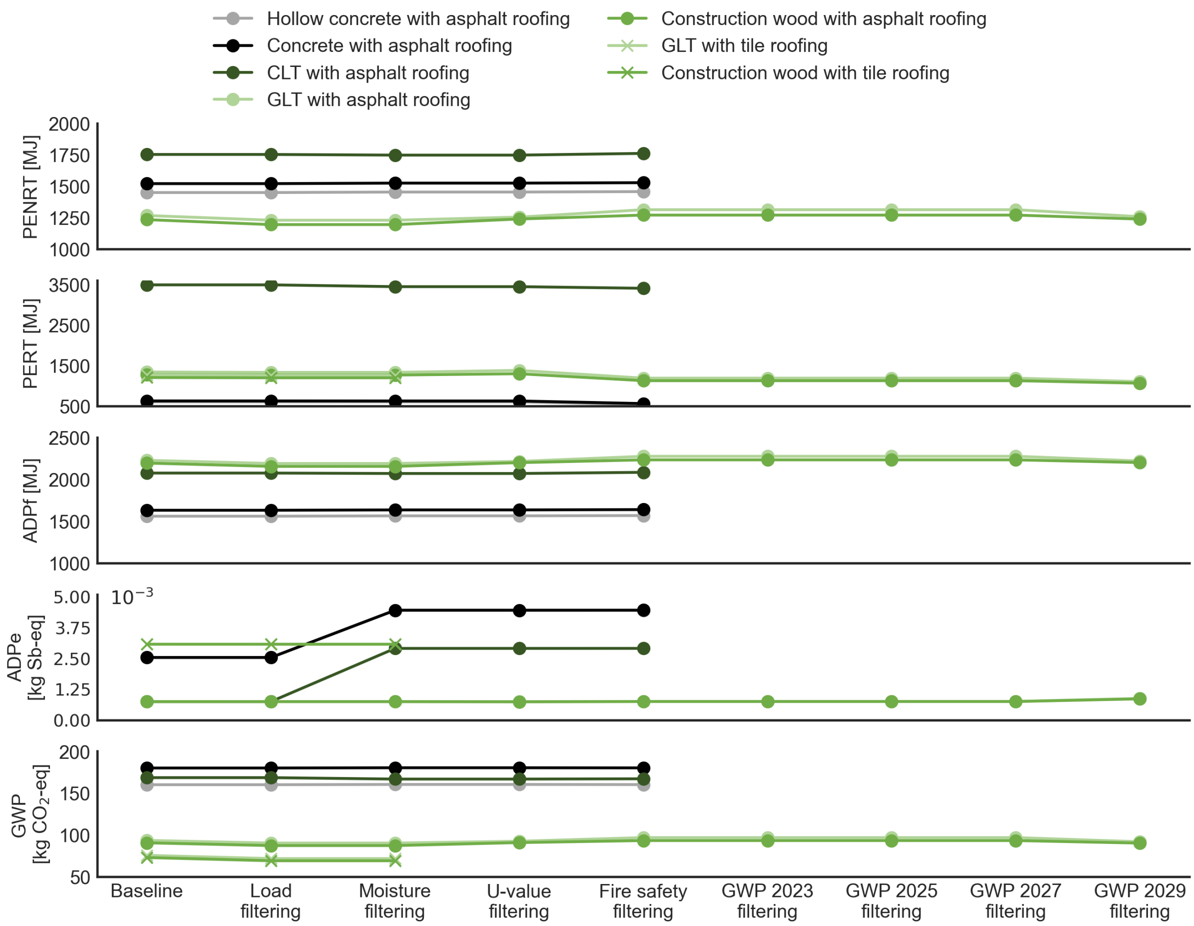


Figure C.45. Mean values for LCA indicators after successive application of filters for roofs in the four-storey building typology.

C.3.3 Horizontal Divisions - Four-Storey Buildings

The impact from each filter on other selected LCA indicators are shown in figure C.46, divided into the construction groups. The selected LCA indicators are ADPe, ADPf, PERT, and PENRT, and the graph shows the mean value for each indicator for components in each construction group.

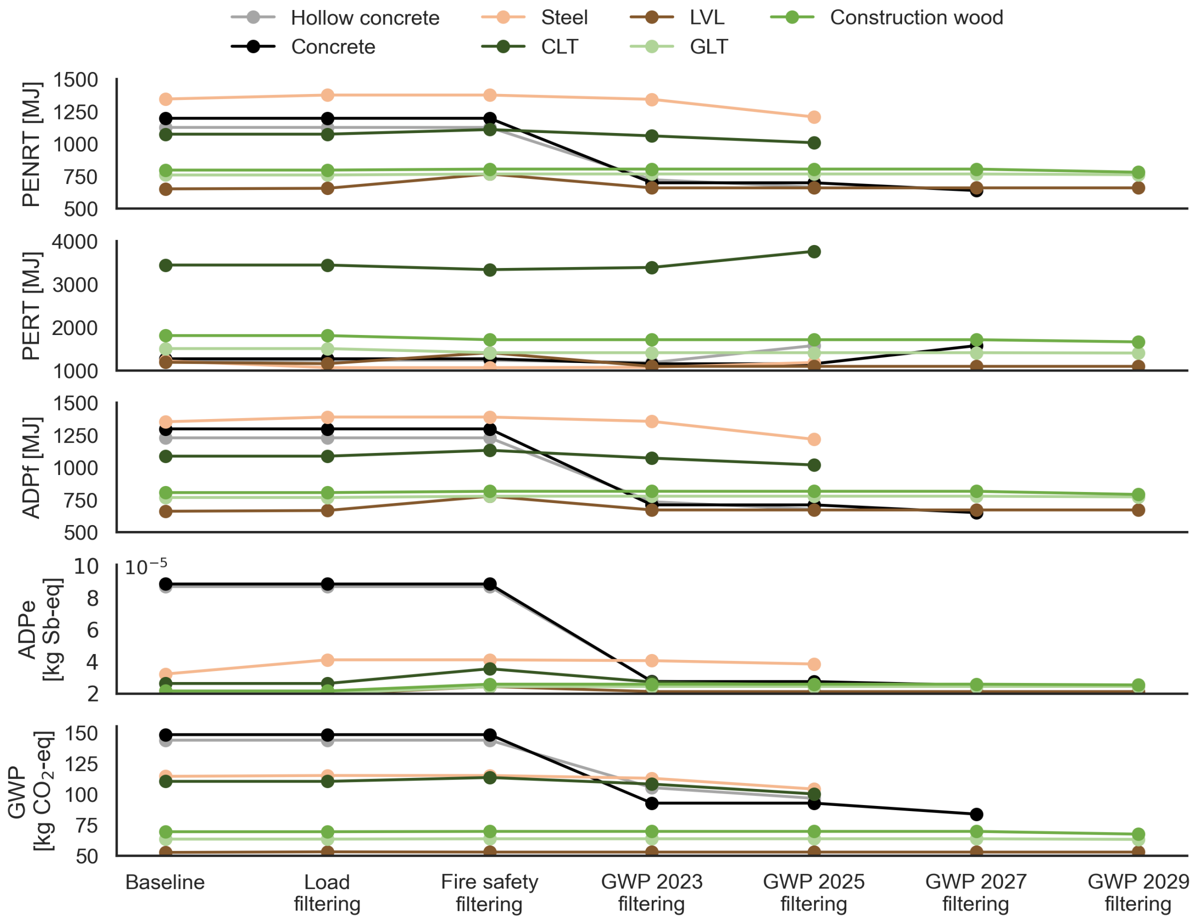


Figure C.46. Mean values for LCA indicators after successive application of filters for horizontal divisions in the four-storey building typology.

C.3.4 Bearing Interior Walls - Four-Storey Buildings

To assess the impact of the filter on other LCA indicators, the ADPe, ADPf, PERT, and PENRT are included in the component evaluation. The mean value for each indicator in each construction category throughout the cumulative filtering is shown in figure C.47.

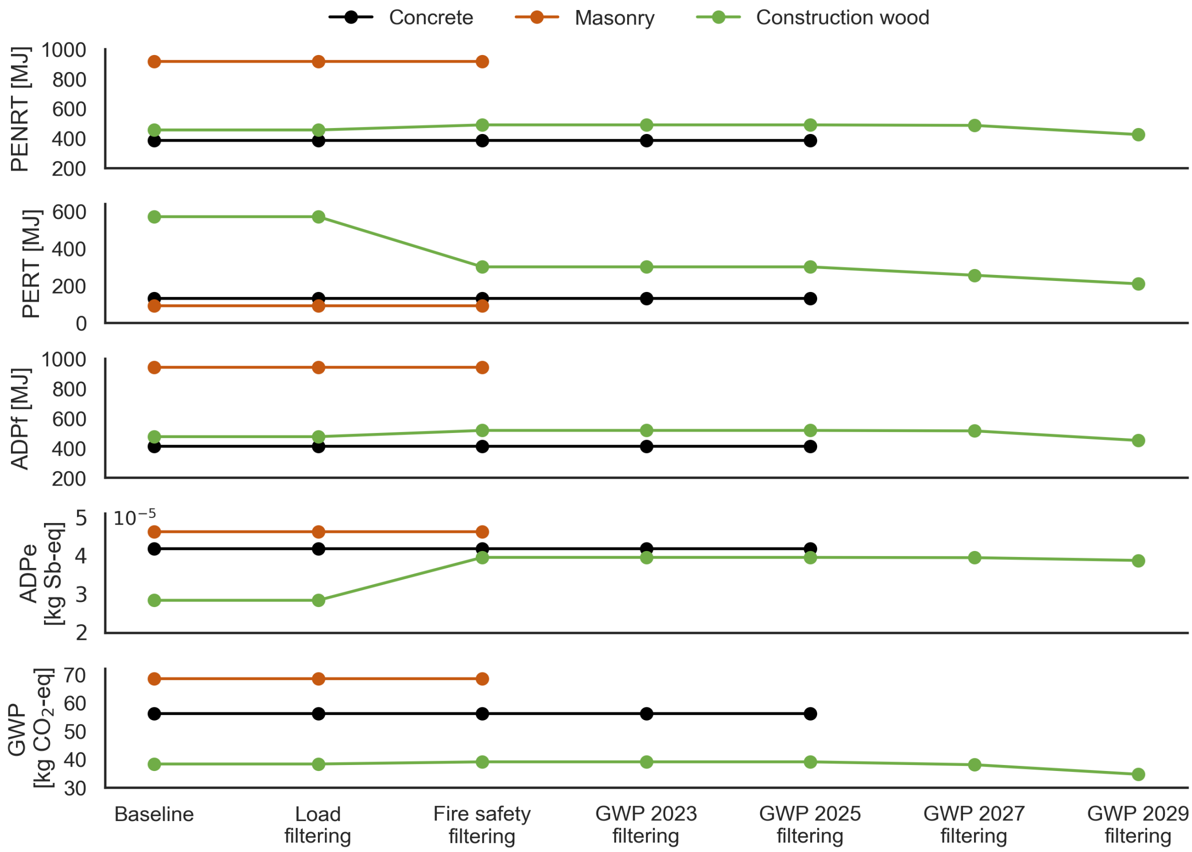


Figure C.47. Mean values for LCA indicators after successive application of filters for bearing interior walls in the four-storey building typology.

C.3.5 Interior Partition Walls - Four-Storey Buildings

To assess the impact of the filter on other LCA indicators, the ADPe, ADPf, PERT, and PENRT are included in the component evaluation. The mean value for each indicator in each construction category throughout the cumulative filtering is shown in figure C.48.

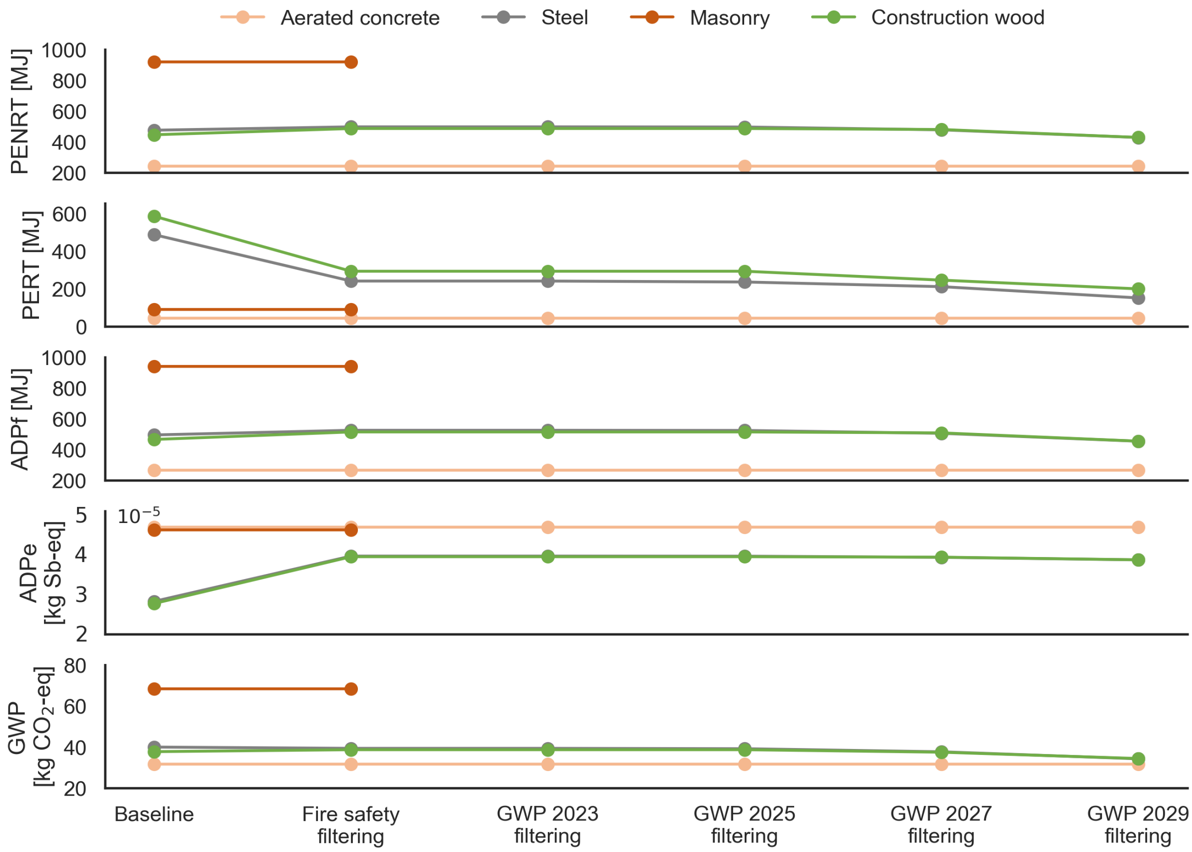


Figure C.48. Mean values for LCA indicators after successive application of filters for interior partition walls in the four-storey building typology.

C.3.6 Exterior walls - Single-Family Houses

As the different filters are applied, the materials used in the remaining components will be more frequent in the remaining set of solutions. As the environmental data differ, the filtration may result in changes in the overall environmental impacts of the components. The mean value for each environmental impact and resource use parameter tracked in this project is shown for each component category in figure C.49. From this figure, the PENRT, PERT, ADP_f, and GWP seem to correlate.

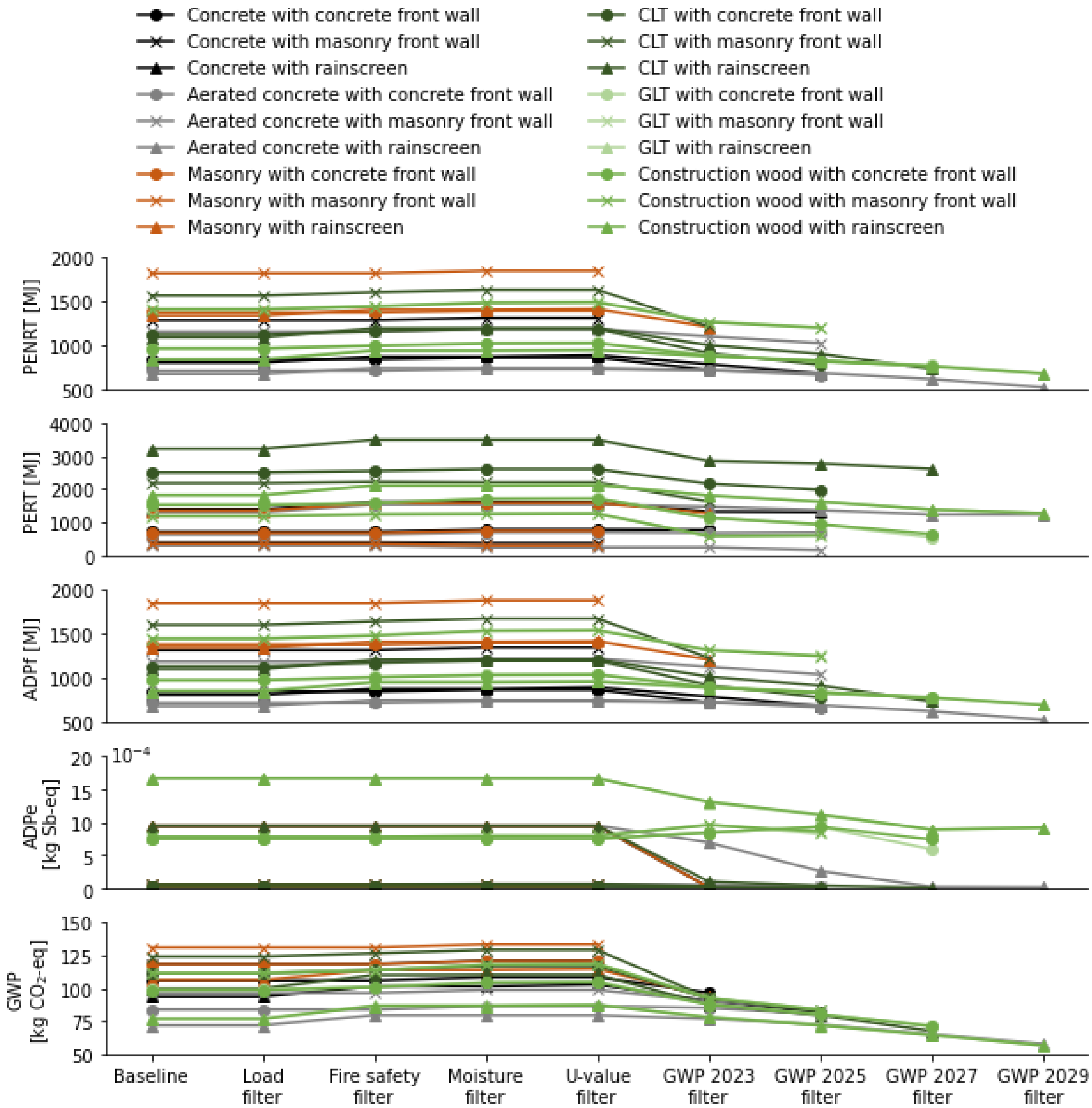


Figure C.49. Mean values for LCA indicators after successive application of filters for exterior walls in the single-family house typology.

C.3.7 Roof Constructions - Single-Family Houses

As the different filters are applied, the frequency of particular materials used in the remaining components will be more frequent in the remaining set of solutions. As the environmental datasets of materials differ, the filtration may result in changes in the overall environmental impacts of the components. The mean value for each environmental impact and resource use parameter tracked in this project is shown for each component category in figure C.49. From this figure, the PENRT, PERT, ADP_f, and GWP seem to correlate.

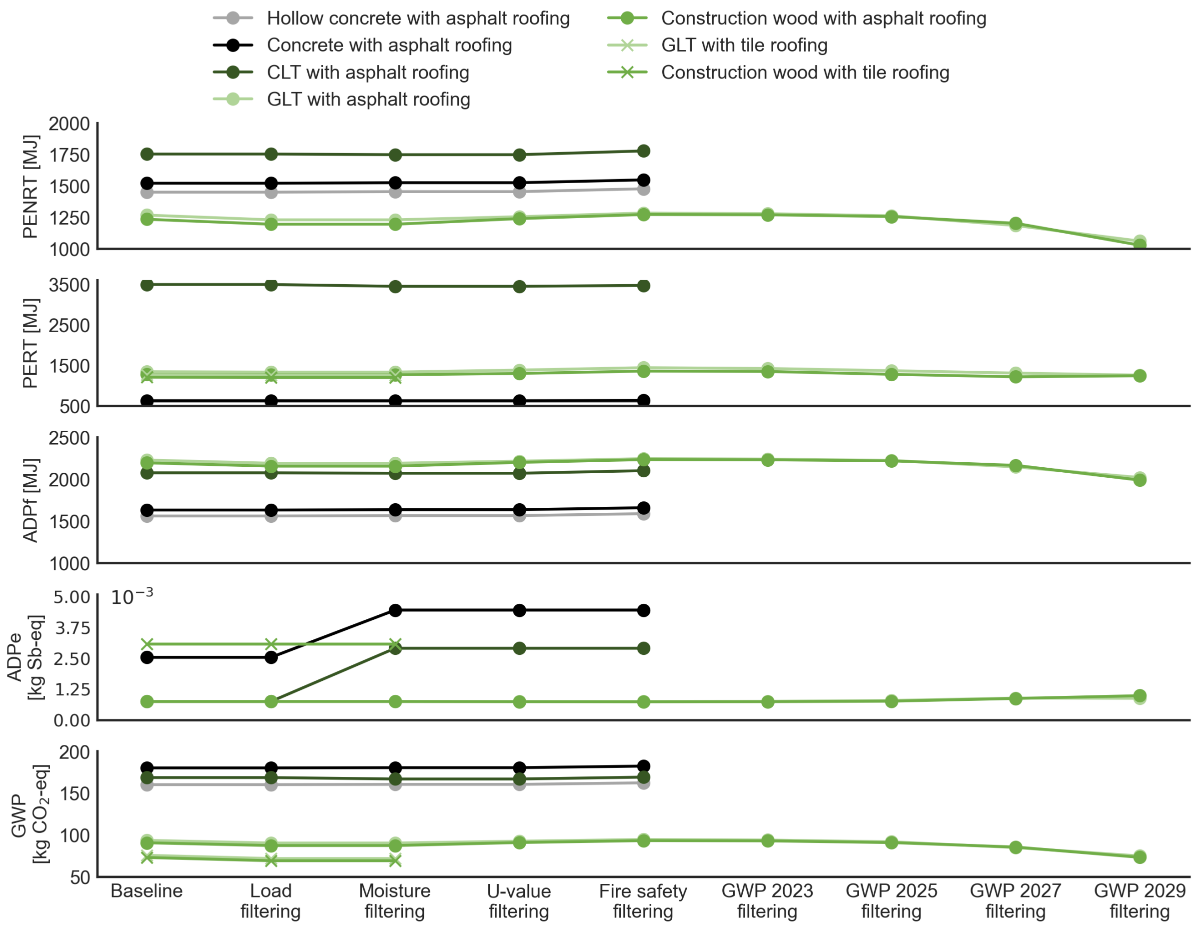


Figure C.50. Mean values for LCA indicators after successive application of filters for roofs in the single-family house typology.

C.3.8 Bearing Interior Walls - Single-Family Houses

To assess the impact of the filter on other LCA indicators, the ADPe, ADPf, PERT, and PENRT are included in the component evaluation. The mean value for each indicator in each construction category throughout the cumulative filtering is shown in figure C.51.

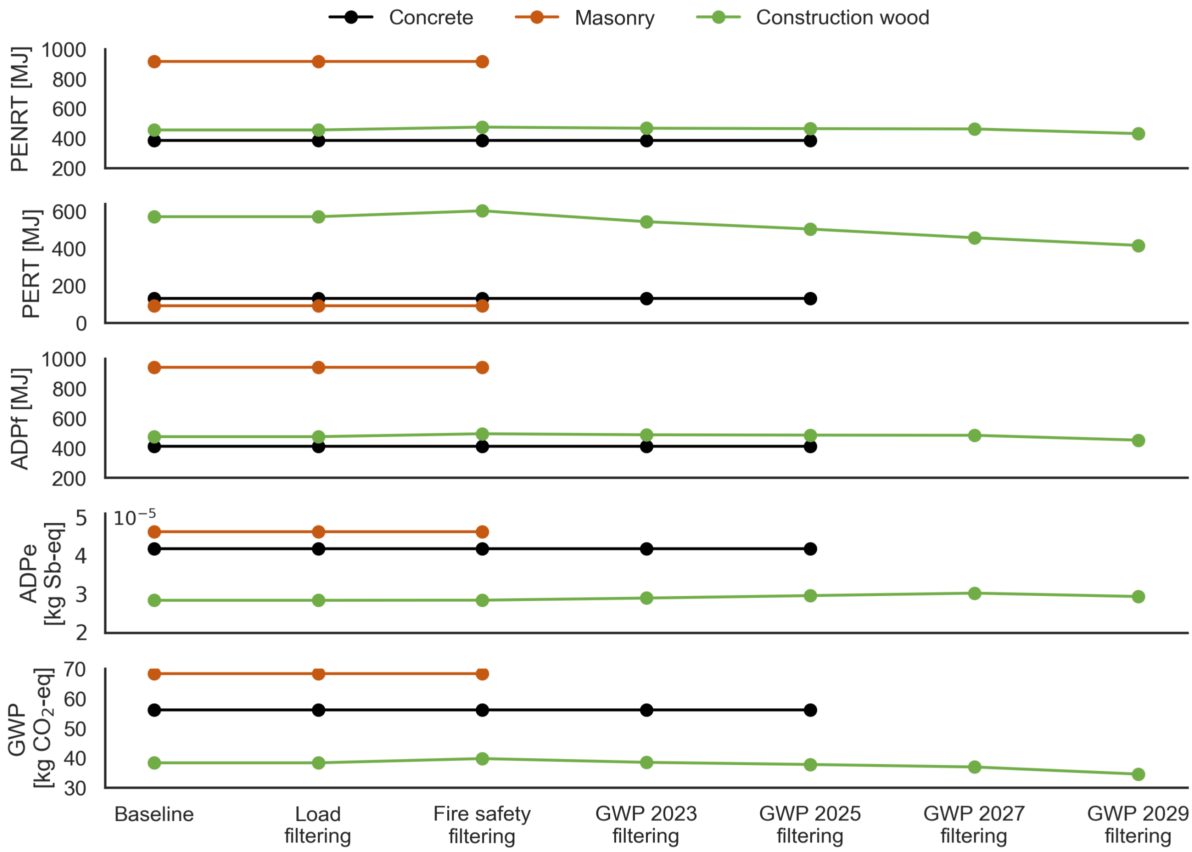


Figure C.51. Mean values for LCA indicators after successive application of filters for bearing interior walls in the single-family house typology.

C.3.9 Interior Partition Walls - Single-Family Houses

To assess the impact of the filter on other LCA indicators, the ADPe, ADPf, PERT, and PENRT are included in the component evaluation. The mean value for each indicator in each construction category throughout the cumulative filtering is shown in figure C.52.

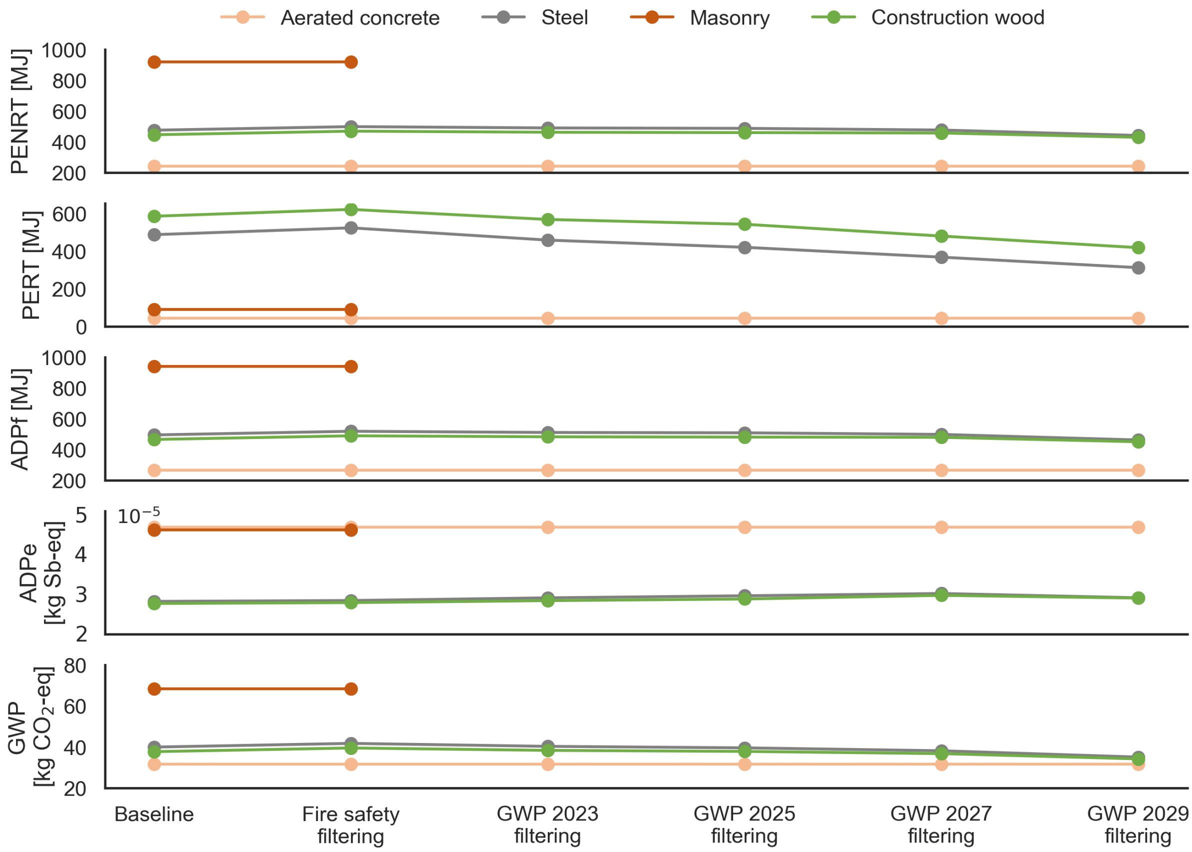


Figure C.52. Mean values for LCA indicators after successive application of filters for interior partition walls in the single-family house typology.

C.4 Summary

Applying the GWP limits for 2023, 2025, 2027, and 2029 discard all components above the limits in the filters. The amount of solutions remaining is highly dependent on the environmental data of the materials used. Utilising other available environmental datasets or EPDs specific to the used products may shift the density of solutions significantly toward a low GWP, resulting in more of the generated set of solutions remaining after the application of the GWP filters.

Note that the solutions investigated in this project only represent a subset of the actual design space as only a handful of design approaches are modelled and further variations for the modelled micro components are possible. Still, general conclusions on the investigated building component designs may be drawn from the components investigated in the present project. When doing this, it is impotent to consider the basis of the filtering and its limitations.

D Description of Component Filters

This appendix includes a description of the filtering process used to filter the macro components generated in this project. This includes the filtering principle for load-bearing capacity, fire safety and moisture performance. Additionally, the appendix includes a study on building regulations and existing new-built buildings in order to determine limits for the U-value and GWP of different constructions. These are used to filter components for GWP and U-value.

D.1 Load-bearing Capacity Filtering

The load-bearing capacity filter is performed as a true or false filter, evaluating the load-bearing capacity in cold and warm scenarios. The filter is true, if the load-bearing capacity is higher than the loads for both the cold and the warm scenario. Calculation of the loads is described in appendix L and calculation of the load bearing capacity is described in appendix H.

D.2 Fire Safety Filtering

This section includes a description of the filtering method used in the fire safety filter. In the generation of macro components, there are generated components that fulfil the prescriptive fire safety solutions and components that do not fulfil specific parts of the regulations. The principle behind filtering is to sort out the components that do not fulfil the Danish prescriptive solutions. The discarded components are components that are build on basis of less strict prescriptive solutions that are inspired by the regulations in other European countries. The study on regulations in Denmark and other countries is shown in appendix A.

Three aspects of the prescriptive solutions are investigated, these are listed below. Filter number one is relevant for both one-storey and four-storey buildings, and filter number two and three are only relevant for the four-storey buildings.

1. Prescriptive method for fulfilling the requirement to the fire protection ability of K_1 10
2. Prescriptive requirement to reaction to fire for interior surfaces in four-storey buildings
3. Prescriptive requirement to reaction to fire for insulation materials when using wooden structures in four-storey buildings

All three requirements are chosen because they have a significant impact on the material choice and possibility of using biogenic materials. Additionally, less strict requirements were found in other countries for all three aspects. Most requirements are relevant for the four-storey building, as the fire safety requirements are more strict. The three filters are described in the following sections. It is assumed that the prescriptive solutions can be deviated from if the other fire resistance requirements for the components are fulfilled.

D.2.1 Filter 1: Fire Protection Ability

This filter is used for both the one-storey building components and the four-storey building components, as K_1 10 is a requirement in all building typologies [BR18, 2022].

The filter is indirectly challenging the prescriptive solutions, as it is based on the method for obtaining a fire protection ability of K_1 10 for cladding, which is described in the European standard DS/EN 13501-2. When the standard is used, the K_1 10 classification is only valid if the cladding material is mounted on a material with a density of at least $300\,\text{kg/m}^3$, which means that the cladding must be mounted on a solid board and not an insulation material [DS/EN 13501-2, 2016]. This limitation may cause a higher environmental impact than necessary because of the higher material use.

The K_1 10 requirement is relevant for both interior cladding and wind protection in frame wall constructions.

D.2.2 Filter 2: Reaction to Fire in Four-storey Buildings

In four-storey buildings, the requirement to the reaction to fire for interior surfaces is stricter than for one-storey buildings. The requirement is a fixed requirement, and thereby this filter is directly challenging the prescriptive solutions.

For this filter, it is assumed that the interior surface reaction to fire requirement from one-storey buildings can be used for the four-storey building components.

Using the requirement for one-storey buildings instead of the four-storey requirement means that the interior cladding of walls and ceilings can be D-s2,d2 or better instead of B-s1,d0 or better [BR18, 2022].

D.2.3 Filter 3: Reaction to Fire for Insulation Materials in Four-storey Buildings

The insulation used in a four-storey building with a wooden load-bearing construction must at least have a reaction to fire of B-s1,d0 [BR18, 2022]. This part of the prescriptive solutions eliminates a lot of potential for using biogenic materials.

As the requirement to the insulation material is a fixed requirement in the prescriptive solutions, this filter directly challenges the regulations.

D.3 Moisture Performance Filtering

From the moisture study performed on the components in this project, several filtration rules are defined to sort out macro components in regard to the moisture performance. The moisture study is described in appendix K, and the rules are based on the name of the micro components. All micro components are listed in appendix M.

D.3.1 Roofs

For flat non-ventilated roofs, the components are discarded in the moisture filtration if they contain any of the following vapour retarders:

- VB.003
- VB.004
- VB.005

D.3.2 Exterior Walls for Single-family Housing

For exterior walls with mineral structures and cladding, the components are discarded in the moisture filtration if they contain:

- EW.EC.004
- Wood fibre insulation and (EW.EC.001, EW.EC.002)
- Wood fibre insulation and EW.EC.005 and (EW.S1.001, EW.S1.003, EW.S1.008, EW.S1.010)
- Cellulose insulation and EW.EC.005 and (EW.S1.001, EW.S1.003) + EW.IC.001
- Cellulose insulation and EW.EC.005 and EW.S1.008, EW.S1.010)

For exterior walls with CLT structures, the components are discarded in the moisture filtration if they contain:

- EW.EC.004
- (Wood fibre insulation, cellulose insulation) and (EW.EC.001, EW.EC.002)

For exterior walls with frame structures and mineral cladding, the components are discarded in the moisture filtration if they contain:

- EW.EC.001
- EW.EC.002 and EW.WP.006
- (Wood fibre insulation, cellulose insulation) and EW.EC.002
- EW.WP.004

D.3.3 Exterior Walls for Four-storey Housing

For exterior walls with mineral structures and cladding, the components are discarded in the moisture filtration if they contain:

- EW.EC.004
- (Wood fibre insulation, cellulose insulation)

For exterior walls with CLT structures, the components are discarded in the moisture filtration if they contain:

- EW.EC.004
- (Wood fibre insulation, cellulose insulation) and (EW.EC.001, EW.EC.002)

For exterior walls with frame structures and mineral cladding, the components are discarded in the moisture filtration if they contain:

- EW.EC.001
- EW.EC.002 and EW.WP.006
- (Wood fibre insulation, cellulose insulation) and (EW.EC.002, EW.EC.003)
- EW.WP.004

D.4 U-value Limit

To be able to filter away building components that does not fit the current requirements to the building envelope, a U-value limit is determined for roof and exterior wall constructions.

D.4.1 Building Regulations and Thermal Bridges

The Danish building regulations include requirements for the U-value of constructions in new-built buildings, which is $0.20\,\mathrm{W/m^2K}$ for roof constructions and $0.30\,\mathrm{W/m^2\,K}$ for exterior walls [BR18, 2022]. To fulfil these requirements, the U-value calculation must cover the total transmission loss of the components, including thermal bridges.

In this project, the calculated U-value for macro components in the building envelope does not take all thermal bridges into account. The building regulations state, that the total transmission loss is typically 50-$70\,\%$ higher when the thermal bridges are included in the calculation [BR18, 2022]. On that basis, the building regulations recommend that the calculated U-value should be increased with a minimum of $50\,\%$ if the thermal bridges are not considered [BR18, 2022]. This corresponds to a $33\,\%$ decrease in the U-value requirement from the building regulations. In table D.1, the requirement is shown along with the $33\,\%$ decreased U-value.

Table D.1. Danish requirement to U-values and recommendation to U-value when not considering thermal bridges [BR18, 2022].

Construction	BR18 requirement [W/m^2 K]	BR18 recommendation without thermal bridges [W/m^2 K]
Exterior Wall	0.30	0.20
Roof	0.20	0.13

The impact of thermal bridges stated in the building regulations has been tested in a study on transmission loss of typical Danish buildings including thermal bridges [Mads Hulmose et al., 2018]. The study verified that thermal bridges are responsible for a significant part of the total transmission loss. In the study, the U-value correction for thermal bridges was determined for ten different buildings and the result was that exterior walls were corrected with $40\,\%$ on average and the roof constructions were corrected with $15\,\%$ on average.

D.4.2 U-value of Constructions in Existing Buildings

The U-values of roof and wall constructions in new-built buildings are calculated and compared in this chapter to determine the U-value limit on basis of existing low emission buildings. The constructions covered in the investigation is from the case library from Videncenter on Bygningers Klimapåvirkninger including 20 low emission buildings [Videnscenter om Bygningers Klimapåvirkninger, 2023]. Only 17 of the buildings are included in this study, as the remaining three buildings did not fulfil the requirement from the Danish building regulations to GWP.

For the buildings in the case library, the U-values are calculated using the same method as for the generated macro components in this project. The calculated U-values are shown in table D.3 along with general information on the buildings in the library.

The buildings are sorted based on the GWP per gross area per year and the LCA requirement for 2023 and potential LCA requirements for 2025, 2027, and 2029. In each group, the mean value and median of the construction U-values are determined and shown in table D.2.

Table D.2. Mean and median U-values for existing low-emission buildings based on which GWP requirement the buildings attain.

	Requirement	Number of buildings [-]	Mean U-value [W/m^2 K]	Median U-value [W/m^2 K]
Exterior wall	LCA2023	4	0.12	0.12
	LCA2025	3	0.16	0.17
	LCA2027	4	0.14	0.13
	LCA2029	6	0.14	0.15
	Total	17	0.14	0.13
Roof	LCA2023	4	0.10	0.11
	LCA2025	3	0.08	0.08
	LCA2027	4	0.10	0.10
	LCA2029	6	0.13	0.14
	Total	17	0.10	0.09

D.4.3 Determined Limit

The U-values found in the existing low-emission buildings are lower than the recommendation from the building requirements, shown in table D.1. In this project it is decided to use the recommendation from the building requirements to determine the U-value limit, which result in 20-$30\,\%$ higher U-values than the reference building mean values. The limits are $0.20\,$W/m^2 K for exterior walls and $0.13\,$W/m^2 K for roofs.

Table D.3. General information and U-value specific information on buildings from the building library [Videnscenter om Bygningers Klimapåvirkninger, 2023].

Building	Year of construction [-]	Gross Area [-]	Number of storeys [m^2]	Total GWP [kg CO_2-eq/m^2 year]	U-value [W/m^2 K] EW	U-value [W/m^2 K] R
BOFA	2022	880	4	10.7 (LCA2023)	0.11	0.07
DTU Science Park	2019	5946	3	11.1 (LCA2023)	0.12	0.09
E.C. Hansens Hus	2020	16297	5	8.6 (LCA2027)	0.11	0.10
Engdraget	2019	12878	2	6.8 (LCA2029)	0.13	0.14
Erlev Skole	2020	6014	2	8.6 (LCA2027)	0.15	0.09
Karolinelund	2017	860	1	11.2 (LCA2023)	0.11	0.11
Kongebrohuset	2022	4280	7	8.8 (LCA2027)	0.13	0.11
Lisbjerg Bakke	2018	4150	4	7.8 (LCA2027)	0.15	0.11
Markhaven	2022	4996	1	8.7 (LCA2027)	0.12	0.08
Nordlandsvej II	2019	1467	4	10.3 (LCA2025)	0.12	0.07
Pakhusene	2017	9670	10	11.3 (LCA2023)	0.12	0.11
Sophushaven	2023	4422	3	6.5 (LCA2029)	0.16	0.11
Tankefuld	2020	2855	2	6.1 (LCA2029)	0.10	0.08
Teglsøerne	2022	5402	2	9.4 (LCA2025)	0.19	0.08
Tømmerup haveby	2022	5027	2	7.5 (LCA2029)	0.18	0.08
Viila Grenaa	2019	135	1	9.8 (LCA2025)	0.17	0.08
Vision Park	2023	92572	2	7.3 (LCA2029)	0.15	0.19

EW: Exterior walls
R: Roof constructions
LCA2023: Value below 2023 requirement to GWP
LCA2025: Value below potential 2025 requirement to GWP
LCA2027: Value below potential 2027 requirement to GWP
LCA2028: Value below potential 2029 requirement to GWP

D.5 GWP Limits

In the building regulations, no recommendations exist for GWP of building components. The limits to sort the macro components in this project is therefore determined based on buildings from the case library from Videnscenter om Bygningers Klimapavirkninger that fulfil the 2023 GWP requirement to buildings above $1000\,\mathrm{m}^2$ gross area [Videnscenter om Bygningers Klimapåvirkninger, 2023].

The GWP limits are determined for the single-family house case and the four-storey building case separately. To determine limits for the single-family house case, 1-2 storey buildings is used from the case library. The four-storey case is a four-storey building, and in this case, buildings with three to five storeys are used from the case library. All buildings used to determine the GWP limits are shown in table D.5.

The chosen buildings from the building library are obtaining a lower total GWP than the Danish building regulations require. Therefore, the buildings are used for determining the fraction of the total GWP covered by the different constructions, after which the mean fractions for each construction type are used to determine the GWP limits for components based in the requirement to the total GWP. The factions are shown in table D.5 and the determined GWP limits for components are shown in figure D.1 and table D.4.

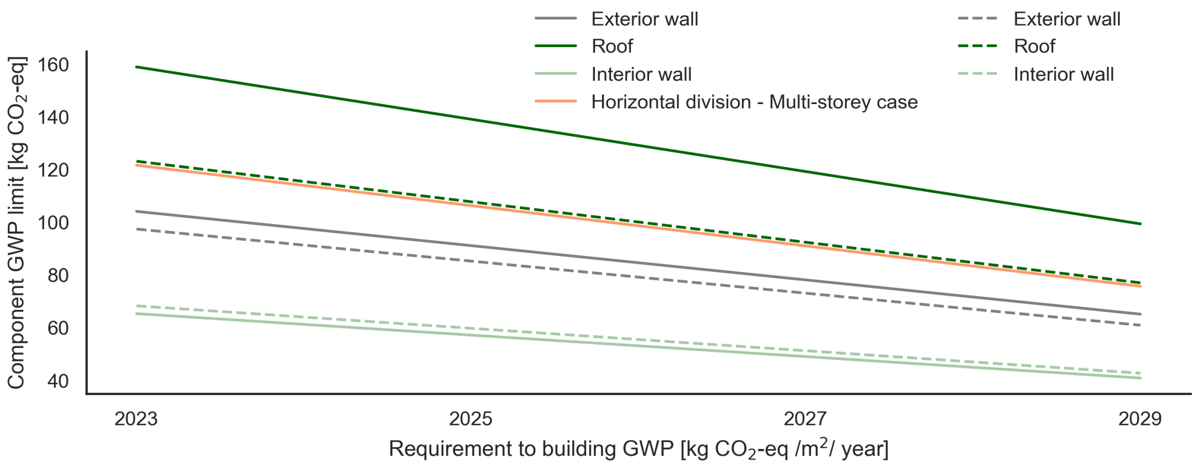


Figure D.1. GWP limits for each component type based on Danish requirements.

Table D.4. GWP limits based on Danish requirements to the GWP of buildings in kg CO_2-eq/m^2 component.

	GWP limit for components components.						
Requirement	**Single-family house case**			**Four-storey building case**			
	EW	**R**	**IW**	**EW**	**R**	**HD**	**IW**
LCA2023	97.3	123.1	68.2	104.0	158.9	122.5	65.2
LCA2025	85.1	107.7	59.6	91.0	139.0	107.2	57.1
LCA2027	73.0	92.3	51.1	78.0	119.1	91.9	48.9
LCA2029	60.8	76.9	42.6	65.0	99.3	76.6	40.8

EW: Exterior wall R: Roof
HD: Horizontal division IW: Interior walls

Table D.5. General information and GWP specific information on buildings from the building library [Videnscenter om Bygningers Klimapåvirkninger, 2023].

Building	Year of construction [-]	Gross Area [-]	Number of storeys [m^2]	Total GWP [kg CO_2-eq/m^2 year]	Fraction of GWP in building [%]			
					EW	R	HD	IW
BOFA	2022	880	4	10.7 (LCA2023)	12.5	4.2	12.6	6.5
DTU Science Park	2019	5946	3	11.1 (LCA2023)	2.8	10.6	20.3	5.7
E.C. Hansens Hus	2020	16297	5	8.6 (LCA2027)	6.7	4.4	20.3	11.3
Engdraget	2019	12878	2	6.8 (LCA2029)	10.0	11.1	-	4.5
Erlev Skole	2020	6014	2	8.6 (LCA2027)	4.2	15.0	-	6.2
Karolinelund	2017	860	1	11.2 (LCA2023)	3.9	25.6	-	3.5
Lisbjerg Bakke	2018	4150	4	7.8 (LCA2027)	5.2	5.4	15.4	8.7
Markhaven	2022	4996	1	8.7 (LCA2027)	5.7	17.4	-	4,.3
Nordlandsvej II	2019	1467	4	10.3 (LCA2025)	11.3	7.2	12.0	-
Sophushaven	2023	4422	3	6.5 (LCA2029)	3.3	8.3	5.2	7.1
Tankefuld	2020	2855	2	6.1 (LCA2029)	9.16	12.7	-	7.2
Teglsøerne	2022	5402	2	9.4 (LCA2025)	10.2	10.7	-	9.6
Tømmerup haveby	2022	5027	2	7.5 (LCA2029)	8.2	5.7	-	8.1
Viila Grenaa	2019	135	1	9.8 (LCA2025)	2.8	30.0	-	0.7
Vision Park	2023	92572	2	7.3 (LCA2029)	7.9	10.9	-	7.9

EW: Exterior walls
R: Roof constructions
HD: Horizontal divisions
IW: Interior walls
LCA2023: Value below 2023 requirement to GWP
LCA2025: Value below potential 2025 requirement to GWP
LCA2027: Value below potential 2027 requirement to GWP
LCA2028: Value below potential 2029 requirement to GWP

E Setup of Micro Component Databases and Material Database

This appendix covers a description of the databases created for the automated generation of macro components. This includes the database setup, the data collection procedure, and a description of each parameter in the databases.

E.1 Micro Component Databases

Micro component databases are created for the automated creation of macro components. The building components covered in the project are exterior walls, roofs, interior walls, and horizontal divisions. The micro components are specified in the databases based on data from existing buildings in Denmark.

E.1.1 Data Collection Procedure

The procedure for data entry in the micro component databases is illustrated in figure E.1. The micro component are based on the composition of existing building components from existing buildings, see appendix F. The micro component database include a systematic use of unique keys to organise materials, micro components, and data origin.

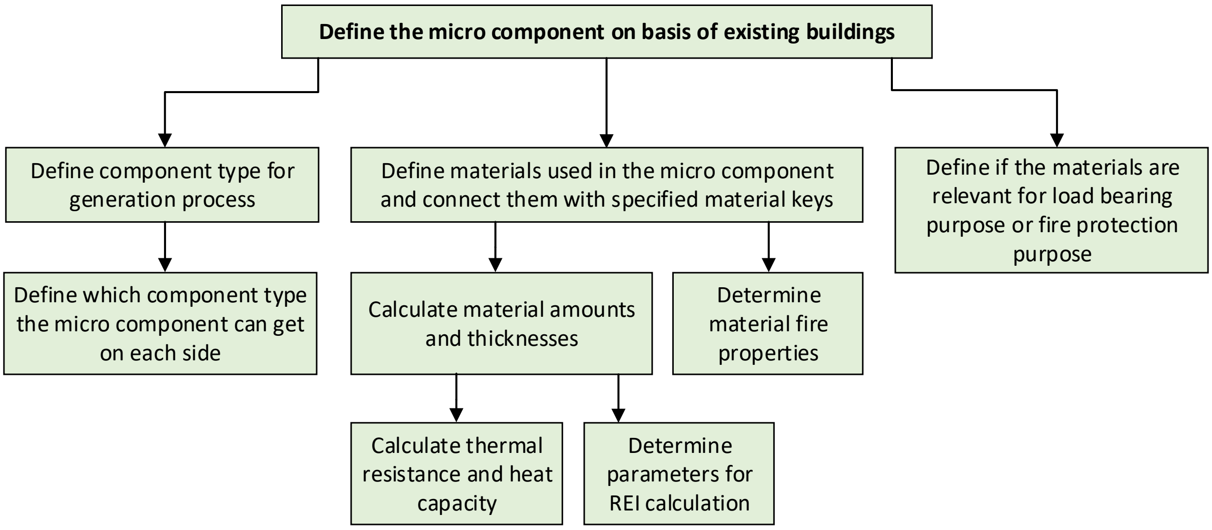


Figure E.1. Procedure for data collection in micro component databases.

The number of micro components in a macro component depend on the component type. In total, seven different micro components are included in the study, but not all micro components are relevant for every building component type. Table E.1 shows which micro components are defined for each building component type. If a micro component that should not be included in the macro component, a "None" micro component is used. If only a few micro components are found, it is easier to define multiple micro components as one. This is the case for roofs, where a wind protection micro component database is not defined but the wind protection element is included in the exterior cladding. An overview of all micro components specified for the present project is available in appendix M.

Table E.1. Micro component type included in each building component type.

Component type	Micro components included EC	WP	S	INS	VB	IL	IC
Exterior walls	●	●	●	●	●	●	●
Roofs	●		●	●	●	●	●[1]
Interior walls			●	●			●
Horizontal divisions	●[2]		●	●		●	●[1]

EC: Exterior cladding
WP: Wind protection
S: Structural part
INS: Insulation
VB: Vapor barrier
IL: Installation layer
IC: Interior cladding

1: Ceiling cladding
2: Floor cladding

The insulation micro component is different from the others as it is defined partly in the micro components and partly in the material database. The insulation material amount and thickness are described in the micro components that make use of insulation material, while all other specifications are defined in the material database.

In the following sections, the collected data is described. The micro component databases are constructed with a focus on how to assemble micro components to generate the macro components.

E.1.2 Component Data

A systematic approach for data navigation is needed in the micro component databases, because of the large amount of data. The navigation system consists of unique keys and micro component compatibility indicators that are used throughout the generation of components.

Component Type

To automate the generation of macro components, the micro components are equipped with a compatibility designation indicating which other micro components they can be assembled with. The main indicator for compatibility is *F* and *NF* designation meaning frame constructions and non-frame constructions. When a new micro component is introduced, it is defined as *F* or *NF*, which is used to model the assembly of the defined type. This approach makes it possible to navigate the components and assemble components efficiently. For roof constructions, an additional indicator is introduced as the roofing depends on the slope of the roof. Here, the structural micro component and exterior cladding micro component are divided into *angled*, *flat*, and *all*.

Unique Keys

A system of unique keys is introduced to be able to trace back to the data in the micro component databases. Each micro component is assigned a key that also denotes the macro component type and micro component type, for instance, EW.VB.001. When macro components are assembled they are assigned a unique macro component key. The macro component data include a list of keys referencing the micro components used in the macro component.

In the micro component databases, building keys are used to reference the existing building from which the micro component originates. This key also denote of the building typology of the existing building, for instance SFH03.

In the material database, each material has been assigned a unique material key. These keys are used in the micro component database to reference material information defined in the material database.

Material Purpose

In the micro component database, each material is assigned two indicators defining the purpose of the material. One indicator defines if the material is a part of the load-bearing construction, here defined as materials exposed to vertical acting loads. The other indicator defines whether the material has a fire protection purpose. A fire protection material is here defined as a material for which the main purpose is to increase the fire safety, when aesthetics and sound reduction purposes are not considered. For a interior cladding with two boards, this means that the outer board is assigned a fire protective role, while the inner is not. If only one board exists in the interior cladding, no fire protective material is assigned.

Material Amount

The amount of material in the micro components given in m^3/m^2 building component. The material amounts are determined based on technical drawings from the existing building where the micro component was found.

For roofs, data on wooden truss constructions are very limited in the technical drawings from existing buildings. In this case, the load-bearing constructions are designed to fit the geometries of the some specified reference buildings, described in appendix L using guidance from TRÆ 78 [2022] and TRÆ 59 [2004]. For wooden battens used to strengthen the construction and create ventilated cavities in roofs and exterior walls, guidance from TRÆ 56 [2021], TRÆ 67 [2013], and TRÆ 67 [2013] are used to determine the material amount.

For steel frame wall constructions and steel profile horizontal divisions, the data on the load bearing materials were limited. In this case, a design tool from Knauf [2020] is used to determine the size of the steel profiles. Again, the calculations are based on the geometries of the reference buildings.

E.1.3 Fire Safety Data

To ensure an acceptable level of fire safety, fire safety data is collected on the materials used in the micro components. The fire safety data consists of the reaction to fire for surface materials and the material with the worst reaction to fire, the fire protection ability for cladding materials, parameters for calculation of load bearing capacity in the warm scenario, and parameters for calculation of insulation and integrity during fire exposure.

Reaction to Fire

The reaction to fire is a classification specific to the building product and its use. This classification is not given in the data from Ökobaudat, but determined by considering market products with similar properties and predetermined classifications established by the European Commission. A further description is available in appendix H.

Fire Protection Ability

The fire protection ability is a classification for surface cladding. Like for the reaction to fire, this classification is not given in the data from Ökobaudat, but determined by considering predetermined classifications established by the European Commission and through calculations using equations from studies on fire tests. A further description is available in appendix H. The fire protection ability is determined for all micro components, mostly relevant for the interior cladding micro components and wind protection micro components.

In the present study, the materials relevant to the fire protection ability are plasterboards and wooden boards used as cladding. If a cladding obtains a K_1 10 classification, this classification is assigned in the database. If a cladding does not obtain a classified fire protection ability, it is still possible to test the cladding on the specific construction in the building component, and this unclassified type of cladding are assigned *test* in the databases. Mineral material layers with a reaction to fire classification of A1 are rarely assigned a fire protection ability, as these materials are deemed to have a fire protection ability, if the thickness of the material layer is sufficient. In this project, concrete, aerated concrete, and masonry wall layers are considered as having a fire protection ability equal to or better than K_1 10.

Load Bearing Capacity in the Warm Scenario, Insulation and Integrity

The Danish building regulations include requirements to the load bearing capacity in the warm scenario, R, and the insulation and integrity, EI, of building components during a design fire event. To be able to evaluate macro components based on R and EI, the variables for the calculation is determined and stored in the micro component databases. The calculation is performed in accordance to Eurocodes. The calculation method and determined variables are described in appendix H and H.

As the calculation of R require information from both the structural part of the component and the cladding, variables for this calculation are stored in the structural micro component databases and the cladding micro component databases

EI is calculated for all components, but the requirement from the building regulations is only relevant for fire partitioning constructions. This covers all horizontal divisions and interior walls between fire compartments and fire cells. Variables used to calculate EI are stored in the structural, interior cladding, exterior cladding and wind protection micro component databases.

E.1.4 Thermal Performance Data

The thermal properties addressed in the present study is the U-value of building envelope components and the effective heat capacity of all components. To calculate these properties, the thermal resistance is calculated and specified for the micro components included in building envelope components and the heat capacity is calculated for the structural and interior cladding micro components.

Thermal Resistance

The thermal resistance is calculated for exterior wall and roof components. The calculations are performed in accordance to DS 418 [2011], described in appendix J. To facilitate varying the insulation material in the generation of macro components, the thermal resistance for micro components containing insulation is expressed as dependant on the thermal conductivity of the insulation material.

Heat Capacity

The heat capacity of micro components relevant for the total heat capacity is calculated in accordance to the simplified method in DS 418-2 [2014], described in appendix J.

E.2 Material Database

The material database contain information on the materials which can be used in the micro component specification. Each material and associated use is assigned a row containing the material specific information.

E.2.1 Data Collection Procedure

When a micro component is being defined, the materials used in the micro component are entered into the material database so they can be referenced in the micro component database. The procedure for data entry in the material database is illustrated in figure E.2.

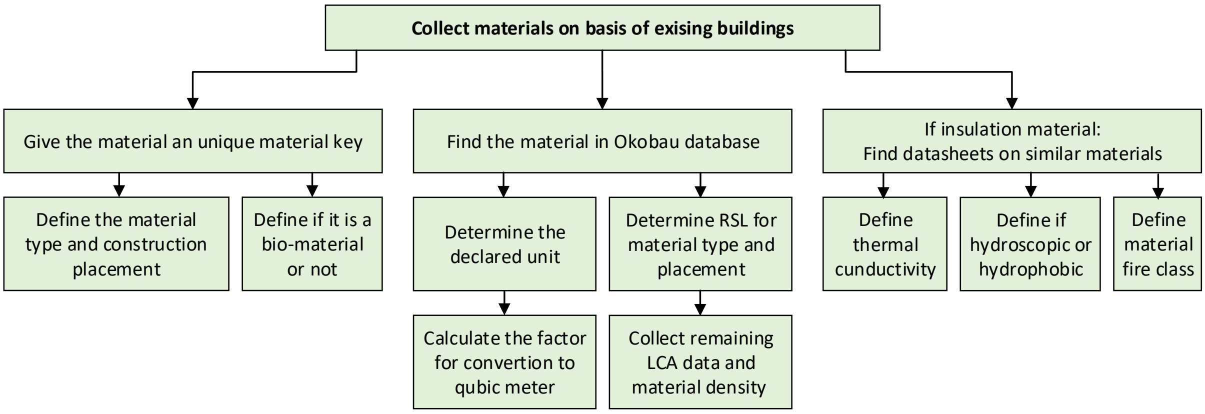


Figure E.2. Procedure for data collection in the material database.

E.2.2 General information

Material family

A material family is used to group the materials in broad categories, such as 'wood', 'paint', or 'Insulation'. These designations can help indicate to the reader of the database what the material is, rather than having to rely on the names alone. No further use has been made of this material family designation.

Unique keys

A unique key is specified for each material such that references to the material and the data contained in the row for said material can be easily referenced. This allows for information on the composition of components to be preserved in later stages of assembly. This also allow for smaller and more manageable result files, as the extraction of material information can be extracted only when needed.

Material placement

The material placement is a designation that indicates the intended installation of the building material in the building. This is relevant for the entry of the reference service life of the material, as this vary based on where they are installed. The designation is intended as an aid for the person doing data entry and data quality assurance in the material database and has no further use.

Material description

The material description contains a name for the material given in the data entry by the person performing the data entry. This is useful as other names, such as the name of the environmental dataset associated with the material, may not be an easily read description of the material at hand.

Product Name

The product name contains the name of the material as defined by the source of the environmental information. As the sources of the environmental data and material densities in the present study originate from Ökobaudat, the product name for the material is the name of the Ökobaudat dataset.

Thermal Conductivity and Reaction to Fire for Insulation Materials

Insulation materials are not specified directly in micro components, but is instead allowed to vary such that each structural micro component can be generated with different insulation materials. For this purpose, insulation materials has a thermal conductivity defined in the material database. Thereby, the thermal conductivity of the insulation material can be imported to the calculation of the thermal resistance of a building component. Likewise, the reaction to fire of the insulation material is registered independent of the micro component and able to be read if necessary in fire related evaluations.

Bio Material

Every material is categorised as being either biogenic or not biogenic. This is a subjective evaluation based on the origin of the largest share of the material. The categorisation can be used to determine the volumetric content of biogenic materials in a component.

E.2.3 LCA Data

The environmental data used to in the LCA is generic data from Okobaudat. This is to ensure that all data used in this project has the same origin. Additionally, the Okobaudat data is approved as the generic data for use in building LCAs in Denmark.

Environmental Data Type

The type of environmental data is noted for each material. In the present project, two types of environmental datasets, both originating from Ökobaudat, are used: generic datasets, and a representative dataset. All but one material are based on generic datasets. The one type of material described by a representative dataset is oriented strand board. The generic dataset type in Ökobaudat is not based on industrial data and the datasets are in accordance with the EN 15804 life cycle information structure [Federal Institute for Research on Building, Urban Affairs and Spatial Development, 2020]. In the material database, the environmental dataset for a material can be a generic dataset taken directly from Ökobaudat, or it can be an assembled dataset, where the information modules in the end-of-life stage is substituted in if this stage is not covered in the original dataset. In this case, the basis for the type of environmental data of the material is regarded as the data type used for the stages A1-A3.

Environmental Dataset

If the dataset is an assembled dataset with generic end-of-life stage information, the substituted information modules are noted to keep track of the origins of the data. The stages and information modules from the LCA method described in DS/EN 15978 [2012] is illustrated in figure E.3. The building assessment modules included in the material database are modules A1-A3, A5, and C3-C4. A5 is included to account for disposal of packaging. The environmental impact categories and resource use parameters described in ÖKOBAUDAT [2021], which are included in the present study and registered in the material database are listed in table E.2 and E.3 respectively.

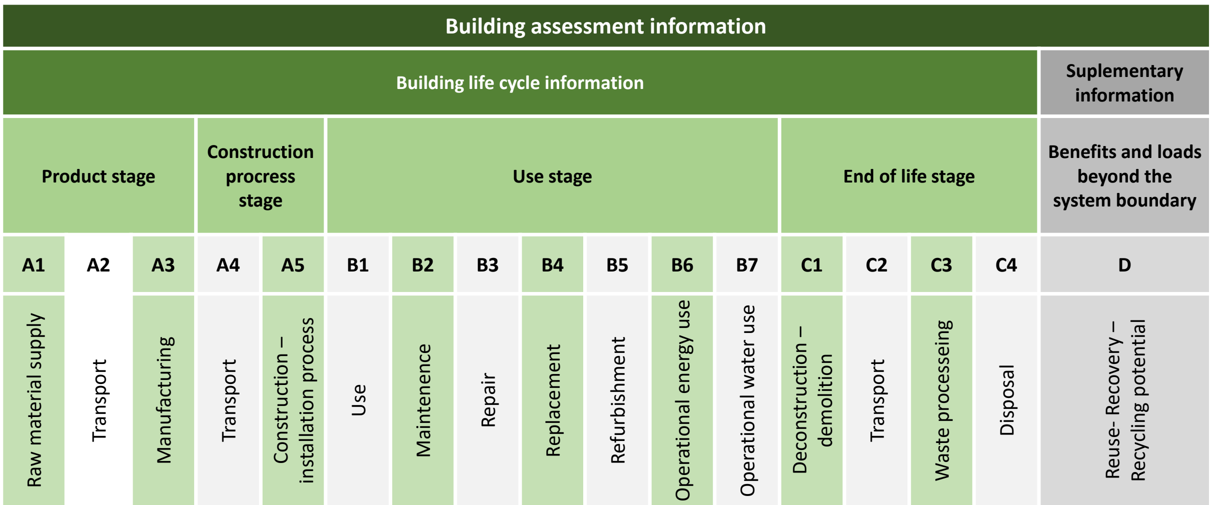


Figure E.3. Stages and modules in a building life cycle as described in DS/EN 15978 [2012].

Table E.2. Environmental impact categories included in the material database.

Impact category	Indicator	Short designation	Unit
Climate change - fossil	Global Warming Potential fossil fuels	GWP_{fossil}	kg CO_2-eq
Climate change - biogenic	Global Warming Potential biogenic	$GWP_{biogenic}$	kg CO_2-eq
Climate change - land use and land use change	Global Warming Potential land use and land use change	GWP_{LULUC}	kg CO_2-eq
Depletion of abiotic resources - minerals and metals	Abiotic depletion potential for non-fossil resources	ADP_e	kg Sb-eq
Depletion of abiotic resources - minerals and metals	Abiotic depletion for fossil resources potential	ADP_f	MJ

Table E.3. Resource use parameters included in the material database.

Parameter	Short designation	Unit
Total use of renewable primary energy resources	PERT	MJ
Total use of non-renewable primary energy resources	PENRT	MJ

Material Density and Declared Unit

The material database stores the density of the material which is given in the dataset from Ökobaudat or estimated using the planeweight of the material given also in Ökobaudat dataset. The density can be used to determine the weight of the macro component in which the material is used and is also used to determine the conversion factor to convert the declared unit to $1\,\mathrm{m}^3$.

The material density and environmental data of a material are used to calculate the biogenic content of each material. The calculation method and an overview of the biogenic content in each material is shown in appendix I.

F Building Data for Micro Component Generation

The micro components used in this project are all based on existing buildings or literature describing possible constructions. The buildings and literature used will be described in this appendix.

A description of the buildings used to define micro components can be found in table F.2.

The micro components that do not originate from existing buildings are CLT elements, steel constructions, and some of the wooden cladding. The literature used to define these constructions can be seen in table F.1.

Table F.1. Description of literature used as source of the micro components.

Key	Source
Lilleheden	[Lilleheden, 2023]
Knauf	[Knauf, 2023]
Trae	[TRÆ 78, 2022]

Table F.2. Description of the buildings used as source to the micro components.

Key	Typology	YOC	Location	Area	NOS	Source
AB01	Apartment building	2014	2620 Albertslund	7.690	2-3	Weblager
AB02	Apartment building	2022	7000 Fredericia	880	4	Byggeriogklima
AB03	Apartment building	2019	4200 Slagelse	12.878	2	Byggeriogklima
AB04	Apartment building	2022	6400 Sønderborg	4.280	7	Byggeriogklima
AB05	Apartment building	2018	8200 Aarhus	4.150	4	Byggeriogklima
AB06	Apartment building	2019	8245 Risskov	1467	4	Byggeriogklima
AB07	Apartment building	2023	4200 Slagelse	4422	3	Byggeriogklima
AB08	Apartment building	2018	4700 Næstved	2100	3	Weblager
INS01	Institution	2017	9000 Aalborg	860	1	Byggeriogklima
OB01	Office building	2019	2970 Hørsholm	5.946	4	Byggeriogklima
OB02	Office building	2020	1799 København V	16.297	5	Byggeriogklima
OB03	Office building	2017	8000 Aarhus	9.670	10	Byggeriogklima
OB04	Office building	2008	8405 Samsø	588	2	Byggeriogklima
OB05	Office building	2023	9260 Gistrup	7.845	4	Rambøll
SCH01	School	2020	6100 Haderslev	6.014	2	Byggeriogklima
SCH02	School	2022	9760 Vraa	9.630	2	Byggeriogklima
SFH01	Single-family house	2018	6040 Egtved	143	1	Weblager
SFH02	Single-family house	2018	7100 Vejle	177	1	Weblager
SFH03	Single-family house	2015	9260 Gistrup	173	1	Weblager
SFH04	Single-family house	2010	9210 Aalborg SØ	192	1	Weblager
SFH05	Single-family house	2007	8920 Randers NV	212	1	Weblager
SFH06	Single-family house	2016	2300 København	210	1.5	Public.filarkiv
SFH07	Single-family house	2007	8920 Randers NV	201	1	Weblager
SFH08	Single-family house	2007	8920 Randers NV	237	1	Weblager
SFH09	Single-family house	2015	6040 Egtved	199	1	Weblager
SFH10	Single-family house	2008	8920 Randers NV	176	1	Weblager
SFH11	Single-family house	2007	8920 Randers NV	268	2	Weblager
SFH12	Single-family house	2005	8920 Randers NV	196	2	Weblager
SFH13	Single-family house	2021	8920 Randers NV	177	1	Weblager
SFH14	Single-family house	2021	3100 Hornbæk	190	2	Public.filarkiv
SFH15	Single-family house	2012	8960 Randers SØ	224	2	Weblager
SFH16	Single-family house	2012	5400 Bogense	197	1.5	Public.filarkiv
SFH17	Single-family house	2019	8960 Randers SØ	206	2	Weblager
SFH18	Single-family house	2017	7323 Give	243	1	Weblager
SFH19	Single-family house	2019	8500 Grenaa	135	1	Byggeriogklima
SFH20	Single-family house	2017	8830 Tjele	159	1	Filarkiv
TH01	Terraced house	2022	5320 Agedrup	4.996	1	Byggeriogklima
TH02	Terraced house	2020	5700 svendboorg	2855	2	Byggeriogklima
TH03	Terraced house	2022	2990 Nivå	5.402	2	Byggeriogklima
TH04	Terraced house	2022	2770 Kastrup	5.027	2	Byggeriogklima

YOC : Year of construction
NOS : Number of storeys

G Mapping of Common Building Components

This chapter describes a study on commonly build construction in Denmark. The study has been made on four newly built neighbourhoods, where 3-10 houses in each neighboorhood has been looked at. The address of the roads that have been looked at is:

- Elkærholmparken, 6040 Egtved
- Seiferts alle & Kiplings alle, 9220 Aalborg East
- Øksen, 8920 Randers
- Vindinghave, 7100 Vejle

A random cluster of houses was selected on each road, and in this cluster all houses are looked up on in the building case archives WebLager [2023] or FilArkiv [2023]. Construction details was found on 34 different single-family houses. 31 in one storey and three in two storeys.

What is found to be commonly built as roof, horizontal division, exterior walls, and interior walls are described in the next sections.

G.1 Roofs

The roof construction is investigated based on the following component parts:

- Roof type
- Exterior cladding
- Interior cladding
- Load-bearing construction
- Wind barrier
- Moisture barrier.
- Insulation

Roof Type

Roofs can be built in a lot of different ways, some of the more popular ones are illustrated in figure G.1. In this study, the roof types are distributed as shown in table G.1.

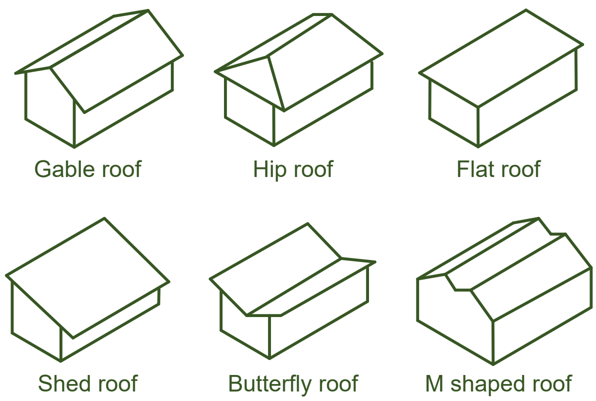


Figure G.1. Overview of common roof types.

Table G.1. Distribution of roof types found in the study on common buildings.

Roof type	Number
Gable roof	8
Hip roof	7
Flat roof	9
Shed roof	9
Butterly roof	0
M-shaped roof	1

As seen in table G.1, the distribution between the open gabled roof, the hip roof, the shed roof and the flat roof is quite even, and the conclusion is therefore that these four roof types are the most commonly built roof types.

Exterior Cladding

For the exterior cladding only two different kind of cladding was found: roof tiles and roofing felt. The distribution of the exterior cladding on the different roof types can be seen in table G.2.

Table G.2. Distribution of exterior cladding on the different roof types found in the study on common buildings.

Roofing	Gable roof	Hip roof	Flat roof	Shed roof	Butterfly roof	M-shaped roof	Total
Roof felt	0	0	9	9	0	0	18
Roof tiles	8	7	0	0	0	1	16

It can be concluded that flat roofs and roofs with a small slope are most commonly built with roofing felt. The roofs with a bigger slope, like gable roofs, is more commonly built with roof tiles.

Ceilings

Two different kinds of ceilings are used in the buildings, and these are plasterboards and troldtekt. The distribution is shown in table G.3.

Table G.3. Distribution of ceiling found in the study on common buildings.

Cladding	Number
Plasterboard	25
Troldtekt	11

It is evident that plasterboards are the most widely used ceilings in these buildings.

Load-bearing Construction

All of the 34 buildings addressed in this study has a load-bearing construction of construction wood.

Wind Barrier

Four different wind barriers were used in the buildings, these are:

- Plasterboard
- Plywood
- Underroofing open to diffusion

- Wood boards

The distribution of these windbarriers between the different roof types can be seen in table G.4.

Table G.4. Distribution of wind barriers on the different roof types found in the study on common buildings.

Cladding	Gable roof roof	Hip roof	Flat roof	Shed roof	Butterfly roof	M-shaped roof	Total
Plasterboard	6	2	0	0	0	1	9
Plywood	0	0	9	7	0	0	16
Sub-roof membrane	2	5	0	0	0	0	7
Wood boards	0	0	0	2	0	0	2

The flat roof and shed roof always use plywood and wooden boards as a wind barrier, while the other two roof types do not, but they use the two other wind barriers.

Vapor Barrier

All the constructions in this study uses a PE vapor barrier.

Insulation

In a lot of the descriptions of the buildings, the insulation material was not specified. In the ones where it was specified, it was always mineral wool that was the insulation material.

G.2 Exterior Walls

The exterior walls are investigated based on the following components:

- Structure
- Interior cladding
- Insulation
- Vapor barrier
- Wind barrier
- Exterior cladding

Structure

Three different kinds of load-bearing structures are used in these 34 buildings, and these are construction wood, aerated concrete, and bricks. The distribution of these can be seen in table G.5.

Table G.5. Distribution of exterior wall structures found in the study on common buildings.

Structure	Number
Construction wood	2
Aerated concrete	26
Brick	5

As shown in table G.5, aerated concrete is most widely used in these buildings.

Interior Cladding

The interior cladding used in these buildings are plaster and paint on the solid construction, and plasterboards are used on the two frame constructions.

Insulation

In the investigated buildings only mineral wool was used.

Vapor Barrier

The solid constructions in this study did not have a vapor barrier, but the two frame constructions had a PE vapor barrier.

Wind Barrier

Only the frame constructions had a wind barrier. The wind barrier in these two cases was bitumen coated boards.

Exterior Cladding

All the buildings in this study had brick as exterior cladding.

G.3 Interior Walls

The interior walls investigated consisted of the following components:

- Structure
- Cladding
- Insulation

Structure

The interior walls in this study was build of construction wood, aerated concrete or brick masonry. The distribution of the different structures is shown in table G.6.

Table G.6. Distribution of interior wall structures found in the study on common buildings.

Structure	Number
Construction wood	1
Aerated concrete	28
Brick	3

The table shows that aerated is the most commonly used material in the interior wall structures.

Cladding

The interior cladding used is plaster and paint on the brick and aerated concrete constructions, and plasterboard on the wood frame construction.

Insulation

The solid constructions in this study did not consist of any insulation, but the wood frame construction had mineral wool insulation within the wooden frame.

H Determination of Fire Technical Properties

This appendix covers the method used to determine the fire technical properties, including the fire technical classification of materials, calculation of R, and calculation of EI. The appendix also covers a study on the fire protection ability of plasterboard cladding.

H.1 Reaction to Fire and Fire Protection Ability

The fire technical classification of building materials is required in order to document the level of fire safety. The requirements for the fire technical classification are covered in appendix A.

H.1.1 Reaction to Fire

For products where the reaction to fire cannot be determined without the need for tests, a classification of the reaction to fire has been made by considering market products similar to the modelled building product for which a classification is available.

Wood

The reaction to fire for wooden boards and panels used on walls and ceilings or as flooring are determined according to The Commission of the European Communities [2007] and The Commission of the European Communities [2014b] respectively. The reaction to fire for Glued laminated timer products is determined according to The Commission of the European Communities [2017a]. For cross-laminated timber and laminated veneer lumber products, the reaction to fire is determined according to The Commission of the European Communities [2017b]. The reaction to fire for construction wood is determined according to The Commission of the European Communities [2003].

Gypsum Plasterboards

The gypsum plasterboards are assumed to have a core density of $800\,\mathrm{kg/m^3}$ and a paper grammage $\leq 220\,\mathrm{kg/m^3}$ whereby the reaction to fire of the gypsum plasterboard is A2-s1,d0 for thicknesses $6.5\,\mathrm{mm}$ to $9.5\,\mathrm{mm}$ if mounted on any wood based product with density $\geq 400\,\mathrm{kg/m^3}$ or any product of at least A-s1,d0 [The Commission of the European Communities, 2006]. If the thickness is $\geq 9.5\,\mathrm{mm}$, the board may maintain its reaction to fire if mounted on any E-d2 insulation product or better.

Concrete, Bricks, Steel and Mortar

In the project, non-biogenic construction materials such as concrete, bricks, steel and mortar are used. These construction materials are all assigned reaction to fire A1, as the materials are not combustible.

H.1.2 Fire Protection Ability

For products where the fire protection ability cannot be determined without the need for tests, a classification of the fire protection ability has been made by considering market products similar to the modelled building product for which a classification is available. Information about the fire protection ability is needed for the assembly of building components conforming with the prescriptive solutions of BR18 using the European classification system. The fire protection ability is not described for building materials in the datasets from Ökobaudat.

Wooden Cladding

The fire protection ability of wooden boards and panels is determined according to The Commission of the European Communities [2014a].

Gypsum Plasterboard Cladding

Gypsum plasterboards are used in this project as sheathing. In the Danish building regulations, D-s2,d2 insulation or worse can be used, but the insulation must be protected using a EI30 wall component or a K_1 10 / B-s1,d0 sheathing. In this project two types of plasterboards are introduced from the datasets from the Ökobaudat database: "*Gypsum plaster board (impregnated; 12.5 mm); 10 kg/m2*" and "*Gypsum plaster board (fire protection; 12.5 mm); 10 kg/m2*" [ÖKOBAUDAT, 2021]. The *Gypsum plaster board (impregnated; 12.5 mm); 10 kg/m2* is assumed to be of the gypsum plasterboard type E, while the *Gypsum plaster board (fire protection; 12.5 mm); 10 kg/m2* is assumed to be of the gypsum plasterboard type F. In order to use the gypsum plasterboards in the components of this project, a classification of the fire protection ability of K_1 10 is needed. Higher ratings are not needed for the scope of the present study. In this project, the fire protection ability of the gypsum plasterboards is estimated using the start of charring time which is calculated using equations presented by Just et al. [2010]. The equations originate from an analysis of a database of gypsum plasterboards and fire tests. It is assumed that the start of charring time can be representative of the criteria for fire protection ability. The estimated fire protection ability for the gypsum plasterboards used in the present project is listed in table H.1. The gypsum plasterboards in the present study are assigned K_1 10 if the start of charring time is greater than 10 min. The start of charring times are calculated for both one and two layers of plasterboard. The total thicknesses are compared with market products for which a fire protection ability can be found. Note that not all thicknesses can be described by the equations derived by Just et al. [2010].

Table H.1. Calculated start of charring time for the type E and F gypsum plasterboards.

Configuration	Start of charring time Type E [min]	Type F [min]
9.5 mm	10.1	10.1
12.5 mm	15.5	15.5
15 mm	20.0	20.0
2x9.5 mm	-	-
2x12.5 mm	33.0	50.8
2x15 mm	37.0	59.5

Comparison With Market Products

The results in table H.1 are compared to information gathered from available data on market products. Gypsum plasterboards from the manufacturers Knauf and Gyproc were investigated, where a classification of a fire protection ability was found on seven Knauf products and zero Gyproc products. An overview of the products covered in the investigation on market products can be seen in table H.2. The investigation distinguishes between plasterboards type F and plasterboards other than type F. Gypsum plasterboard products often exist with the common thicknesses: 9.5 mm, 12.5 mm, and 15 mm.

Table H.2. Gypsum plasterboard products selected for investigation Knauf [2019].

Manufacturer	Product name	Type
Knauf	Climate Board	EH
	Classic Board	A
	Solid board	I
	Solid Wet Board	H
	Secura Board	A
	Climate Secura Board	EF
	Ultra Board	DFH3IR

The calculated start of charring times from table H.1 are compared with the fire protection ability of the investigated products by equating the time rating and the start of charring time, thereby making a lower limit reference, see figures H.1 and H.2. The calculated start of charring time are higher than the time rating of the fire protection ability of the products. Note that the data point for the single layer 9.5 mm gypsum plasterboard is hidden behind a product data point in figure H.2. From this investigation, it is concluded that the approach for assigning a K_1 10 rating to generic gypsum plasterboards is sufficiently reasonable for the scope of the present project.

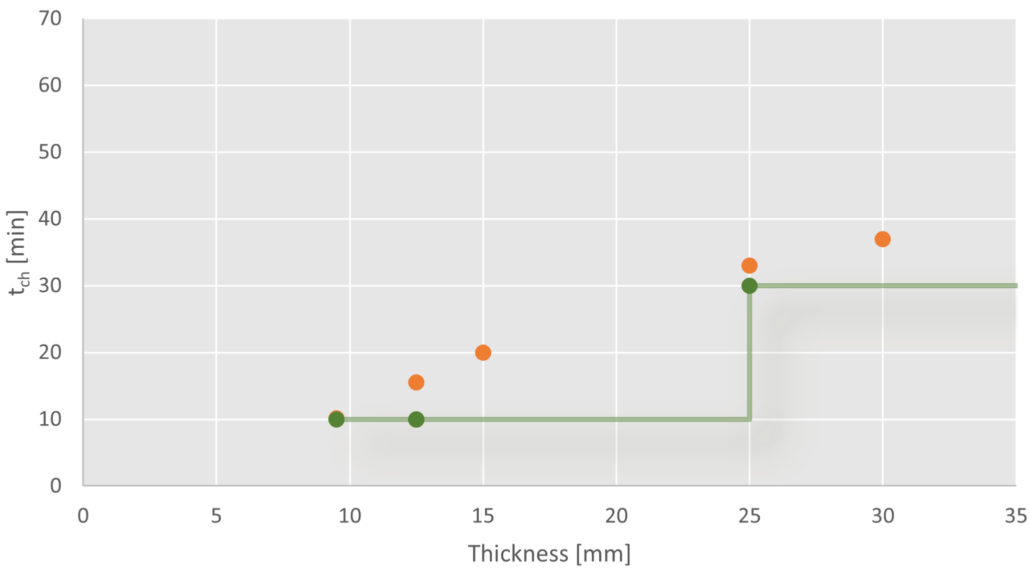


Figure H.1. Comparison of the total thicknesses of type non-F gypsum plasterboards achieving fire protection ability classification K_1 10 and K_2 30 for the investigated products and generic estimates.

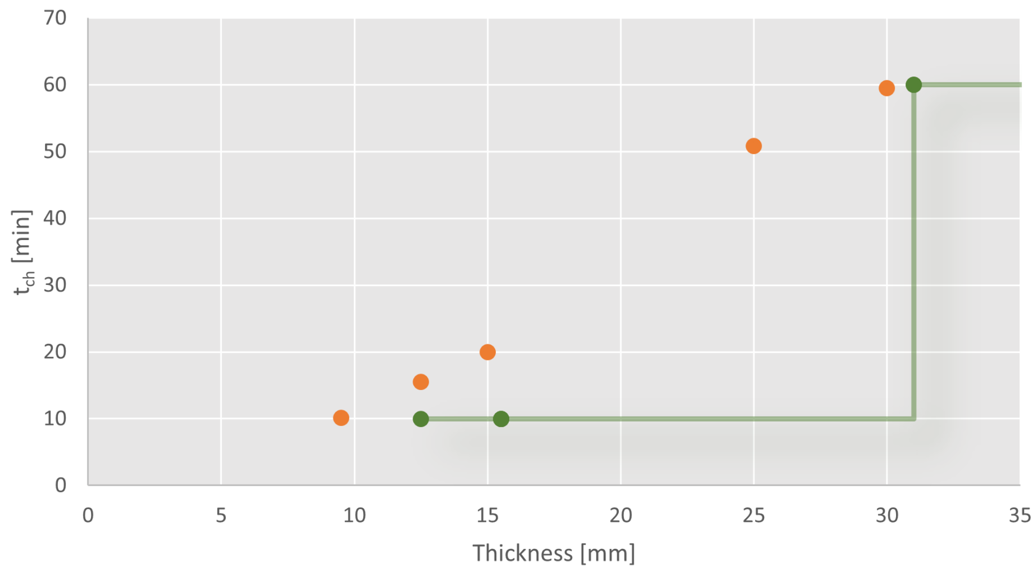


Figure H.2. Comparison of the total thickness of gypsum plasterboards type F in the product study and total thickness of generic estimates type F achieving fire protection ability classification K_1 10 and K_2 60.

H.2 Load-Bearing Capacity

The calculation of the load-bearing capacity of components is dependent on the type of construction and the loads acting on it. The calculations are divided into the load-bearing capacity for compression and bending. The method used for different cases and components within the case is described in the following sections.

The load-bearing capacity in the compression case is relevant for all vertical components including exterior walls and interior walls. The bending case is relevant for all horizontal components including roofs and horizontal divisions.

H.2.1 Concrete Constructions

The load-bearing capacity of concrete constructions is found in tables in DS/EN 1992-1-2 [2013]. Here, different tables are used for columns, walls, beams and slabs. In this project, the tables for walls, and slabs are used.

H.2.2 Masonry Constructions

The load-bearing capacity of masonry walls is found in tables in DS/EN 1996-1-2 [2007]. Here there are different tables that belongs to different materials, these are:

- Clay masonry
- Calcium silicate masonry
- Dense and lightweight aggregate concrete masonry
- Autoclaved aerated concrete masonry
- Manufactured stone masonry

The ones used in this project is the ones for clay brick walls and aerated concrete walls.

H.2.3 Wooden Constructions

The load-bearing capacity for wooden constructions are calculated using the method in DS/EN 1995-1-2 [2009]. The main parts of the calculation method is described in this section. Step 1 in the calculation is identical for both horizontal and vertical, after which step 2 is different for vertical and horizontal constructions.

In the calculation, wood is divided into the following three layers:

- A charred layer
- A zero-strength layer
- A layer where the load-bearing capacity is kept

The charred layer is where the wood is burning. The zero-strength layer is a layer where there is no load-bearing capacity, this is due to high temperatures decomposing the wood before burning [TRÆ 78, 2022]. The last layer is a layer, where the load-bearing capacity is kept. This is due to the fact that the fire and the high temperatures have not reached this part of the wood yet.

The main concept behind calculating the load-bearing capacity in wooden constructions is to calculate how much capacity the wooden cross-section has after a certain amount of time in a fire scenario, then this capacity is compared to the loads acting on the component. The method for calculation of loads are shown in appendix L.

The calculation of the load-bearing capacity is based on "Reduced cross-section" method. This calculation can be split into two main steps, which will be described in the following sections.

H.2.4 Step 1: Find the Reduced Cross section

First, it is determined how much time the construction should withhold its load-bearing capacity. Then the size of the cross-section that is left at this time is determined.

A wooden frame construction will often have a cladding covering the load-bearing wood. This means that wood will not be exposed to the fire at first, therefore the time where these cladding fails and the start of charring time has to be determined.

Find the Start of Charring Time

The moment the charring of the wood start is determined using different methods, depending on what type of cladding is covering the wooden structure.

Wood-based boards and cladding
The charring rate of wood-based boards and cladding can be found using equation (H.1) [DS/EN 1995-1-2, 2009].

$$t_{ch} = \frac{h_p}{\beta_0} - 4 \tag{H.1}$$

Where

t_{ch}	Start of charring [min]
h_p	Thickness of the cladding [mm]
β_0	Design charring rate [mm/min]

The design charring rate depends on the kind of wood-based cladding used. Typical design charring rates are shown in table H.3.

Table H.3. Design charring rates for wood panels [DS/EN 1995-1-2, 2009].

Wood Panels	β_0 **[mm/min]**
Wood panelling	0.9
Plywood	1.0
Wood-based panels other than plywood	0.9

Plasterboards

The study on gypsum plasterboards described for the fire protection ability concludes that the composition of gypsum plasterboards have changed a lot since the standard was published [Just et al., 2010]. Therefore, it is chosen to use equations from the study instead of the ones listed in the standard, where these are more strict than in the standard.

Find the Failure Time of the Cladding

The failure time of the cladding is determined in different ways depending on what kind of cladding that is used.

For wood-based cladding, the start of charring time for the underlying wood is assumed to be equal to the failure time of the cladding [DS/EN 1995-1-2, 2009]. Thus:

$$t_f = t_{ch} \tag{H.2}$$

t_f	Failure time [min]
t_{ch}	Start of charring [min]

The failure times for plasterboards, are found using the study from Just et al. [2010].

If the wood starts to char before the protection boards have failed, $t_{ch} \leq t \leq t_f$, the charring is happening at a reduced rate.

Find the Time Where an Increased Charring Rate Ceases

When the fire protection cladding has collapsed, the charring rate will increase for a certain amount of time, and t_a is the time where this increased charring rate stops. Between the time when cladding fails and the time when the increased charring rate ceases, the charring rate should be multiplied by a factor.

Find the Charring Rate

The charring rate of the wood is found using the values in table H.4. β_n is the notional charring rate that takes charring from multiple sides into consideration.

Table H.4. Design charring rates for wooden products [DS/EN 1995-1-2, 2009].

Material	β_0 [mm/min]	β_0 [mm/min]
a) Softwood and beech :		
GLT ($\rho \geq 290$ kg/m^3)	0.65	0.7
Solid timber ($\rho \geq 290$ kg/m^3)	0.65	0.8
b) Hardwood :		
Solid or Glue laminated hardwood ($\rho \geq 290$ kg/m^3)	0.65	0.7
Solid or Glue laminated hardwood ($\rho \geq 450$ kg/m^3)	0.50	0.55
c) LVL :		
LVL ($\rho \geq 480$ kg/m^3)	0.65	0.7

Reduced Cross-section

In this step, the reduced cross-section will be determined. The reduced cross-section is found using DS/EN 1995-1-2 [2009]:

$$A' = b_{ef} \cdot h_{ef} \tag{H.3}$$

Where

$$b_{ef} = b - n_b \cdot d_{red} \tag{H.4}$$

Where

A'	Effective area [mm^2]
b_{ef}	Effective width [mm]
b	Width [mm]
n_b	Number of sides reducing in width [-]
d_{red}	Depth of layer with no load-bearing capacity [mm]

and

$$h_{ef} = h - n \cdot d_{red} \tag{H.5}$$

Where

h_{ef}	Effective thickness [mm]
h	Thickness [mm]
n_h	Number of sides reducing in thickness [-]
d_{red}	Depth of layer with no load-bearing capacity [mm]

The reduction is found using:

$$d_{red} = d_{char} + k_0 \cdot d_0 \tag{H.6}$$

Where

d_{red}	Depth of layer with no load-bearing capacity [mm]
d_{char}	Depth of charring [mm]
k_0	Factor [-]
d_0	Depth of pyrolysis [mm]

For beams and columns, d_0 is 7 mm [DS/EN 1995-1-2, 2009].

The calculation of the load-bearing capacity is different depending on the construction type. If it is a vertical construction, the method for calculating load-bearing capacity can be seen in section H.2.5. If it is a horizontal construction the calculation method can be seen in section H.2.6.

H.2.5 Step 2: Find the Load-bearing Capacity - Vertical Constructions

When the reduced cross-section is determined, the load-bearing capacity can be found using:

$$F_{c,d,fi} = k_c \cdot A' \cdot f_{c,d,fi} \tag{H.7}$$

Where

$F_{c,d,fi}$	Compression strength of when wood in fire scenario [MPa]
k_c	Column factor [-]
A'	Area of reduced cross-section [-]
$f_{c,d,fi}$	Design compression strength in fire scenario [MPa]

k_c is a column factor that has to be determined in accordance with the method described in DS/EN 1995-1-2 [2009].

$f_{d,fi}$ is calculated using:

$$f_{c,d,fi} = k_{fi} \cdot f_{c,0,k} \tag{H.8}$$

Where

$f_{c,d,fi}$	Design compression strength in fire scenario [MPa]
k_{fi}	Factor [-]
$f_{c,d,fi}$	Characteristic compression strength [MPa]

$f_{c,0,k}$ is found in a datasheet for the specific wood used. k_{fi} is found using the values in table H.5.

Table H.5. Values of k_{fi} for different wooden products [DS/EN 1995-1-2, 2009].

Material	k_{fi}
Construction wood	1.25
Glue laminated timber	1.15
Laminated veneer lumber	1.10

H.2.6 Step 2: Find the Load-bearing Capacity - Horizontal Constructions

The load-bearing capacity for the horizontal constructions is calculated using:

$$F_{m,d,fi} = k_h \cdot f_{m,d,fi} \tag{H.9}$$

Where

$F_{m,d,fi}$	Bending strength of wood in the fire scenario [MPa]
k_h	Thickness coefficient [-]
$f_{m,d,fi}$	Design bending strength in fire scenario [MPa]

The coefficient k_h is determined from tables in DS/EN 1995-1-2 [2009]. $f_{m,d,fi}$ is determined using:

$$f_{m,d,fi} = k_{fi} \cdot f_{m,0,k} \tag{H.10}$$

Where

$f_{m,d,fi}$	Design bending strength in fire scenario [MPa]
k_{fi}	Coefficient [-]
$f_{m,0,k}$	Characteristic bending strength [MPa]

$f_{m,0,k}$ is found in a datasheet for the specific wood used. The k_{fi} values are shown in table H.5.

The reduced cross-section area is introduced in calculation of the bending stress in the beam, calculated using:

$$\sigma_{m,fi} = \frac{M_{d,fi}}{1/6 \cdot b_{ef} \cdot (h_{ef})^2} \tag{H.11}$$

Where

$\sigma_{m,fi}$	Bending stress in fire scenario [MPa]
$M_{d,fi}$	Bending torque [kNm]
b_{ef}	Effective width [mm]
h_{ef}	Effective thickness [mm]

The load-bearing capacity in the bending case is acceptable, if $F_{m,d,fi}$ is greater than $\sigma_{m,fi}$.

H.2.7 Steel Constructions

The main concept behind calculating the load-bearing capacity for steel constructions is to calculate how much capacity the steel cross-section has and then compare this to the load. :

$$E_{fi,d} < R_{fi,d,t} \tag{H.12}$$

Where

$E_{fi,d}$	Load-bearing capacity [kN]
$R_{fi,d,t}$	Load [kN]

The method used is found in DS/EN 1993-1-2 [2009], but the main concepts can be seen in the following sections.

Standard Fire Curve

The load-bearing capacity of steel is dependent on the temperature of the steel. In order to find the steel temperature, the gas temperature of the surrounding air has to be determined. There are different ways to show the temperature levels in a fire scenario. In this project, the standard fire curve is used. The standard fire curve is given by:

$$\theta_g = 20 + 345 \cdot \log_{10}(8 \cdot t + 1) \tag{H.13}$$

Where

θ_g	Gas temperature [°C]
t	Time [min]

Load-bearing Capacity

The load-bearing capacity of steel structures can be found using equation (H.14).

$$R_{fi,d,t} = k_{y,\theta} \cdot M_{Rd} \cdot \frac{\gamma_{M0}}{\gamma_{M,fi}} \tag{H.14}$$

Where

$R_{fi,d,t}$	Design load-bearing capacity at time t [MPa]
$k_{y,\theta}$	Reduction factor [-]
M_{Rd}	Torque load-bearing capacity [MPa]
γ_{M0}	Partial coefficient at normal temperatures [-]
$\gamma_{M,fi}$	Partial coefficient for specific material [-]

Equation (H.14) is for horizontal constructions, but the principles of vertical constructions are the same. Here the torque load-bearing capacity is switched with a load-bearing capacity for compression members.

The partial coefficients and the load-bearing capacity of the steel members can be found using DS/EN 1993-1-1 [2007].

$k_{y,\theta}$ is found using table H.6.

Table H.6. The reduction factor for steel at different steel temperatures [DS/EN 1993-1-2, 2009].

Steel temperature	Reduction factor
→ 400°C	1.00
→ 500°C	0.78
→ 600°C	0.47
→ 700°C	0.23
→ 800°C	0.11
→ 900°C	0.06
→ 1000°C	0.04
→ 1100°C	0.02
→ 1200°C	0.00

As shown in table H.6, the reduction factor is dependent on the steel temperature. The determination of the steel temperature depends on, whether the steel is protected or unprotected. The constructions investigated in this project are always protected for a certain amount of time. In order determine how long the steel is protected, the failure times from section H.2.4 is used. The steel is then assumed to be protected until the cladding fails and is afterwards assumed to be unprotected.

Protected Steel Members
The temperature of protected steel members can be found using equation (H.15).

$$\Delta\theta_{a,t} = \frac{\lambda_p \cdot \frac{A_p}{V} \cdot (\theta_{g,t} - \theta_{a,t})}{d_p \cdot c_a \cdot \rho_a \cdot (1 + \frac{\phi}{3})} \cdot \Delta_t - (e^{\frac{\phi}{10}} - 1) \cdot \Delta\theta_{g,t} \tag{H.15}$$

Where

$\theta_{a,t}$	Steel temperature at time t [°C]
λ_p	Thermal conductivity of the fire protection system [W/m K]
$\frac{A_p}{V}$	The section factor for steel members [m^{-1}]
A_p	Fire insulation area per unit length of the member [m^2/m]
V	Volume of the member per unit length [m^{3}m]
$\theta_{g,t}$	Ambient gas temperature at time t [°C]
d_p	Thickness of fire protection material [m]
c_a	Specific heat capacity of steel [J/kg K]
ρ_a	Density of steel [kg/m^3]
ϕ	Configuration factor [-]
t	time [s]

Unprotected Steel Members
The temperature of unprotected steel members can be found using equation (H.16).

$$\Delta\theta_{a,t} = k_{sh} \cdot \frac{\frac{A_m}{V}}{c_a \cdot \rho_a} \cdot h_{net} \cdot \Delta t \tag{H.16}$$

Where

$\theta_{a,t}$	Steel temperature at time t [°C]
k_{sh}	Correction factor for shadow effect [-]
$\frac{A_m}{V}$	The section factor for steel members [m^{-1}]
A_m	Surface area per unit length of the member [m^2/m]
V	Volume of the member per unit length [m^{3}m]
c_a	Specific heat capacity of steel [J/kg K]
ρ_a	Density of steel [kg/m^3]
h_{net}	Design heat net flux [-]
t	time [s]

Load Reduction

The load used to compare the load-bearing capacity in the fire scenario is reduced. The reduction is calculated using equation (H.17).

$$E_{fi,d} = \eta_{fi} \cdot E_d \tag{H.17}$$

Where

$E_{fi,d}$	Design load in fire scenario [MPa]
η_{fi}	Reduction factor [−]
E_d	Design load in the critical load combination [MPa]

As directed in DS/EN 1993-1-2 [2009], η_{fi} can be set to 0.65, to simplify the calculation.

H.3 Insulation & Integrity

The calculation of the insulation & integrity properties dependent of the type of construction that is addressed. The method for the different construction types is described in this section.

H.3.1 Frame Constructions

The integrity requirements for frame constructions are assumed to be kept if the insulation requirements are kept.

A simplified method for investigating the insulating properties of frame constructions is shown in this section. Equation (H.18) is used to calculate the amount of time the walls keep their insulating properties.

$$t_{ins} = \sum_i t_{ins,0,i} \cdot k_{pos} \cdot k_j \tag{H.18}$$

Where

t_{ins}	Time taken for temperature to increase on unexposed side [min]
$t_{ins,0,i}$	Basic insulation value [mm]
k_{pos}	Position coefficient [-]
k_j	Joint coefficient [-]

In the following sections the different parameters in the calculation will be described.

Basic Insulation Values

In order to find the basic insulation values, different equations are used for different materials to demonstrate the basic insulation values for a fire scenario up to 60 minutes.

Plywood - density larger than 450 kg/m^3
The basic insulation value can be found using equation (H.19) for plywood cladding with a density larger than 450 kg/m^3. Where h_p is the thickness of the board.

$$t_{ins,0} = 0.95 \cdot h_p \tag{H.19}$$

Chipboards and wood fiber boards - density larger than 600 kg/m^3
For chip and wood fiber boards, the basic insulation value can be found using equation (H.20).

$$t_{ins,0} = 1.1 \cdot h_p \tag{H.20}$$

Wood cladding - density larger than 400 kg/m^3
For wooden cladding with a density larger than 400 kg/m^3 equation (H.21) is used.

$$t_{ins,0} = 0.5 \cdot h_p \tag{H.21}$$

Plasterboards
For plasterboards equation (H.22) is used.

$$t_{ins,0} = 1.4 \cdot h_p \tag{H.22}$$

Cavities filled with mineral wool
Insulation materials also has a basic insulation value. The values are different for rock fiber and glass wool. The calculation is shown in equation (H.23) and (H.24).

For rock fibre:

$$t_{ins,0} = 0.2 \cdot h_{ins} \cdot k_{dens} \tag{H.23}$$

For glass fibre:

$$t_{ins,0} = 0.1 \cdot h_{ins} \cdot k_{dens} \tag{H.24}$$

This project includes biogenic insulation materials, which are not described in the standard. The basic insulation value for cavities with biogenic insulation is assumed to correspond to a void cavity.

Void cavities with a depth of 45-200 mm
For void cavities with a depth between 45 and 200 mm, the basic insulation value is set to $t_{ins,0} = 5$ min.

Position Coefficient

The position coefficient dependent on the number of layers in the cladding and on what side of the construction the cladding is.

One layer cladding on fire exposed side
For walls with one layer of cladding, the position coefficient can be found using equation (H.25) for a cladding that covers glass fibre and rock fibre insulation.

$$k_{pos} = \min \begin{cases} 0.02 \cdot h_p + 0.54 \\ 1 \end{cases} \tag{H.25}$$

Where

k_{pos}	Position factor [-]
h_p	Thickness of the board [mm]

For cladding with void cavities underneath $k_{pos} = 0.8$.

One layer cladding on non-fire exposed side
For walls with one layer of cladding, the position coefficient can be found by using table H.7 for cladding on the non-fire-exposed side of the wall.

Table H.7. Position coefficient for one layer of cladding on non-fire exposed side.

Panel	Thickness of panel [mm]	Position coefficient for panel				
		Glass fiber	Rock fiber 45 to 95	Rock fiber 145	Rock fiber 195	Void
Plywood	9 to 25	Equation (H.26)				0.6
Particle- & fibreboards	9 to 25	Equation (H.26)				0.6
Wood panelling	15 19	0.45 0.67	1.5	3.9	4.9	0.6
Plasterboard	9 to 15	Equation (H.26)				0.7

Where equation (H.26) is:

$$k_{pos} = 0.07 \cdot h_p - 0.17 \tag{H.26}$$

Where

k_{pos}	Position factor [-]
h_p	Thickness of the board [mm]

Two layer cladding
For two layers of cladding, the position coefficient can be found in table H.8.

Table H.8. Position coefficient for two layers of cladding[DS/EN 1995-1-2, 2009].

Construction: Layer number and material :		Layer number 1	2	3	4	5
1,2,4,5 3	Wood-based panel Void	0.7	0.9	1.0	0.5	0.7
1,2,4,5 3	Plasterbord Void	1.0	0.8	1.0	0.8	0.7
1,5 2,4 3	Plasterboard Wood-based panel Void	1.0	0.8	1.0	0.8	0.7
1,5 2,4 3	Wood-based panel Plasterboard Void	1.0	0.6	1.0	0.8	0.7
1,2,4,5 3	Wood-based panel Rock fibre batts	0.7	0.6	1.0	1.0	1.5
1,2,4,5 3	Plasterboard Rock fibre batts	1.0	0.6	1.0	0.9	1.5
1,5 2,4 3	Plasterboard Wood-based panel Rock fibre batts	1.0	0.8	1.0	1.0	1.2
1,5 2,4 3	Wood-based panel Plasterboard Rock fibre batts	1.0	0.6	1.0	1.0	1.5

Insulation - Not Type F plasterboard cladding
For constructions where the cladding on the fire-exposed side is other materials than plasterboard type F, then the position coefficient for a void and an insulation layer is set to $k_{pos} = 1$.

Insulation - Type F plasterboard cladding
For constructions where the cladding on the fire-exposed side is plasterboard type F, then k_{pos} is set to:

$$k_{pos} = 1.5 \quad \text{for void cavities, and rock wool insulation} \tag{H.27}$$

$$k_{pos} = 2.0 \quad \text{for glass wool insulation} \tag{H.28}$$

Joint Coefficient

The joint coefficient can be set to $k_j = 1$ for the following constructions:

- Joints of cladding fixed to a batten, of at least the same thickness or to a structural element
- Wood panelling/cladding
- Insulation batts

The joint coefficient for cladding that are not fixed to battens can also be seen in the standard [DS/EN 1995-1-2, 2009].

H.3.2 Solid Constructions

For aerated concrete, bricks and concrete the EI specification can be found in tables in DS/EN 1992-1-2 [2013] and DS/EN 1996-1-2 [2007].

For CLT the EI specification is found in technical datasheets, where tests have been made to determine a constructions ability to withstand the insulation and integrity requirement.

I Biogenic Carbon Content in Materials

This appendix includes a description of the method used to calculate the biogenic carbon content and an overview of the biogenic carbon mass percent and density for each building material used in this project.

I.1 Calculation Method

The calculation method is based on the method of converting carbon to GWP_{bio} in DS/EN 16449 [2014], and the calculation is shown in equation (I.1). The weight of one carbon atom is 12.01 g/mol and the weight of one CO_2 molecule is 44.01 g/mol.

$$M_{bio} = GWP_{bio} \cdot \frac{W_{carbon}}{W_{CO2}} \tag{I.1}$$

Where

M_{bio}	Amount of biogenic carbon per m^3 [kg/m^3]
GWP_{bio}	GWP_{bio} per m^3 [kg CO_2-eq/m^3]
W_{carbon}	Atomic weight of carbon [g/mol]
W_{CO2}	Molecule weight of CO_2 [g/mol]

The conversion from biogenic carbon amount to a mass percent of biogenic carbon is calculated using equation (I.2).

$$cp_{bio} = \frac{M_{bio\ carbon}}{\rho} \cdot 100 \tag{I.2}$$

Where

cp_{bio}	Mass percent of biogenic carbon [%]
M_{bio}	Mass of biogenic carbon per m^3 [kg/m^3]
ρ	Material density [kg/m^3]

The calculation is performed for each material in the material database.

I.2 Overview of Biogenic Carbon Content in Materials

Figure I.1 is an overview of the biogenic mass percent and density of each material type in the material database. The data is based on information in the datasets from Ökobaudat.

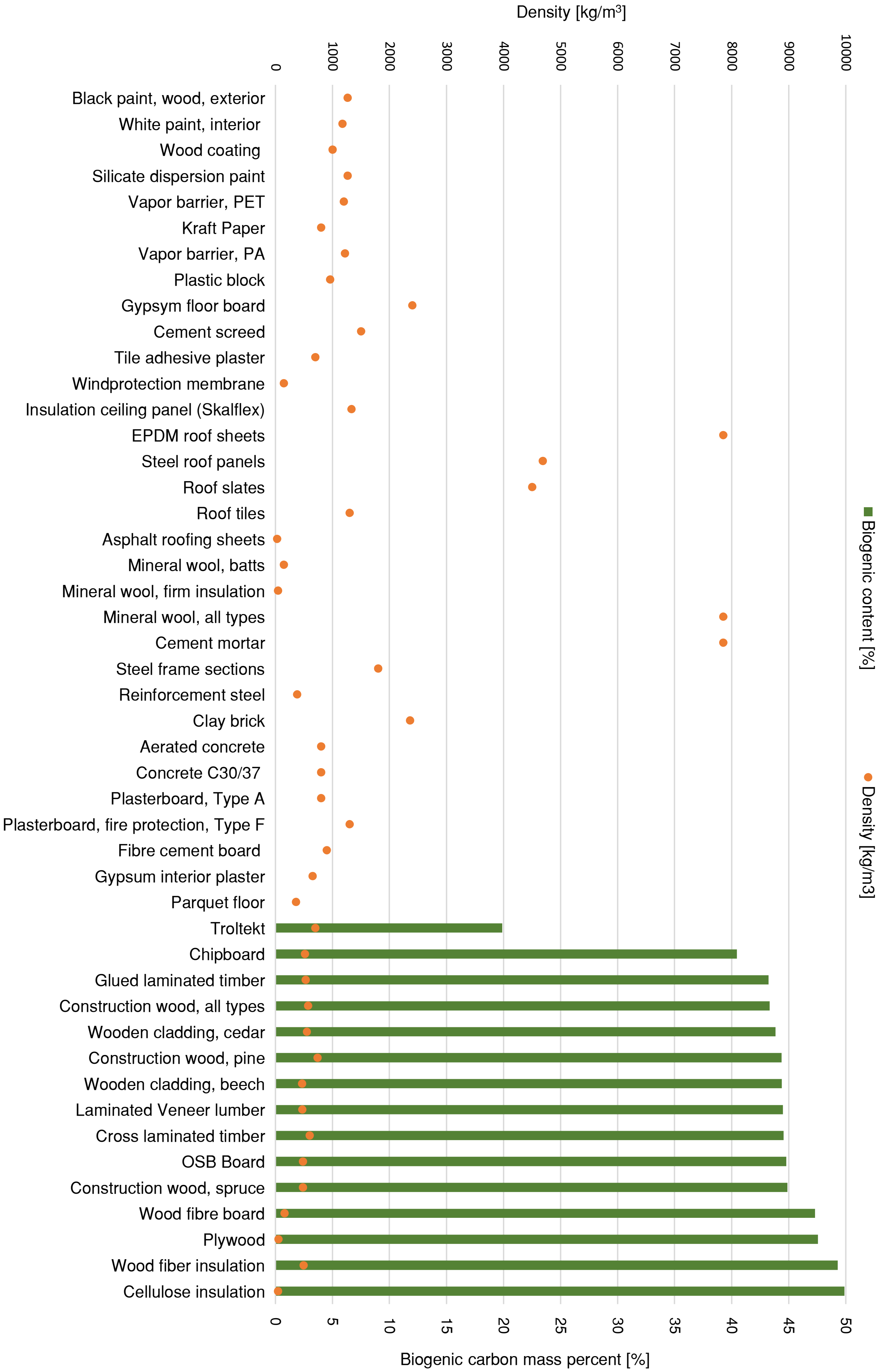


Figure I.1. Overview of the biogenic mass percent and density of each material type in the material database.

J Determination of Thermal Properties

This appendix covers a description of the method used to evaluate the thermal insulation and effective heat capacity of the generated macro components.

J.1 Thermal Conductivity of Insulation Materials

In order to include the insulation materials in the present project, more information is required about the properties of the materials than what is available in Ökobaudat. The missing properties are estimated based on the available information in Ökobaudat and similar products on the market. An overview of the insulation materials from Ökobaudat is available in table J.1. The basis for the estimated thermal conductivities is described in the following sections.

The wood fibre batt in table J.1 is a modified dataset. This is a result of a modification of the generic material that exist in Ökobaudat, which was necessary to get a representative wood fiber insulation material in the project. The dataset uses a modification of the Wood fibre board (wet process) dataset to define a new material with a reduced density.

Table J.1. Insulation materials defined for the present study, the name of the selected Ökobaudat dataset reference, the material density, and the estimated thermal conductivity [ÖKOBAUDAT, 2021].

Insulation material	Reference Ökobaudat dataset	Density [kg/m^3]	Estimated λ [W/m K]
Mineral wool board	Mineral wool insulation panel; 145 kg/m3	145	0.034
Mineral wool batt	Mineral wool (facade insulation)	46	0.034
Mineral wool partition batt	Mineral wool (partition walls insulation)	26	0.036
Cellulose fibre batt	Cellulose fibre blowing insulation material	45	0.040
Wood fibre board	Wood fibre board (wet process)	160	0.038
Wood fibre batt	Wood fibre board (wet process) - modified	50	0.037

For wool-based insulation materials, there is a relation between the density of the insulation material and its thermal conductivity. This is taken into account in the investigation.

J.1.1 Mineral Wool Insulation

Products with available density information are selected and the data on these products is shown in table J.2. The data include insulation product lines with products which are similar but has different thermal conductivities and densities.

Table J.2. Mineral insulation products selected for investigation.

Manufacturer	Product	Number of products
Isover[1]	Flex	1
	Formstykke	4
	Murfilt	4
URSA[2]	Timber Frame slab	1
	Cavity batt	1
Rockwool[3]	Flexibatt	3
	BD-60 Flexibatt	1
	Skillevægsbatt	1
	Murbatt	3
	A-batt	1
Paroc[4]	eXtra pro	1
	eXtra A-byg	1
	eXtra plus, Super A-byg	1
	eXtra A-mur	1
	eXtra plus, Super A-mur	1
	UNS 37z eAsy	1
	Sonus	1

1: From Isover [2023]
2: From URSA [2023]
3: From Rockwool [2023]
4: From Paroc [2023]

The thermal conductivity is plotted against the density and a power regression is made on the glass wool and the stone wool as well as on a mix of the two, see figure J.1. Since the mineral wool dataset from Ökobaudat is based on a 50/50 mixture of glass wool and stone wool, the regression equation for the mixed data is used to estimate the thermal conductivity of the mineral wool insulation materials. The regression equation from the mixed data is rather imprecise, which make sense as the regression is based on two different materials. It is, however, sufficient for an estimate of the thermal conductivity for the generic mineral wool insulation materials. Using this equation, thermal conductivities are calculated based on their density and rounded upwards to the nearest $0.001\,\mathrm{W/m\,K}$. The rigid Mineral wool board with a density of $145\,\mathrm{kg/m^3}$ is assumed to have an thermal conductivity equal to the mineral wool facade batt.

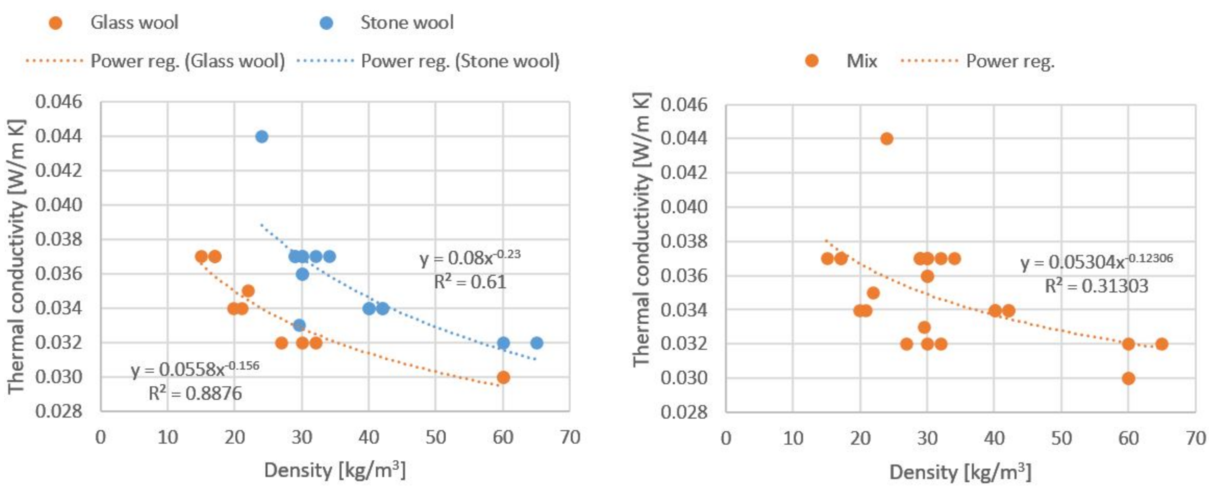


Figure J.1. Regressions on collected data on glass wool and stone wool and on a mix between the two, respectively.

J.1.2 Cellulose Insulation

Products with available density information are selected and the data on these products is shown in table J.3.

Table J.3. Cellulose insulation products selected for investigation.

Manufacturer	Product	Number of products
ECI[1]	Cellulose fiber insulation insulation	1
iCell[2]	Träregelskiva	1

1: From ECI [2023]
2: From iCell [2023]

The thermal conductivities for the insulation materials are 0.036 and 0.040 W/m K. The more conservative value of 0.040 W/m K is adopted as the thermal conductivity for cellulose insulation batts.

J.1.3 Wood Fibre Insulation

Products with available density information are selected and the data on these products is shown in table J.4. The data include insulation product lines with products which are similar but has different thermal conductivities and densities.

Table J.4. Wood fibre insulation products selected for investigation.

Manufacturer	Product	Number of products
Hunton[1]	Nativo	1
Thermocell[2]	FeelingWood	1
STEICO[3]	Flex	1
BISCHOFF SCHÄFER[4]	Flex	2
Schneider[5]	Flex	1
GUTEX[6]	Thermoflex	1

1: From Hunton [2019]
2: From Thermocell [2023]
3: From STEICO [2023]
4: From SCHÄFER [2023]
5: From Schneider [2023]
6: From GUTREX [2023]

The thermal conductivity is plotted against the density and a power regression is made on the data for the wood fibre insulation, see figure J.2. Using this equation, thermal conductivities for the new wood fibre insulation material is calculated based on the density and rounded upwards to the nearest 0.001 W/m K. In this process, the value used for the new wood fibre material was rounded down to 0.037 W/m K instead of up. The rigid wood fibre board with a density of 160 kg/m^3 is assumed to have a thermal conductivity of 0.038 W/m K.

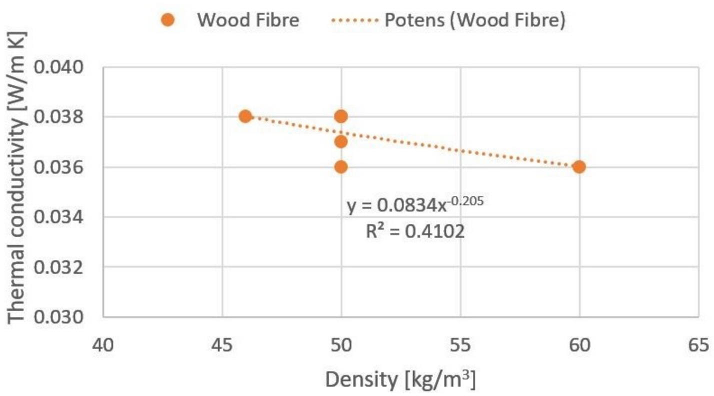


Figure J.2. Regressions on collected data on wood fibre insulation.

J.2 Transmission Loss Coefficient

In this project, the U-value is used for to describe and compare the insulation performance of macro components. The U-value is calculated according to DS 418 [2011] without accounting for the effect from non-repeating thermal bridges.

In Denmark, the U-value is calculated as the upper limit, which can be found by calculating the U-value of the construction using the area weighted average heat conductivity for each non-homogeneous layer. The area weighted average heat conductivity is calculated as:

$$\lambda_{nh} = \frac{\sum A_i \lambda_i}{\sum A_i} \tag{J.1}$$

Where

$\lambda_n h$	Heat conductivity of the non-homogeneous layer [W/m K]
A_i	Area of material i [m^2]
λ_i	Design heat conductivity of material i [W/m K]

From this, the uncorrected U-value can be calculated as:

$$U' = \frac{1}{R_{si} + R_{si} + \sum R_h + \sum R_{nh}} \tag{J.2}$$

Where

U'	Uncorrected U-value [W/m^2 K]
$\sum R_h$	Sum of thermal resistances of homogeneous material layers in the construction [m^2 K/W]
$\sum R_{nh}$	Sum of thermal resistances of non-homogeneous material layers in the construction [m^2 K/W]

From here, the final U-value not accounting for non-repeating thermal bridges can be calculated as:

$$U = U' + \Delta U \tag{J.3}$$

Where

U'	The uncorrected U-value [W/m^2 K]
ΔU	The correction to the uncorrected U-value [W/m^2 K]

The correction to the U-value consists of corrections for air gaps in the insulation, wall ties and other mechanical fasteners regularly penetrating the insulation layer, and rain on inverted roof, see equation (J.4).

$$\Delta U = \Delta U_g + \Delta U_f + \Delta U_r \tag{J.4}$$

Where

ΔU_g	Correction for air gaps in the insulation [W/m^2 K]
ΔU_f	Correction for wall ties and other mechanical fasteners [W/m^2 K]
ΔU_r	Correction for rain on inverted roof [W/m^2 K]

J.2.1 Corrections to the U-value

The correction values can be looked up in tables or calculated, as described in DS 418 [2011].

Corrections for air gaps in the insulation are calculated based on the thermal insulation of the insulation layers and the thermal insulation of the entire construction, as shown in equation (J.5). The addressed correction values are shown in table J.5.

$$\Delta U_g = \Delta U'' \left(\frac{R_i}{R_T}\right)^2 \tag{J.5}$$

Where

$\Delta U''$	Correction for air gaps in the insulation layer [W/m^2 K]
ΔR_i	Thermal insulation of insulation layers [m^{2}K/W]
ΔR_T	The total thermal insulation of the construction [m^2 K/W]

Table J.5. Correction for air gaps in the insulation layer [DS 418-2, 2014].

ΔU″	Description
0.00	No air gaps across the entire insulation layer
0.01	Possibility of air gaps across the insulation No air circulation on the warm side of the insulation
0.04	Possibility of air gaps across the insulation Possibility of air circulation on the warm side of the insulation

J.3 Effective Heat Capacity

The effective heat capacity of a building and the building components is a parameter that influences the building energy demand for heating and cooling as well as the thermal indoor comport. The heat capacity is investigated to determine significant advantages and disadvantages in this context for the generated components.

J.3.1 Calculation Method

The effective heat capacity is calculated on basis of the thermal mass, which depends on the interior cladding materials. The calculation is performed using the method described in DS 418-2 [2014].

To calculate the effective heat capacity for each building component, equation (J.6) is used [DS 418-2, 2014].

$$\kappa_m = \frac{\rho \cdot c_p \cdot d_T}{3600} \tag{J.6}$$

Where

ρ	Material density [kg/m^3]
c_p	Material heat capacity [J/kg K]
d_T	Thickness of effective material layer [m]

J.3.2 Conditions and Simplifications

The conditions and simplifications used in the calculation of the thermal mass are listed below [DS 418-2, 2014].

- The heat capacity is determined without considering the interior surface thermal resistance.
- The method covers the thermal mass of a maximum of 100 millimetres of the building material on the interior side. However, 108 millimetres are used in the calculation of masonry walls.
- Less than 100 millimetre material is used in the calculation if: 1) an insulation layer is reached. 2) the middle of the construction thickness is reached (symmetric constructions) - or haft the thermal resistance is reached (asymmetric constructions).

J.3.3 Material Properties for Heat Capacity Calculation

To perform the heat capacity calculation, several material properties are needed. The material properties is collected from DS 418-2 Annex A, where typical material properties is listed for common building materials [DS 418-2, 2014]. The values used are shown in table J.6.

Table J.6. Material properties used for calculation of building heat capacity [DS 418-2, 2014].

Material	Density [kg/m^2]	Heat capacity [J/kg K]
Concrete	2400	1000
Aerated concrete	535	1000
Brick	1800	840
Plasterboard with paper	900	1000
Wooden cladding	500	1600
Wooding flooring	500	1600
Plasterboard ceiling panel	900	1000

K Numerical Study on Moisture Performance in Building Components

This appendix covers the setup and assessment of 218 numerical simulations performed on wall and roof assemblies. The simulations are used to gain an insight into the performance of different assemblies of micro components, such that guidelines for removal of poorly performing assemblies can be established, as seen in appendix D.

Moisture evaluations can be used to determine whether a building component is likely to be compromised by too high or to low moisture contents. In this project, only problems related to excess moisture are investigated. Excess moisture in building components can lead to different types of problems. Some problems related to excess moisture contents in constructions are listed below [WUFI, 2018].

- **Wood rot** can occur at suitably high moisture and temperature conditions allowing for growth of wood-decay fungi.
- **Mold growth** can occur at suitably high moisture and temperature conditions allowing for growth of mold fungi.
- **Heat loss** of constructions may significantly increase at high moisture contents through the increase of thermal conductivity of moist materials.
- **Frost damage** can occur in porous materials in climates with frost cycles due to the volume expansion of freezing water.
- **Corrosion** of metallic components such as reinforcing steel in concrete.
- **Condensation runoff** can lead to moisture related damages elsewere in the construction.

Frost damage, corrosion, condensation runoff, and excessive heat loss are not considered further in the present project. Wood rot may occur when the mass moisture content of wood for a period of time exceeds $20\,\%$ or $15\,\%$ for previously attacked wood [BYG-ERFA, 2003]. Mold fungi can thrive on the surface of organic building products or soiled surfaces at high relative air humidity levels. While mold fungi do not degrade the wood like species of wood-decay fungi, they may introduce aesthetically undesirable growth and can pollute the indoor air.

Growth risk of wood-decay fungi and mold growth depend on the temperature and humidity of the evaluated environment as well as the duration of exposure to these conditions. Experimental studies of suitable growth conditions for mould fungi and decay fungi in spruce and pine sapwood by Viitanen [1997b,a] show that the minimum temperature and humidity conditions for mould often is lower than those for decay fungi, and that mould attacks on wood occur more rapidly [Hukka and Viitanen, 1999]. In this project, mould growth is therefore used as an indicator of undesirable moisture conditions in building components. This may also cover other issues such as wood rot and excessive heat loss from damp insulation.

Different approaches exist for the estimation of humidity and temperature conditions in constructions. Stationary methods for evaluation of intestinal humidity and condensation include the Glaser method as described in DS/EN ISO 13788 [2013]. Software for detailed transient calculation of hygrothermal conditions include WUFI, Match, Delphin, and Comsol. In this project, the humidity and temperature conditions in building components are calculated numerically using WUFI software. The WUFI software family includes the following products for building component simulation:

- **WUFI Pro** - an easy to use tool for evaluation of one-dimensional cross-sections.
- **WUFI 2D** - an expanded tool for evaluation of two-dimensional geometries.

The purpose of the moisture evaluation in this project is to determine whether the generated walls and roof constructions can be safely used in a building envelope in a Danish climate setting. In frame constructions where the wooden studs create a thermal bridge, the temperature will be increased near the thermal bridge lowering the relative air humidity in this area. In this case, a one-dimensional calculation through the insulation is assumed sufficient to describe these building components. This also applies for homogeneous components.

WUFI Pro 6.6 is used for the temporal calculation of hygrothermal conditions in the building components of this project [WUFI, 2022a]. Results from calculations in WUFI include time series of relative humidity, mass moisture content of materials, and temperatures. These results can be used to assess constructions or they can be used in a post processor which may further assist the assessment. Risk of mould growth is assessed using the WUFI Mould Index VTT post processor developed by Viitanen et al. [2022].

K.1 Evaluation Criteria

Moisture evaluations are performed for roof components and exterior wall components. In the parameter variation, a large number of components are generated. Ideally, individual examinations are required for each component in the conditions under which they are to be installed. The time required to do individual examinations for each component is, however, greater than what is available within the scope of this project. Instead, examinations are performed on worst case scenarios on each component assembly type where the exterior micro component with the greatest vapor resistance and the interior micro component with the lowest vapor diffusion resistance are selected. Through iterative examinations of the failing components, acceptable designs limits are sought determined. A macro component is accepted if:

- There is no yearly increase in the moisture content of the construction at the end of the five year simulation period.
- Mold index is below thresholds at monitoring positions.
- There is no yearly increase in the mold index at the end of the five year simulation period.

These evaluation criteria are applied at monitoring positions inside the constructions. The monitoring positions are located toward the outer part of the components, see figure K.1.

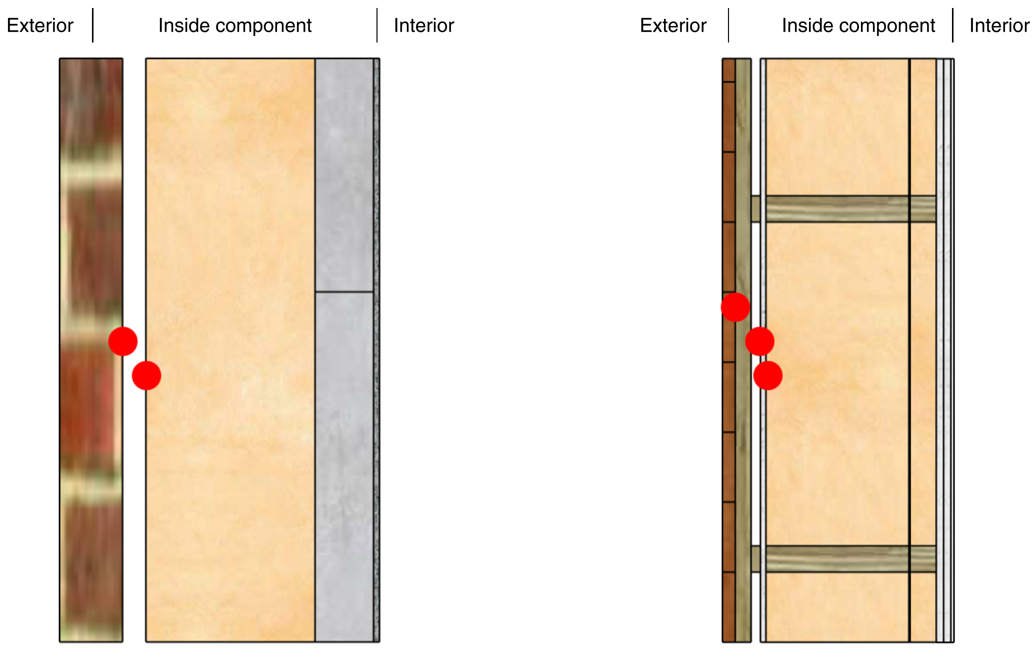


Figure K.1. Horizontal cross sections showing monitoring positions inside of two wall examples.

K.2 Modelling of Building Components and Model Setup

Build-in moisture is not examined in this study. The goal is to achieve the state of typical yearly fluctuations and evaluate this state. To do this, the simulation is run for a five year period. The first year is disregarded and the evaluation is performed on the remaining four years. Initial conditions for the humidity of materials are constant for each layer at $80\,\%$ at $20\,°C$, but may be changed to $75\,\%$ if the results show too large a dependence on the initial conditions. All components are examined in an northward orientation. *Driving Rain Coefficients* for exterior wall components are set to $R1 = 0$ and $R2 = 0.07\,s/m$. For roof components the coefficients are set to $R1 = 1$ and $R2 = 0\,s/m$. *Interior Surface Heat Resistance* and *Exterior Surface Heat Resistance* are set in accordance with DS 418-2 [2014]. *Short-wave Radiation Absorptivity* is set according to the surface material of the examined component. If multiple colors are available for a particular surface material, a brighter variant with a lower absorptivity is used. *Ground Short-Wave Reflectivity* is set to the default 0.2. *Explicit Radiation* is enabled for simulation of roofs components. *Adhering Fraction of Rain* is set to depend on the inclination of the component.

K.2.1 Exterior Walls

The investigated constructions are made into one-dimensional models in WUFI Pro, as shown in figure K.2. Ventilated cavities containing battens are assumed to consist entirely of air. Likewise, insulated cavities are assumed to consist entirely of insulation. Paint layers are not modelled as a geometry but as a Sd-value on the interior surface.

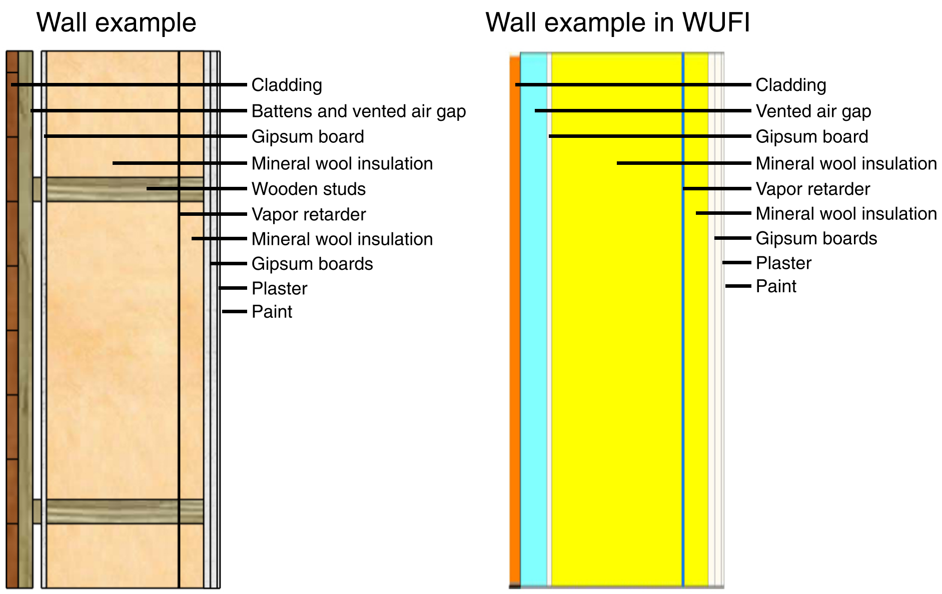


Figure K.2. Composition example of an exterior wall and its one-dimensional composition in WUFI Pro.

Exterior cavity walls with no vented cladding such as the one depicted in figure K.3 are all assumed to be build with a slightly vented cavity using openings in the top and bottom of the facade for instance by use of open head joints in masonry walls. The air change rate inside of the cavity and behind cladding for walls with vented cladding is important for the drying potential of the wall. Inputs for the air change rate must be determined for the simulation of the exterior walls.

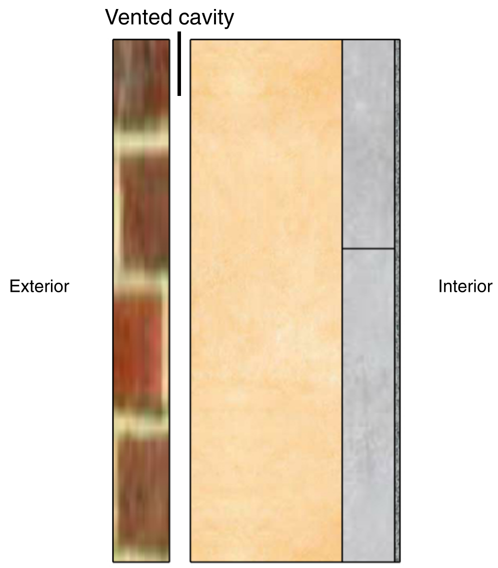


Figure K.3. Exterior wall with vented brick veneer wall.

A parameter study by Langmans et al. [2016] investigates the air change rate behind brick veneer walls and fibre cement sidings in full scale experiments. In a study period of February to May, the brick veneer wall and the fibre cement siding were both tested in a north-east orientation. For the brick veneer wall, the air change rate was found to be at least $3.4\,\mathrm{h}^{-1}$ for $50\,\%$ of the measurements in the study period [Langmans et al., 2016]. The opening area in the tested veneer wall was $11.7\,\mathrm{cm}^2/\mathrm{m}$ at both the top and bottom of the wall. The opening area of the examined walls of the present study is assumed to be $9\,\mathrm{cm}^2/\mathrm{m}$ at the top and bottom corresponding to one open head joint for every third brick in a brick veneer wall with bricks measuring $228{\times}108{\times}54$ mm and 12 mm joints. A simple reduction of the above air change using the opening areas, puts the air change rate behind walls in the present study at at $2.6\,\mathrm{h}^{-1}$. This air change rate is used for both masonry walls and concrete walls. For the fibre cement sidings, the air change rate was found to be at least $226.7\,\mathrm{h}^{-1}$ for $50\,\%$ and at least $100\,\mathrm{h}^{-1}$ for $85\,\%$ of the measurements in the study period [Langmans et al., 2016]. The more conservative air change rate at $100\,\mathrm{h}^{-1}$ is used in the present study for all walls with vented cladding as the cross section in the cavity may be reduced due to the mounting system. Also, the lower air change rate helps with the numerical stability of the simulations.

Vented air gaps are modelled using the material *Air Layer; Without additional moisture capacity* in a layer thickness roughly corresponding to that of the modelled air gap. The venting is modelled by introduced a *Air Change Source*, see figure K.4 with a constant air change of $2.6\,\mathrm{h}^{-1}$ or $100\,\mathrm{h}^{-1}$ for vented cavities and vented cladding respectively.

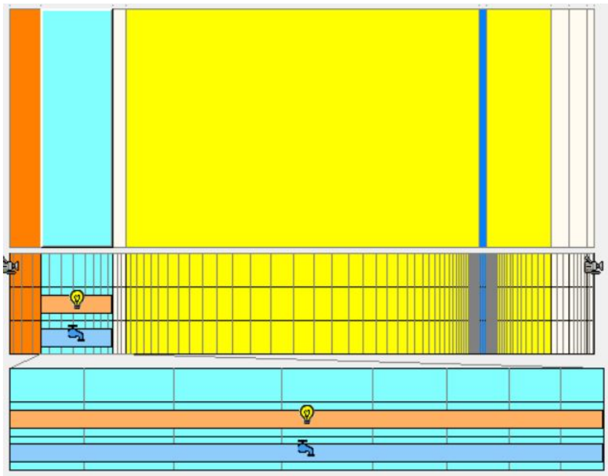


Figure K.4. Air change source in air gap behind vented cladding modelled using a heat source (bulb) and moisture source (tap).

K.2.2 Roofs

Roofs investigated in the present study include unventilated warm roofs and ventilated cold roofs. Moisture from exfiltration is modelled as described in the guide *Handling of typical constructions in WUFI* by Fraunhofer IBP [2014] as a *Moisture Source* spread across 5 mm in a position where condensation is likely to occur, see figure K.5. As a source type *Air Infiltration model IBP* is used with a *Stack Height* of 2.9 m and an *Envelope Infiltration q50* of $3.6\,\mathrm{m}^3/\mathrm{m}^2$ h corresponding to the minimum requirements in the Danish building regulations [BR18, 2022].

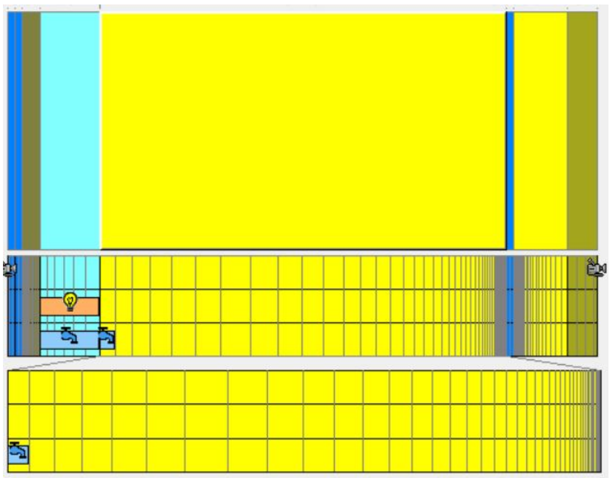


Figure K.5. Moisture source (bulb) in roof to account for air exfiltration.

The air change rate below the sheathing/membrane in cold roofs is set to an assumed value of $3.4\,\mathrm{h}^{-1}$ for flat roofs. For angled roofs, the air change rate is set to $30\,\mathrm{h}^{-1}$. The roof covering and the cavity below is not modelled geometrically in WUFI Pro. Instead, the *short-Wave Radiation Absorptivity* is set according to the material of the roof covering and the *Adhering Fraction of Rain* is deactivated (*No absorption*) as described in the guide *Handling of typical constructions in WUFI* by Fraunhofer IBP [2014], see figure K.6.

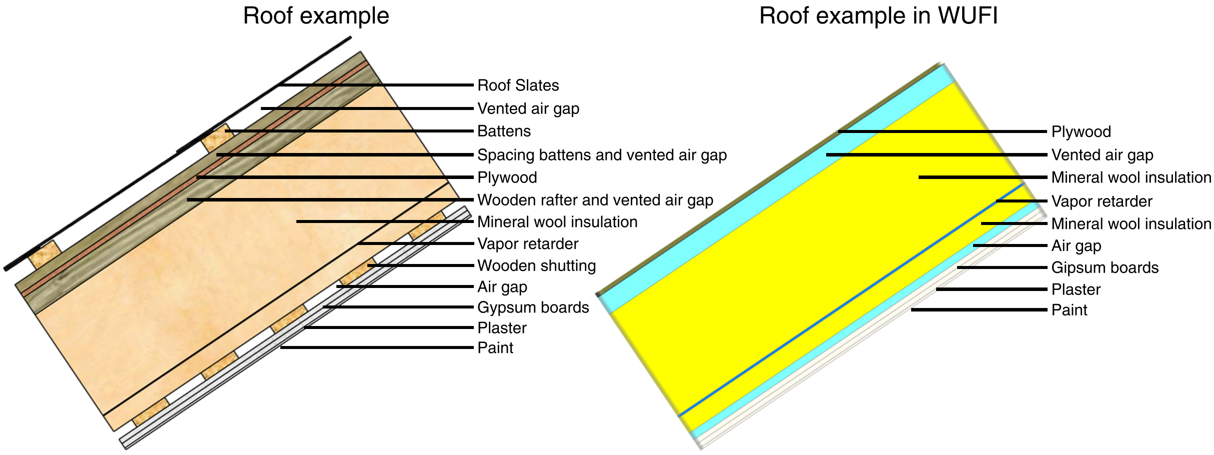


Figure K.6. Composition example of a roof and its one-dimensional composition in WUFI Pro.

Attics in roofs with ventilated cold attics are modelled with an air gap of $50\,\mathrm{mm}$ with two adjacent $10\,\mathrm{mm}$ air layers on either side, see figure K.7. The air change in the attics is evaluated as $3\,\mathrm{h}^{-1}$ three metres into the attic and applied to the $50\,\mathrm{mm}$ air gap as described in the study by Mundt Petersen [2015].

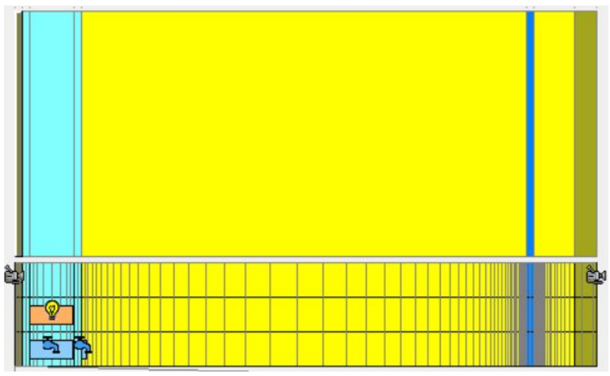


Figure K.7. Ventilated attic modelled using a heat source (bulb) and moisture source (tap).

K.2.3 Material Properties

Due to the one-dimensional modelling of building components in WUFI Pro, only a subset of the materials used in the components of the present study is actually modelled in WUFI Pro. For each of the modelled materials, a corresponding material has be sought found in the database integrated in WUFI Pro 6.6. These modelled materials and their corresponding WUFI-database representative is shown in table K.1. For most of the materials, the bulk density of the material from the WUFI database has been altered to match the density of the material of the present study. Changing the material bulk density impacts the thermal conductivity of materials for which a moisture-dependent thermal conductivity is described as density dependency. The bulk density also affects the specific heat value entering the calculation. The actual simulations are not very sensitive to this value and approximate values are sufficient [WUFI, 2022c]. The bulk density is also used by WUFI to convert results for moisture contents into moisture contents by weight.

Table K.1. Materials used to model building components in WUFI Pro along with their original and modified density.

Material code	Material name in WUFI Pro 6.6 database	Orig. density [kg/m^3]	Mod. density [kg/m^3]
m002	Cellulose Fibre (heat cond.: 0,04 W/mK)[1]	70	45
m003	Solid Brick Masonry[1]	1900	1800
m008	Concrete, C35/C45[1]	2220	2360
m011	Gypsum Board[1]	850	800
m013	Silicate paint[1]	-	-
m015	PA-membrane[1]	65	65
m016	Aerated Concrete (density: 400 kg/m^3)[1]	400	380
m019	Oriented Strand Board (density: 595 kg/m^3)[1]	595	600
m020	Interior Plaster (Gypsum Plaster)[1]	850	932
m022	Gypsum Board[1]	850	800
m028	Wood fibre softboard #2[1]	165	160
m030	veneer plywood BFU 100[1]	427	490
m031	Fibrecementboard[2]	1610	1600
m032	Spruce, radial[1]	455	529
m035	Gypsum Board[1]	850	800
m037	Solid Brick Masonry[1]	1900	1800
m039	Concrete, C35/C45[1]	2220	2360
m040	veneer Plywood BFU 100[1]	427	490
m041	Mineral wool (heat cond.: 0.04 W/mK)[1]	60	46
m043	Roof membrane V13[1]	2400	1300
m045	Membrane of laminated polypropylen[3]	130	700
m048	Chipboard[1]	600	700
m049	AiF Flexible Wood-Fiber Insulation WF[1]	50	50
m050	Gypsum Board[1]	850	800
m051	veneer plywood, BFU 100[1]	427	490
m054	Mineral insulation board[1]		145
m055	Silicate paint[1]	-	-
m058	EPDM, 60 mil, black[4]	1500	1500
m059	XLam wood panel & XLam glue layer[1]	399	399
m060	XLam wood panel & XLam glue layer[1]	399	399
m061	Kraft papir[1]	120	120
m065	Cement lime plaster (stucco, A-value: 1.0 kg/m2h0.5)[1]	1900	1833

1: From WUFI [2022d]
2: From WUFI [2022e]
3: From WUFI [2022f]
4: From WUFI [2022b]

In addition to changes in densities, the thermal conductivity has been modified for the insulation materials. The intention behind the changes is to have the thermal conductivities of the insulation materials modelled in WUFI, correspond to the assumed thermal conductivities described in appendix J. The thermal conductivity in WUFI is described as the thermal conductivity of the material in a dry state at $10\,°C$. Additionally, a dependence of the thermal conductivity on temperature and moisture content can be modelled. In the attempt to modify the thermal conductivity of the insulation materials, errors were made, such that the desired thermal conductivity's were not met, see table K.2. However, the precise value of the thermal conductivity does not have a significant influence on the hygrothermal simulation, in particular in regard to the moisture contents and distributions [WUFI, 2022c].

Table K.2. Insulation materials used in the study along with their original thermal conductivity from WUFI Pro, the goal for modification, and the actual used value [WUFI, 2022d].

Material	Original [W/m K]	Goal [W/m K]	Used [W/m K]
Mineral wool	0.040	0.034	0.036
Cellulose fibre wool	0.044	0.040	0.035
Wood fiber	0.036	0.040	0.037

K.2.4 Boundary Conditions

The simulation of moisture conditions in constructions in WUFI require two boundary conditions - one for the exterior and one for the interior. The exterior boundary condition used in this study is of climate data containing time series of vertical rain load, solar radiation, air temperature, relative air humidity, and wind speed and direction. The climate data used is Lund; LTH Data which is included in WUFI [2022a]. The interior boundary conditions are modelled according to DS/EN 15026 [2007] normal occupancy.

K.3 Component Evaluation

When a simulation is completed, local climate data for the monitoring positions are assessed using the VTT Mould index post processor. For interfaces between two material layers, both materials are evaluated. Material properties are assigned by selecting a suitable material provided in the post processor. Using the climate data and the assigned material properties, the mould index growth rate is calculated and results are given as time series of the growth rate and the mould index. In this examination, the mould index time series is of interest, see figure K.8. The results dialog allow for a selection of the starting point of the mould index calculation. The calculation is to begin one year into the study period as described.

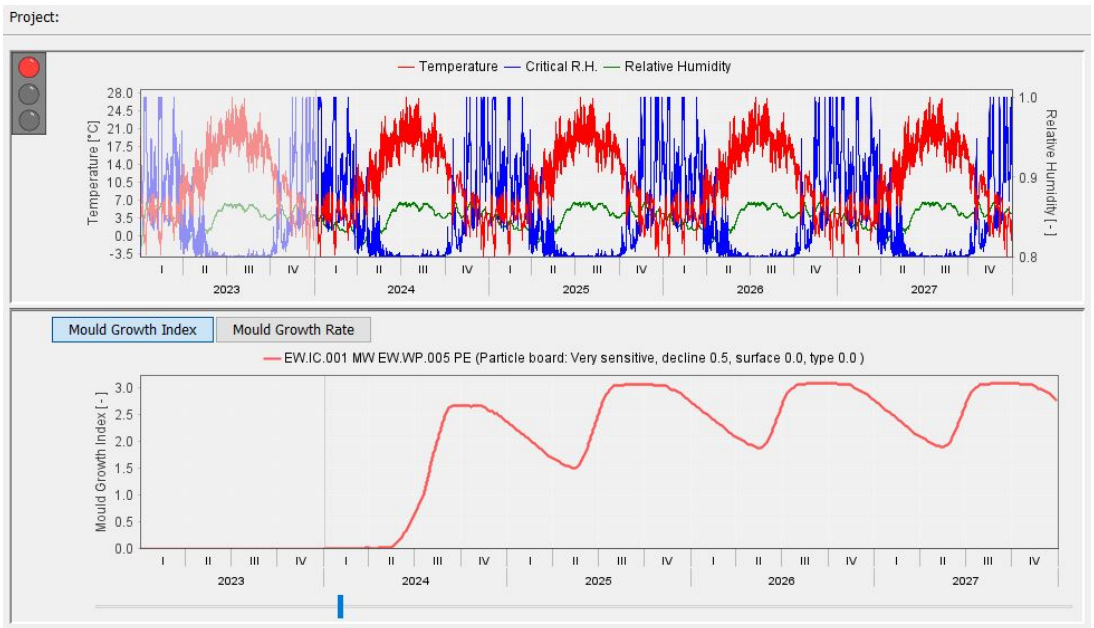


Figure K.8. Result dialog for the WUFI Mould Index VTT 2.3 post processor.

Conclusions are drawn from the mould index time series resulting in a component being either accepted or not accepted. Examples of encountered outputs from the post processor are shown in figures K.9, K.10, K.11, K.12, and K.13. In figure K.9, the mould index is far from the limit and the component is accepted. In figure K.10, the mould index has yearly fluctuations, but as it does not exceed the limit, which is accepted. In figure K.11, the mould index does not exceed the limit within the study period, but is steadily rising which indicates a yearly buildup of moisture in the component.

Figure K.9. Mould index time series, example 1.

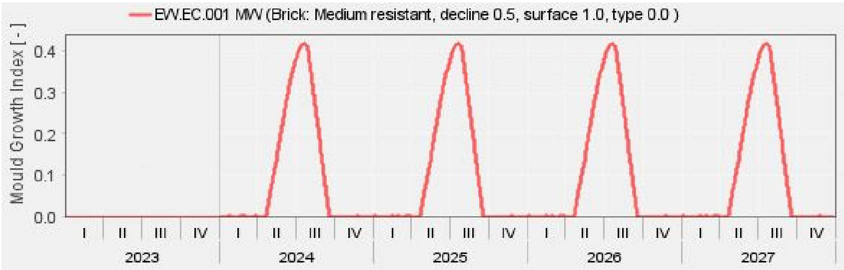


Figure K.10. Mould index time series, example 2.

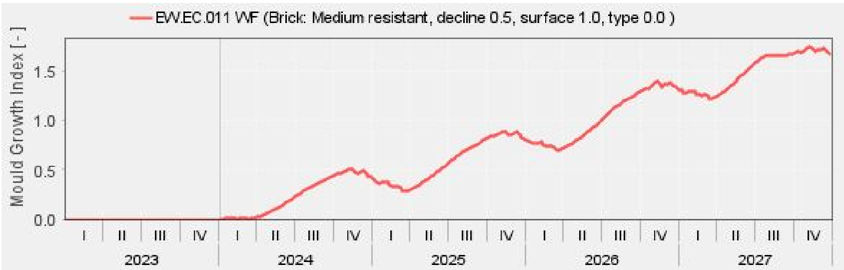


Figure K.11. Mould index time series, example 3.

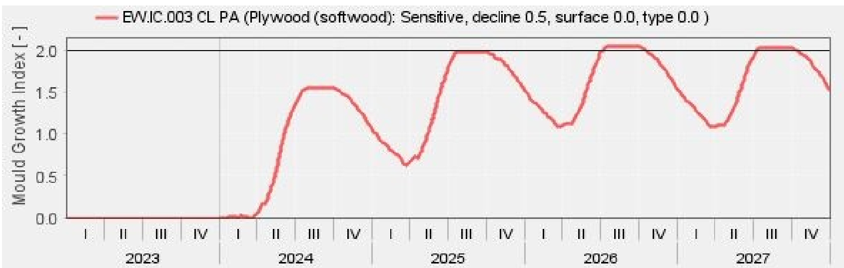


Figure K.12. Mould index time series, example 4.

Figure K.13. Mould index time series, example 5.

It is possible that the buildup of moisture will result in a mould index exceeding the limit given a longer study period and the component is not accepted. In figure K.12, the mould index exceed the limit slightly and is not accepted. If the mould index in the final year of the study period were below the limit, this component would have been accepted, due to the small size of the exceedance. In figure K.13, the mould index significantly exceeds the limit and is not accepted.

K.4 Results

The results from the selected component evaluations give an insight into the component as well as components with a similar composition. If components of a particular composition are not accepted, further investigations are performed to gain information on which combinations of micro components are associated with insufficient performance. Critical component compositions which are accepted, are used as indicators for the acceptance of lessor critical composition variations. From the analysis, rules are defined intended for use as moisture-related filtration guidelines for the purpose of the study in the present project. The resulting guidelines are specific to the present study, as macro climate, local climate, orientation, initial conditions, material properties, component compositions, assumed component details, evaluation criteria, model assumptions, and expertise of the person evaluating the results all have an influence on the results. The guidelines defined in the present moisture study are based on 218 hygrothermal simulations distributed across categories as shown in figure K.14.

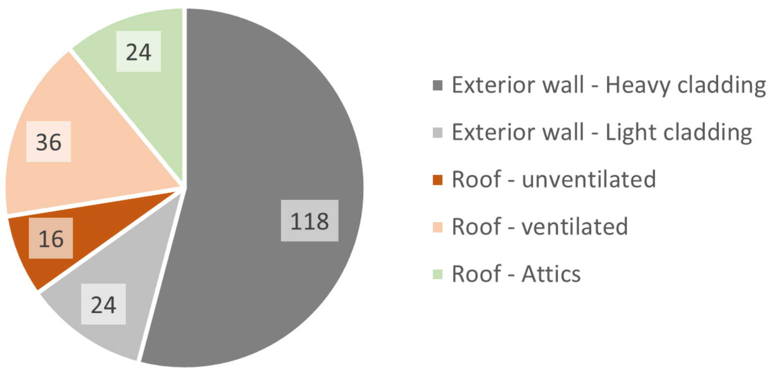


Figure K.14. Distribution of 218 simulations and moisture evaluations divided into general categories.

The studies performed are used to create moisture-related filtration rules to sort out macro components that perform poorly. The rules are shown in appendix D.

L Determination of Loads on Reference Buildings

This appendix contains the method used to calculate loads acting on the load-bearing constructions. The loads are calculated to be able to evaluate the load-bearing capacity in both the warm and cold scenarios. The calculation is delimited to only consider loads in the downward direction, as these are the main loads affecting the building components. The loads are calculated based on Eurocodes, considering load from self-weight, imposed loads, snow loads, and wind loads.

The load calculation is performed on reference buildings, to be able to quantify the loads and compare them to the load-bearing capacity. The reference buildings are presented in the following section.

L.1 Reference Buildings

The two reference buildings used in the load calculation is: a one single-family house in one storey and a four-storey apartment building.

L.1.1 Reference Building 1: Single-family House

The first reference building is the single-family house, which is selected from a case library from Videnscenter om Bygningers Klimapåvirkninger, where technical drawings and LCA data are given for 20 cases from external consulting engineering companies [Videnscenter om Bygningers Klimapåvirkninger, 2023].

The single-family house reference building is called Villa Grenaa and is a one-storey single-family house with a gross area of $135\,\mathrm{m}^2$. The house is built in 2019 and has a separate carport [Videnscenter om Bygningers Klimapåvirkninger, 2023]. The main building of Villa Grenaa is shown in figure L.1. The floor plan of the reference building is shown in figure L.2. The two skylights located in the bathroom and dining area are not considered when calculating the loads in the building.

Figure L.1. Reference single-family house house [Videnscenter om Bygningers Klimapåvirkninger, 2023].

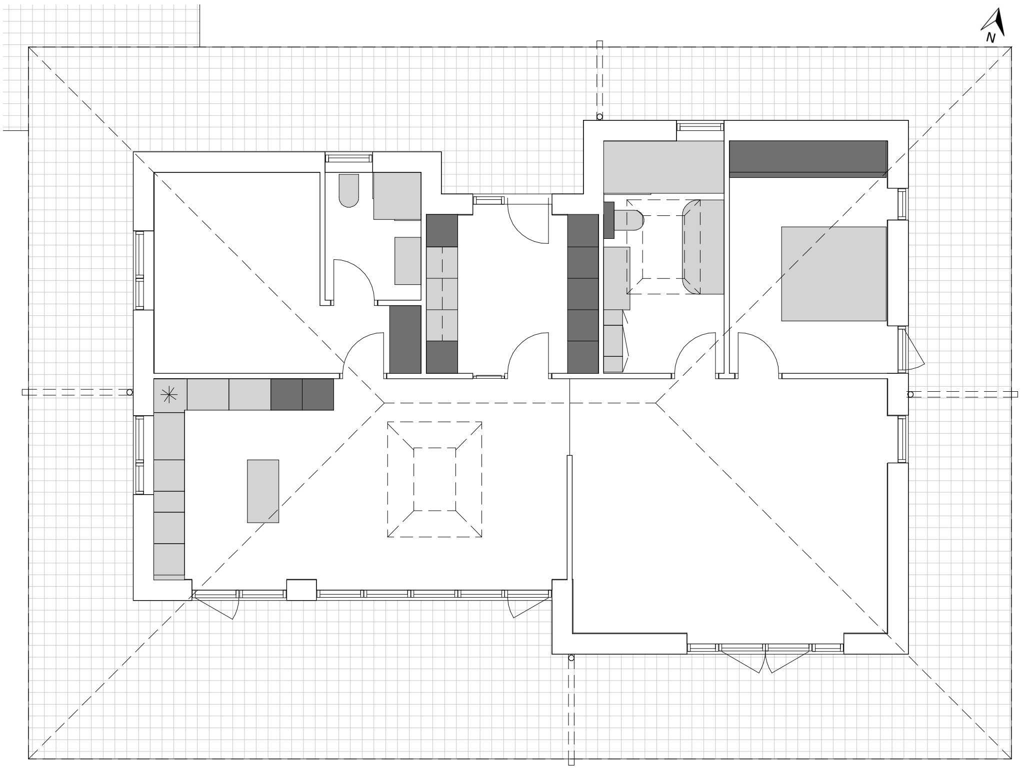


Figure L.2. Reference Single-family house floor plan [Videnscenter om Bygningers Klimapåvirkninger, 2023].

L.1.2 Reference Building 2: Four-storey Apartment Building

This reference building is a group of six apartment buildings in 3-4 storeys which are built in 2016-2018. The data is from the case library [Videnscenter om Bygningers Klimapåvirkninger, 2023], and the buildings are shown in figure L.3. An example floor plan from one of the buildings is shown in figure L.4. All floors have the same size but different room layouts.

Figure L.3. Apartment reference building [Videnscenter om Bygningers Klimapåvirkninger, 2023].

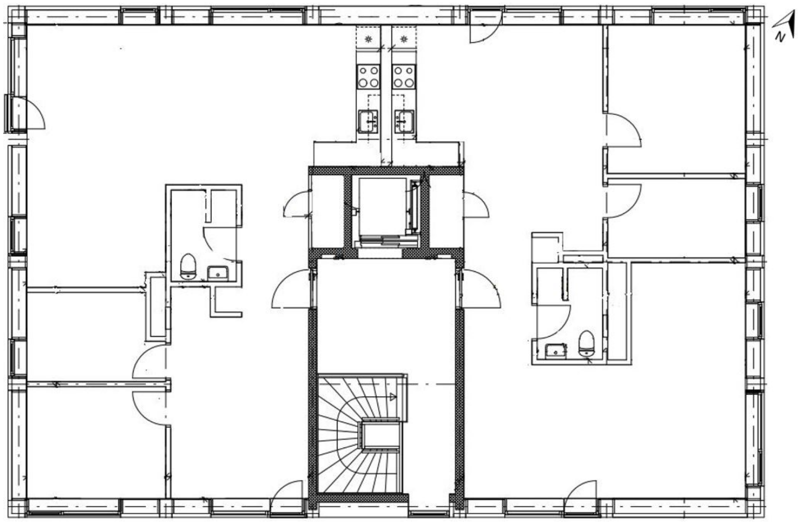


Figure L.4. Apartment reference building floor plan [Videnscenter om Bygningers Klimapåvirkninger, 2023].

L.2 Load Calculation

In the following sections, the load calculation is described. The calculation method is incorporated in the automated generation and evaluation of macro components, where the highest resulting load combination is used in the evaluation of the load-bearing capacity.

L.2.1 Self-weight

The method used to calculate the self-weight is described in DS/EN 1991-1-1 [2007]. The self-weight is determined based on the component weight, calculated in the generation of macro components. The weight is calculated using the information about the amount and density of each material, that is stored in the databases:

$$M = \Sigma(V_i \cdot \rho_i) \tag{L.1}$$

Where

M	Weight of component [kg]
V_i	Volume of material [m^3]
ρ_i	Density of material [kg/m^3]

To convert the component weight into a load, the weight in kilograms is converted to newton using the gravitational constant:

$$G = M \cdot g \tag{L.2}$$

Where

G	Self-weight [N]
M	Weight of component [kg]
g	Gravitational constant [m/s^2]

In this project, it is desired to be able to use all macro components in combination with each other on building level. To be able to do this, the self-weight is calculated on basis of the heaviest component of each type.

L.2.2 Imposed Loads

The imposed loads are determined using tables in DS/EN 1991-1-1 [2007]. The loads are delimited to the characteristic loads acting on the surface area. No local loads are considered. In table L.1, the characteristic imposed loads are shown [DS/EN 1991-1-1, 2007].

Table L.1. Characteristic imposed loads [DS/EN 1991-1-1, 2007].

Construction	Characteristic imposed load [kN/m^2]
Roof	1.5
Horizontal Division	2.0

L.2.3 Snow Loads

The snow load on the roof is determined using the snow load shape coefficient for the critical roof type. The snow load shape coefficients are determined using graphs in DS/EN 1991-1-3 [2007]. The calculation of the snow load is performed according to the standard, as shown in equation (L.3).

$$s = \mu \cdot C_e \cdot C_t \cdot s_k \tag{L.3}$$

Where

s	Snow load [kN/m^2]
μ	Snow load shape coefficient [-]
C_e	Exposure coefficient [-]
C_t	Thermal coefficient [-]
s_k	Characteristic value for snow load on ground [kN/m^2]

In this project, the coefficients C_e and C_t is set to 1 according to the standard [DS/EN 1991-1-3, 2007]. Thereby, it is assumed that the building is located in normal typography.

The characteristic value for snow load on ground is 1 kN/m^2 [DS/EN 1991-1-3, 2007].

The snow load shape coefficient is set to 0.8, as the determined coefficient for all the roof types in the micro component database are resulting in this value.

L.2.4 Wind Loads

The wind loads on the roofs are calculated using graphs in DS/EN 1991-1-4 [2010]. Wind loads are delimited significantly by only considering loads in a downward direction. The load is calculated according to the standard as shown in equation (L.4).

$$w = q_p \cdot c \tag{L.4}$$

Where

w	Wind load [kN]
q_p	Peak velocity pressure [kN/m^2]
c	Size coefficient [-]

The peak velocity pressure is set to $0.45\,\text{kN/m}^2$ [DS/EN 1991-1-4, 2010]. This is assuming that the building is located in normal typography.

The load is determined for all roof types in the micro component database and for a wind direction towards both the facade and the gable. The highest calculated value occurred for the gable roof type with a wind direction towards the facade. In this case, the size factor was determined to be 0.7, which is the value used in the load calculation.

L.2.5 Load Combinations

The load combinations are relevant for loads on the roof. The load combinations for the considered loads are determined using DS/EN 1990 FU [2021].

The relevant load combinations are dominating imposed loads, dominating snow load, and dominating wind load. The load combination coefficients needed in the calculations are determined according to the standard and it the coefficients apply for dwelling building typologies. The coefficients are shown in table L.2.

Table L.2. Coefficients for load combinations [DS/EN 1990 FU, 2021].

Coefficient	Value [-]
Coefficient ψ_1	0.5
Coefficient ψ_2	0.3
Coefficient ψ_3	0.2

The load combinations are calculated using the coefficients from table L.2. The calculations are performed according to the standard, and shown in equation (L.5), (L.6), and (L.7) for the relevant load combinations [DS/EN 1990 FU, 2021].

Dominating imposed loads:

$$P_{dom\ imposed\ loads} = G + \psi_1 \cdot q + \psi_2 \cdot s + \psi_2 \cdot w \tag{L.5}$$

Dominating snow loads:

$$P_{dom\ snow\ loads} = G + \psi_2 \cdot q + \psi_1 \cdot s + \psi_2 \cdot w \tag{L.6}$$

Dominating wind loads:

$$P_{dom\ wind\ loads} = G + \psi_2 \cdot q + \psi_2 \cdot s + \psi_1 \cdot w \tag{L.7}$$

Where

P	Permissible load on roof [kN/m^2]
G	Load from self-weight [kN/m^2]
ψ_1	Load combination coefficient for dominating load [-]
s	Snow load [kN/m^2]
ψ_2	Load combination coefficient for not-dominating loads [-]
w	Wind load [kN/m^2]

Calculation of the load combinations are incorporated in the automated generation and evaluation of macro components. Thereby, the most critical load combination can vary according to the specific component evaluated.

M Micro Component Catalogue

This chapter will hold a description of all micro components looked at in this project. All micro components are described by the parameters listed in table M.1.

Table M.1. Description of parameters used to describe micro components.

Method	Description
Component reference:	This parameter describes where the micro component is found. A description of the buildings from where the micro components are found can be seen in appendix F.
Compatible with:	This parameter describes what kind of load-bearing construction the specific micro component is able to be mounted on.
Construction type:	This parameter describes if it is a frame construction or a solid construction.
Exterior side compatible with:	Some solid load-bearing constructions are able to mount the same type of cladding as frame constructions, this parameter describes what type of cladding that can be mounted on the exterior side of the construction.
Interior side compatible with:	This parameter describes what type of cladding that can be mounted on the interior side of the construction.
Component thickness:	This parameter describes the thickness of the micro component.
Component plane weight:	This parameter describes the weight of 1 m^2 of component.
Total environmental component impact:	This parameter describes the total amount of global warming potential that is emitted during a period of 50 years.
Heat capacity:	This parameter is the calculated heat capacity of the inner side of a wall. This parameter is further described in appendix E.
R-value:	This parameter is the thermal resistance for the micro component. It is used to calculate the U-value of the entire macro component. How the R-value is calculated is described in appendix E.
Fire technical classification:	The fire technical classification parameters are parameters describing the component's reaction to fire and fire protection ability. The reaction to fire is both given from the surface materials and also for the material with the lowest reaction to fire in the micro component.
Fire technical parameters:	The fire technical parameters are the parameters used to calculate the load-bearing capacity, insulation, and integrity of components. A description of this calculations are given in appendix H.

M.1 Exterior Walls

The exterior walls are split into six micro components, these are:

- IC - Interior cladding
- EC - Exterior cladding
- S1 - Structure & insulation - one storey buildings
- S4 - Structure & insulation - four storey buildings
- WP - Wind protection
- VB - Vabor barrier
- IL - Installation layer
- INS - Insulation

The micro components for the exterior walls are described in this section.

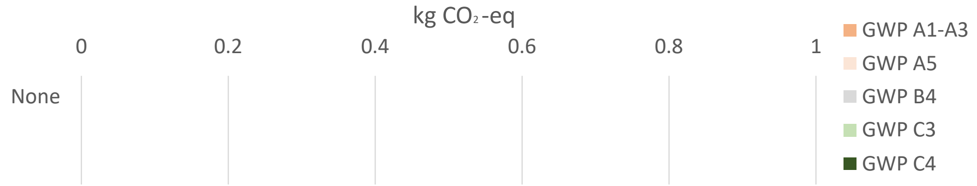
IC 01 - None

Component reference	:	None
Compatible with	:	Solid constructions
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 $kg\ CO_2-eq/m^2$

Heat capacity
0 Wh/m^2 K

R-value
0.13 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
None

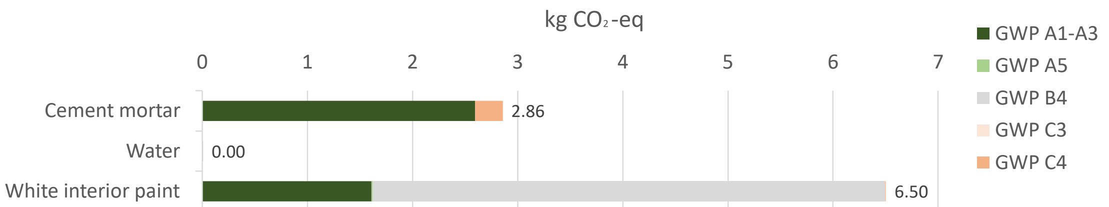
IC 02 - 10 mm mortar + Paint

Component reference	:	AB02
Compatible with	:	Solid constructions
Component thickness	:	10 mm
Component plane weight	:	18.7 kg/m^2
Total environmental component impact	:	9.4 $kg\ CO_2-eq/m^2$

Heat capacity
0 Wh/m^2 K

R-value
0.141 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

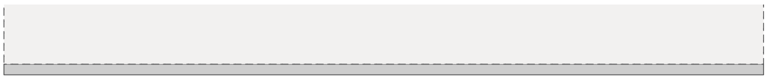
Component material class
None

IC 03 - 9.5 mm Plasterboard + Plaster + Paint

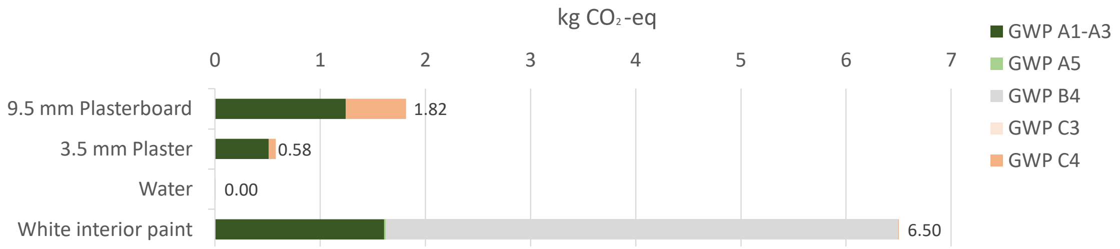
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	14.5 mm
Component plane weight	:	20.5 kg/m^2
Total environmental component impact	:	8.9 kg CO_2-eq/m^2

Heat capacity
2.4 Wh/m^2 K

R-value
0.194 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

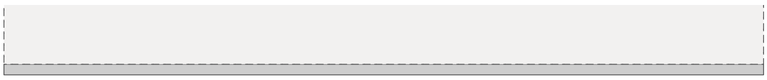
t_{ins} = 13.3 min | t_{ch} = 10.1 min | t_f = 18.8 min | N_{60} = 13.6

IC 04 - 12.5 mm Plasterboard + Plaster + Paint

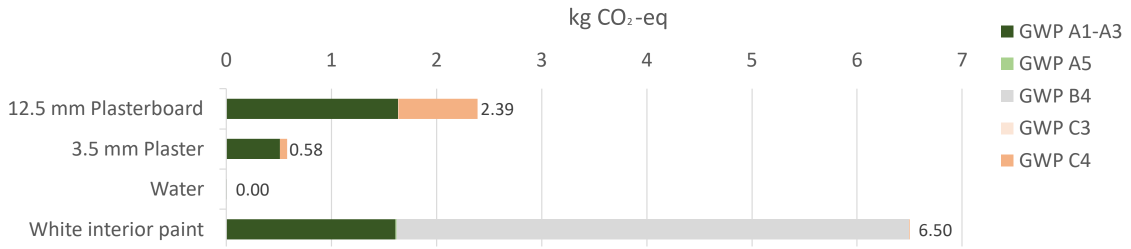
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	17.5 mm
Component plane weight	:	22.9 kg/m^2
Total environmental component impact	:	9.5 kg CO_2-eq/m^2

Heat capacity
3.13 Wh/m^2 K

R-value
0.209 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

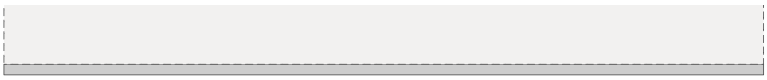
t_{ins} = 17.5 min | t_{ch} = 15.5 min | t_f = 32.25 min | N_{60} = 13.6

IC 05 - 15 mm Plasterboard + Plaster + Paint

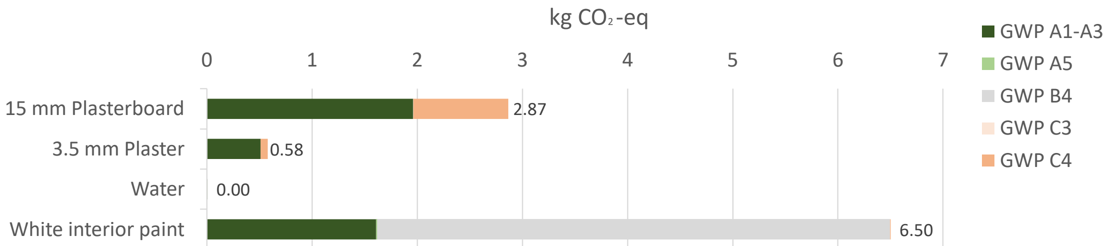
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	20 mm
Component plane weight	:	24.9 kg/m^2
Total environmental component impact	:	10 kg CO_2−eq/m^2

Heat capacity
3.75 Wh/m^2 K

R-value
0.222 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 21 min | t_{ch} = 20 min | t_f = 43.5 min | N_{60} = 13.6

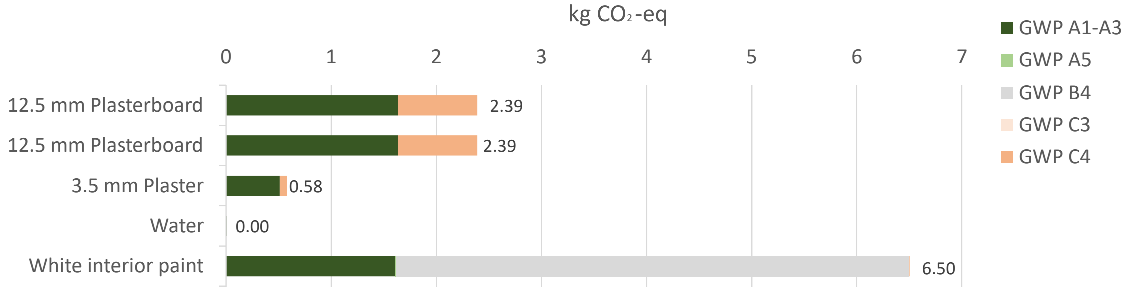
IC 06 - 2 x 12.5 mm Plasterboard + Plaster + Paint

Component reference	:	AB05
Compatible with	:	Frame constructions
Component thickness	:	30 mm
Component plane weight	:	32.9 kg/m^2
Total environmental component impact	:	11.9 kg CO_2-eq/m^2

Heat capacity
6.25 Wh/m^2 K

R-value
0.272 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 28 min

t_{ch} = 45.5 min

t_f = 60 min

N_{60} = 265.3

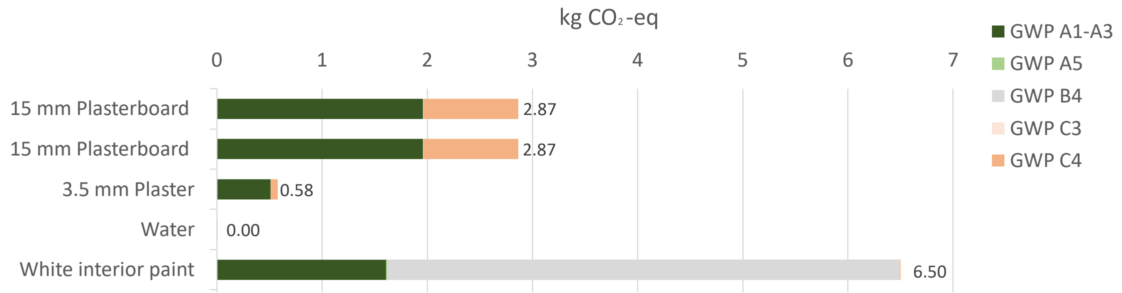
IC 07 - 2 x 15 mm Plasterboard + Plaster + Paint

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	35	mm
Component plane weight	:	36.9	kg/m^2
Total environmental component impact	:	12.8	$kg\ CO_2-eq/m^2$

Heat capacity
7.5 $Wh/m^2\ K$

R-value
0.297 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

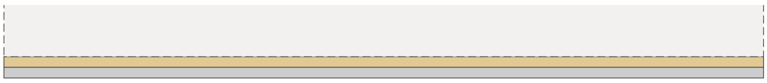
t_{ins} = 33.6 min | t_{ch} = 56 min | t_f = 80 min | N_{60} = 265.3

IC 08 - 12 mm OSB + 12.5 mm Plasterboard + Plaster + Paint

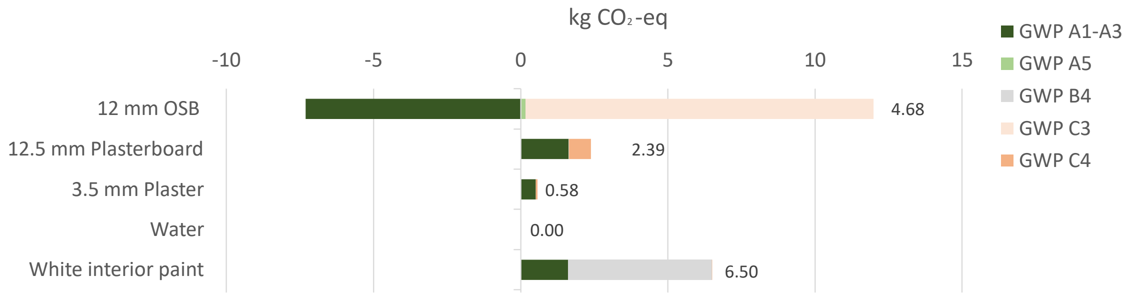
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	29.5	mm
Component plane weight	:	30.1	kg/m^2
Total environmental component impact	:	14.15	$kg\ CO_2{-}eq/m^2$

Heat capacity
5.8 $Wh/m^2\ K$

R-value
0.302 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

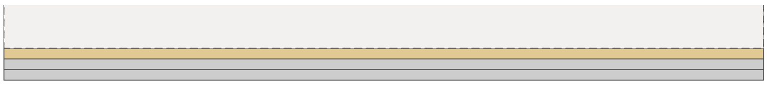
$t_{ins} = 28$ min	$t_{ch} = 18.5$ min	$t_f = 18.8$ min	$N_{60} = 13.6$

IC 09 - 12 mm OSB + 2 x 12.5 mm Plasterboard + Plaster + Paint

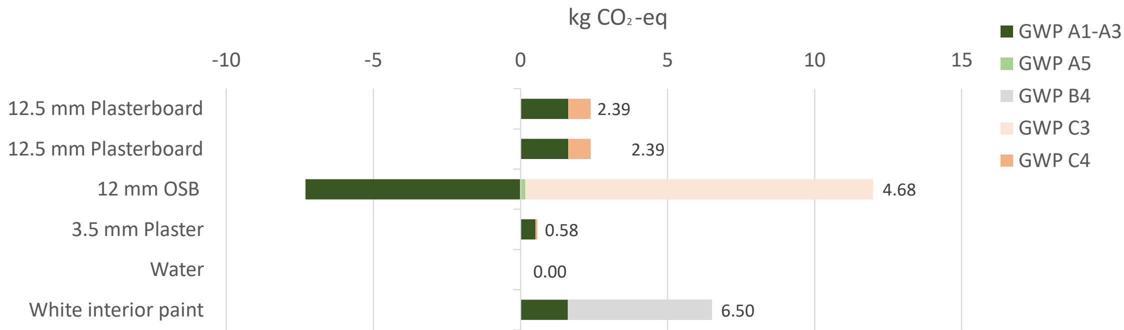
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	40.1	kg/m^2
Total environmental component impact	:	16.5	$kg\ CO_2-eq/m^2$

Heat capacity
8.9 Wh/m^2 K

R-value
0.364 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

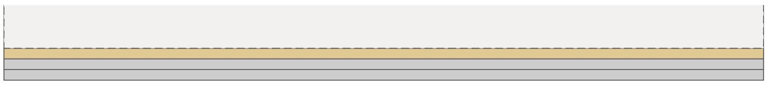
$t_{ins} = 38.5$ min | $t_{ch} = 55$ min | $t_f = 60$ min | $N_{60} = 265.3$

IC 10 - 15 mm OSB + 2 x 15 mm Plasterboard + Plaster + Paint

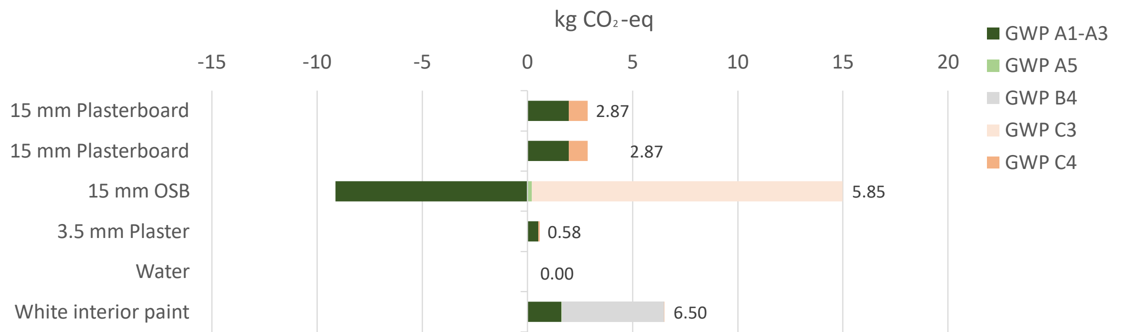
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	50 mm
Component plane weight	:	45.9 kg/m^2
Total environmental component impact	:	18.7 kg CO_2−eq/m^2

Heat capacity
10.8 Wh/m^2 K

R-value
0.412 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

$t_{ins} = 46.8$ min | $t_{ch} = 71.8$ min | $t_f = 80$ min | $N_{60} = 265.3$

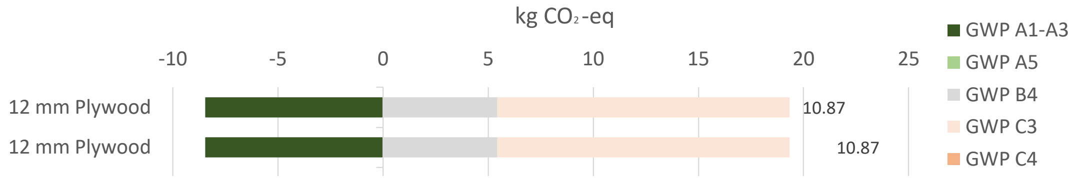
IC 11 - 2 x Plywood

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	24 mm
Component plane weight	:	11.8 kg/m^2
Total environmental component impact	:	21.7 kg CO_2-eq/m^2

Heat capacity
5.33 Wh/m^2 K

R-value
0.315 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 14.8 min

t_{ch} = 20 min

t_f = 20 min

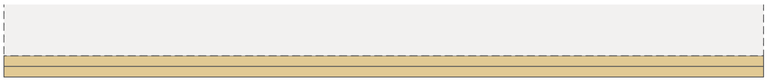
N_{60} = 13.6

IC 12 - 2 x OSB

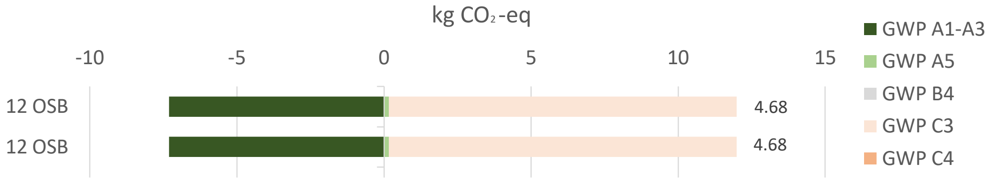
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	24	mm
Component plane weight	:	14.4	kg/m^2
Total environmental component impact	:	9.4	$kg\ CO_2-eq/m^2$

Heat capacity
5.33 $Wh/m^2\ K$

R-value
0.315 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 17.8$ min

$t_{ch} = 22.7$ min

$t_f = 22.7$ min

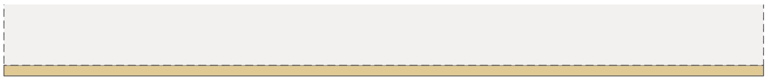
$N_{60} = 13.6$

IC 13 - 15 mm Plywood

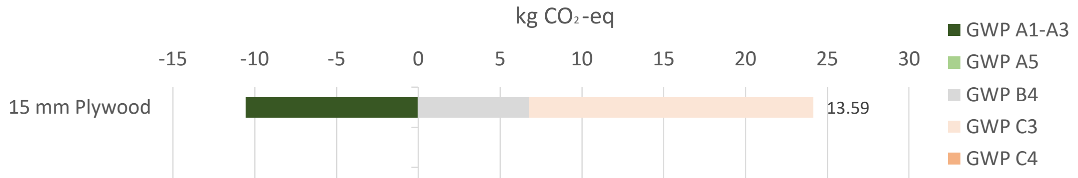
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	15 mm
Component plane weight	:	7.4 kg/m^2
Total environmental component impact	:	13.6 kg CO_2−eq/m^2

Heat capacity
3.33 Wh/m^2 K

R-value
0.245 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	D-s2,d0	D-s2,d0

Fire technical parameters

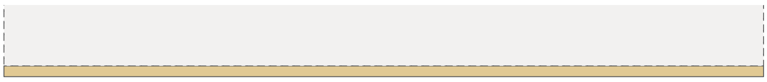
$t_{ins} = 9.6$ min | $t_{ch} = 9$ min | $t_f = 9$ min | $N_{60} = 13.6$

IC 14 - 15 mm OSB

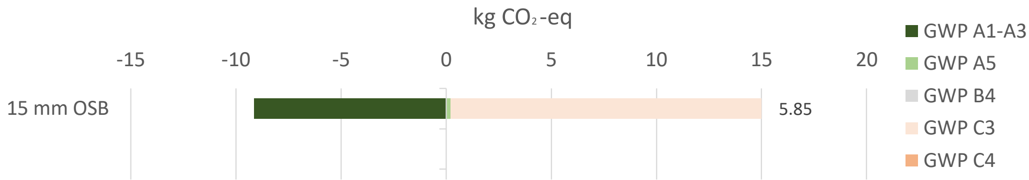
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	15 mm
Component plane weight	:	9 kg/m^2
Total environmental component impact	:	5.9 kg CO_2-eq/m^2

Heat capacity
3.33 Wh/m^2 K

R-value
0.245 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	D-s2,d0	D-s2,d0

Fire technical parameters

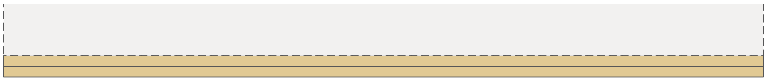
$t_{ins} = 11.1$ min | $t_{ch} = 10.4$ min | $t_f = 10.4$ min | $N_{60} = 13.6$

IC 15 - 2 x 21 mm Plywood

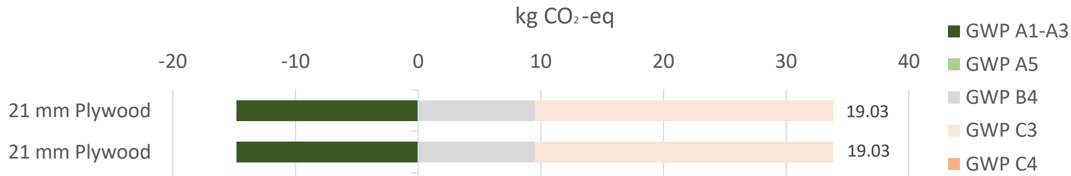
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	20.6	kg/m^2
Total environmental component impact	:	38.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
$9.33\ Wh/m^2\ K$

R-value
$0.453\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 25.9$ min

$t_{ch} = 38$ min

$t_f = 38$ min

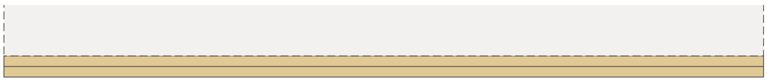
$N_{60} = 13.6$

IC 16 - 2 x 21 mm OSB

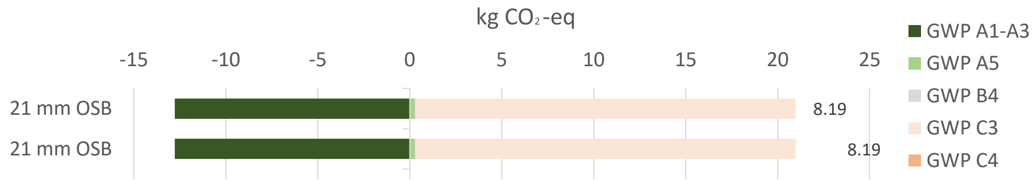
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	16.4	$kg\ CO_2{-}eq/m^2$

Heat capacity
$9.33\ Wh/m^2\ K$

R-value
$0.453\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 30$ min

$t_{ch} = 42.7$ min

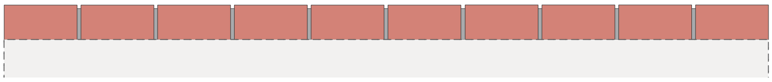
$t_f = 42.7$ min

$N_{60} = 13.6$

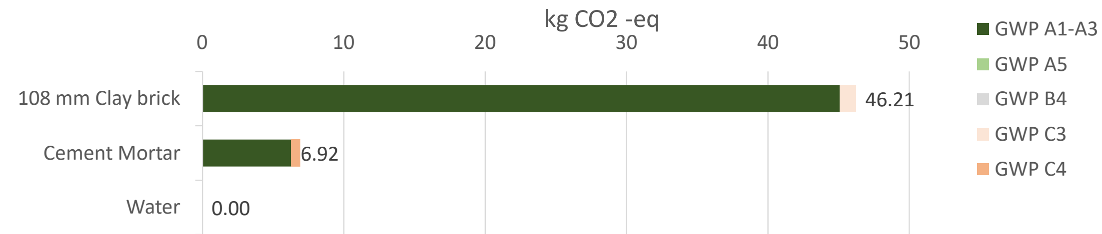
EC 01 - 108 mm Brick

Component reference	:	SFH02
Compatible with	:	Solid constructions
Component thickness	:	108 mm
Component plane weight	:	195.2 kg/m^2
Total environmental component impact	:	53.1 $kg\ CO_2{-}eq/m^2$

R-value
0.188 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1-s0,d0

Component material class
A1-s0,d0

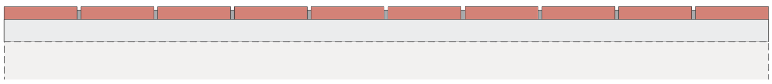
Fire technical parameters

EI120

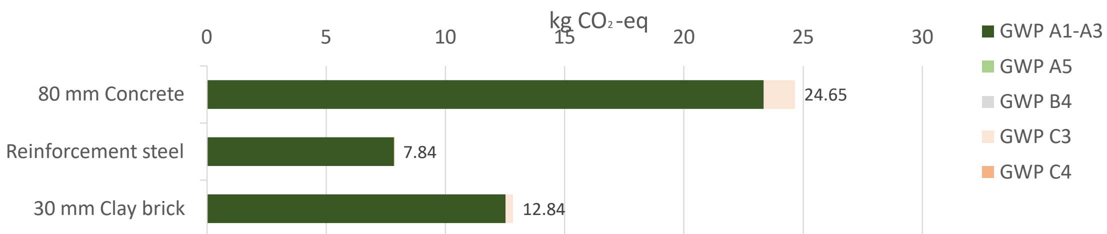
EC 02 - 80 mm concrete + 30 mm Brick

Component reference	:	AB02
Compatible with	:	Solid constructions
Component thickness	:	110 mm
Component plane weight	:	243 kg/m^2
Total environmental component impact	:	45.3 $kg\ CO_2{-}eq/m^2$

R-value
0.121 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1-s0,d0

Component material class
A1-s0,d0

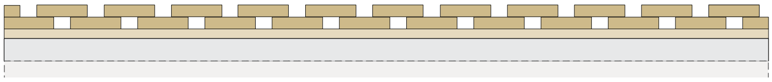
Fire technical parameters

EI60

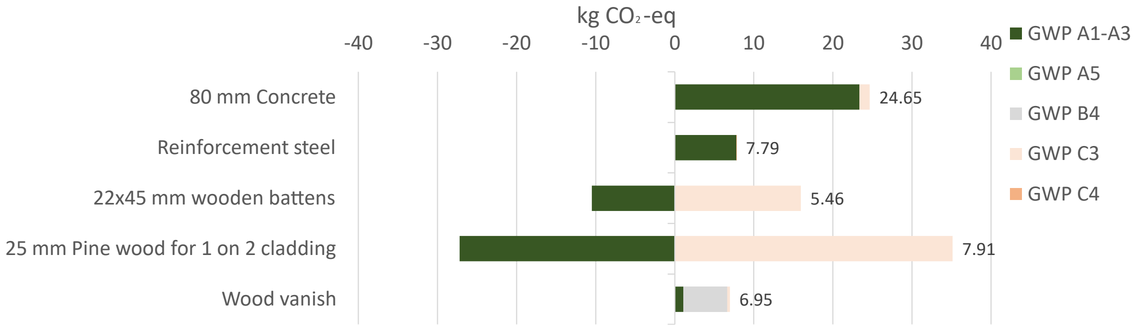
EC 03 - 80 mm concrete + Wooden battens + 1 on 2 wooden cladding

Component reference	:	AB02	
Compatible with	:	Solid constructions	
Component thickness	:	152	mm
Component plane weight	:	229.4	kg/m^2
Total environmental component impact	:	52.8	$kg\ CO_2{-}eq/m^2$

R-value
0.17 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

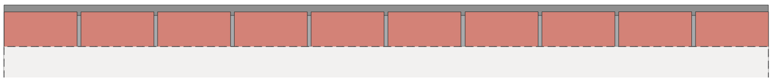
Fire technical parameters

EI60

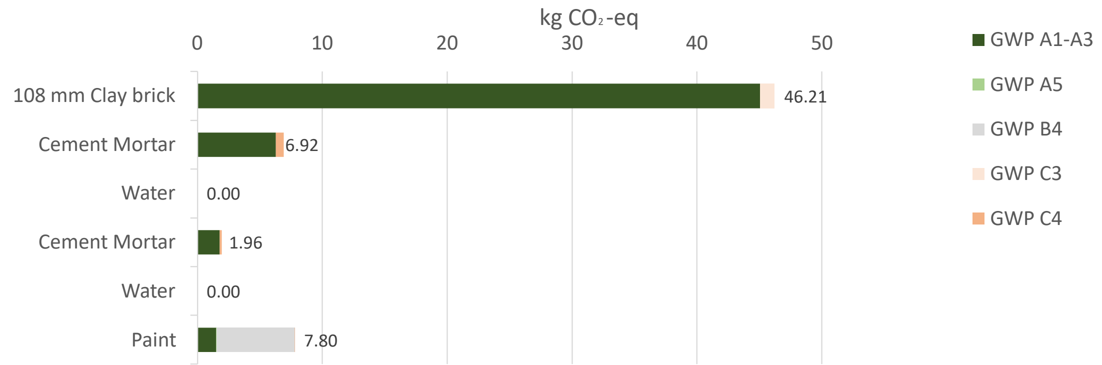
EC 04 - 108 mm brick + 6 mm plaster

Component reference	:	SFH12	
Compatible with	:	Solid constructions	
Component thickness	:	114	mm
Component plane weight	:	207.9	kg/m^2
Total environmental component impact	:	62.9	$kg\ CO_2{-}eq/m^2$

R-value
0.194 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A2-s0,d0

Component material class
A2-s0,d0

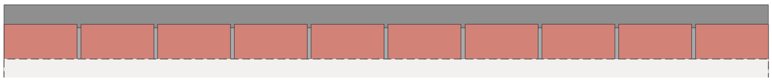
Fire technical parameters

EI120

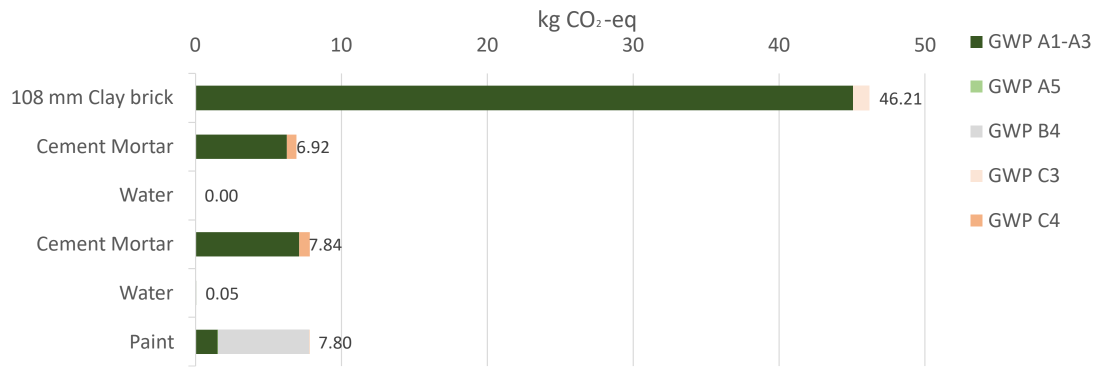
EC 05 - 108 mm brick + 24 mm plaster

Component reference	:	SFH13	
Compatible with	:	Solid constructions	
Component thickness	:	132	mm
Component plane weight	:	634.1	kg/m^2
Total environmental component impact	:	68.8	$kg\ CO_2-eq/m^2$

R-value
0.211 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A2-s0,d0

Component material class
A2-s0,d0

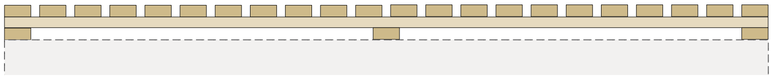
Fire technical parameters

EI120

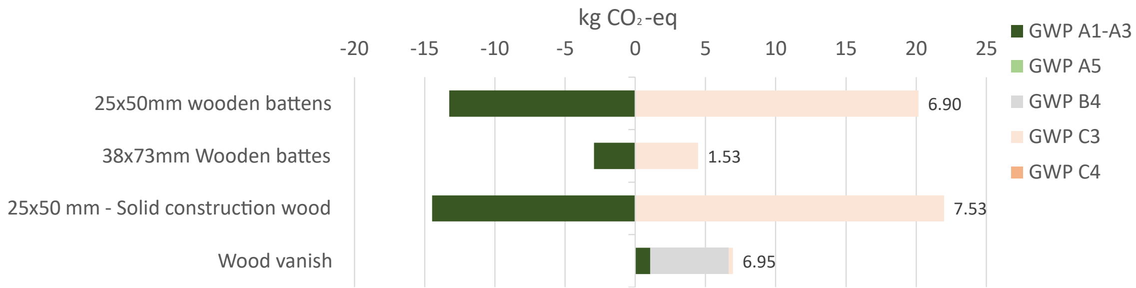
EC 06 - Wooden battens + Open vertical wooden cladding

Component reference	:	INS01	
Compatible with	:	Frame constructions	
Component thickness	:	88	mm
Component plane weight	:	25.9	kg/m^2
Total environmental component impact	:	22.9	$kg\ CO_2{-}eq/m^2$

R-value
$0.13\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

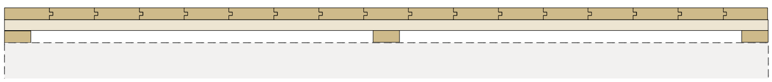
Fire technical parameters

$t_{ins} = 0$

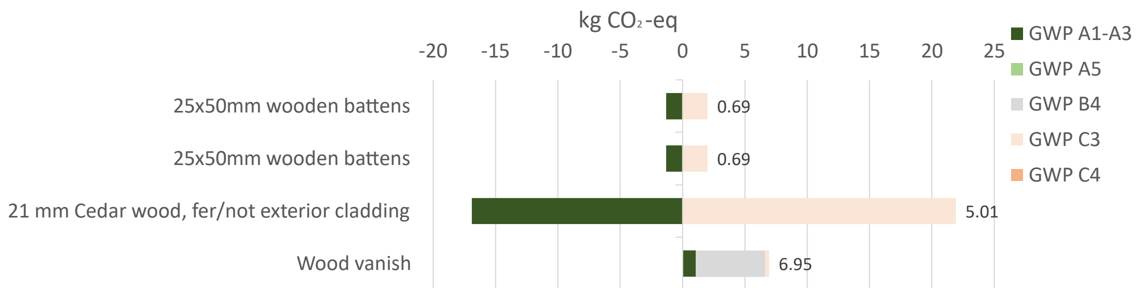
EC 07 - Wooden battens + Fer/not wooden cladding

Component reference	:	SCH02	
Compatible with	:	Frame constructions	
Component thickness	:	71	mm
Component plane weight	:	14.6	kg/m^2
Total environmental component impact	:	13.4	$kg\ CO_2{-}eq/m^2$

R-value
$0.13\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

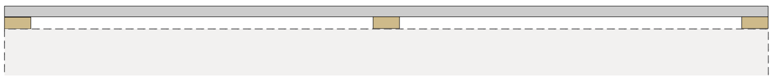
Fire technical parameters

$t_{ins} = 20.8$

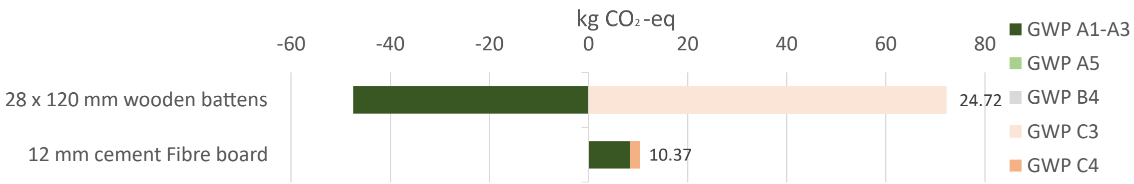
EC 08 - Wooden battens + Cement fiber board

Component reference	:	OB02
Compatible with	:	Frame constructions
Component thickness	:	40 mm
Component plane weight	:	55.1 kg/m^2
Total environmental component impact	:	35.1 kg CO_2−eq/m^2

R-value
0.13 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

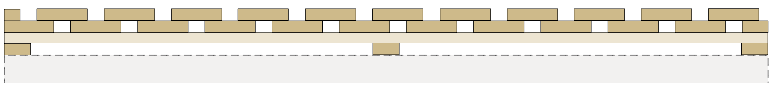
Fire technical parameters

t_{ins}= 20.2

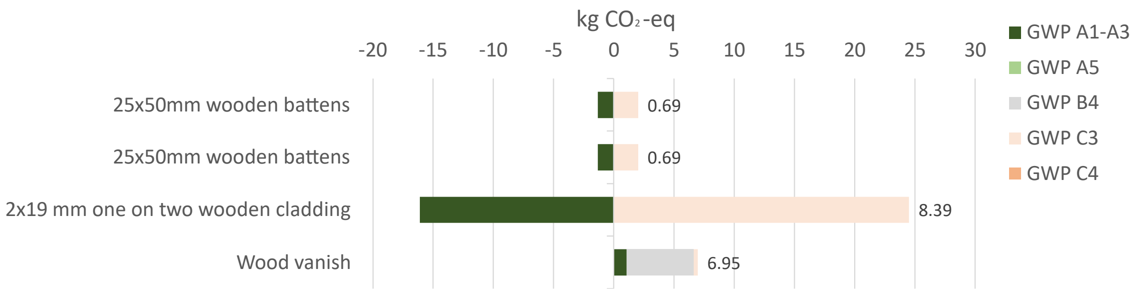
EC 09 - Wooden battens + 1 on 2 wooden cladding

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	88 mm
Component plane weight	:	16 kg/m^2
Total environmental component impact	:	16.7 kg CO_2−eq/m^2

R-value
0.13 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

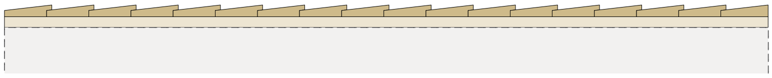
Fire technical parameters

t_{ins}= 19.3

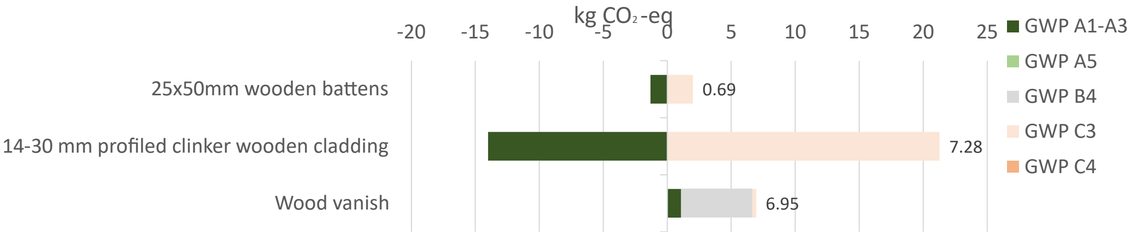
EC 11 - Wooden battens + Profiled clinker wooden cladding

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	47 mm
Component plane weight	:	13.1 kg/m^2
Total environmental component impact	:	14.9 $kg\ CO_2{-}eq/m^2$

R-value
0.13 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

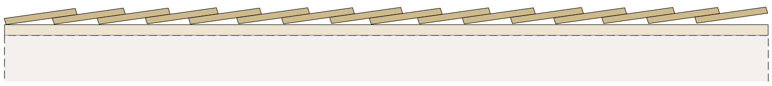
Fire technical parameters

t_{ins}= 16.5

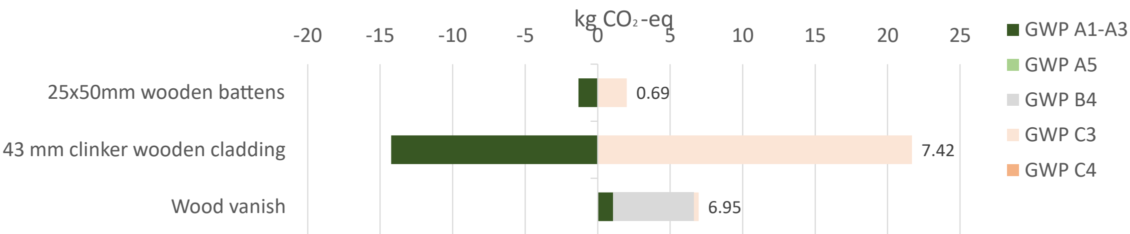
EC 12 - Wooden battens + Clinker wooden cladding

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	68 mm
Component plane weight	:	13.3 kg/m^2
Total environmental component impact	:	15.1 $kg\ CO_2{-}eq/m^2$

R-value
0.13 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

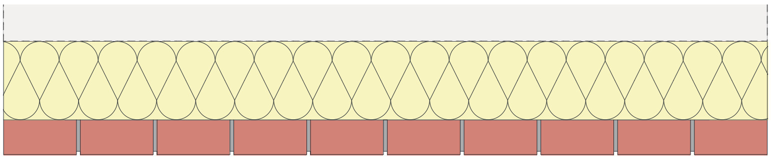
t_{ins}= 14.3

S1 01 - 108 mm Clay brick + 245 mm Insulation

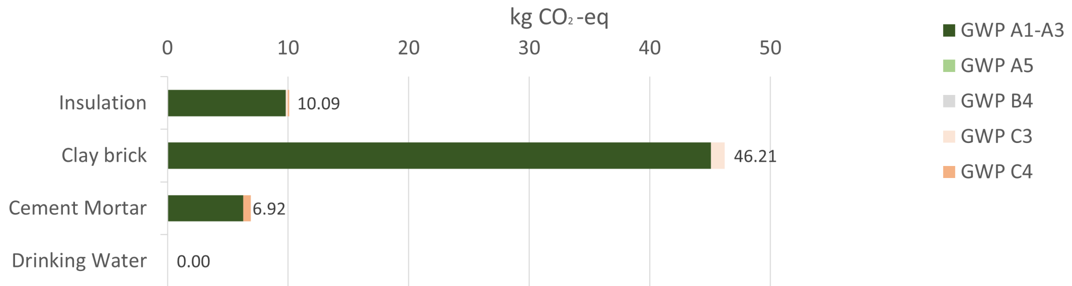
Component reference	:	SFH01	
Construction type	:	Solid construction	
Exterior side compatible with	:	Solid construction cladding	
Interior side compatible with	:	Solid construction cladding	
Component thickness	:	353	mm
Component plane weight	:	201.6	kg/m^2
Total environmental component impact	:	63.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
45.4 $Wh/m^2\ K$

R-value
0.245/L+0.17
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R120

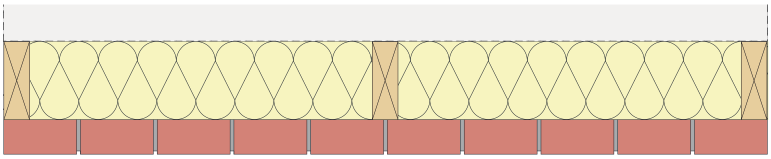
EI120

S1 02 - 108 mm Clay brick + 245 mm Wooden studs & Insulation

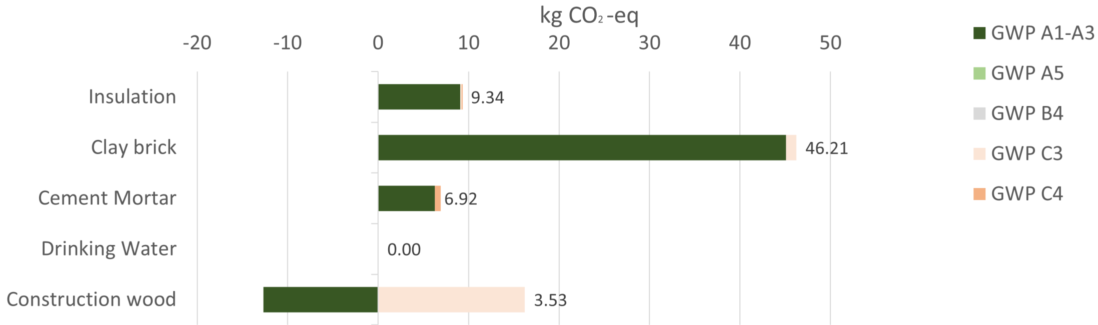
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	353 mm
Component plane weight	:	210 kg/m^2
Total environmental component impact	:	66 kg CO_2-eq/m^2

Heat capacity
45.4 Wh/m^2 K

R-value
$0.245/(0.00975+0.925 \cdot L)+0.17$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R120

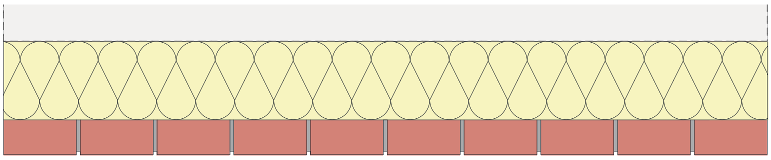
EI120

S1 03 - 108 mm Clay brick + 290 mm Insulation

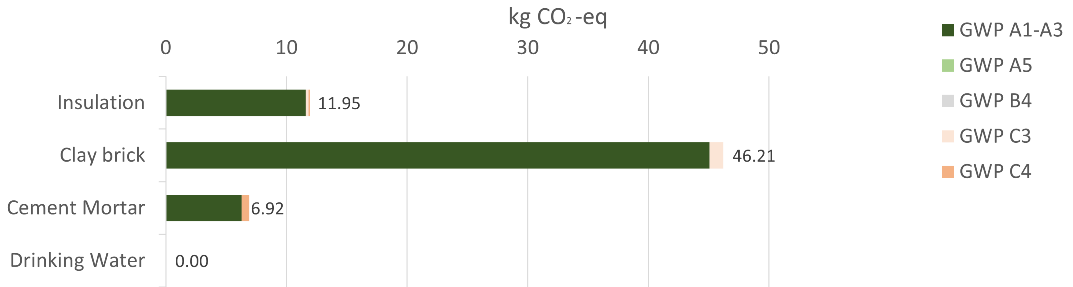
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	398 mm
Component plane weight	:	202.8 kg/m^2
Total environmental component impact	:	65.1 kg CO_2-eq/m^2

Heat capacity
45.4 Wh/m^2 K

R-value
0.29/L+0.17
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R120

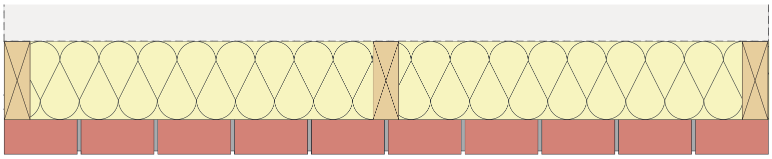
EI120

S1 04 - 108 mm Clay brick + 290 mm Wooden studs & Insulation

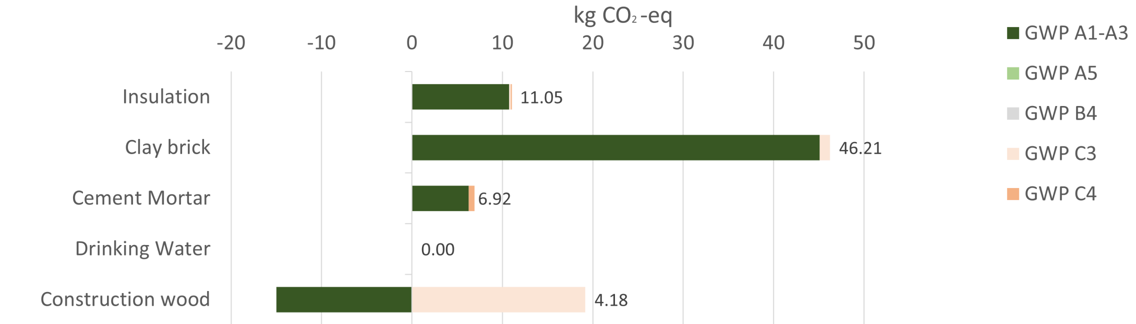
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	398 mm
Component plane weight	:	212.7 kg/m^2
Total environmental component impact	:	68.4 kg CO_2−eq/m^2

Heat capacity
45.4 Wh/m^2 K

R-value
0.29/(0.00975+0.925 · L)+0.17 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

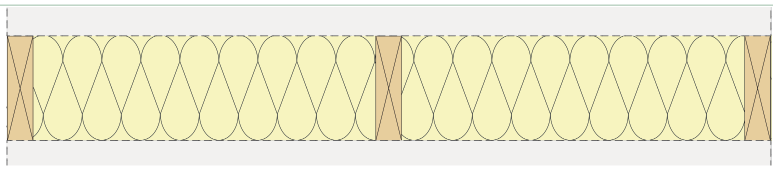
R120

EI120

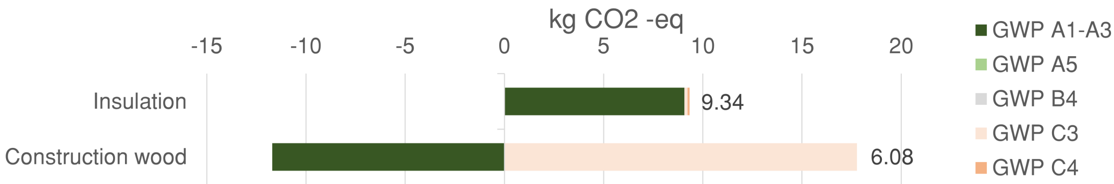
S1 05 - 245 mm Wooden frame structure & Insulation

Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	15.4 kg CO_2−eq/m^2

R-value
$0.245/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class	Component material class
None	D-s2,d0

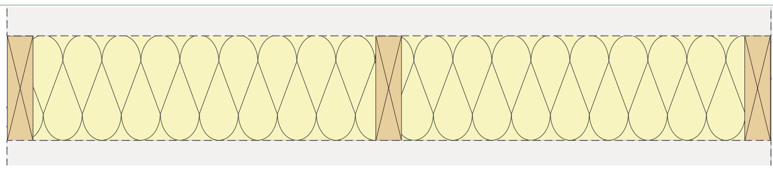
Fire technical parameters

$t_{ins} = 29.4$ $f_{c,0,k} = 24$ MPa

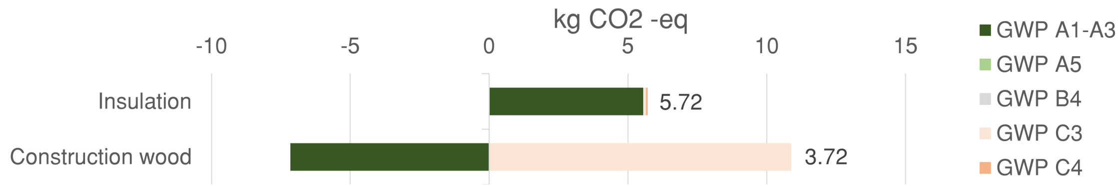
S1 06 - 150 mm Wooden frame structure & Insulation

Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	150 mm
Component plane weight	:	9.6 kg/m^2
Total environmental component impact	:	9.4 kg CO_2−eq/m^2

R-value
0.15/(0.00975 +0.925 · L) K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class	Component material class
None	D-s2,d0

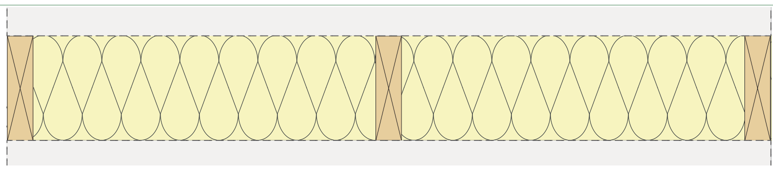
Fire technical parameters

$t_{ins} = 18$ $f_{c,0,k} = 24$ MPa

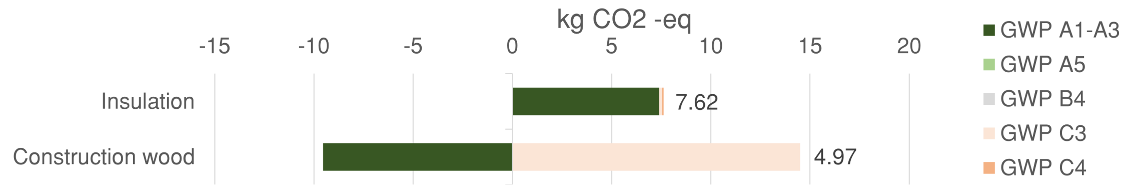
S1 07 - 200 mm Wooden frame structure & Insulation

Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	12.7 kg/m^2
Total environmental component impact	:	12.6 kg CO_2-eq/m^2

R-value
$0.2/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 24$

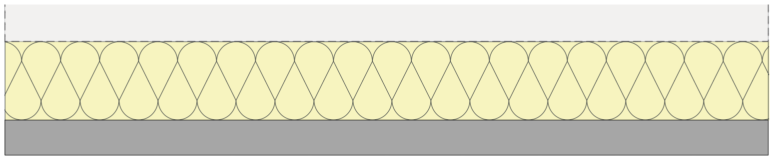
$f_{c,0,k} = 24$ MPa

S1 08 - 100 mm Aerated concrete + 245 mm Insulation

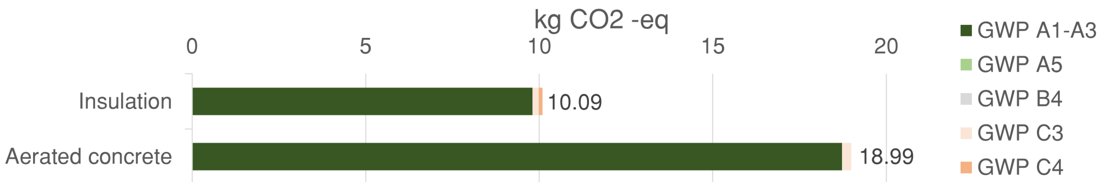
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	345 mm
Component plane weight	:	44.4 kg/m^2
Total environmental component impact	:	29.1 kg CO_2-eq/m^2

Heat capacity
14.9 Wh/m^2 K

R-value
0.245/L+0.625
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R120

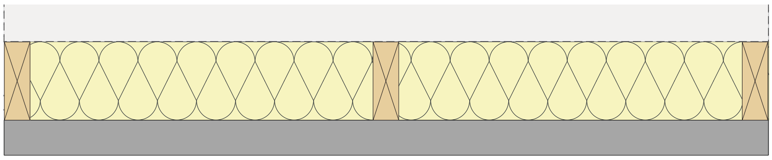
EI240

S1 09 - 100 mm Aerated concrete + 245 mm Wooden studs & Insulation

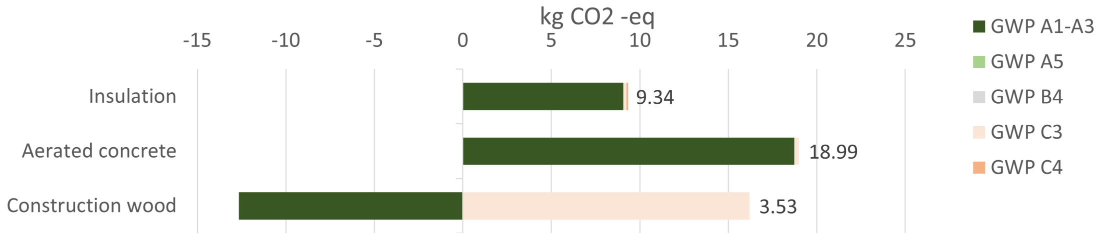
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	345 mm
Component plane weight	:	52.7 kg/m^2
Total environmental component impact	:	31.9 kg $CO_2\text{-eq}/m^2$

Heat capacity
14.9 Wh/m^2 K

R-value
$0.245/(0.00975+0.925 \cdot L)+0.625$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R120

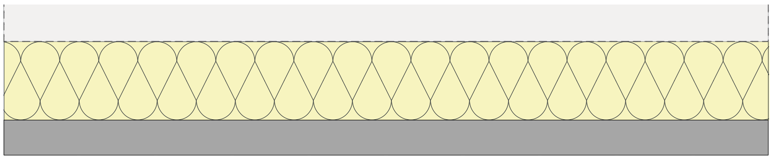
EI240

S1 10 - 100 mm Aerated concrete + 290 mm Insulation

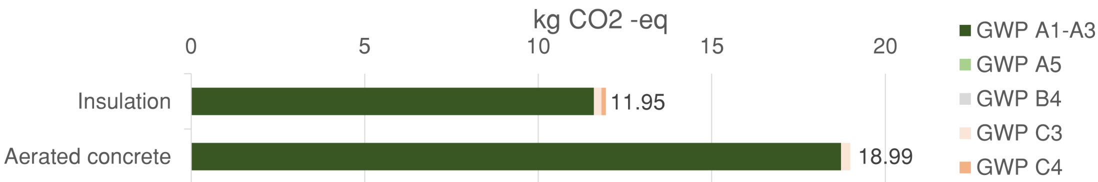
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	390 mm
Component plane weight	:	45.5 kg/m^2
Total environmental component impact	:	30.9 kg CO_2−eq/m^2

Heat capacity
14.9 Wh/m^2 K

R-value
0.29/L+0.625
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R120

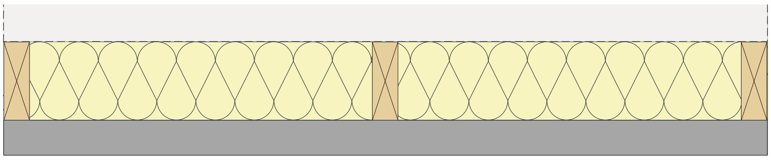
EI240

S1 11 - 100 mm Aerated concrete + 290 mm Wooden studs & Insulation

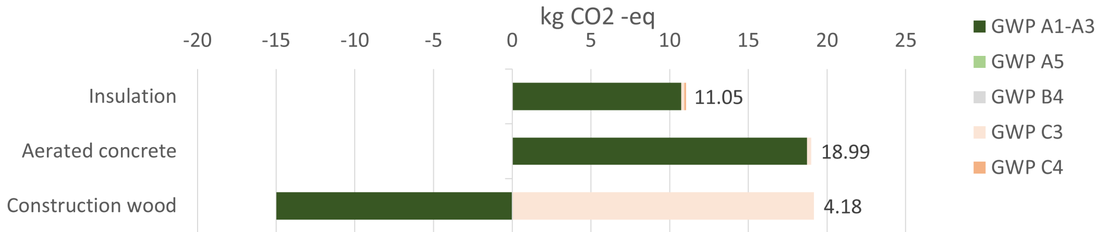
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	390 mm
Component plane weight	:	55.4 kg/m^2
Total environmental component impact	:	34.2 kg CO_2−eq/m^2

Heat capacity
14.9 Wh/m^2 K

R-value
0.29/(0.00975+0.925 · L)+0.625 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R120

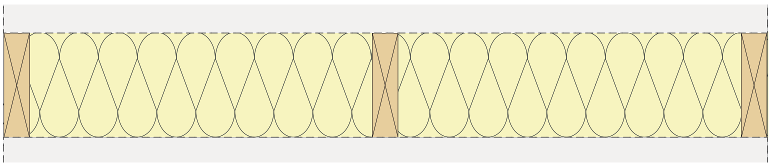
EI240

S1 12 - 245 mm Wooden studs & Insulation

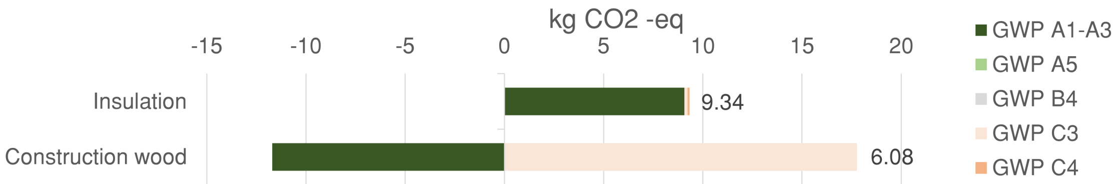
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	15.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.245/(0.00975+0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

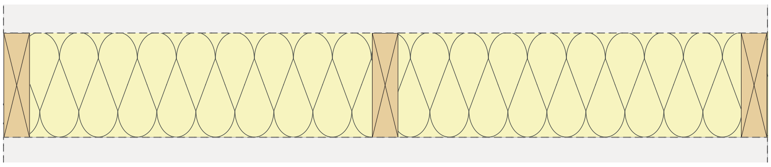
$f_{c,0,k} = 18$ MPa

S1 13 - 150 mm Wooden studs & Insulation

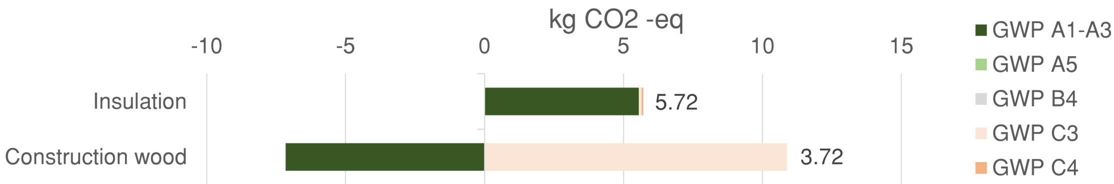
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	150 mm
Component plane weight	:	9.6 kg/m^2
Total environmental component impact	:	9.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.15/(0.00975+0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 18$

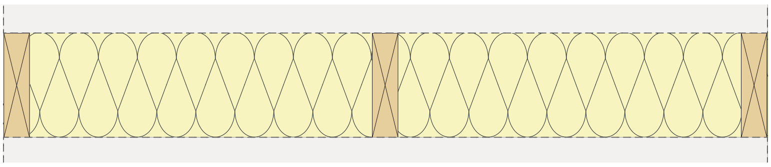
$f_{c,0,k} = 18$ MPa

S1 14 - 200 mm Wooden studs & Insulation

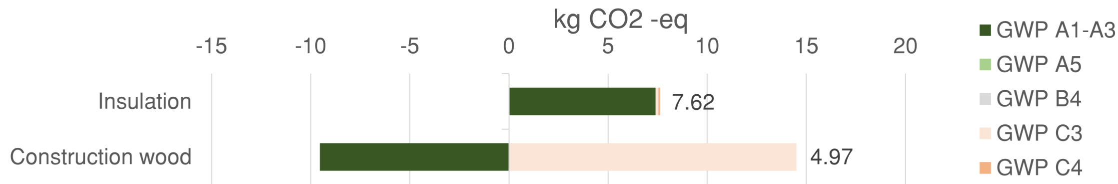
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	12.7 kg/m^2
Total environmental component impact	:	12.6 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.2/(0.00975+0.925 \cdot L)$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 24$

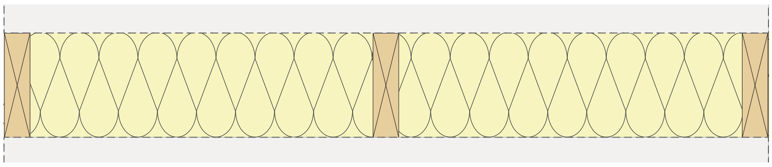
$f_{c,0,k} = 18$ MPa

S1 15 - 245 mm Wooden studs & Insulation

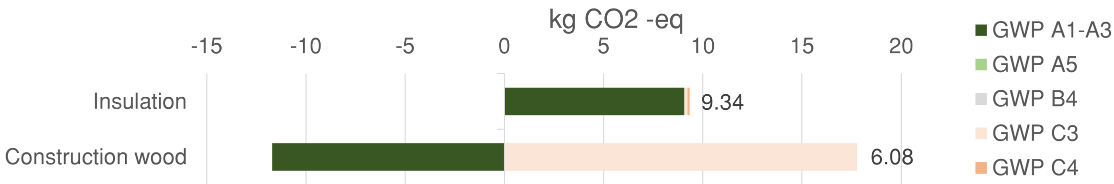
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	15.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.245/(0.00975+0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

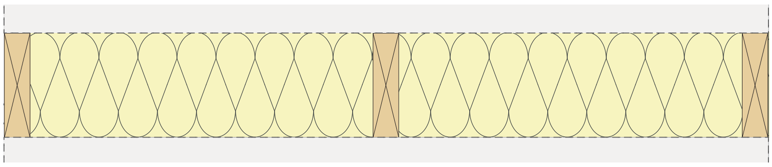
$f_{c,0,k} = 21$ MPa

S1 16 - 150 mm Wooden studs & Insulation

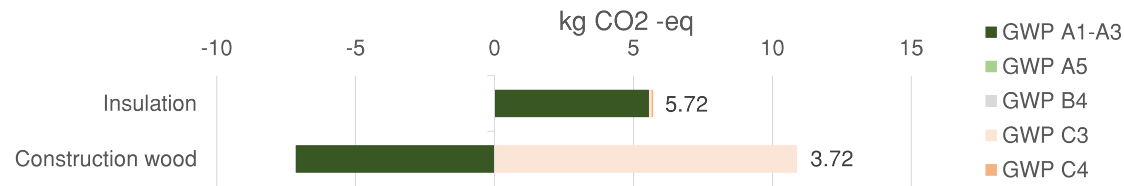
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	150 mm
Component plane weight	:	9.6 kg/m^2
Total environmental component impact	:	9.4 kg CO_2–eq/m^2

Heat capacity
None

R-value
0.15/(0.00975+0.925 · L)
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 18$

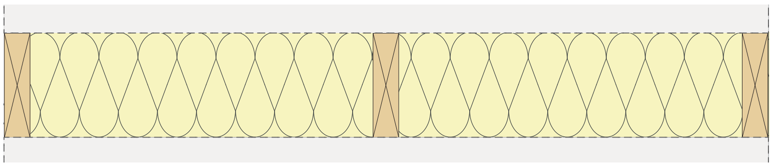
$f_{c,0,k} = 21$ MPa

S1 17 - 200 mm Wooden studs & Insulation

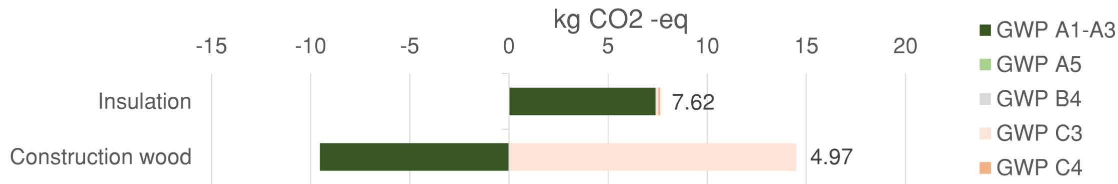
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	12.7 kg/m^2
Total environmental component impact	:	12.6 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.2/(0.00975+0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 24$

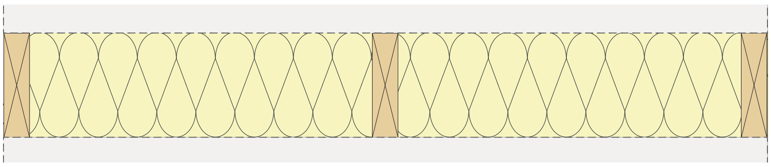
$f_{c,0,k} = 21$ MPa

S1 18 - 245 mm Wooden studs & Insulation

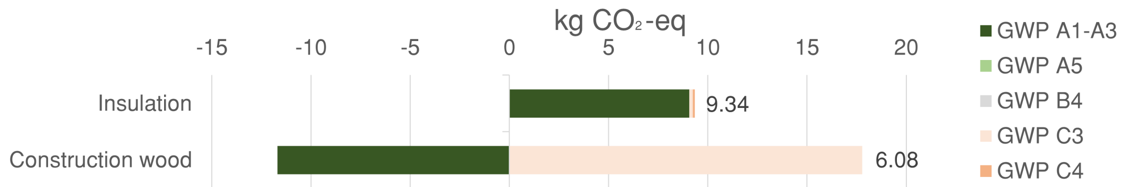
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	15.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.245/(0.00975+0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

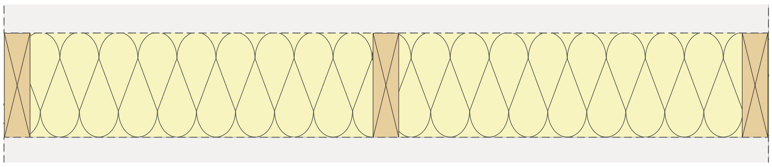
$f_{c,0,k} = 21$ MPa

S1 19 - 150 mm Wooden studs & Insulation

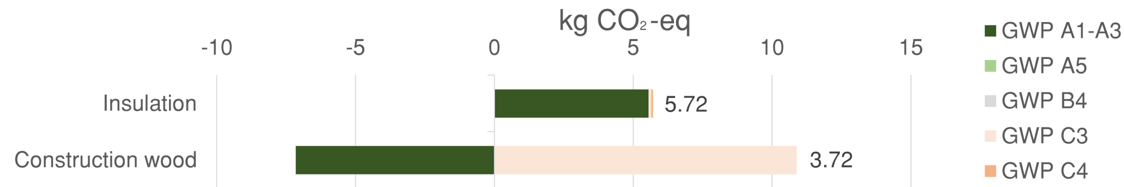
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	150 mm
Component plane weight	:	9.6 kg/m^2
Total environmental component impact	:	9.4 kg CO_2–eq/m^2

Heat capacity
None

R-value
0.15/(0.00975+0.925 · L)
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 18$

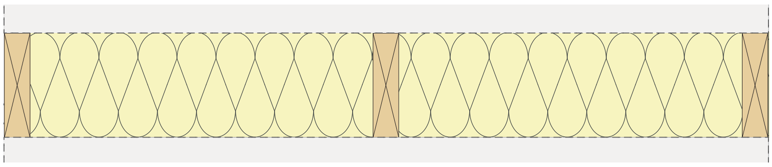
$f_{c,0,k} = 21$ MPa

S1 20 - 200 mm Wooden studs & Insulation

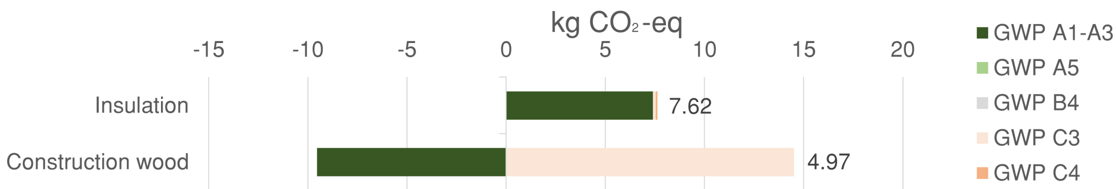
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	12.7 kg/m^2
Total environmental component impact	:	12.6 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.15/(0.00975+0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 24$

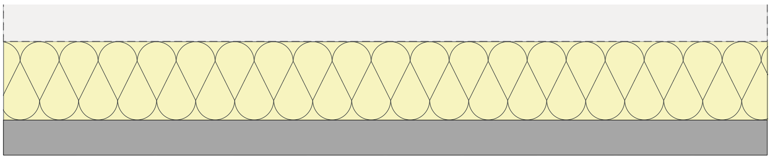
$f_{c,0,k} = 21$ MPa

S1 21 - 100 mm Concrete + 245 mm Insulation

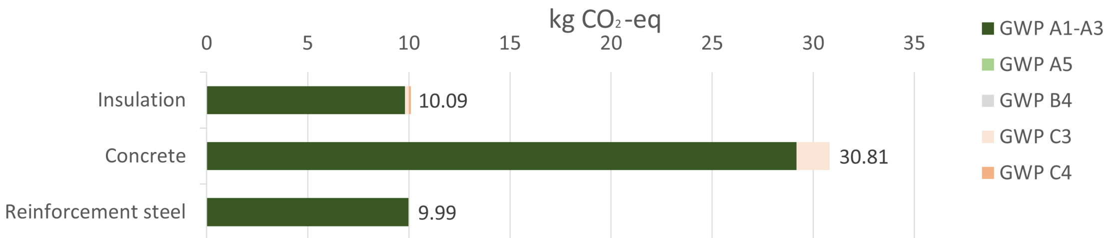
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	345 mm
Component plane weight	:	258.1 kg/m^2
Total environmental component impact	:	50.9 kg CO_2-eq/m^2

Heat capacity
14.9 Wh/m^2 K

R-value
0.245/L+0.05
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R30

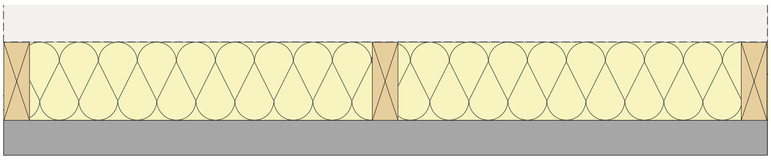
EI90

S1 22 - 100 mm Concrete + 245 mm Wooden studs & Insulation

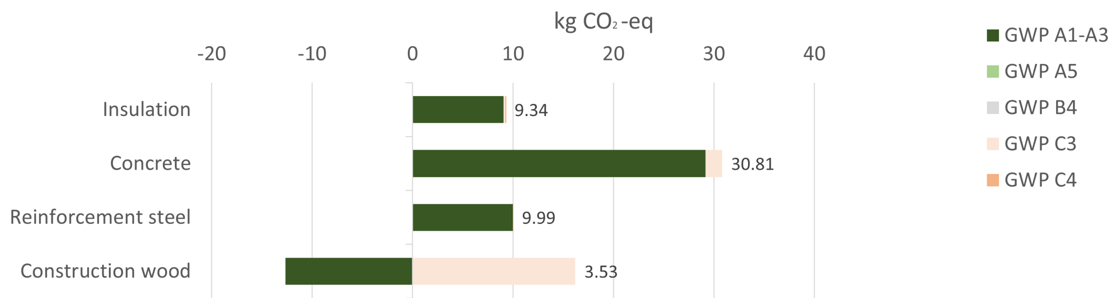
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	345 mm
Component plane weight	:	266.5 kg/m^2
Total environmental component impact	:	53.7 kg CO_2-eq/m^2

Heat capacity
14.9 Wh/m^2 K

R-value
$0.245/(0.00975+0.925 \cdot L)+0.05$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R30

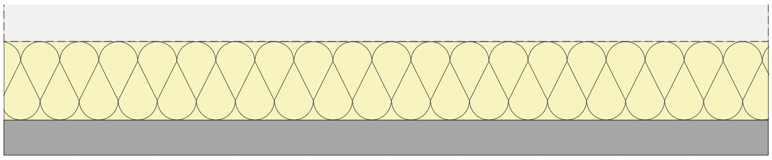
EI90

S1 23 - 100 mm Concrete + 290 mm Insulation

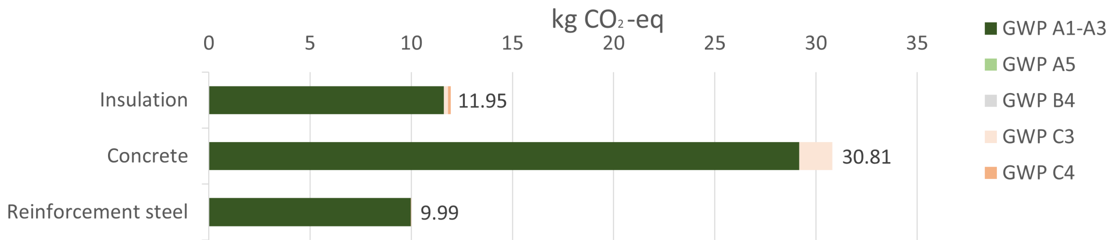
Component reference	:	SFH01	
Construction type	:	Solid construction	
Exterior side compatible with	:	Solid construction cladding	
Interior side compatible with	:	Solid construction cladding	
Component thickness	:	390	mm
Component plane weight	:	259.3	kg/m^2
Total environmental component impact	:	52.7	$kg\ CO_2-eq/m^2$

Heat capacity
14.8 $Wh/m^2\ K$

R-value
0.29/L+0.05
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R30

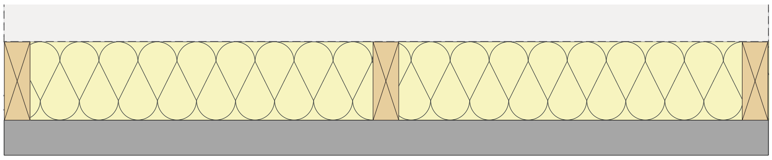
EI90

S1 24 - 100 mm Concrete + 290 mm Wooden studs & Insulation

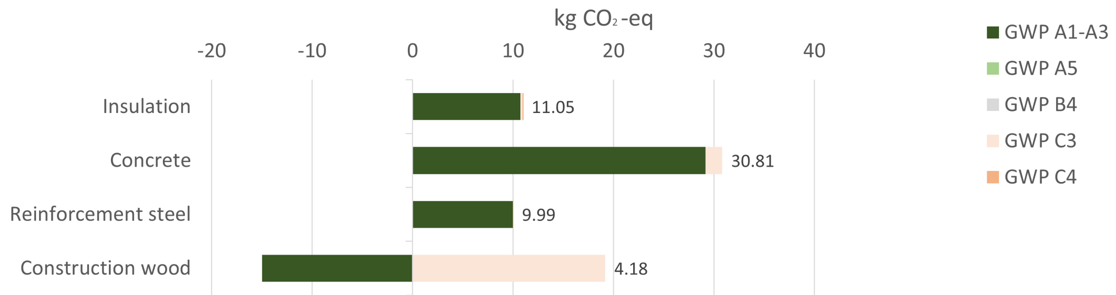
Component reference	:	SFH01	
Construction type	:	Solid construction	
Exterior side compatible with	:	Frame construction cladding	
Interior side compatible with	:	Solid construction cladding	
Component thickness	:	390	mm
Component plane weight	:	269.2	kg/m^2
Total environmental component impact	:	56	$kg\ CO_2-eq/m^2$

Heat capacity
14.9 Wh/m^2 K

R-value
0.29/(0.00975+0.925 · L)+0.05 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R30

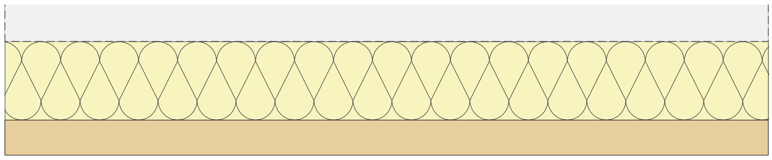
EI90

S1 25 - 100 mm CLT + 245 mm Insulation

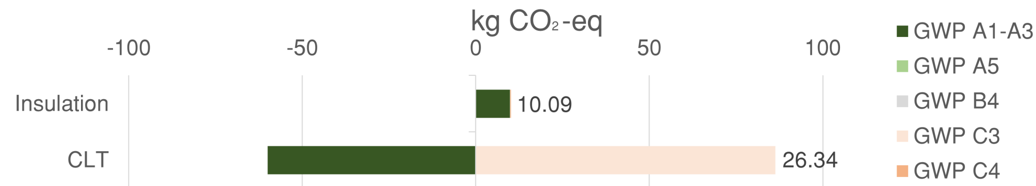
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	345 mm
Component plane weight	:	53.6 kg/m^2
Total environmental component impact	:	36.4 kg CO_2−eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
0.245/L+0.77
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

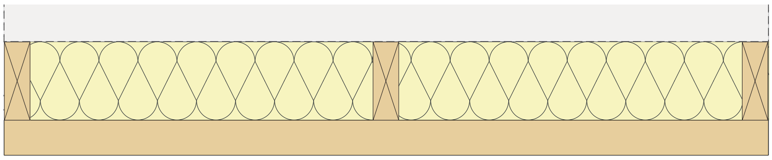
EI60

S1 26 - 100 mm CLT + 245 mm Wooden studs & Insulation

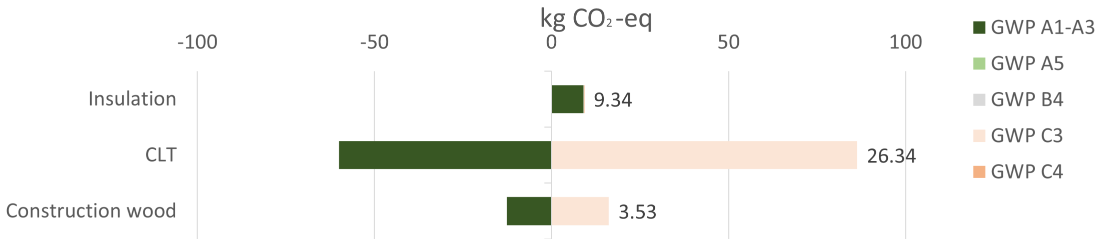
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	345 mm
Component plane weight	:	61.9 kg/m^2
Total environmental component impact	:	39.2 kg CO_2-eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
$0.245/(0.00975+0.925 \cdot L)+0.77$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

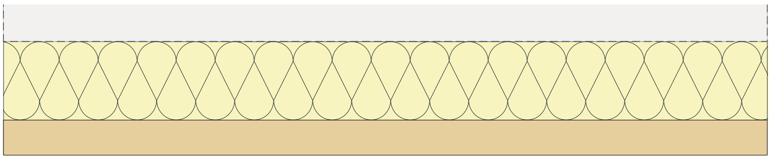
R60 EI60

S1 27 - 100 mm CLT + 290 mm Insulation

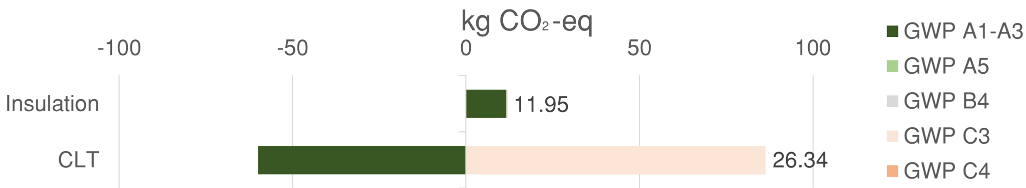
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	390 mm
Component plane weight	:	54.7 kg/m^2
Total environmental component impact	:	38.3 kg CO_2-eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
0.29/L+0.77
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

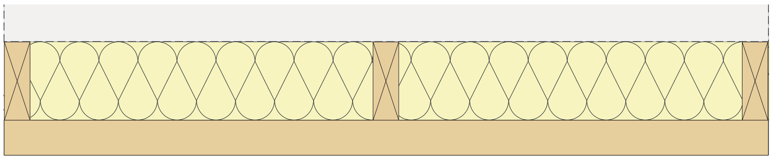
EI60

S1 28 - 100 mm CLT + 290 mm Wooden studs & Insulation

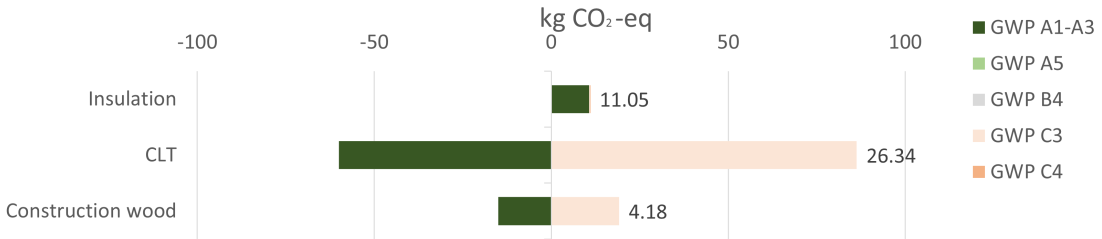
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	290 mm
Component plane weight	:	64.6 kg/m^2
Total environmental component impact	:	41.6 kg CO_2−eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
0.29/(0.00975+0.925 · L)+0.77 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

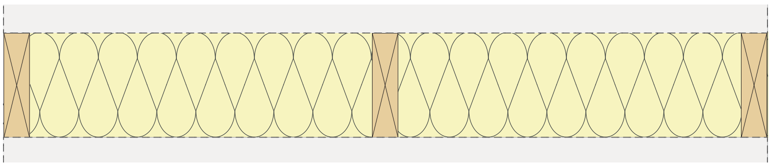
EI60

S1 29 - 245 mm GLT studs & Insulation

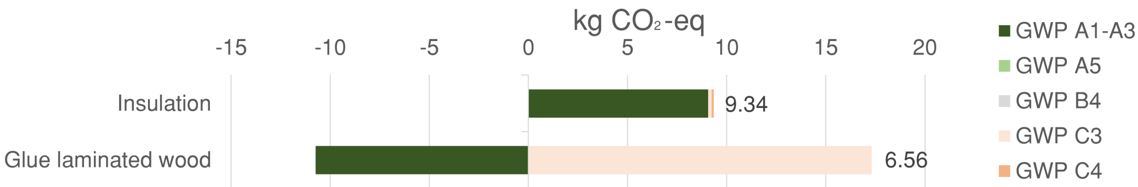
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.4 kg/m^2
Total environmental component impact	:	15.9 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.245/(0.00975+0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

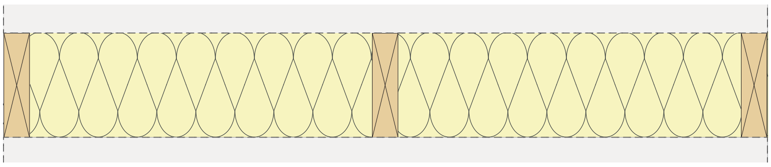
$f_{c,0,k} = 24$ MPa

S1 30 - 150 mm GLT studs & Insulation

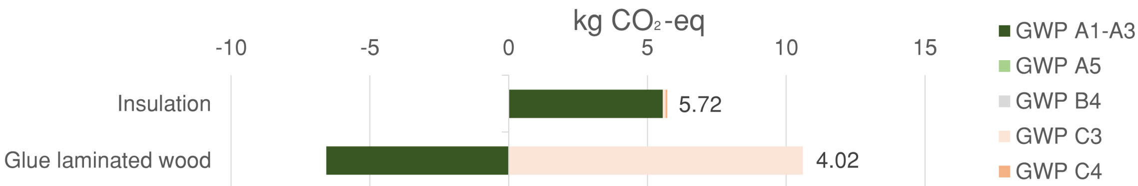
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	150 mm
Component plane weight	:	9.4 kg/m^2
Total environmental component impact	:	9.7 kg CO_2−eq/m^2

Heat capacity
None

R-value
0.245/(0.00975+0.925 · L) K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 18$

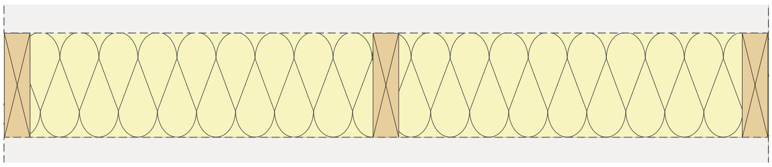
$f_{c,0,k} = 24$ MPa

S1 31 - 200 mm GLT studs & Insulation

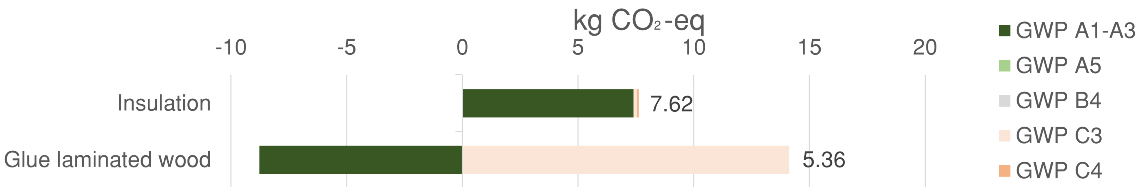
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	12.5 kg/m^2
Total environmental component impact	:	13 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.245/(0.00975+0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 24$

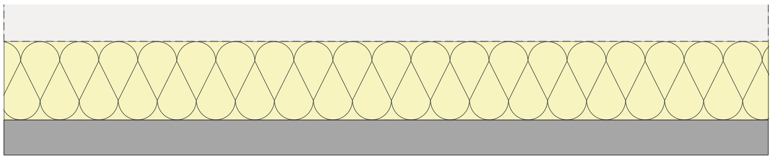
$f_{c,0,k} = 24$ MPa

S4 01 - 182 mm Concrete + 245 mm Insulation

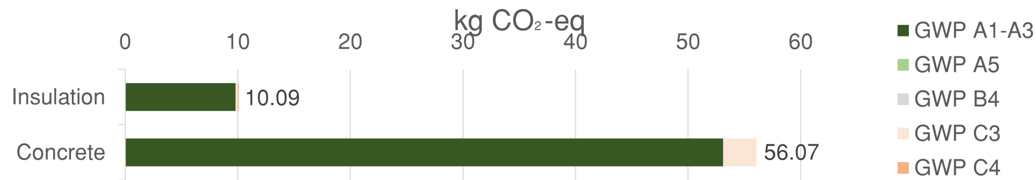
Component reference	:	AB04
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	427 mm
Component plane weight	:	435.9 kg/m^2
Total environmental component impact	:	66.2 $kg\ CO_2{-}eq/m^2$

Heat capacity
66.7 $Wh/m^2\ K$

R-value
0.245/L+0.091
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R180

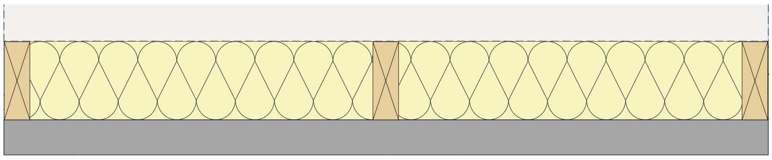
EI240

S4 02 - 182 mm Concrete + 245 mm Wooden studs & Insulation

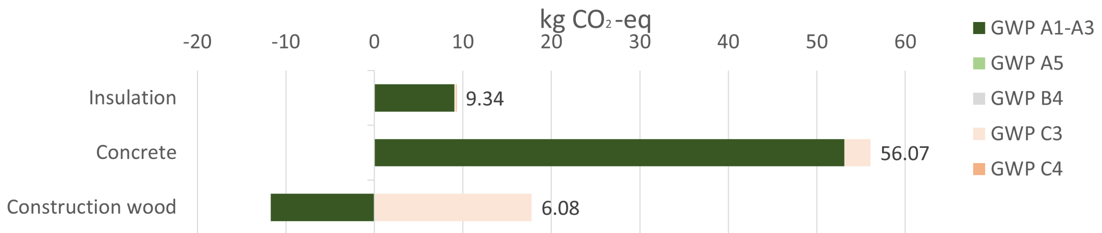
Component reference	:	AB04	
Construction type	:	Solid construction	
Exterior side compatible with	:	Frame construction cladding	
Interior side compatible with	:	Solid construction cladding	
Component thickness	:	427	mm
Component plane weight	:	445.1	kg/m^2
Total environmental component impact	:	71.5	$kg\ CO_2{-}eq/m^2$

Heat capacity
66.7 $Wh/m^2\ K$

R-value
$0.245/(0.00975 + 0.925 \cdot L)+0.091$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R180

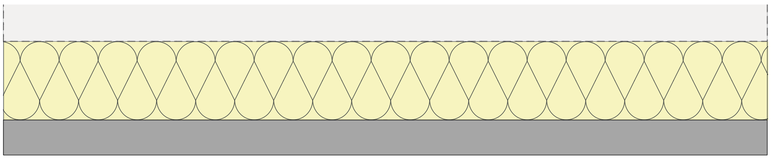
EI240

S4 03 - 200 mm Concrete + 245 mm Insulation

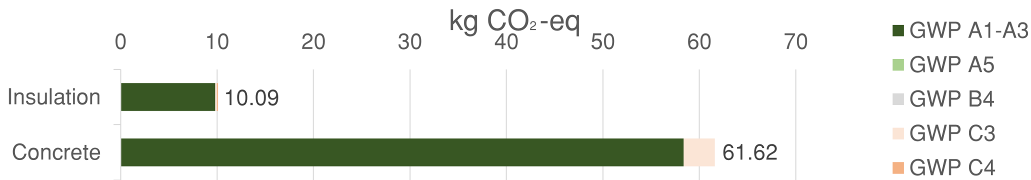
Component reference	:	AB04	
Construction type	:	Solid construction	
Exterior side compatible with	:	Solid construction cladding	
Interior side compatible with	:	Solid construction cladding	
Component thickness	:	445	mm
Component plane weight	:	478.4	kg/m^2
Total environmental component impact	:	71.7	$kg\ CO_2-eq/m^2$

Heat capacity
66.7 $Wh/m^2\ K$

R-value
0.245/L+0.091
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R180

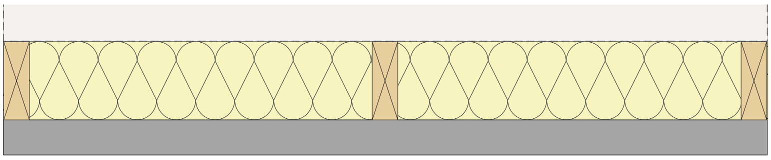
EI240

S4 04 - 200 mm Concrete + 245 mm Wooden studs & Insulation

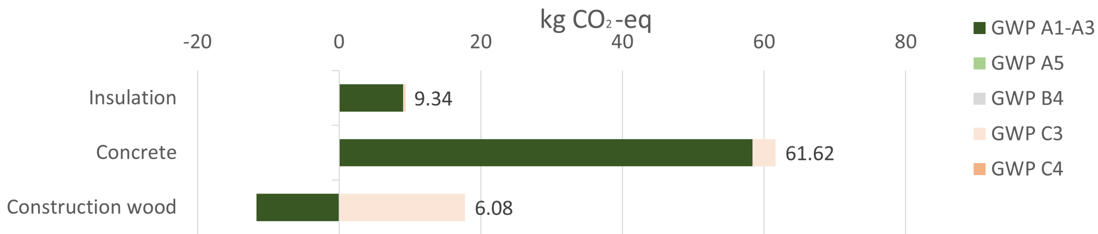
Component reference	:	SFH01
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Solid construction cladding
Component thickness	:	445 mm
Component plane weight	:	487.6 kg/m^2
Total environmental component impact	:	77 kg CO_2-eq/m^2

Heat capacity
66.7 Wh/m^2 K

R-value
$0.245/(0.00975 + 0.925 \cdot L)+0.1$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
A1

Component material class
D-s2,d0

Fire technical parameters

R180

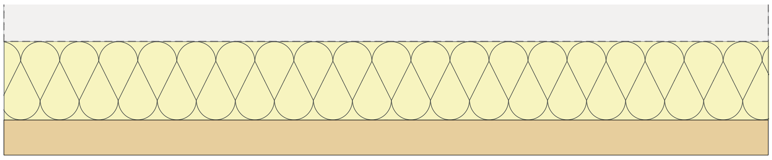
EI240

S4 05 - 120 mm CLT (5 Layer) + 245 mm Insulation

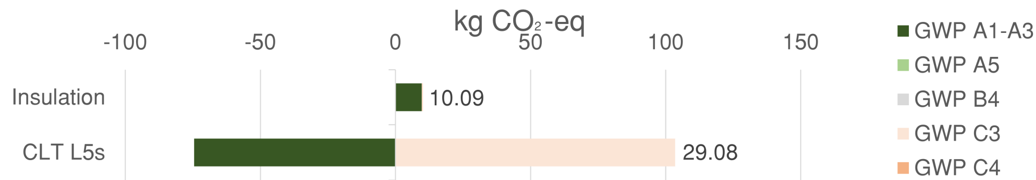
Component reference	:	AB04	
Construction type	:	Solid construction	
Exterior side compatible with	:	Solid construction cladding	
Interior side compatible with	:	Frame construction cladding	
Component thickness	:	365	mm
Component plane weight	:	63	kg/m^2
Total environmental component impact	:	39.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
22.2 $Wh/m^2\ K$

R-value
0.245/L+0.092
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

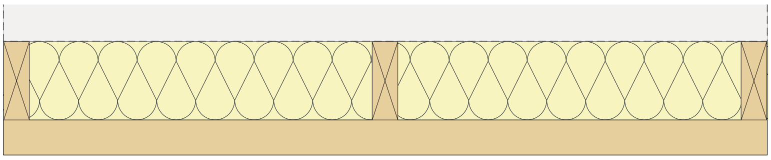
EI60

S4 06 - 120 mm CLT (5 Layer) + 245 mm Wooden studs & Insulation

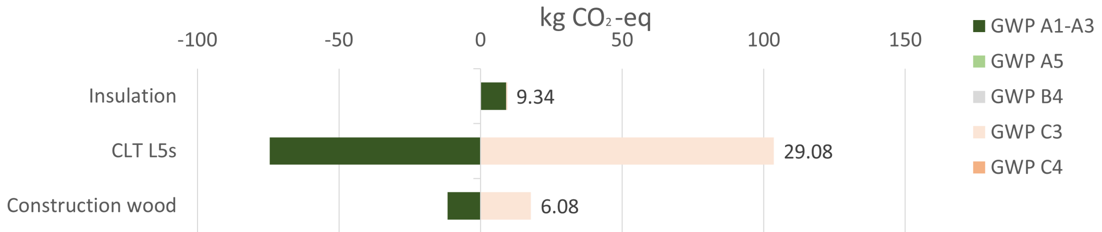
Component reference	:	Lilleheden
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	365 mm
Component plane weight	:	72.3 kg/m^2
Total environmental component impact	:	44.5 kg CO_2-eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
$0.245/(0.00975 + 0.925 \cdot L)+0.92$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

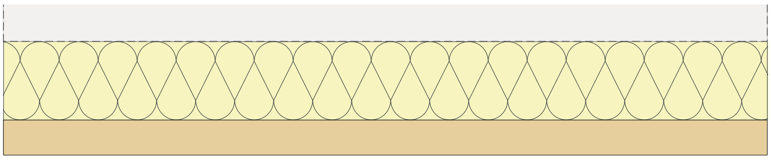
EI60

S4 07 - 160 mm CLT (5 Layer) + 245 mm Insulation

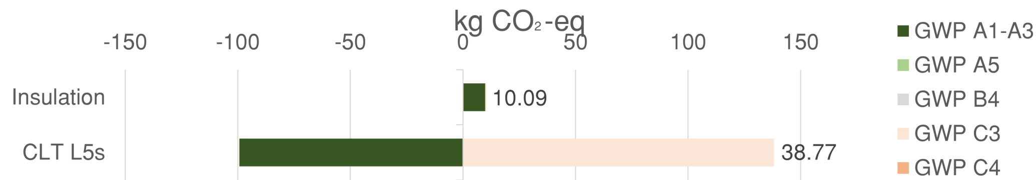
Component reference	:	Lilleheden
Construction type	:	Solid construction
Exterior side compatible with	:	Solid construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	405 mm
Component plane weight	:	82.9 kg/m^2
Total environmental component impact	:	46.9 kg CO_2-eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
0.245/L+1.23
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

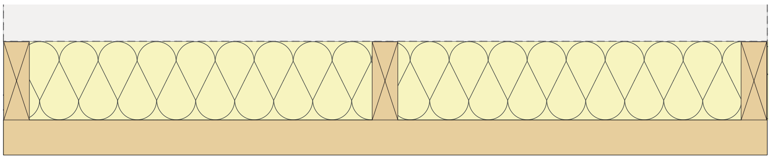
EI60

S4 08 - 160 mm CLT (5 Layer) + 245 mm Wooden studs & Insulation

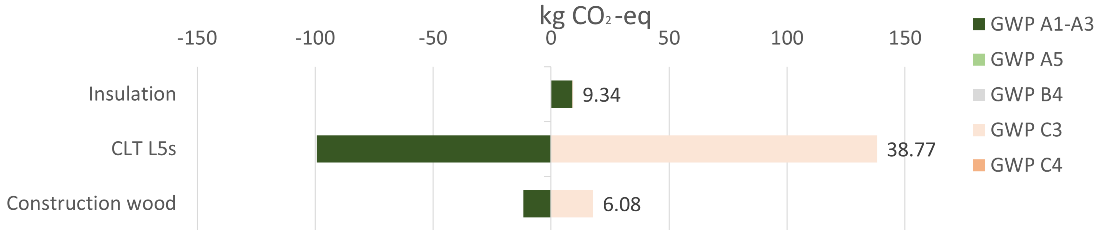
Component reference	:	Lilleheden
Construction type	:	Solid construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	405 mm
Component plane weight	:	91.1 kg/m^2
Total environmental component impact	:	54.2 $kg\ CO_2{-}eq/m^2$

Heat capacity
22.2 $Wh/m^2\ K$

R-value
$0.245/(0.00975 + 0.925 \cdot L)+1.2$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

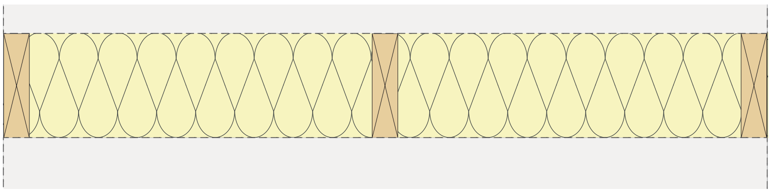
EI60

S4 09 - 340 mm Wooden studs & Insulation

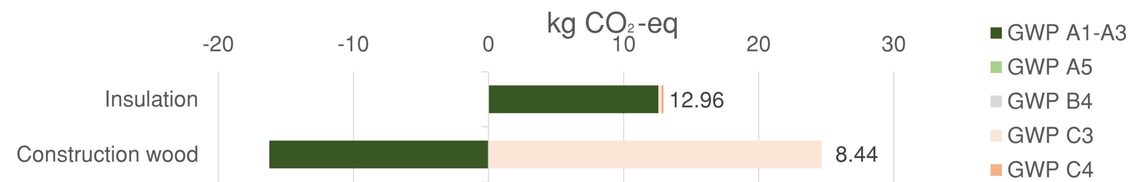
Component reference	:	AB05
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	340 mm
Component plane weight	:	21.7 kg/m^2
Total environmental component impact	:	21.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.34/(0.00975 + 0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical Parameters

$t_{ins} = 40.8$

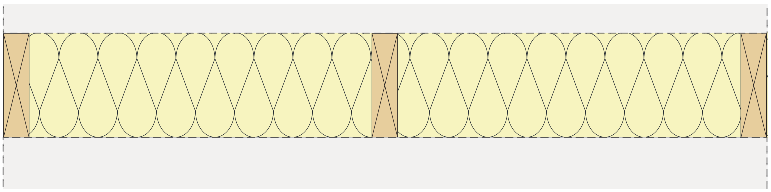
$f_{c,0,k} = 21$ MPa

S4 10 - 245 mm Wooden studs & Insulation

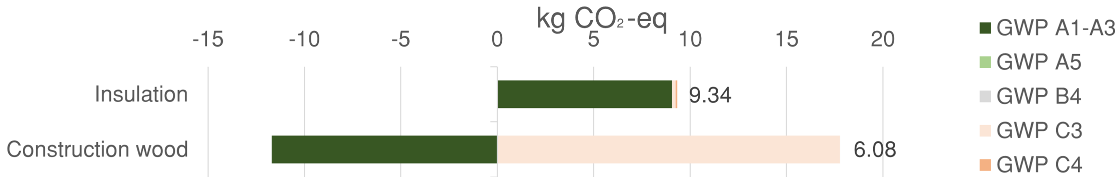
Component reference	:	AB05	
Construction type	:	Frame construction	
Exterior side compatible with	:	Frame construction cladding	
Interior side compatible with	:	Frame construction cladding	
Component thickness	:	245	mm
Component plane weight	:	15.6	kg/m^2
Total environmental component impact	:	15.4	$kg\ CO_2-eq/m^2$

Heat capacity
None

R-value
$0.245/(0.00975 + 0.925 \cdot L)$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical Paametes

$t_{ins} = 29.4$

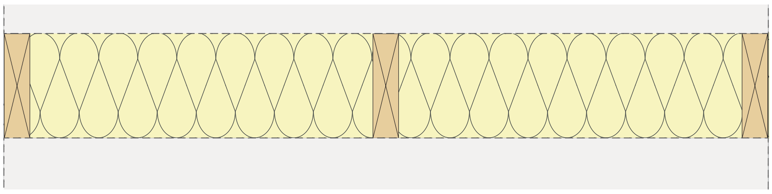
$f_{c,0,k} = 21$ MPa

S4 11 - 245 mm Wooden studs & Insulation

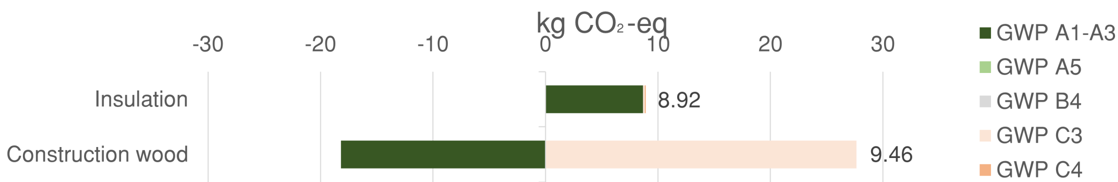
Component reference	:	AB02
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	20.7 kg/m^2
Total environmental component impact	:	18.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
0.34/(0.015 + 0.883 · L)
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical Parameters

$t_{ins} = 29.4$

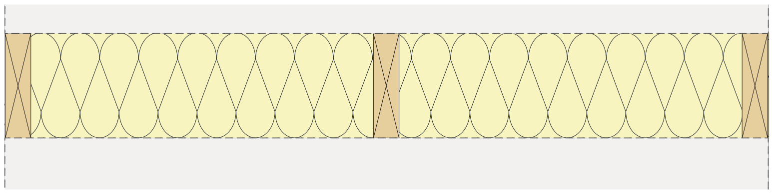
$f_{c,0,k} = 21$ MPa

S4 12 - 340 mm Wooden studs & Insulation

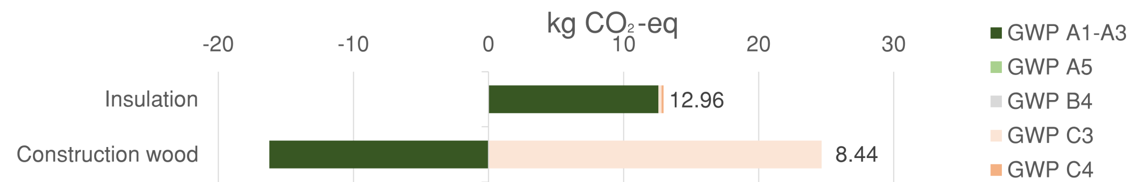
Component reference	:	AB05
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	340 mm
Component plane weight	:	21.7 kg/m^2
Total environmental component impact	:	21.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.34/(0.00975 + 0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$

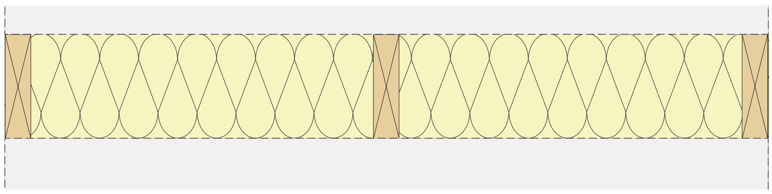
$f_{c,0,k} = 24$ MPa

S4 13 - 245 mm Wooden studs & Insulation

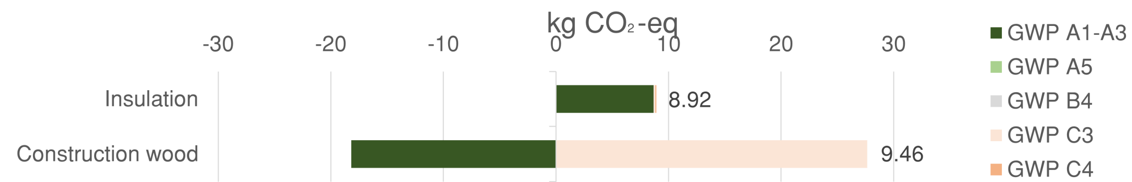
Component reference	:	AB05
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	15.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
0.245/(0.00975 + 0.925 · L)
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

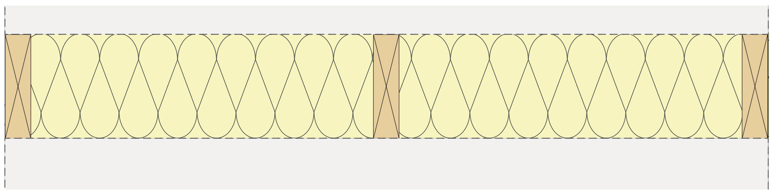
$f_{c,0,k}$ = 24 MPa

S4 14 - 245 mm Wooden studs & Insulation

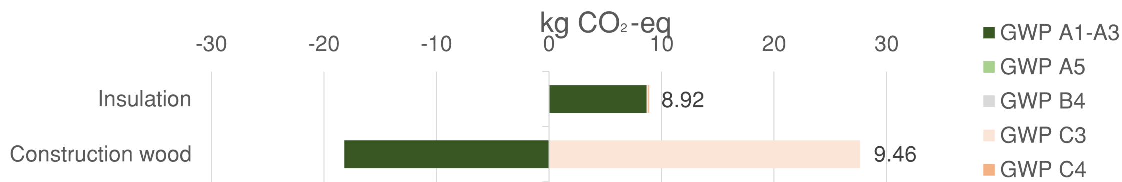
Component reference	:	AB02
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	20.7 kg/m^2
Total environmental component impact	:	18.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.34/(0.015 + 0.883 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

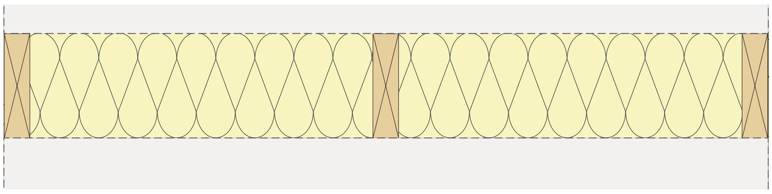
$f_{c,0,k} = 24$ MPa

S4 15 - 340 mm GLT studs & Insulation

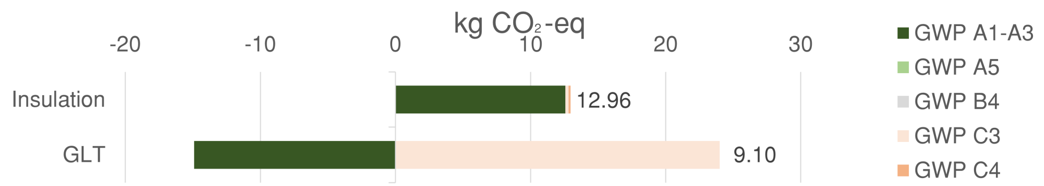
Component reference	:	AB05
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	340 mm
Component plane weight	:	21.3 kg/m^2
Total environmental component impact	:	22.1 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.34/(0.00975 + 0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$

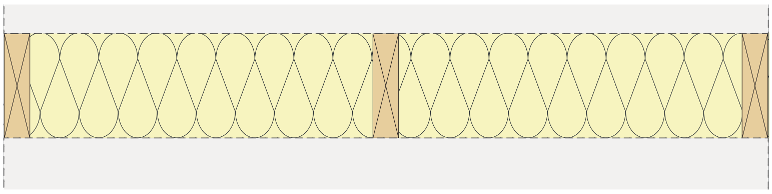
$f_{c,0,k} = 24$ MPa

S4 16 - 245 mm GLT studs & Insulation

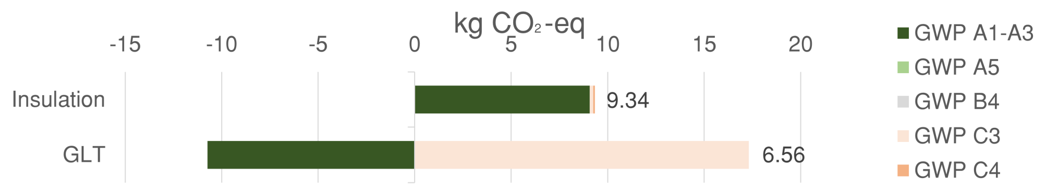
Component reference	:	AB05
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	15.4 kg/m^2
Total environmental component impact	:	15.9 kg CO_2−eq/m^2

Heat capacity
None

R-value
0.245/(0.00975 + 0.925 · L)
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 29.4

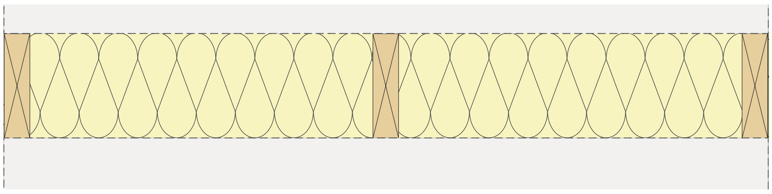
$f_{c,0,k}$ = 24 MPa

S4 17 - 245 mm GLT studs & Insulation

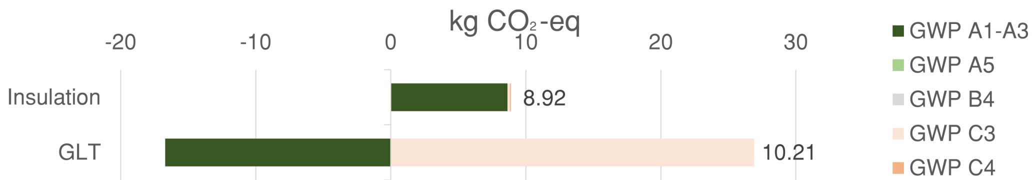
Component reference	:	AB02	
Construction type	:	Frame construction	
Exterior side compatible with	:	Frame construction cladding	
Interior side compatible with	:	Frame construction cladding	
Component thickness	:	245	mm
Component plane weight	:	20.4	kg/m^2
Total environmental component impact	:	19.1	$kg\ CO_2-eq/m^2$

Heat capacity
None

R-value
$0.245/(0.015 + 0.883 \cdot L)$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 29.4$

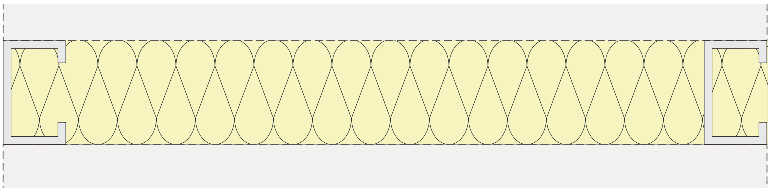
$f_{c,0,k} = 24$ MPa

S4 18 - 200 mm Steel C - profile & Insulation

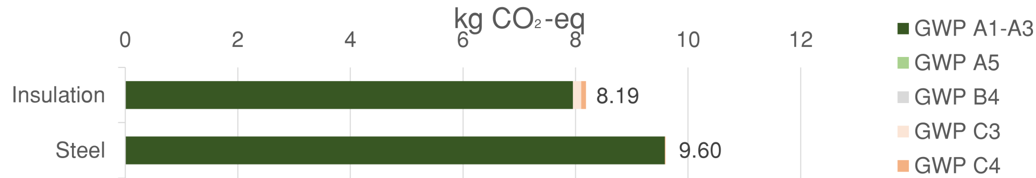
Component reference	:	Knauf
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	200 mm
Component plane weight	:	15.1 kg/m^2
Total environmental component impact	:	17.8 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.2/(0.08 + 1 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

Component material class
A1

Fire technical parameters

$t_{ins} = 24$

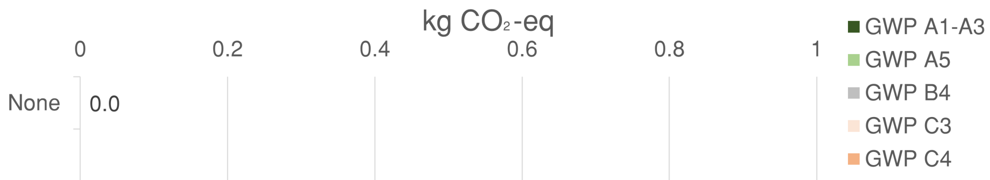
WP 01 - None

Component reference	:	None
Compatible with	:	Solid constructions
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 kg CO_2-eq/m^2

Heat capacity
None

R-value
0 K m^2/W

Environmental impact per m^2 component



Fire technical classification

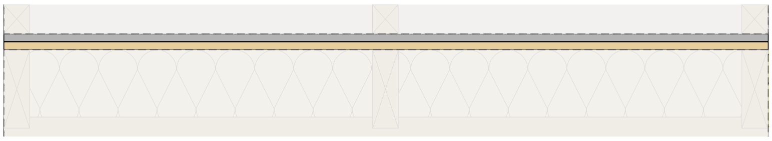
Fire protecting ability	Surface Material Class	Component material class
None	None	None

WP 02 - 12 mm Chipboard + 9 mm Plasterboard

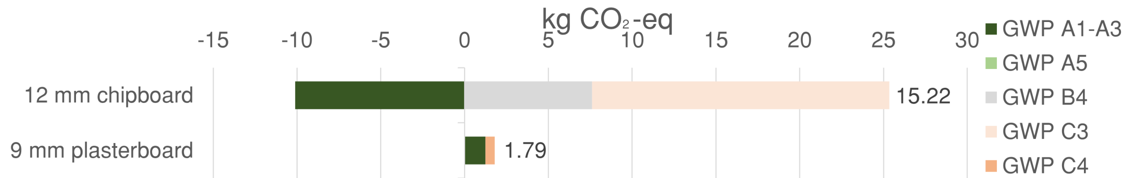
Component reference	:	None
Compatible with	:	Frame constructions
Component thickness	:	21 mm
Component plane weight	:	15.6 kg/m^2
Total environmental component impact	:	17 kg CO_2-eq/m^2

Heat capacity
None

R-value
0.137 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

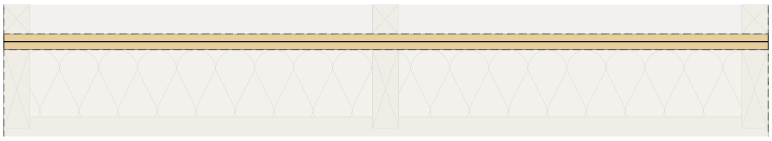
t_{ins} = 25.8 min

WP 03 - 12 mm Chipboard + 18 mm Wood Fiber Boards

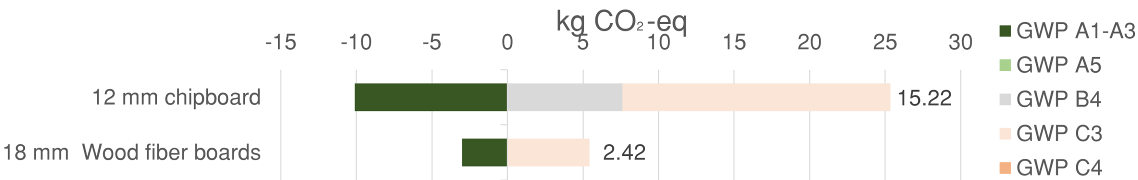
Component reference	:	SFH19
Compatible with	:	Frame constructions
Component thickness	:	30 mm
Component plane weight	:	11.3 kg/m^2
Total environmental component impact	:	17.6 kg CO_2-eq/m^2

Heat capacity
None

R-value
0.231 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

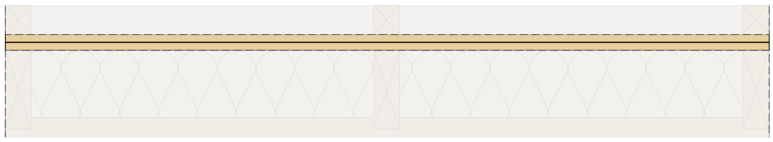
t_{ins} = 33 min

WP 04 - 12 mm Chipboard + 20 mm Plywood

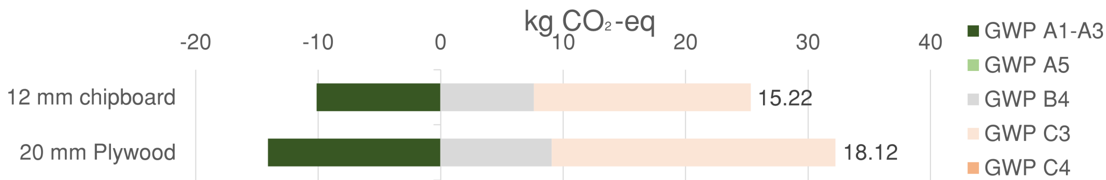
Component reference	:	OB01	
Compatible with	:	Frame constructions	
Component thickness	:	32	mm
Component plane weight	:	18.2	kg/m^2
Total environmental component impact	:	33.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
0.246 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

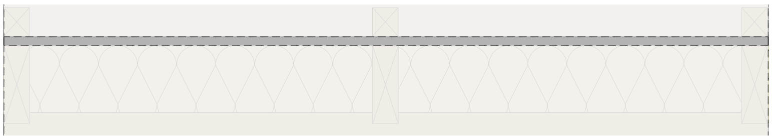
t_{ins} = 32.2 min

WP 05 - 9 mm Plasterboard

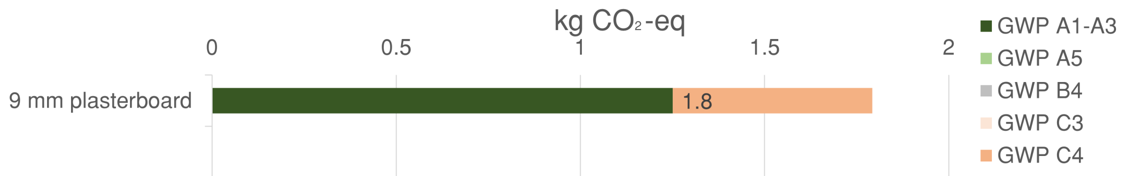
Component reference	:	SFH02
Compatible with	:	Frame constructions
Component thickness	:	9 mm
Component plane weight	:	7.2 kg/m^2
Total environmental component impact	:	1.8 kg CO_2-eq/m^2

Heat capacity
None

R-value
0.045 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A2-s1,d0	A2-s1,d0

Fire technical parameters

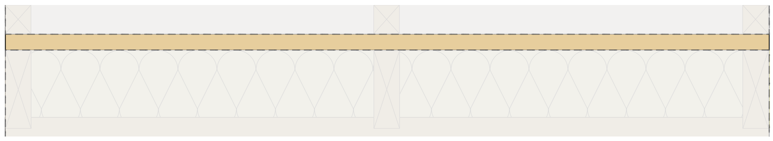
$t_{ins} = 6.6$ min

WP 06 - 18 mm Wood Fiber Boards

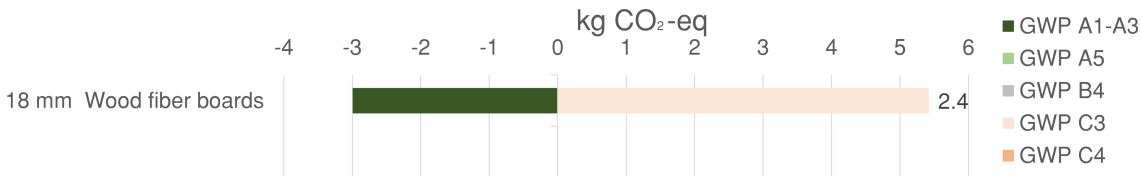
Component reference	:	SFH19
Compatible with	:	Frame constructions
Component thickness	:	18 mm
Component plane weight	:	2.9 kg/m^2
Total environmental component impact	:	2.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
0.138 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

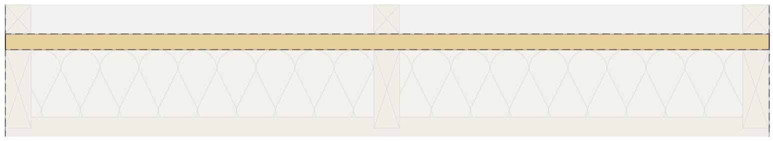
t_{ins} = 21.6 min

WP 07 - 20 mm Plywood

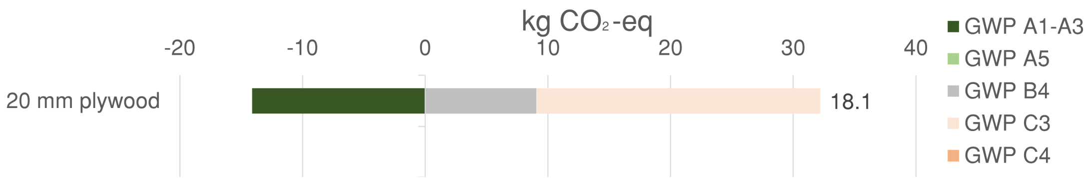
Component reference	:	OB01	
Compatible with	:	Frame constructions	
Component thickness	:	20	mm
Component plane weight	:	9.8	kg/m^2
Total environmental component impact	:	18.1	$kg\ CO_2-eq/m^2$

Heat capacity
None

R-value
0.154 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D-s2,d0

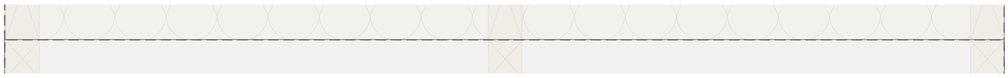
Component material class
D-s2,d0

Fire technical parameters

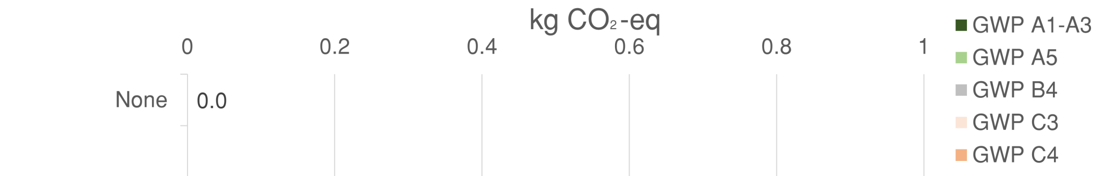
$t_{ins} = 23.4$ min

VB 01 - None

Component reference	:	None
Compatible with	:	Solid constructions
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 $kg\ CO_2{-}eq/m^2$

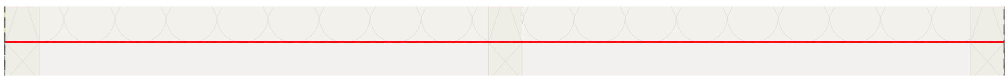


Environmental impact per m^2 component

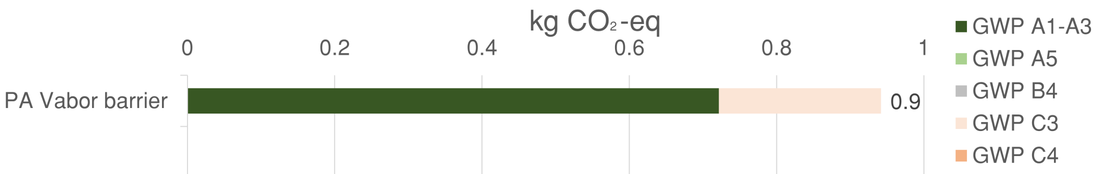


VB 02 - PA Vapor barrier

Component reference	:	None
Compatible with	:	Frame constructions
Component thickness	:	1 mm
Component plane weight	:	0.08 kg/m^2
Total environmental component impact	:	0.9 $kg\ CO_2{-}eq/m^2$



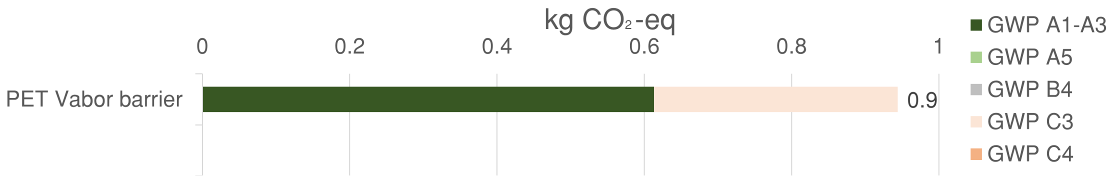
Environmental impact per m^2 component



VB 03 - PET Vapor barrier

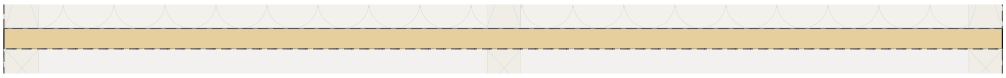
Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	1	mm
Component plane weight	:	0.12	kg/m^2
Total environmental component impact	:	0.9	$kg\ CO_2-eq/m^2$

Environmental impact per m^2 component

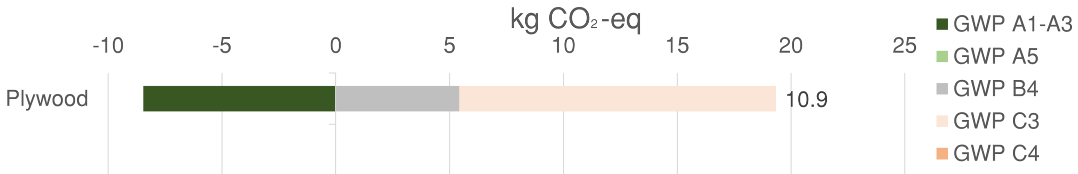


VB 04 - 12 mm plywood

Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	12	mm
Component plane weight	:	5.9	kg/m^2
Total environmental component impact	:	10.9	$kg\ CO_2-eq/m^2$



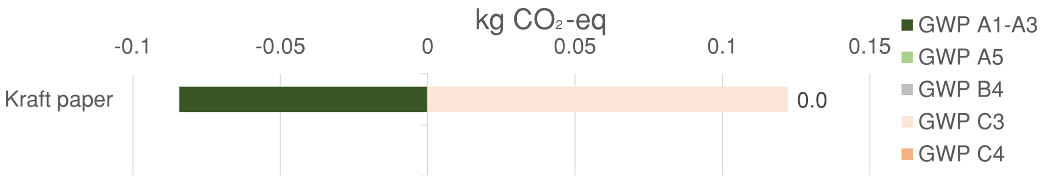
Environmental impact per m^2 component



VB 05 - Kraft paper

Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	1	mm
Component plane weight	:	0.08	kg/m^2
Total environmental component impact	:	0.04	kg CO_2−eq/m^2

Environmental impact per m^2 component



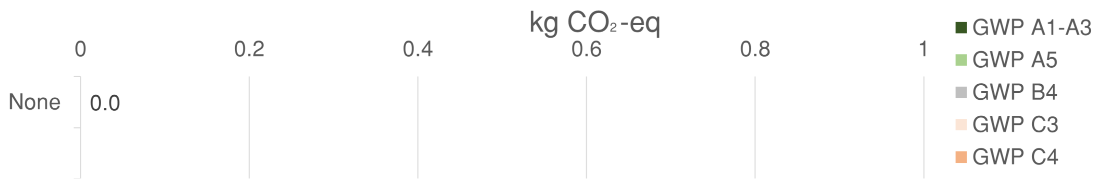
IL 01 - None

Component reference	:	SFH01
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
0 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

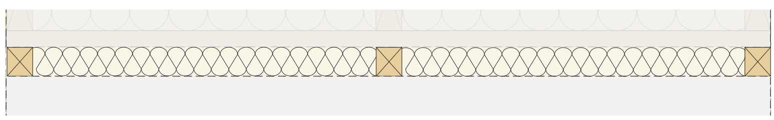
Component material class
None

IL 02 - 45 mm Wooden studs & insulation

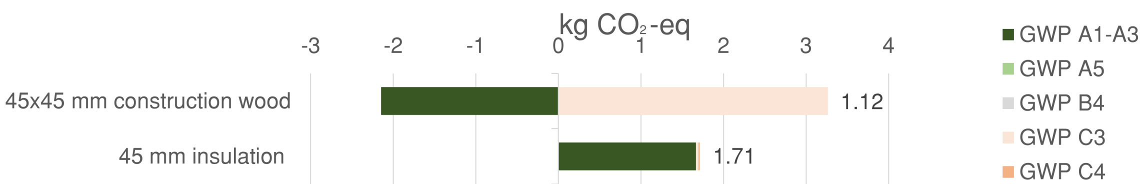
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	45 mm
Component plane weight	:	2.9 kg/m^2
Total environmental component impact	:	2.8 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.045/(0.00975 + 0.925 \cdot L)$ $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

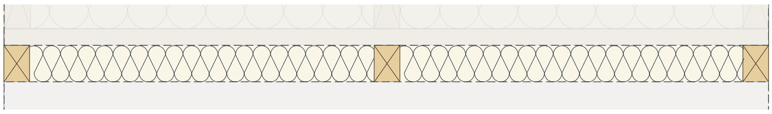
Component material class
D-s2,d0

IL 03 - 70 mm Wooden studs & insulation

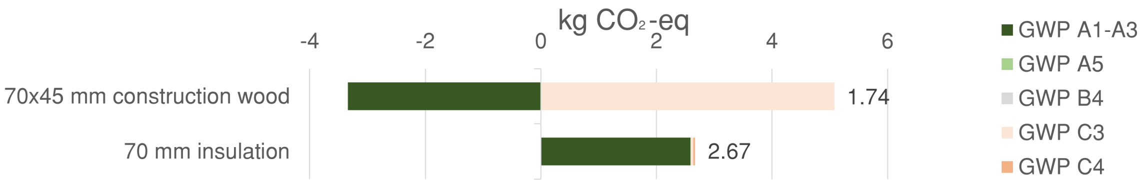
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	70 mm
Component plane weight	:	4.5 kg/m^2
Total environmental component impact	:	4.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.07/(0.00975 + 0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

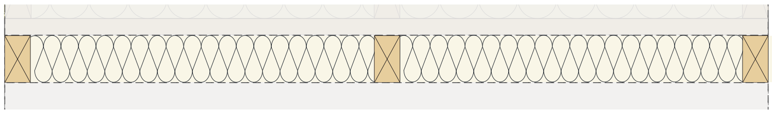
Component material class
D-s2,d0

IL 04 - 95 mm Wooden studs & insulation

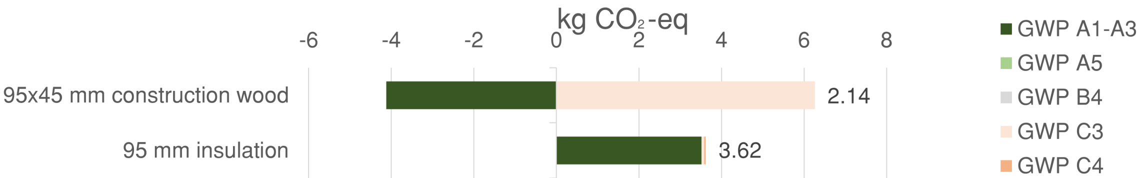
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	5.7 kg/m^2
Total environmental component impact	:	5.8 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

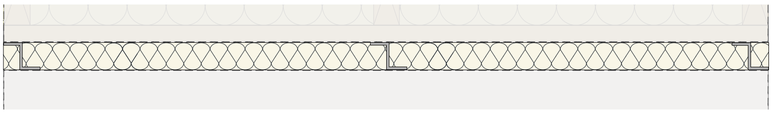
Component material class
D-s2,d0

IL 05 - 70 mm Z steel frame & insulation

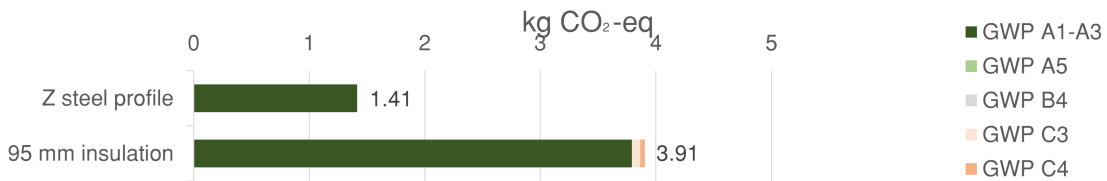
Component reference	:	Knauf
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	3.9 kg/m^2
Total environmental component impact	:	5.3 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

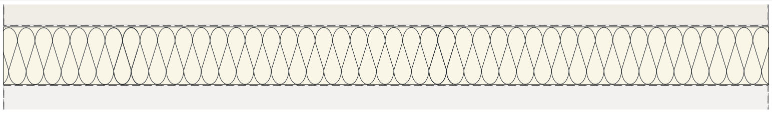
Surface Material Class
None

Component material class
A1

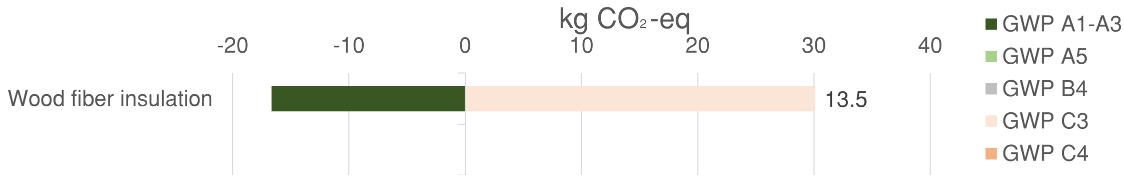
INS 01 - Wood fiber insulation

Component thickness	:	0.1	m
Component plane weight	:	16	kg/m^2
Total environmental component impact	:	13.5	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.038



Environmental impact per m^2 component



Fire technical classification

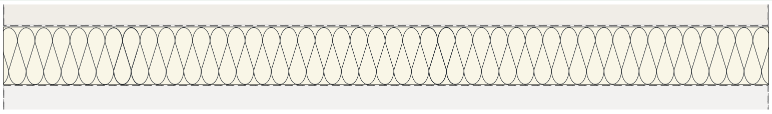
Surface Material Class
None

Component material class
E

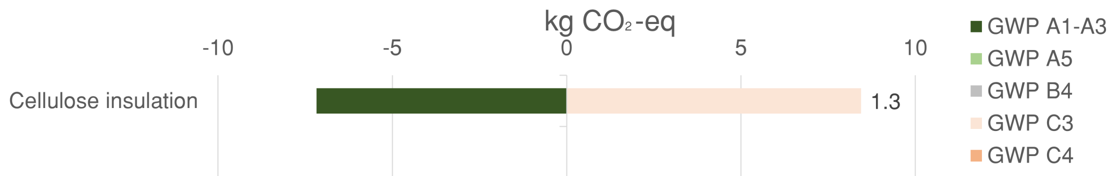
INS 02 - Cellulose insulation

Component thickness	:	0.1	m
Component plane weight	:	4.5	kg/m^2
Total environmental component impact	:	1.3	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.04



Environmental impact per m^2 component



Fire technical classification

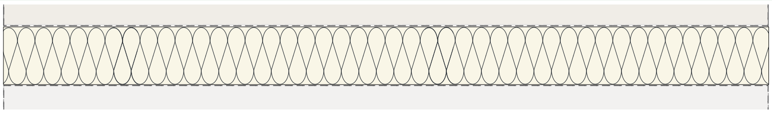
Surface Material Class
None

Component material class
D

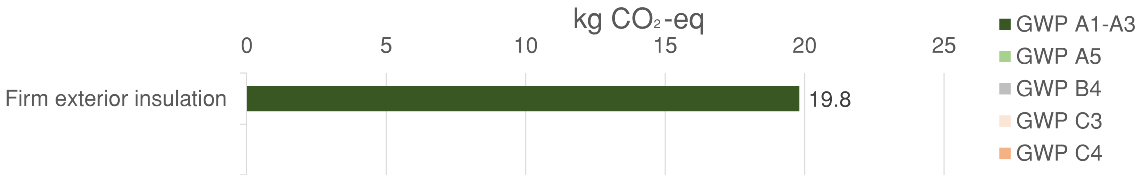
INS 03 - Firm exterior insulation

Component thickness	:	0.1	m
Component plane weight	:	14.6	kg/m^2
Total environmental component impact	:	19.8	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



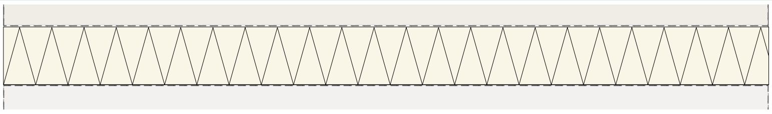
Fire technical classification

Surface Material Class	Component material class
None	A

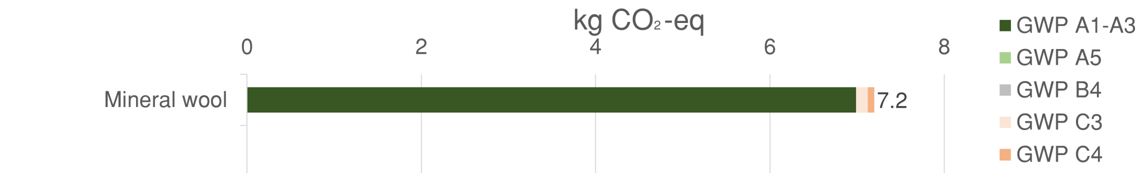
INS 04 - Mineral wool

Component thickness	:	0.1	m
Component plane weight	:	4.6	kg/m^2
Total environmental component impact	:	7.2	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



Fire technical classification

Surface Material Class	Component material class
None	A

M.2 Interior Walls

The interior walls are split into three different micro components, and these are:

- C - Cladding
- INS - Insulation
- LBW - Load-bearing wall
- NLBW - Non-load-bearing walls

These will be described in this section.

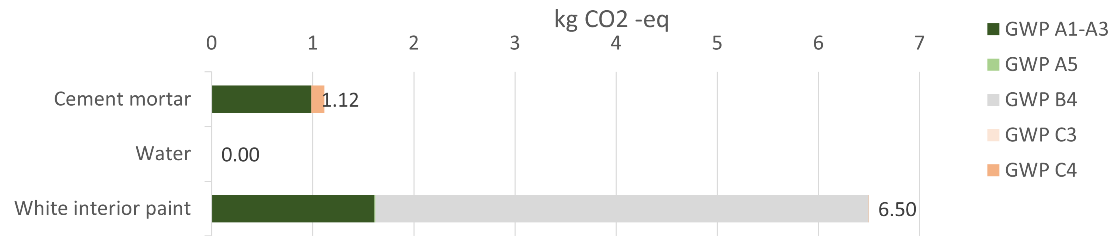
C 01 - 5 mm Mortar

Component reference	:	None	
Compatible with	:	Solid constructions	
Component thickness	:	5	mm
Component plane weight	:	9.5	kg/m^2
Total environmental component impact	:	7.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
0.147 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
None

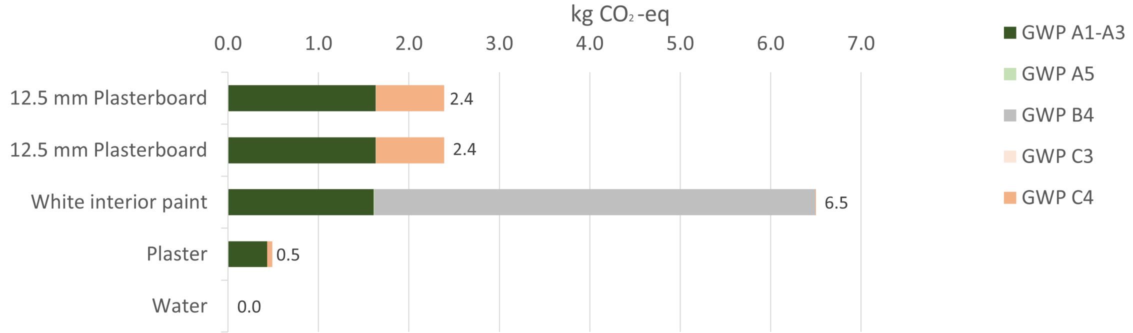
C 02 - 2 x 12.5 mm Plasterboard, A

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	11.8	$kg\ CO_2{-}eq/m^2$

Heat capacity
$6.25\ Wh/m^2\ K$

R-value
$0.272\ K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
A1-s1,d0

Fire technical parameters

$t_{ins} = 28$ min

$t_{ch} = 33$ min

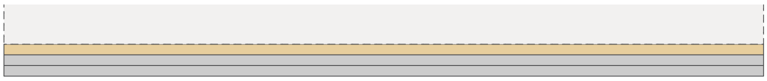
$t_f = 38.5$ min

C 03 - 15 mm OSB + 2 x 12.5 mm Plasterboard, A

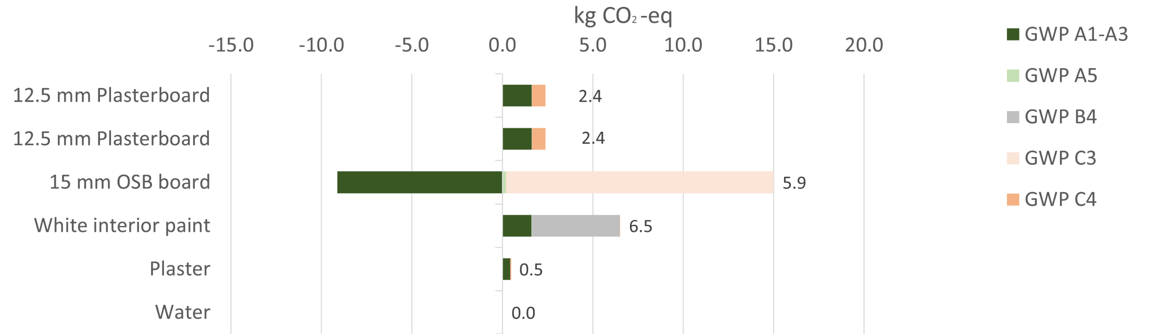
Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	45	mm
Component plane weight	:	34.2	kg/m^2
Total environmental component impact	:	17.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
$9.6\ Wh/m^2\ K$

R-value
$0.387\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 41.2$ min

$t_{ch} = 41.4$ min

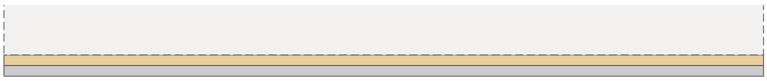
$t_f = 41.4$ min

C 04 - 15 mm OSB + 12.5 mm Plasterboard, A

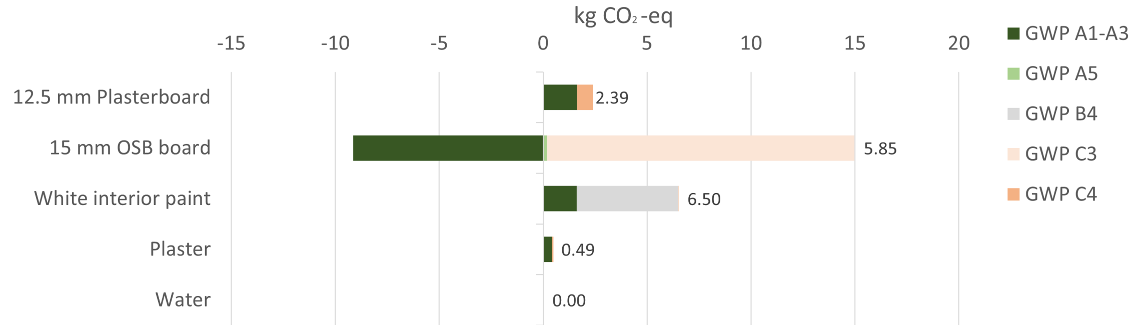
Component reference	:	SFH19	
Compatible with	:	Frame constructions	
Component thickness	:	33	mm
Component plane weight	:	24.2	kg/m^2
Total environmental component impact	:	15.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
6.5 Wh/m^2 K

R-value
0.325 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

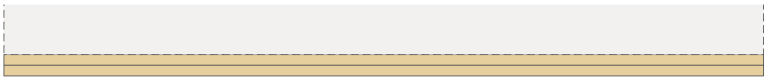
t_{ins} = 30.7 min | t_{ch} = 23.1 min | t_f = 23.1 min

C 05 - 12 mm Plywood + 15 mm Plywood

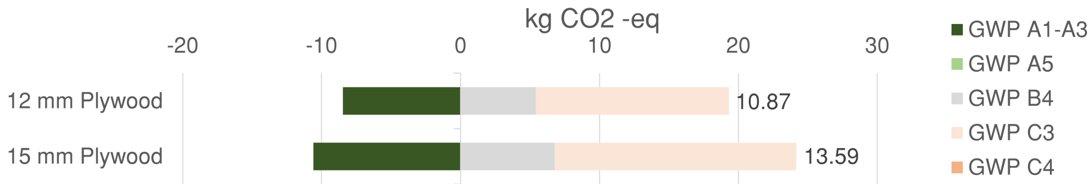
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	27 mm
Component plane weight	:	13.2 kg/m^2
Total environmental component impact	:	24.5 kg CO_2-eq/m^2

Heat capacity
6 Wh/m^2 K

R-value
0.338 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 16.8 min

t_{ch} = 18.3 min

t_f = 18.3 min

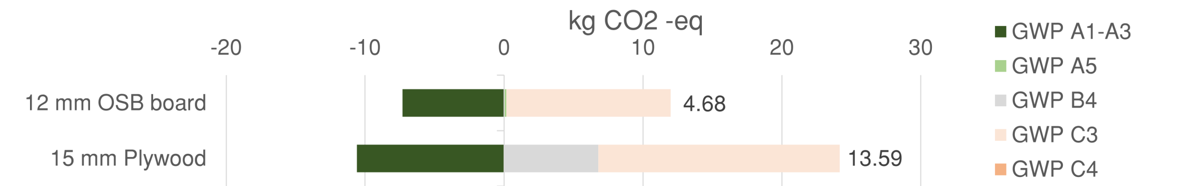
C 06 - 12 mm OSB + 15 mm Plywood

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	27 mm
Component plane weight	:	14.6 kg/m^2
Total environmental component impact	:	18.3 $kg\ CO_2{-}eq/m^2$

Heat capacity
6 Wh/m^2 K

R-value
0.338 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 17.9 min

t_{ch} = 19.3 min

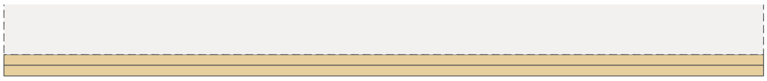
t_f = 19.3 min

C 07 - 2 x 15 mm Plywood

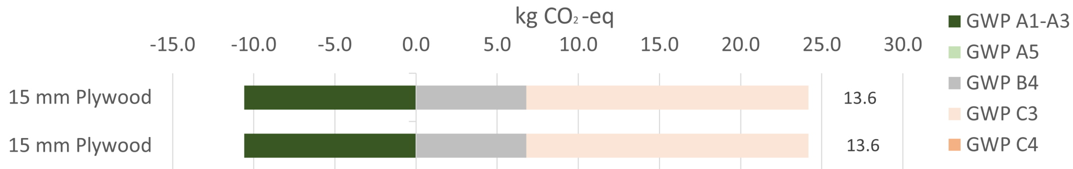
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	14.7	kg/m^2
Total environmental component impact	:	27.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
$6.7\ Wh/m^2\ K$

R-value
$0.361\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 18.5$ min

$t_{ch} = 21.9$ min

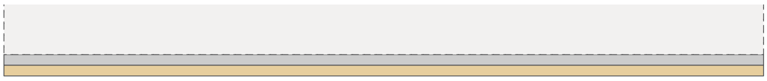
$t_f = 21.9$ min

C 08 - 9.5 mm Plasterboard, A + 12 mm Plywood

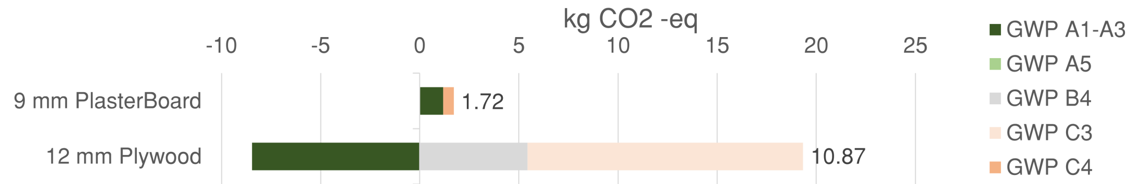
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	21 mm
Component plane weight	:	13.1 kg/m^2
Total environmental component impact	:	12.6 kg CO_2−eq/m^2

Heat capacity
5 Wh/m^2 K

R-value
0.27 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 19.4 min

t_{ch} = 15.4 min

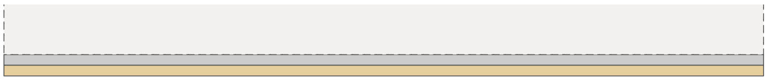
t_f = 16.3 min

C 09 - 12.5 mm Plasterboard, A + 12 mm Plywood

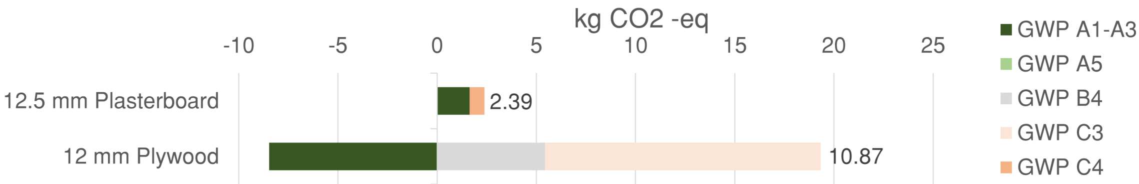
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	25	mm
Component plane weight	:	15.9	kg/m^2
Total environmental component impact	:	13.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
5.8 Wh/m^2 K

R-value
0.285 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 21.9 min

t_{ch} = 20.8 min

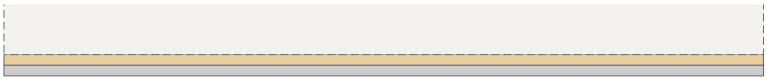
t_f = 22 min

C 10 - 12 mm Plywood + 12.5 mm Plasterboard, A

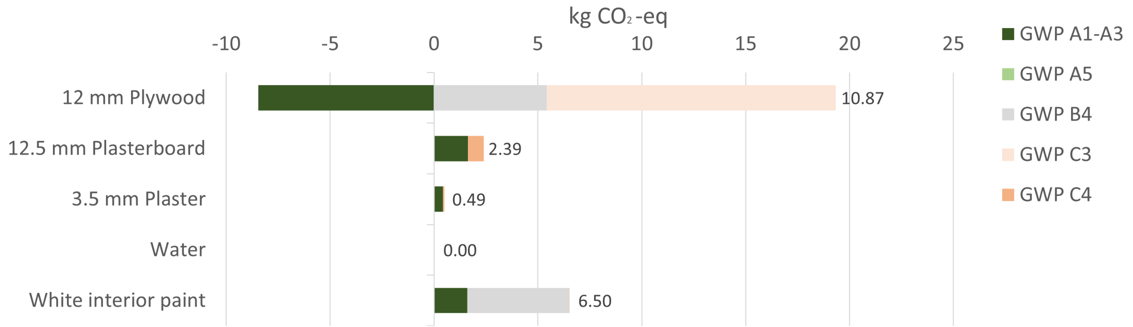
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	21.1	kg/m^2
Total environmental component impact	:	20.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
5.8 $Wh/m^2\ K$

R-value
0.302 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 26.6 min

t_{ch} = 18 min

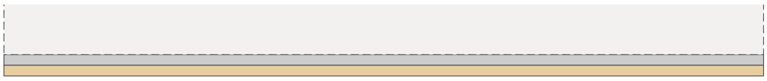
t_f = 18 min

C 11 - 15 mm Plasterboard, A + 15 mm Plywood

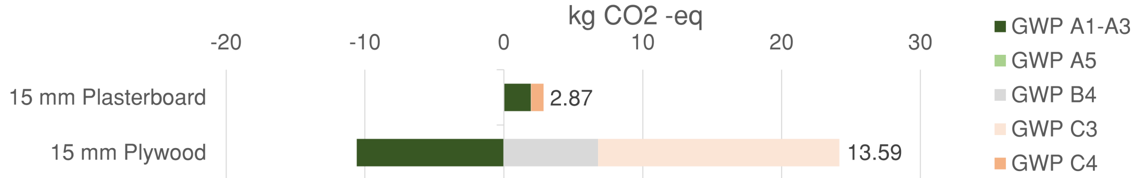
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	19.4	kg/m^2
Total environmental component impact	:	16.5	kg CO_2–eq/m^2

Heat capacity
7.1 Wh/m^2 K

R-value
0.320 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 26.9 min

t_{ch} = 29 min

t_f = 30.5 min

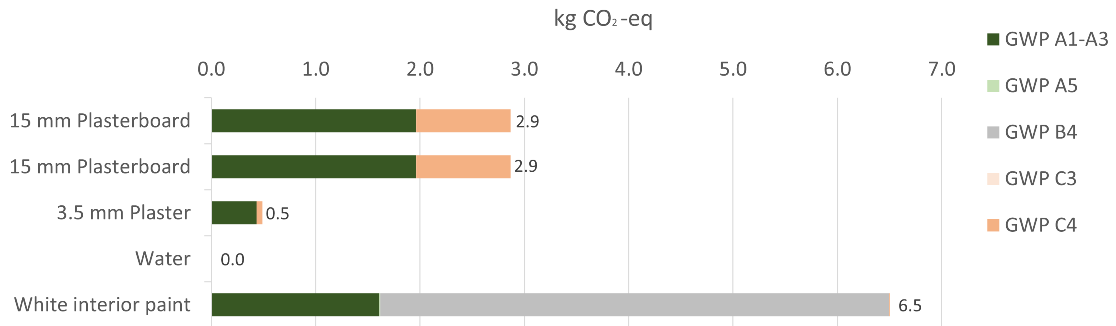
C 12 - 2 x 15 mm Plasterboard, A

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	35	mm
Component plane weight	:	29.2	kg/m^2
Total environmental component impact	:	12.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
7.5 $Wh/m^2\ K$

R-value
0.297 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 33.6$ min

$t_{ch} = 37$ min

$t_f = 49$ min

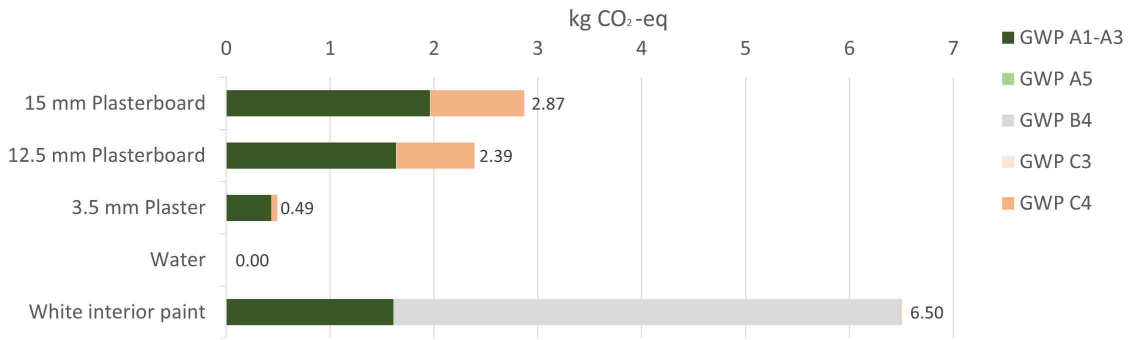
C 13 - 15 mm Plasterboard, A + 12.5 mm Plasterboard, A

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	33	mm
Component plane weight	:	27.2	kg/m^2
Total environmental component impact	:	12.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
6.88 $Wh/m^2\ K$

R-value
0.284 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 30.1 min

t_{ch} = 32 min

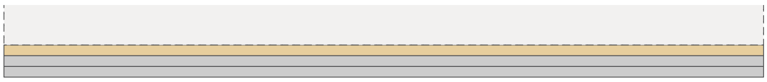
t_f = 43.8 min

C 14 - 15 mm OSB + 2 x 12.5 mm Plasterboard, F

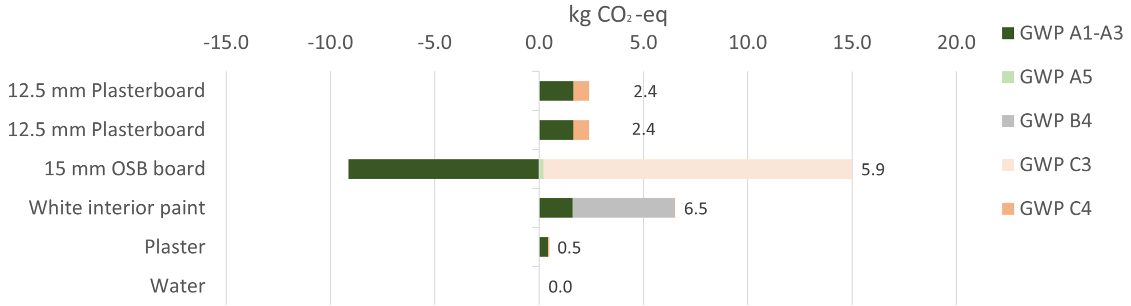
Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	45	mm
Component plane weight	:	34.2	kg/m^2
Total environmental component impact	:	17.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
9.6 $Wh/m^2\ K$

R-value
0.387 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 41.2$ min

$t_{ch} = 60.2$ min

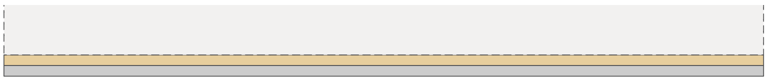
$t_f = 60.2$ min

C 15 - 15 mm OSB + 12.5 mm Plasterboard, F

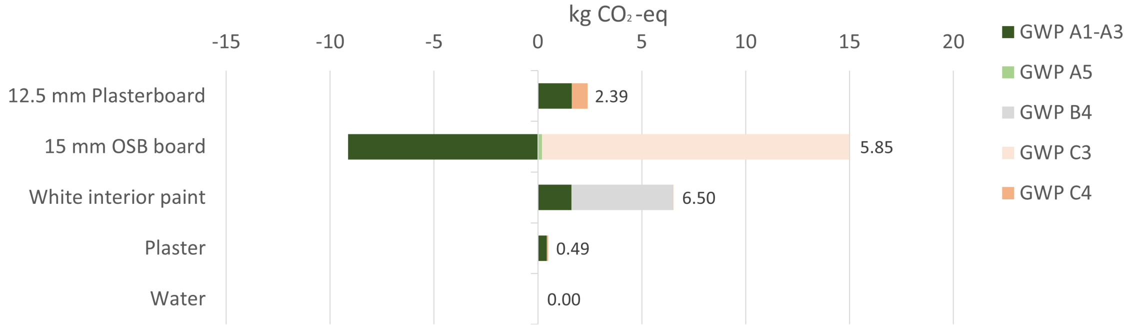
Component reference	:	SFH19	
Compatible with	:	Frame constructions	
Component thickness	:	33	mm
Component plane weight	:	24.2	kg/m^2
Total environmental component impact	:	15.2	$kg\ CO_2-eq/m^2$

Heat capacity
6.5 $Wh/m^2\ K$

R-value
0.325 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

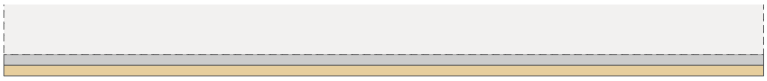
$t_{ins} = 30.7$ min $t_{ch} = 30.1$ min $t_f = 32.3$ min

C 16 - 9.5 mm Plasterboard, F + 12 mm Plywood

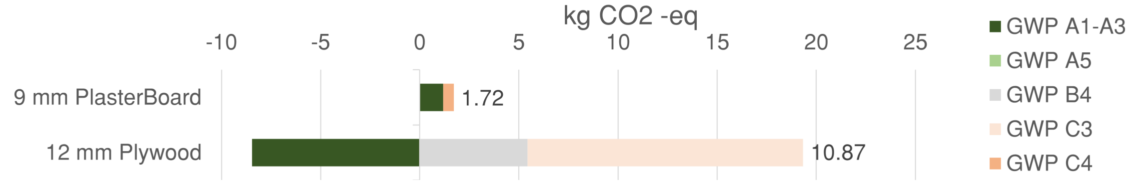
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	24 mm
Component plane weight	:	13.1 kg/m^2
Total environmental component impact	:	12.6 kg CO_2-eq/m^2

Heat capacity
5 Wh/m^2 K

R-value
0.27 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

$t_{ins} = 19.4$ min

$t_{ch} = 15.4$ min

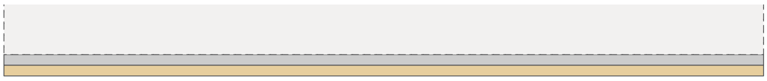
$t_f = 24$ min

C 17 - 12.5 mm Plasterboard, F + 12 mm Plywood

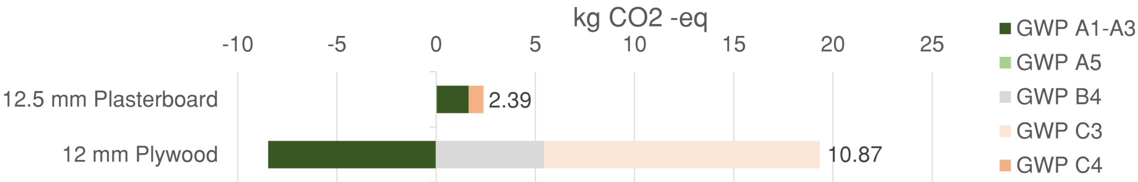
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	27 mm
Component plane weight	:	15.9 kg/m^2
Total environmental component impact	:	13.6 kg CO_2−eq/m^2

Heat capacity
5.8 Wh/m^2 K

R-value
0.285 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 21.9 min

t_{ch} = 20.8 min

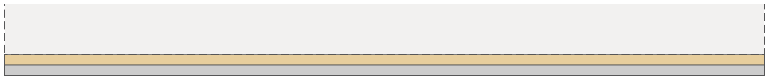
t_f = 37.5 min

C 18 - 12 mm Plywood + 12.5 mm Plasterboard, F

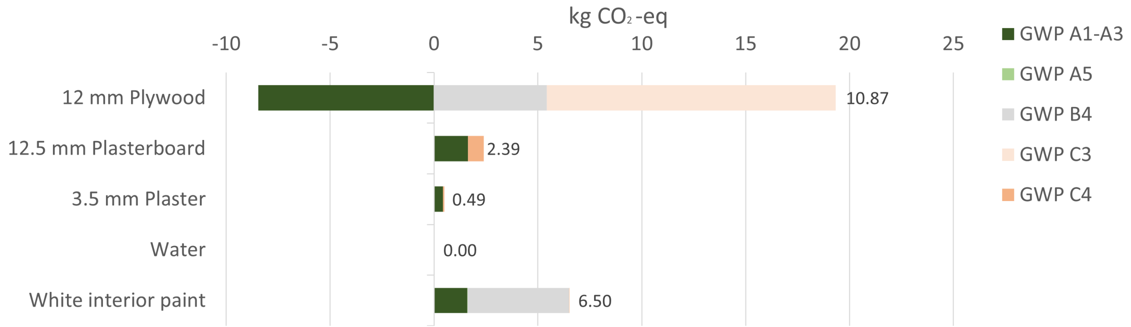
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	27 mm
Component plane weight	:	21.1 kg/m^2
Total environmental component impact	:	20.3 kg CO_2−eq/m^2

Heat capacity
5.8 Wh/m^2 K

R-value
0.302 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

t_{ins} = 26.6 min

t_{ch} = 24 min

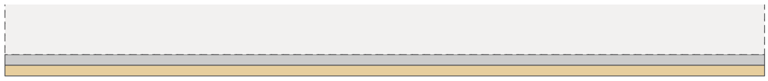
t_f = 32.3 min

C 19 - 12.5 mm Plasterboard, F + 12 mm Plywood

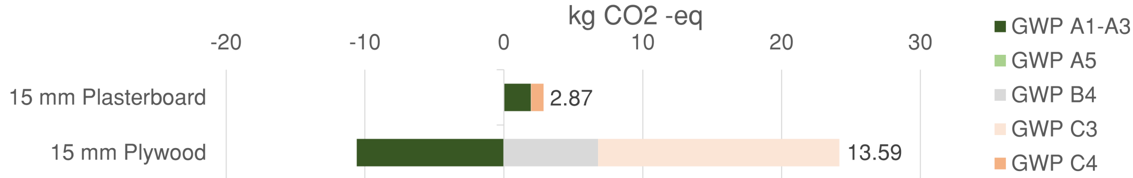
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	19.4	kg/m^2
Total environmental component impact	:	16.5	kg CO_2−eq/m^2

Heat capacity
7.1 Wh/m^2 K

R-value
0.320 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 26.9 min

t_{ch} = 29 min

t_f = 52.5 min

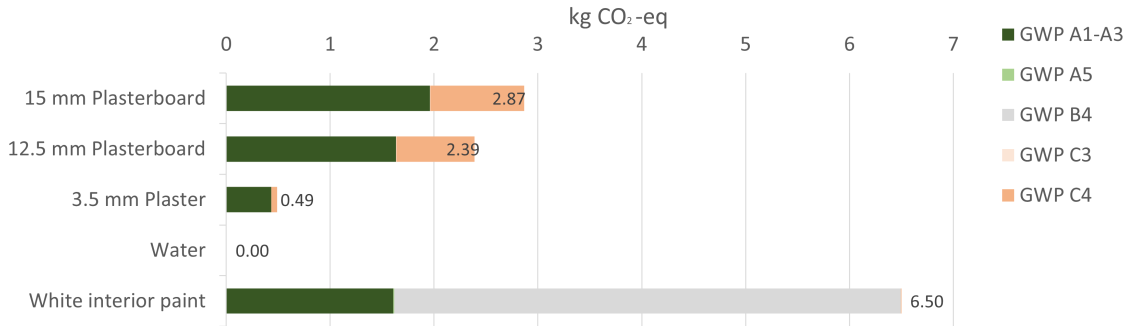
C 20 - 15 mm Plasterboard, F + 12.5 Plasterboard, F

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	25 mm
Component plane weight	:	27.2 kg/m^2
Total environmental component impact	:	12.2 kg CO_2−eq/m^2

Heat capacity
6.9 Wh/m^2 K

R-value
0.284 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 30.1 min

t_{ch} = 50.8 min

t_f = 70 min

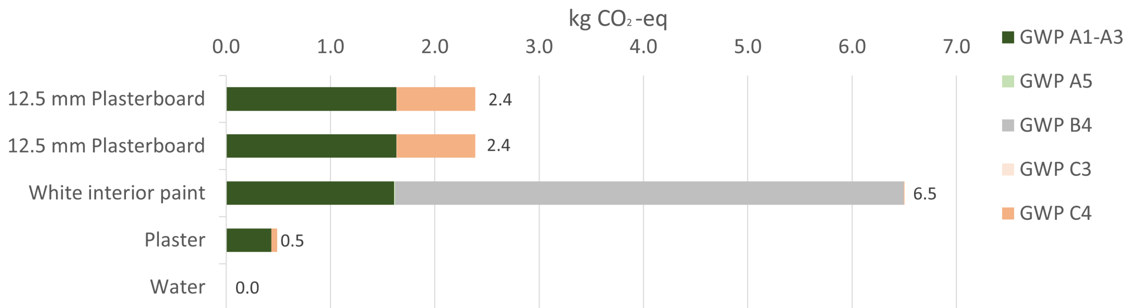
C 21 - 12.5 mm Plasterboard, A + 12.5 Plasterboard, F

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	11.8	kg CO_2−eq/m^2

Heat capacity
6.3 Wh/m^2 K

R-value
0.272 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
A2-s1,d0

Fire technical parameters

t_{ins} = 28 min

t_{ch} = 45.5 min

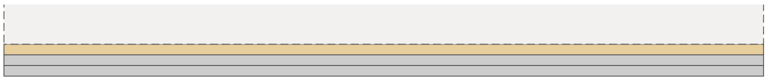
t_f = 81 min

C 22 - 15 mm OSB + 12.5 mm Plasterboard, A + 12.5 Plasterboard, F

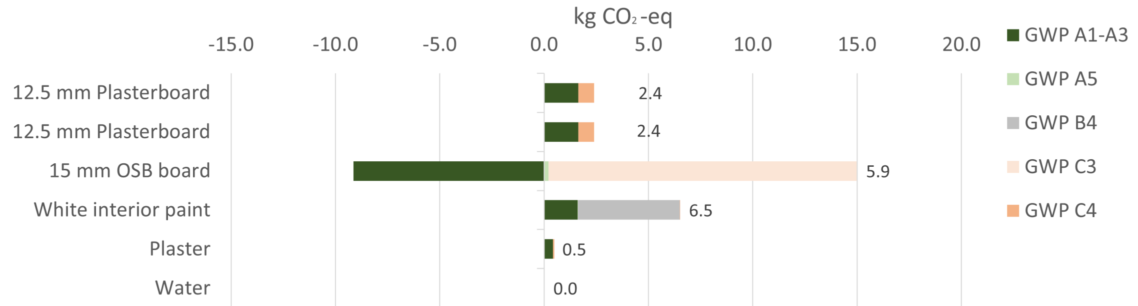
Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	34.2	kg/m^2
Total environmental component impact	:	17.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
9.6 $Wh/m^2\ K$

R-value
0.387 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

$t_{ins} = 41.2$ min $t_{ch} = 60.1$ min $t_f = 81$ min

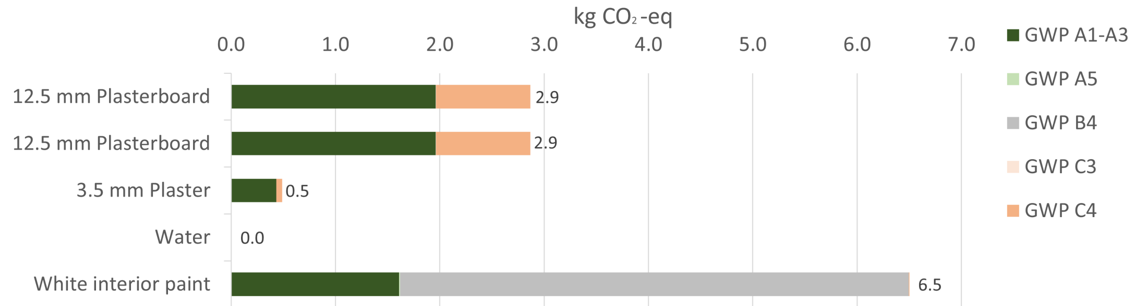
C 23 - 15 mm Plasterboard, A + 15 Plasterboard, F

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	35	mm
Component plane weight	:	29.2	kg/m^2
Total environmental component impact	:	12.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
7.5 $Wh/m^2\ K$

R-value
0.297 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
A2-s1,d0

Fire technical parameters

t_{ins} = 33.6 min

t_{ch} = 56 min

t_f = 81 min

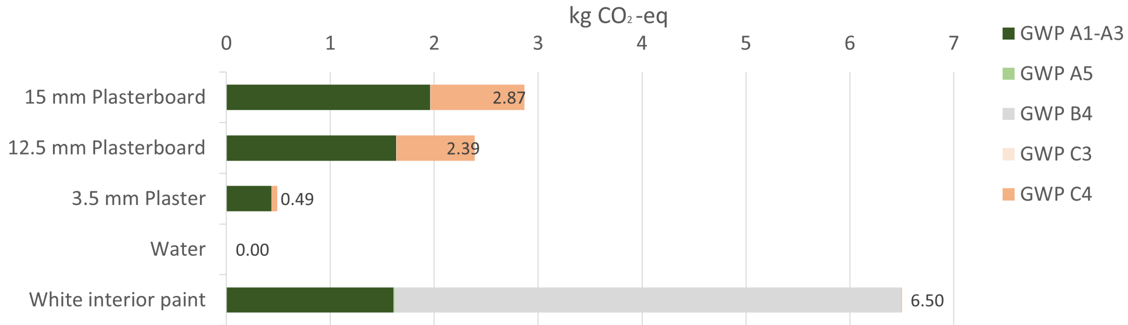
C 24 - 15 mm Plasterboard, A + 12.5 Plasterboard, F

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	33	mm
Component plane weight	:	27.2	kg/m^2
Total environmental component impact	:	12.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
6.9 Wh/m^2 K

R-value
0.284 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 30.1 min

t_{ch} = 50.8 min

t_f = 81 min

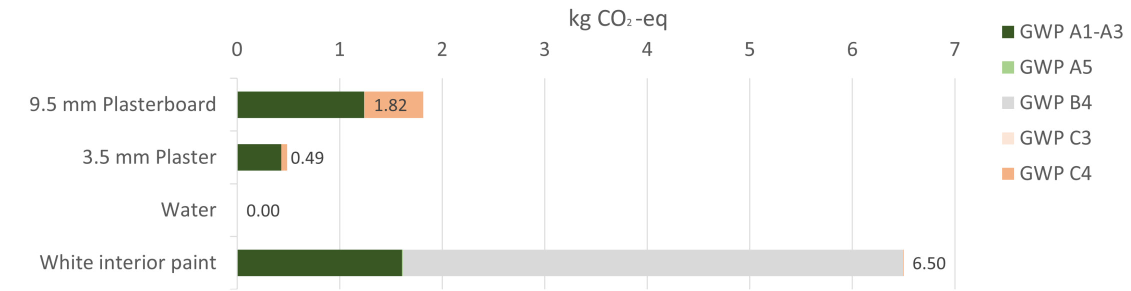
C 25 - 9.5 mm Plasterboard, F

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	14.5 mm
Component plane weight	:	12.8 kg/m^2
Total environmental component impact	:	8.8 kg CO_2−eq/m^2

Heat capacity
2.4 Wh/m^2 K

R-value
0.194 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 13.3 min

t_{ch} = 10.1 min

t_f = 18.8 min

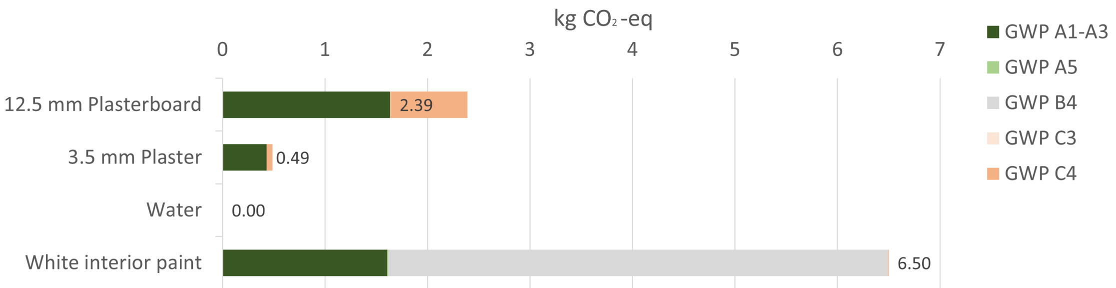
C 26 - 12.5 mm Plasterboard, F

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	17.5 mm
Component plane weight	:	15.2 kg/m^2
Total environmental component impact	:	9.4 kg CO_2-eq/m^2

Heat capacity
3.1 Wh/m^2 K

R-value
0.209 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 17.5 min | t_{ch} = 15.5 min | t_f = 32.3 min

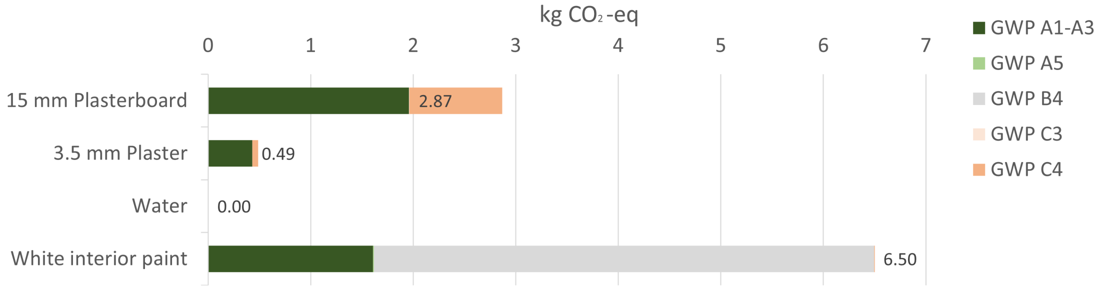
C 27 - 15 mm Plasterboard, F

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	20	mm
Component plane weight	:	17.2	kg/m^2
Total environmental component impact	:	9.9	kg CO_2−eq/m^2

Heat capacity
3.8 Wh/m^2 K

R-value
0.222 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 21 min | t_{ch} = 20 min | t_f = 43.5 min

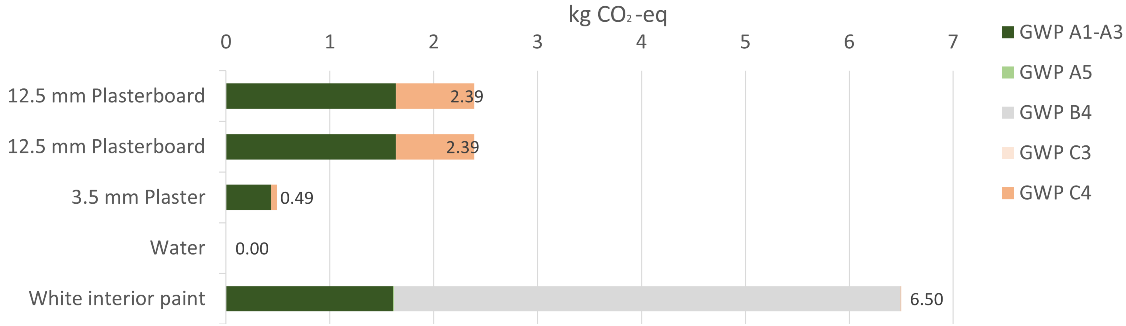
C 28 - 2 x 12.5 mm Plasterboard, F

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	11.8	$kg\ CO_2{-}eq/m^2$

Heat capacity
$6.3\ Wh/m^2\ K$

R-value
$0.272\ K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 28$ min

$t_{ch} = 45.5$ min

$t_f = 60$ min

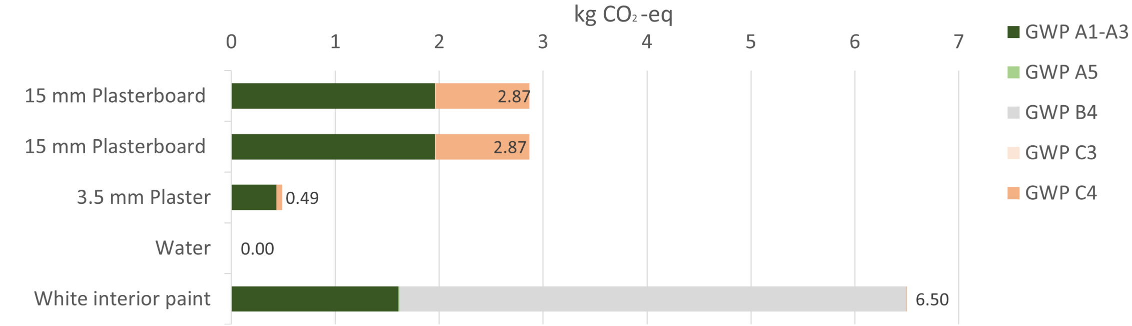
C 29 - 2 x 15 mm Plasterboard, F

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	35	mm
Component plane weight	:	29.2	kg/m^2
Total environmental component impact	:	12.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
7.5 Wh/m^2 K

R-value
0.297 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
A2-s1,d0

Fire technical parameters

t_{ins} = 33.6 min

t_{ch} = 56 min

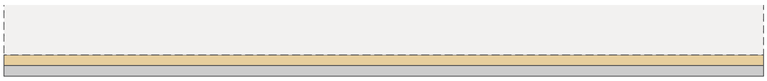
t_f = 80 min

C 30 - 12 mm OSB + 12.5 mm Plasterboard, F

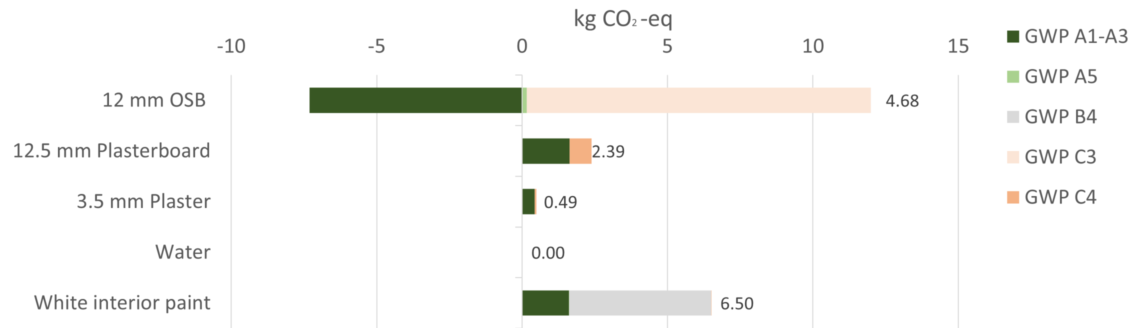
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	29.5	mm
Component plane weight	:	22.4	kg/m^2
Total environmental component impact	:	14.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
5.8 $Wh/m^2\ K$

R-value
0.302 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

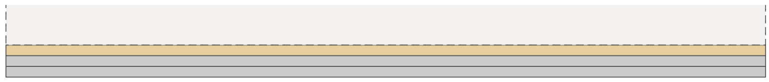
t_{ins} = 28 min | t_{ch} = 18.6 min | t_f = 18.8 min

C 31 - 12 mm OSB + 2 x 12.5 mm Plasterboard, F

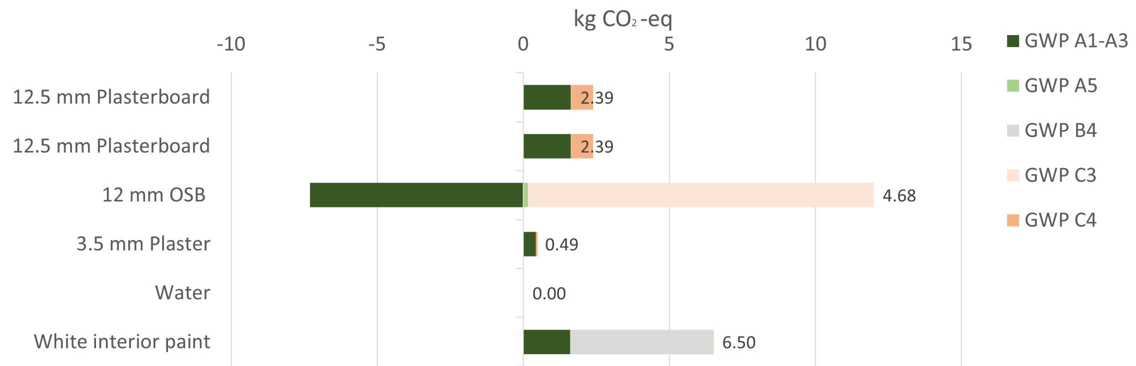
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	32.4	kg/m^2
Total environmental component impact	:	16.5	$kg\ CO_2-eq/m^2$

Heat capacity
8.9 $Wh/m^2\ K$

R-value
0.364 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

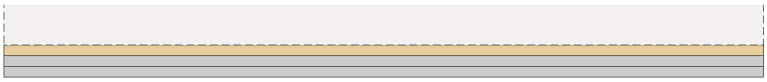
$t_{ins} = 38.5$ min | $t_{ch} = 54.8$ min | $t_f = 60$ min

C 32 - 15 mm OSB + 2 x 15 mm Plasterboard, F

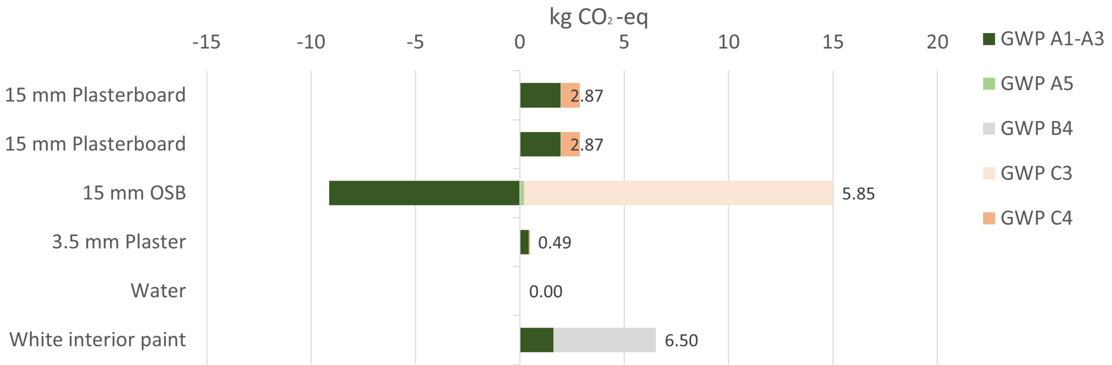
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	50	mm
Component plane weight	:	38.2	kg/m^2
Total environmental component impact	:	18.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
10.8 $Wh/m^2\ K$

R-value
0.412 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 45.8$ min

$t_{ch} = 71.8$ min

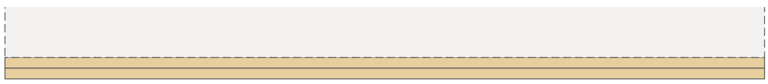
$t_f = 80$ min

C 33 - 2 x 12 mm Plywood

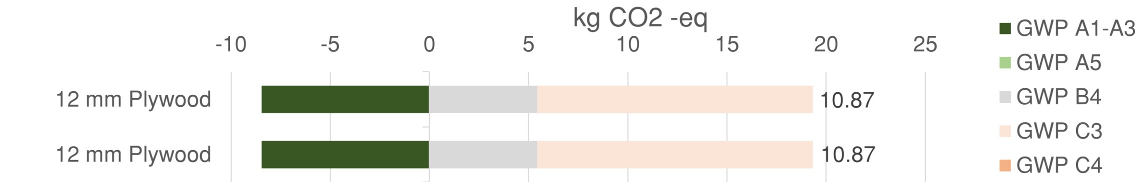
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	24 mm
Component plane weight	:	11.8 kg/m^2
Total environmental component impact	:	21.7 kg CO_2–eq/m^2

Heat capacity
5.3 Wh/m^2 K

R-value
0.315 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 14.8 min

t_{ch} = 20 min

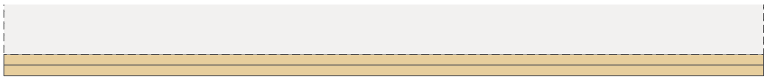
t_f = 20 min

C 34 - 2 x 12 mm OSB

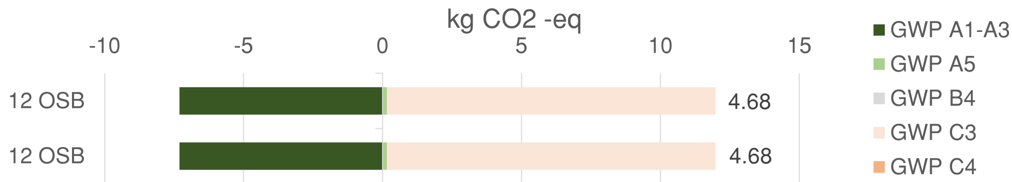
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	24 mm
Component plane weight	:	14.4 kg/m^2
Total environmental component impact	:	9.4 kg CO_2−eq/m^2

Heat capacity
5.3 Wh/m^2 K

R-value
0.315 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 17.2 min

t_{ch} = 22.7 min

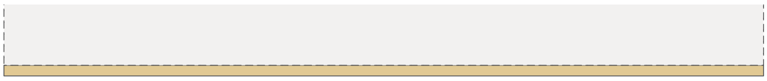
t_f = 22.7 min

C 35 - 15 mm Plywood

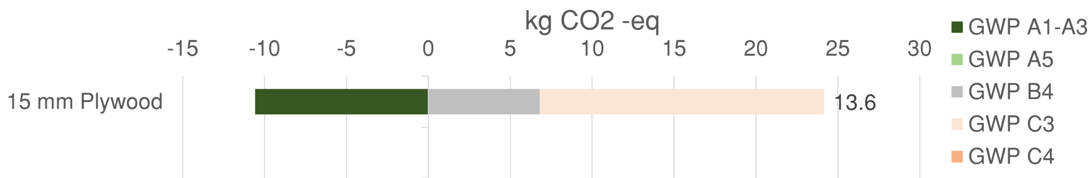
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	15 mm
Component plane weight	:	7.4 kg/m^2
Total environmental component impact	:	13.6 kg CO_2−eq/m^2

Heat capacity
3.3 Wh/m^2 K

R-value
0.245 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 9.6 min

t_{ch} = 9 min

t_f = 9 min

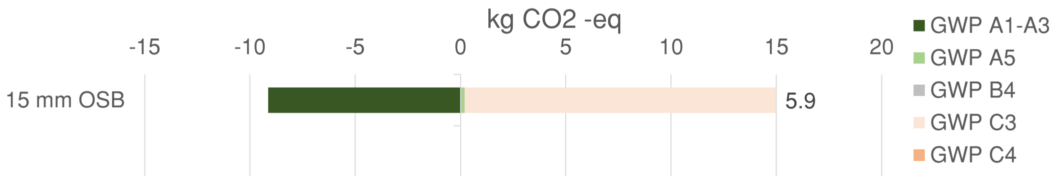
C 36 - 15 mm OSB

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	15	mm
Component plane weight	:	9	kg/m^2
Total environmental component impact	:	5.9	$kg\ CO_2{-}eq/m^2$

Heat capacity
3.3 Wh/m^2 K

R-value
0.245 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	D-s2,d0

Fire technical parameters

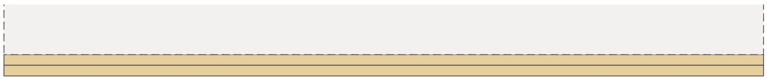
t_{ins} = 11.1 min | t_{ch} = 10.4 min | t_f = 10.4 min

C 37 - 2 x 21 mm Plywood

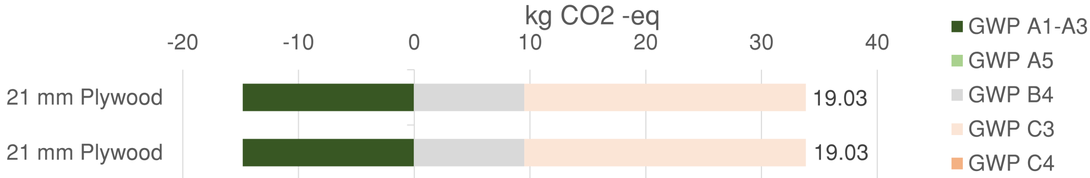
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	20.6	kg/m^2
Total environmental component impact	:	38.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
9.3 Wh/m^2 K

R-value
0.453 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

t_{ins} = 25.9 min

t_{ch} = 38 min

t_f = 38 min

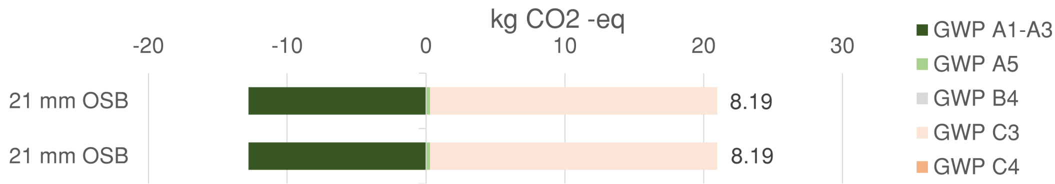
C 38 - 2 x 21 mm OSB

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	16.4	$kg\ CO_2{-}eq/m^2$

Heat capacity
$9.3\ Wh/m^2\ K$

R-value
$0.453\ K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

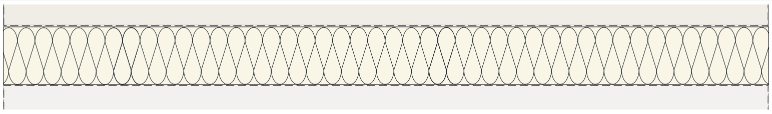
Fire technical parameters

$t_{ins} = 30$ min | $t_{ch} = 42.7$ min | $t_f = 42.7$ min

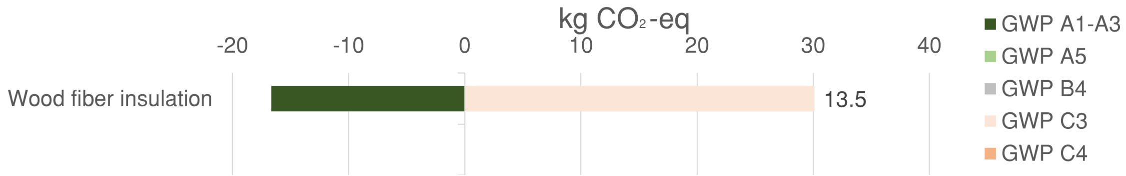
INS 01 - Wood fiber insulation

Component thickness	:	0.1	m
Component plane weight	:	16	kg/m^2
Total environmental component impact	:	13.5	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.038



Environmental impact per m^2 component



Fire technical classification

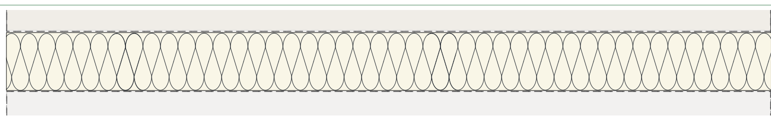
Surface Material Class
None

Component material class
E

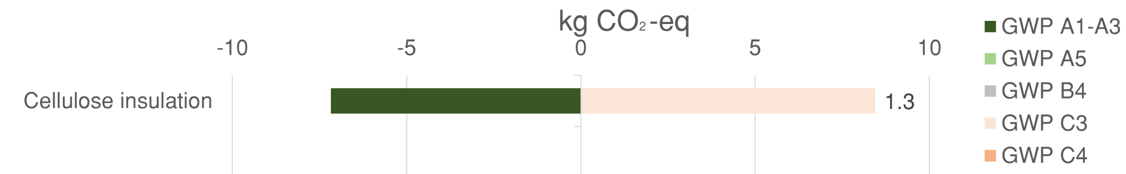
INS 02 - Cellulose insulation

Component thickness	:	0.1	m
Component plane weight	:	4.5	kg/m^2
Total environmental component impact	:	1.3	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.04



Environmental impact per m^2 component



Fire technical classification

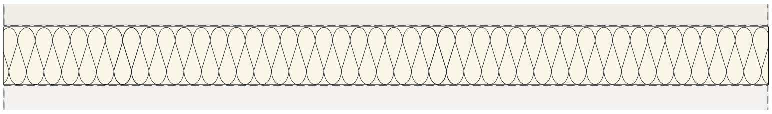
Surface Material Class
None

Component material class
D

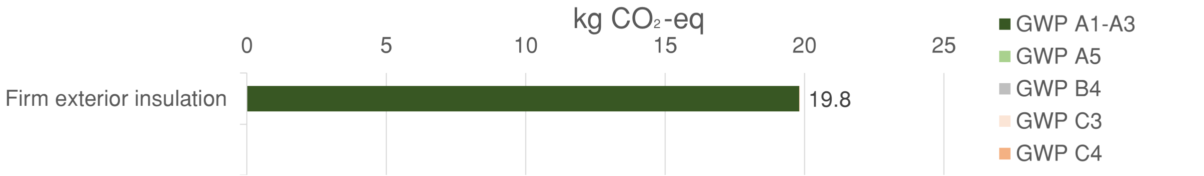
INS 03 - Firm exterior insulation

Component thickness	:	0.1	m
Component plane weight	:	14.6	kg/m^2
Total environmental component impact	:	19.8	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



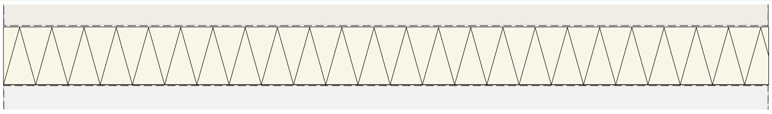
Fire technical classification

Surface Material Class	Component material class
None	A

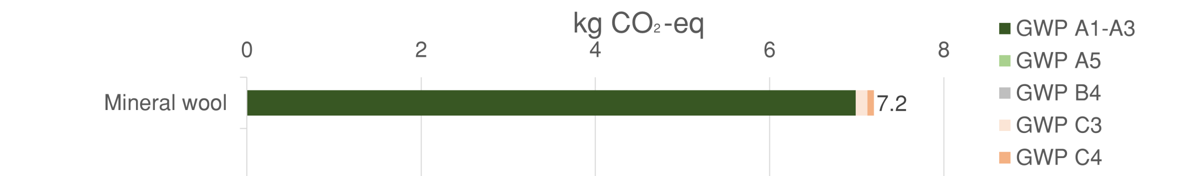
INS 04 - Mineral wool

Component thickness	:	0.1	m
Component plane weight	:	4.6	kg/m^2
Total environmental component impact	:	7.2	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



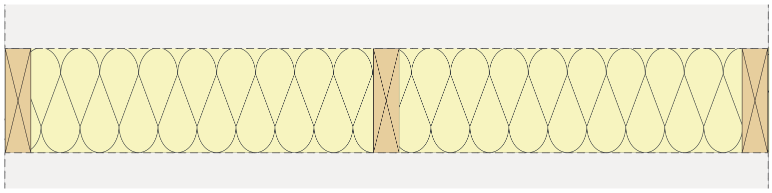
Fire technical classification

Surface Material Class	Component material class
None	A

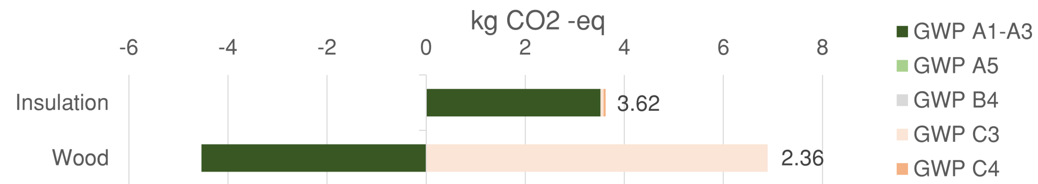
SLB 01 - 95 mm Wooden studs & Insulation

Component reference	:	SFH19
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	6.1 kg/m^2
Total environmental component impact	:	6 kg CO_2−eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

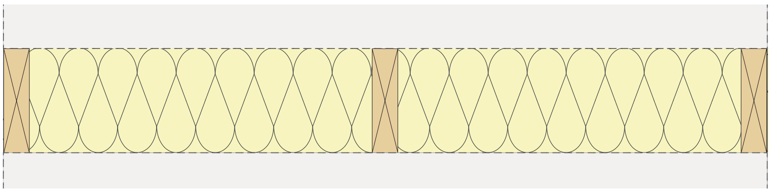
Fire technical parameters

t_{ins} = 11.4 min

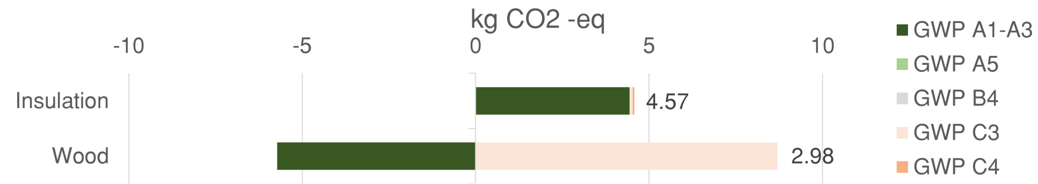
SLB 02 - 120 mm Wooden studs & Insulation

Component reference	:	SFH19
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	120 mm
Component plane weight	:	7.6 kg/m^2
Total environmental component impact	:	7.6 $kg\ CO_2{-}eq/m^2$

Heat capacity
0 $Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

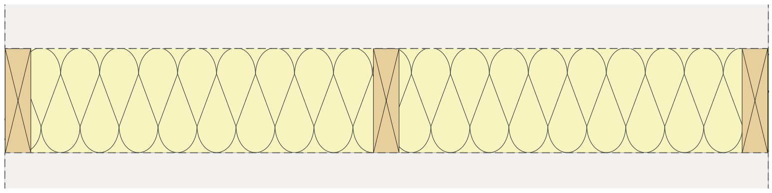
Fire technical parameters

$t_{ins} = 14.4$ min

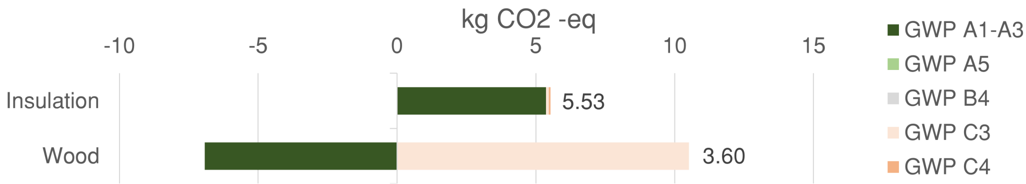
SLB 03 - 145 mm Wooden studs & Insulation

Component reference	:	SFH19
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	145 mm
Component plane weight	:	9.2 kg/m^2
Total environmental component impact	:	9.1 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D-s2,d0

Component material class
None

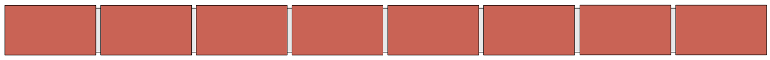
Fire technical parameters

$t_{ins} = 17.4$ min

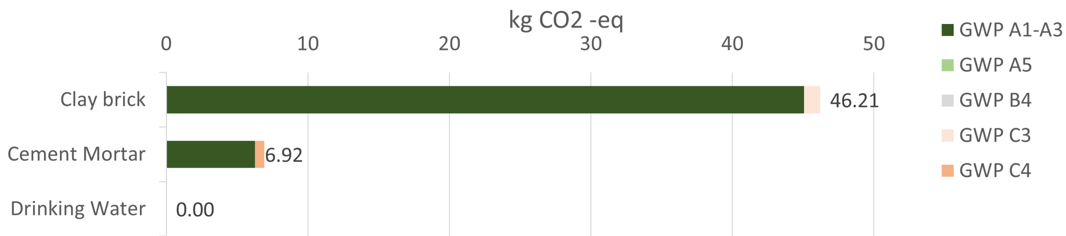
SLB 04 - 108 mm Clay brick

Component reference	:	SFH01	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	108	mm
Component plane weight	:	195.2	kg/m^2
Total environmental component impact	:	53.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
45.4 $Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

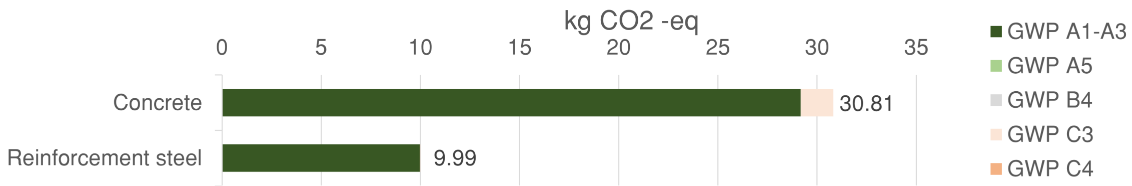
R120 EI120

SLB 05 - 100 mm Concrete

Component reference	:	SFH20
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	100 mm
Component plane weight	:	251.7 kg/m^2
Total environmental component impact	:	40.8 $kg\ CO_2{-}eq/m^2$

Heat capacity
66.6 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

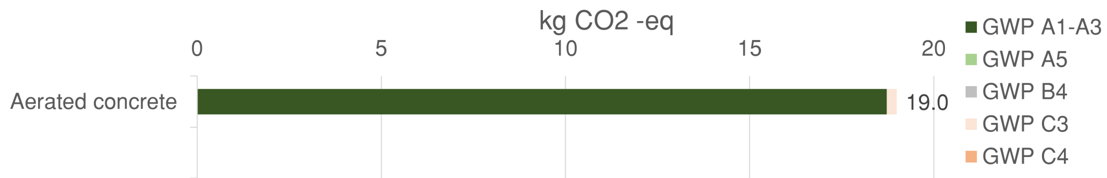
R30 EI90

SLB 06 - 100 mm Aerated Concrete

Component reference	:	TH02
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	100 mm
Component plane weight	:	38 kg/m^2
Total environmental component impact	:	19 $kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

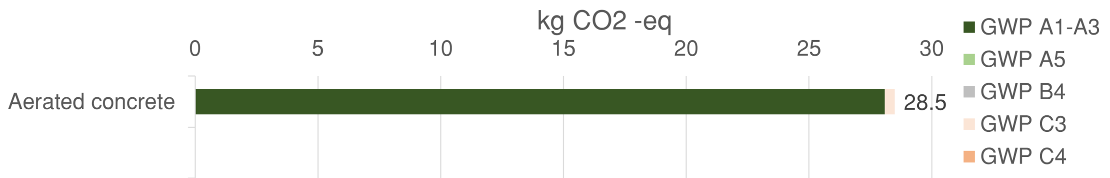
R120 EI240

SLB 07 - 150 mm Aerated Concrete

Component reference	:	TH02	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	150	mm
Component plane weight	:	57	kg/m^2
Total environmental component impact	:	28.5	$kg\ CO_2-eq/m^2$

Heat capacity
14.9 Wh/m^2 K

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

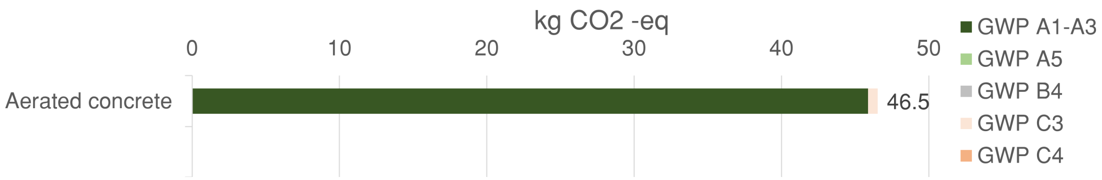
R180 EI240

SLB 08 - 245 mm Aerated Concrete

Component reference	:	TH02	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	245	mm
Component plane weight	:	93.1	kg/m^2
Total environmental component impact	:	46.5	$kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

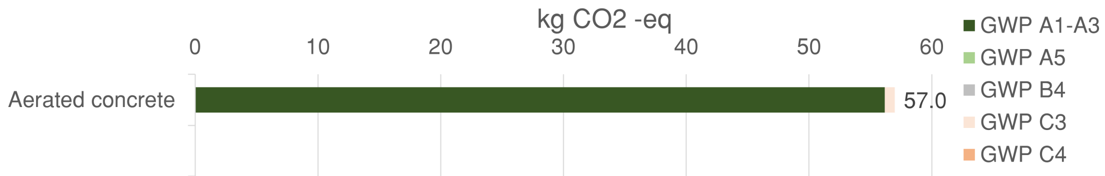
R240 EI240

SLB 09 - 300 mm Aerated Concrete

Component reference	:	TH02
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	300 mm
Component plane weight	:	114 kg/m^2
Total environmental component impact	:	57 $kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

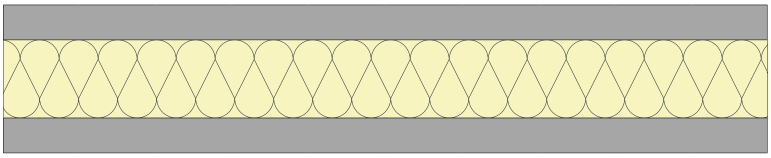
Fire technical parameters

R240 EI240

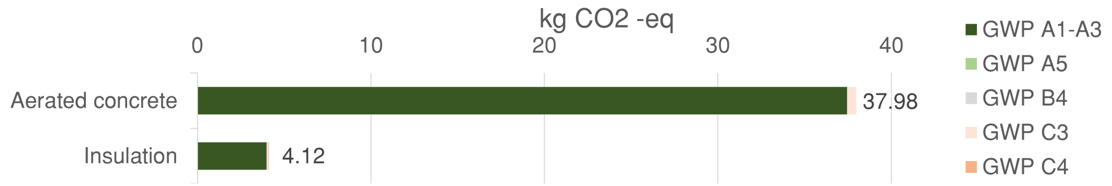
SLB 10 - 2x 100 mm Aerated Concrete + 100 mm Insulation

Component reference	:	TH04
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	300 mm
Component plane weight	:	78.6 kg/m^2
Total environmental component impact	:	42.1 $kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

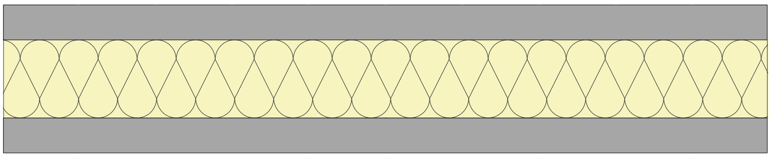
Fire technical parameters

R120 EI240

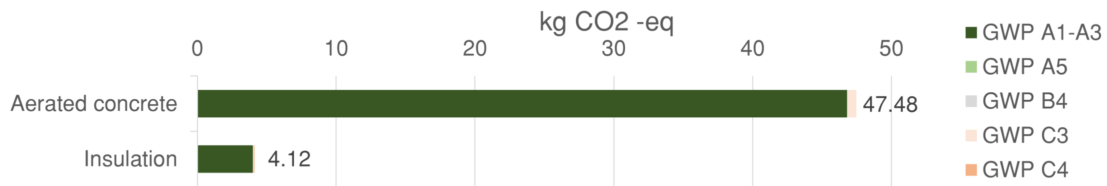
SLB 11 - 2x 125 mm Aerated Concrete + 100 mm Insulation

Component reference	:	TH04
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	350 mm
Component plane weight	:	97.6 kg/m^2
Total environmental component impact	:	51.6 kg CO_2-eq/m^2

Heat capacity
14.9 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

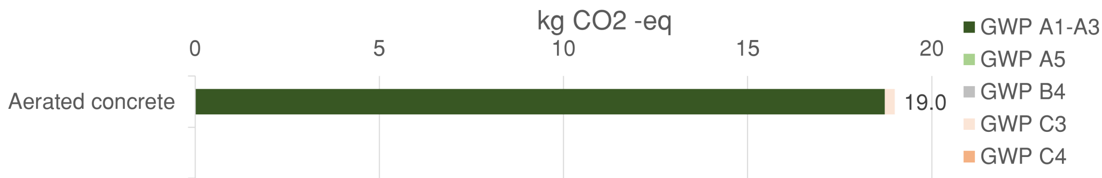
R120 EI240

SNLB 01 - 100 mm Aerated Concrete

Component reference	:	AB02
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	100 mm
Component plane weight	:	38 kg/m^2
Total environmental component impact	:	19 $kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

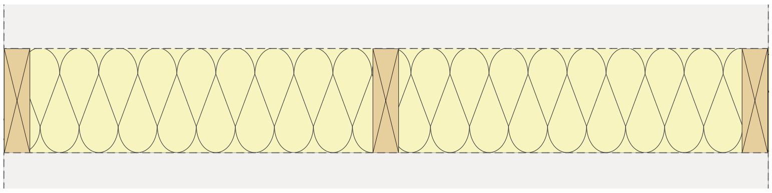
Fire technical parameters

EI240

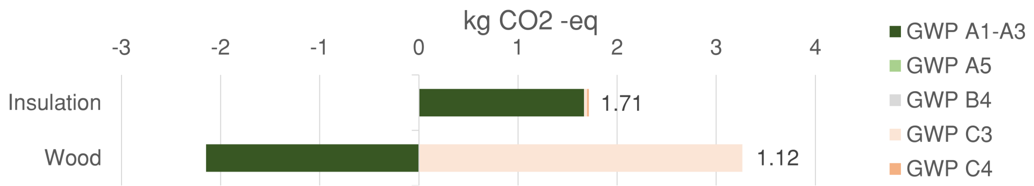
SNLB 02 - 45 mm Wooden studs & Insulation

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	45 mm
Component plane weight	:	2.9 kg/m^2
Total environmental component impact	:	2.8 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

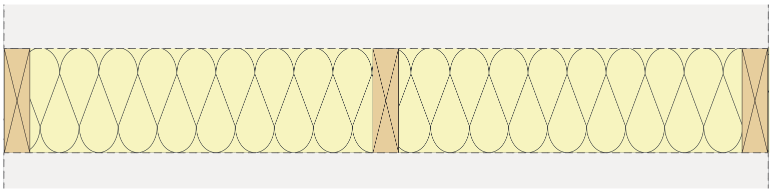
Fire technical parameters

t_{ins} = 5.4 min

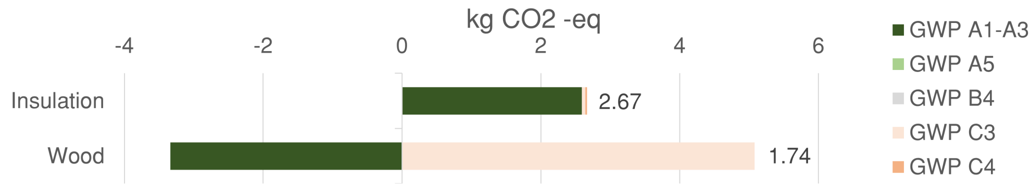
SNLB 03 - 70 mm Wooden studs & Insulation

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	70 mm
Component plane weight	:	4.5 kg/m^2
Total environmental component impact	:	4.4 kg CO_2−eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

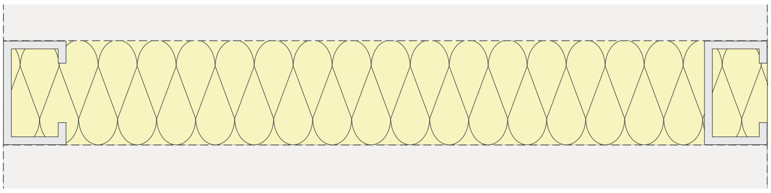
Fire technical parameters

t_{ins} = 9.6 min

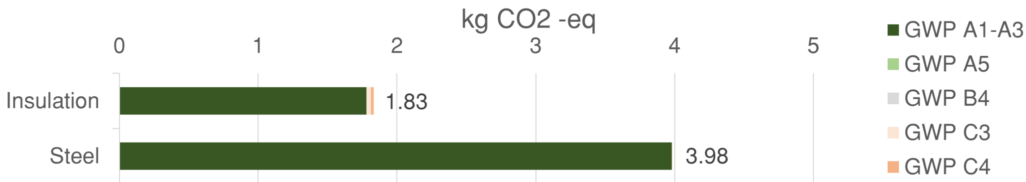
SNLB 04 - 45 mm Steel C profile & Insulation

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	45 mm
Component plane weight	:	5.3 kg/m^2
Total environmental component impact	:	5.8 kg CO_2−eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	None

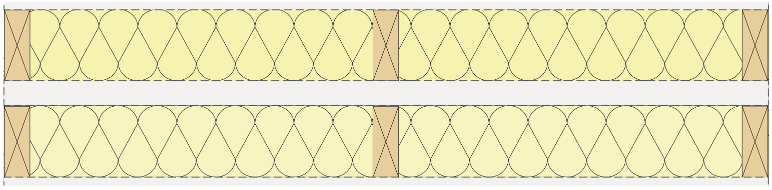
Fire technical parameters

t_{ins} = 5.4 min

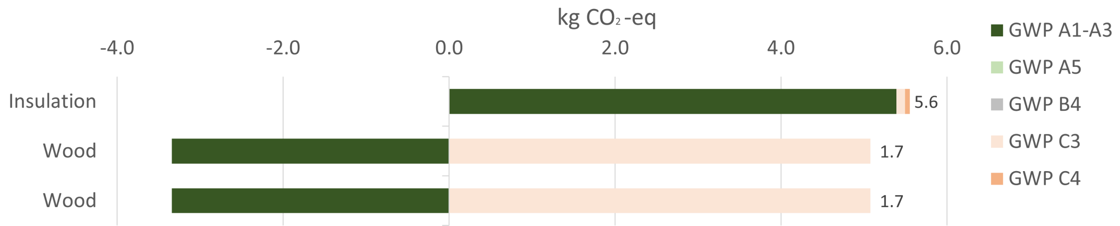
SNLB 05 - 2 x 70 mm wooden studs & Insulation + 108 mm Air gap

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	248 mm
Component plane weight	:	9.1 kg/m^2
Total environmental component impact	:	9 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D-s2,d0

Component material class
None

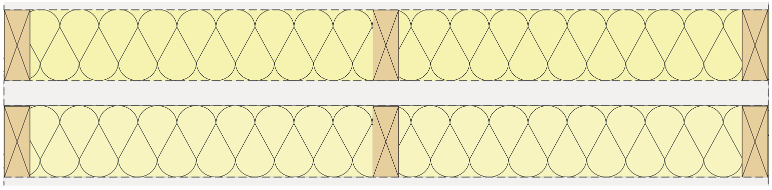
Fire technical parameters

t_{ins} = 21.8 min

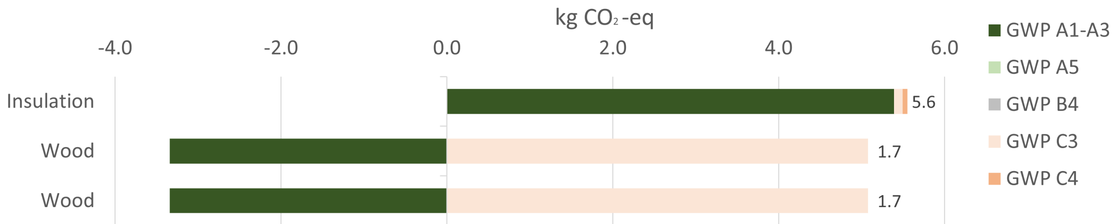
SNLB 06 - 2 x 70 mm wooden studs & Insulation + 113 mm Air gap

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	253 mm
Component plane weight	:	9.1 kg/m^2
Total environmental component impact	:	9 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

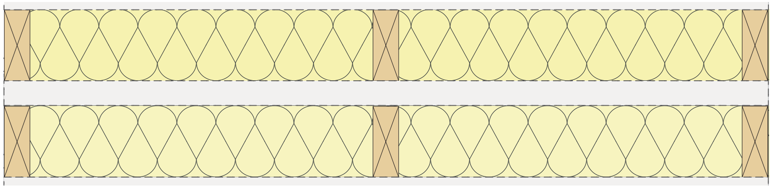
Fire technical parameters

t_{ins} = 21.8 min

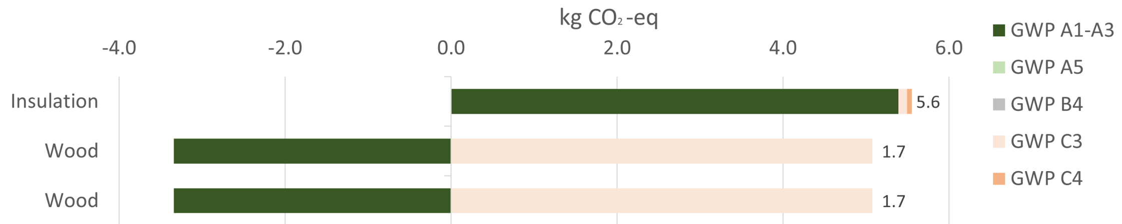
SNLB 07 - 2 x 70 mm wooden studs & Insulation + 128 mm Air gap

Component reference	:	AB05	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	268	mm
Component plane weight	:	9.1	kg/m^2
Total environmental component impact	:	9	kg CO_2−eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

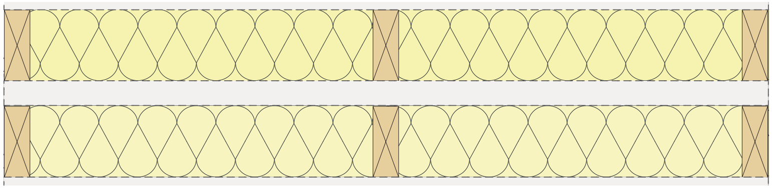
Fire technical parameters

$t_{ins} = 21.8$ min

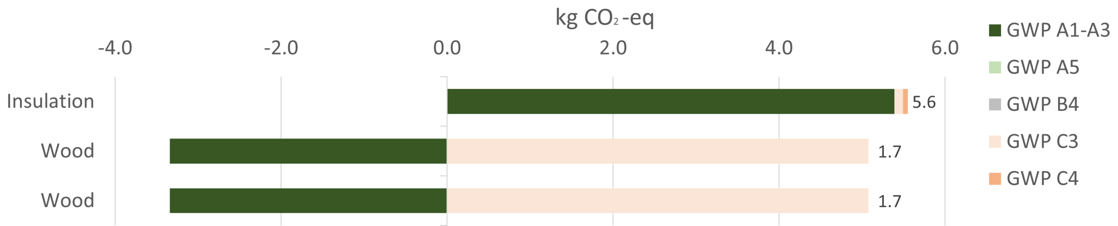
SNLB 08 - 2 x 70 mm wooden studs & Insulation + 80 mm Air gap

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	220 mm
Component plane weight	:	9.1 kg/m^2
Total environmental component impact	:	9 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	None

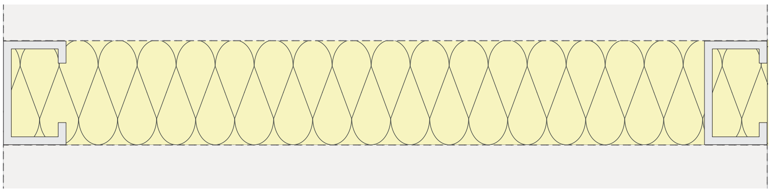
Fire technical parameters

$t_{ins} = 21.8$ min

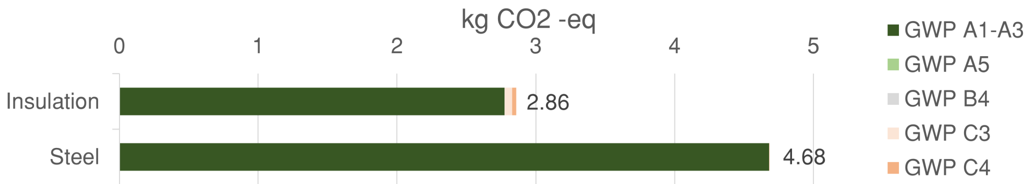
SNLB 09 - 70 mm Steel C profile & Insulation

Component reference	:	AB05
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	70 mm
Component plane weight	:	6.7 kg/m^2
Total environmental component impact	:	7.5 $kg\ CO_2{-}eq/m^2$

Heat capacity
0 $Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	None

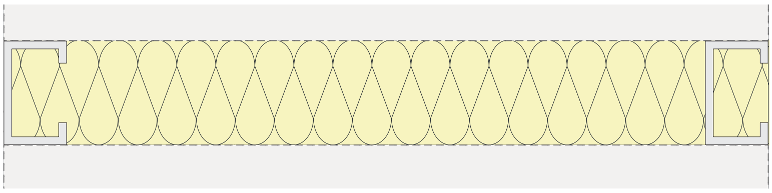
Fire technical parameters

$t_{ins} = 8.4$ min

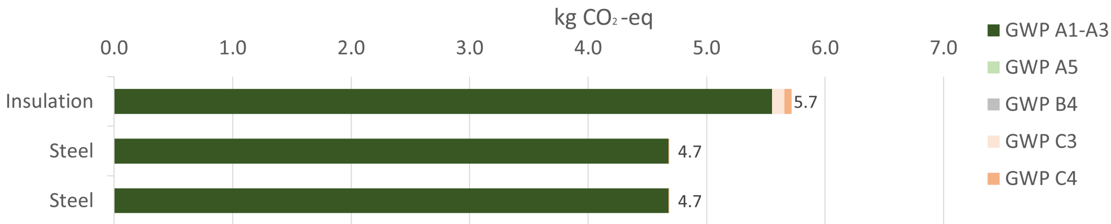
SNLB 10 - 2 x 70 mm Steel C profile & Insulation

Component reference	:	AB04
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	140 mm
Component plane weight	:	13.3 kg/m^2
Total environmental component impact	:	15.1 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
None

Fire technical parameters

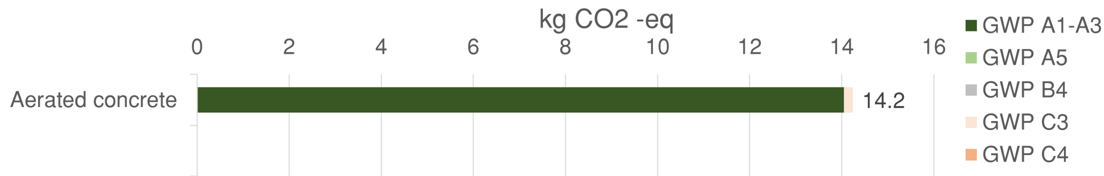
t_{ins} = 16.8 min

SNLB 11 - 75 mm Aerated Concrete

Component reference	:	AB02	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	75	mm
Component plane weight	:	28.5	kg/m^2
Total environmental component impact	:	14.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
14.9 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

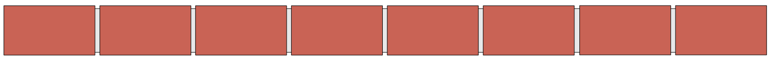
Fire technical parameters

EI120

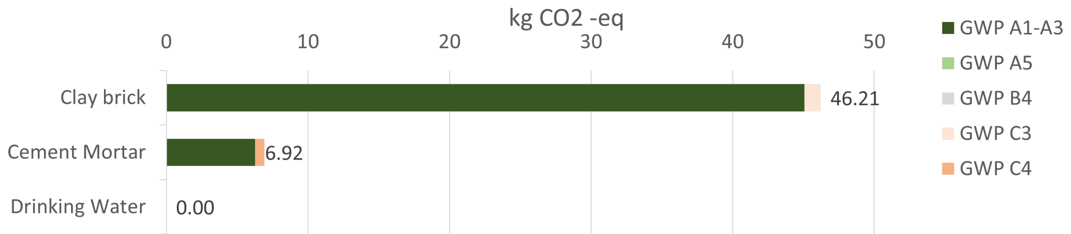
SNLB 12 - 108 mm Clay Brick

Component reference	:	SFH01
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	108 mm
Component plane weight	:	195.2 kg/m^2
Total environmental component impact	:	53.1 kg CO_2-eq/m^2

Heat capacity
45.4 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

EI120

M.3 Roofs

The roof has four different micro components, these are:

- IC - Interior cladding
- EC - Exterior cladding
- S - Structure & insulation
- IL - Installation layer
- INS - Insulation
- VB - Vabor barrier

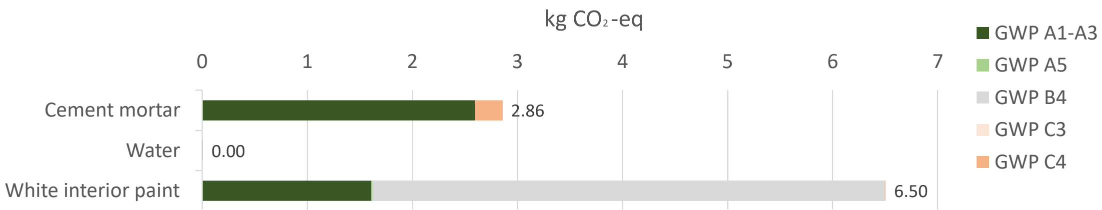
IC 01 - 10 mm mortar + Paint

Component reference	:	AB02	
Compatible with	:	Solid constructions	
Component thickness	:	10	mm
Component plane weight	:	18.7	kg/m^2
Total environmental component impact	:	9.4	$kg\ CO_2{-}eq/m^2$

Heat capacity
0 $Wh/m^2\ K$

R-value
0.141 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

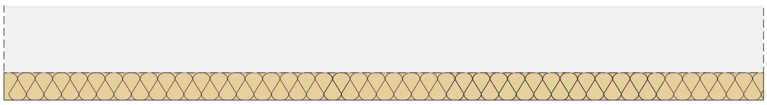
Component material class
None

IC 02 - 60 mm Insulation panel cladding (Skalflex)

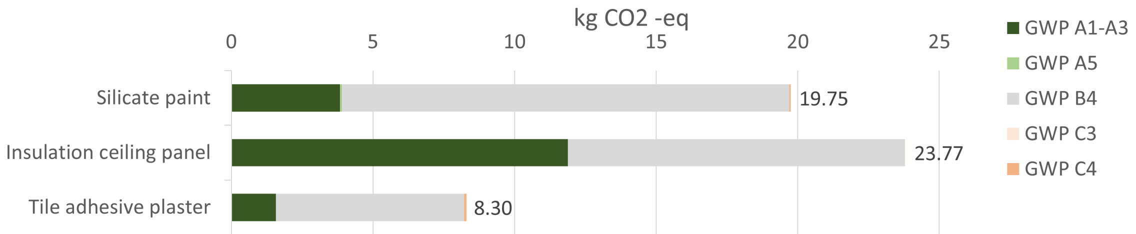
Component reference	:	Self	
Compatible with	:	Solid constructions	
Component thickness	:	63	mm
Component plane weight	:	15.7	kg/m^2
Total environmental component impact	:	51.8	kg CO_2−eq/m^2

Heat capacity
0 Wh/m^2 K

R-value
1.9 K m^2/W



Environmental impact per m^2 component



Fire technical classification

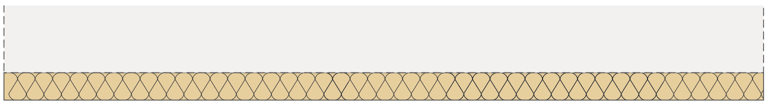
Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

IC 03 - 80 mm Insulation panel cladding (Skalflex)

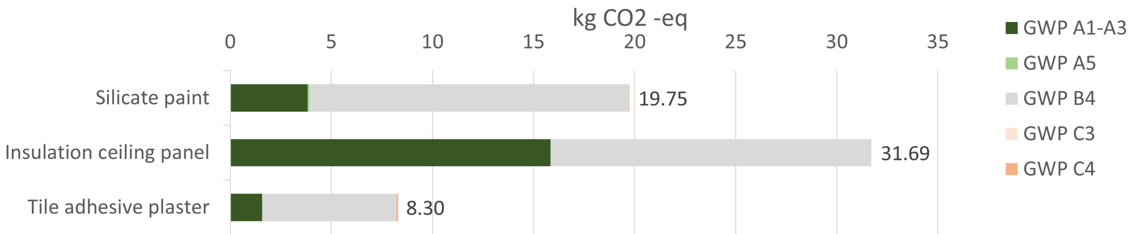
Component reference	:	Self
Compatible with	:	Solid constructions
Component thickness	:	83 mm
Component plane weight	:	18.6 kg/m^2
Total environmental component impact	:	59.7 $kg\ CO_2{-}eq/m^2$

Heat capacity
0 $Wh/m^2\ K$

R-value
1.9 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

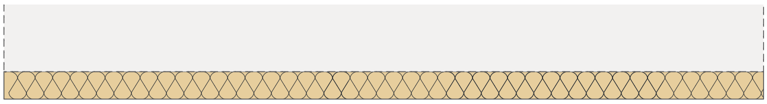
Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

IC 04 - 100 mm Insulation panel cladding (Skalflex)

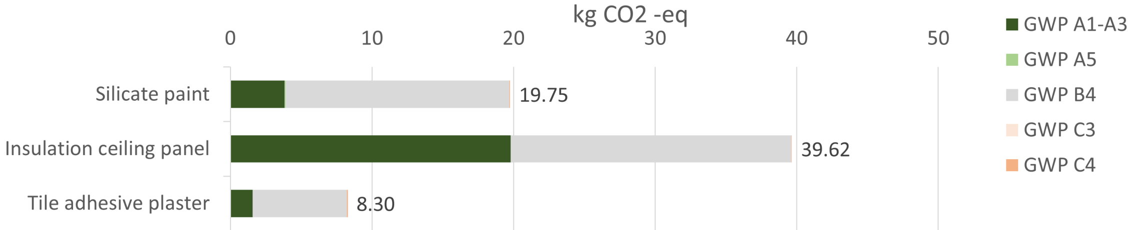
Component reference	:	Self
Compatible with	:	Solid constructions
Component thickness	:	103 mm
Component plane weight	:	21.5 kg/m^2
Total environmental component impact	:	67.7 kg CO_2-eq/m^2

Heat capacity
0 Wh/m^2 K

R-value
1.9 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

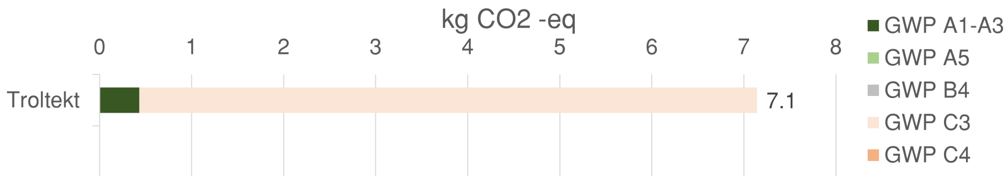
IC 05 - 25 mm Troldtekt

Component reference	:	Self	
Compatible with	:	Frame constructions	
Component thickness	:	25	mm
Component plane weight	:	9	kg/m^2
Total environmental component impact	:	7.1	$kg\ CO_2-eq/m^2$

Heat capacity
4.8 Wh/m^2 K

R-value
0.125 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	B-s1,d0	B-s1,0

Fire technical parameters

$t_{ins} = 27.5$ min

$t_{ch} = 23.8$ min

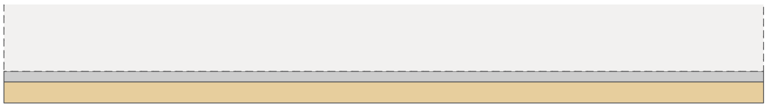
$t_f = 23.8$ min

IC 06 - 12.5 mm Plasterboard, F + 25 mm Troldtekt

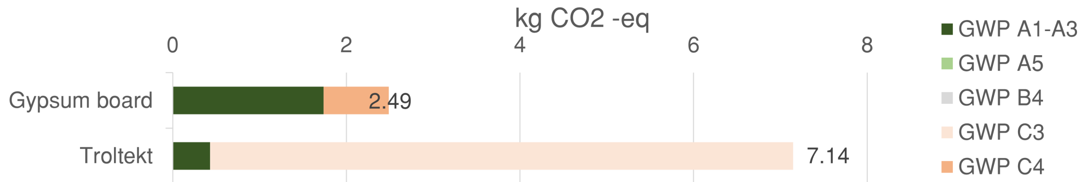
Component reference	:	Self	
Compatible with	:	Frame constructions	
Component thickness	:	37.5	mm
Component plane weight	:	19	kg/m^2
Total environmental component impact	:	9.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
7.9 $Wh/m^2\ K$

R-value
0.188 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	B-s1,d0	B-s1,0

Fire technical parameters

t_{ins} = 38 min

t_{ch} = 33.9 min

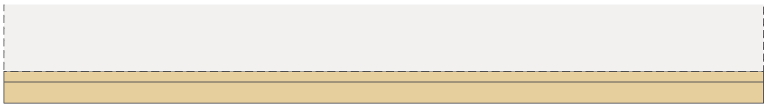
t_f = 42.5 min

IC 07 - 12 mm Plywood, F + 25 mm Troldtekt

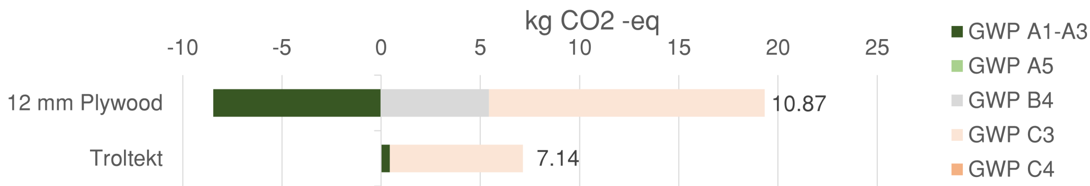
Component reference	:	Self
Compatible with	:	Frame constructions
Component thickness	:	37 mm
Component plane weight	:	14.9 kg/m^2
Total environmental component impact	:	18 kg CO_2−eq/m^2

Heat capacity
8.9 Wh/m^2 K

R-value
0.217 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	B-s1,d0	D-s2,0

Fire technical parameters

t_{ins} = 29.8 min

t_{ch} = 29.1 min

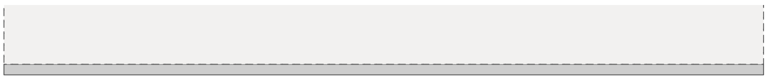
t_f = 29.1 min

IC 08 - 9.5 mm Plasterboard + Plaster + Paint

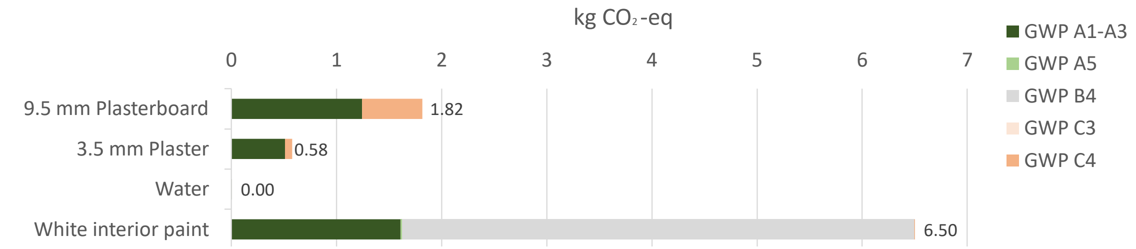
Component reference	:	SFH11	
Compatible with	:	Frame constructions	
Component thickness	:	14.5	mm
Component plane weight	:	20.5	kg/m^2
Total environmental component impact	:	8.9	$kg\ CO_2{-}eq/m^2$

Heat capacity
2.4 $Wh/m^2\ K$

R-value
0.194 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

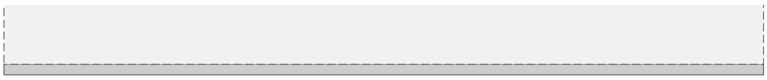
t_{ins} = 13.3 min | t_{ch} = 10.1 min | t_f = 18.8 min | N_{60} = 13.6

IC 09 - 12.5 mm Plasterboard + Plaster + Paint

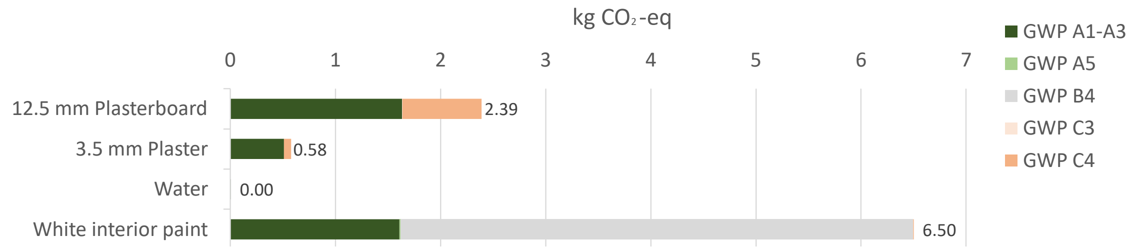
Component reference	:	SFH13	
Compatible with	:	Frame constructions	
Component thickness	:	17.5	mm
Component plane weight	:	22.9	kg/m^2
Total environmental component impact	:	9.5	$kg\ CO_2-eq/m^2$

Heat capacity
$3.13\ Wh/m^2\ K$

R-value
$0.209\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

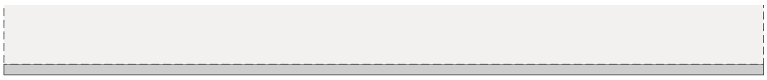
$t_{ins} = 17.5$ min | $t_{ch} = 15.5$ min | $t_f = 32.25$ min | $N_{60} = 13.6$

IC 10 - 15 mm Plasterboard + Plaster + Paint

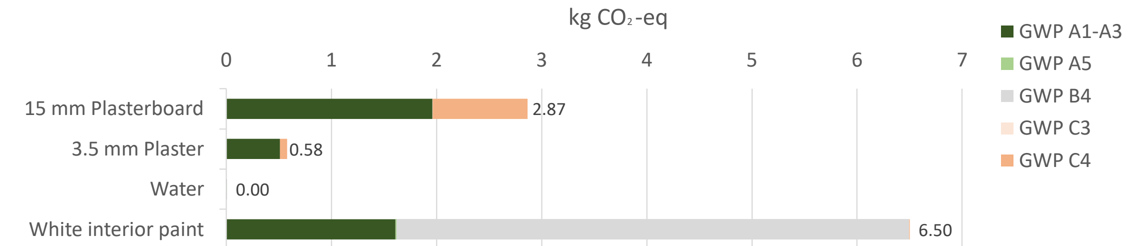
Component reference	:	SFH13	
Compatible with	:	Frame constructions	
Component thickness	:	20	mm
Component plane weight	:	24.9	kg/m^2
Total environmental component impact	:	10	$kg\ CO_2-eq/m^2$

Heat capacity
3.75 $Wh/m^2\ K$

R-value
0.222 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 21$ min

$t_{ch} = 20$ min

$t_f = 43.5$ min

$N_{60} = 13.6$

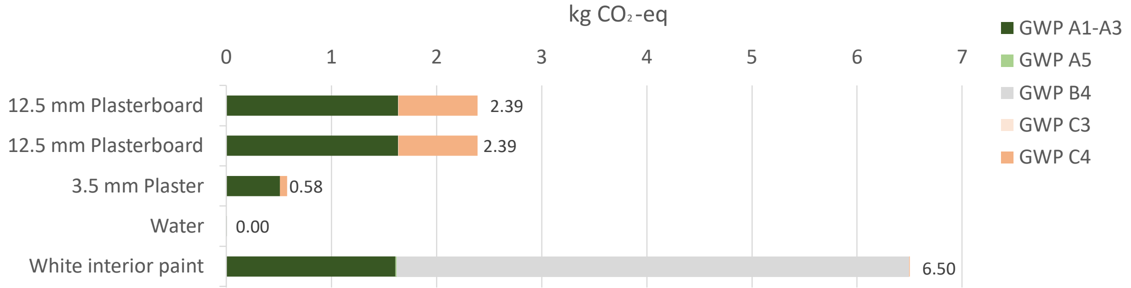
IC 11 - 2 x 12.5 mm Plasterboard + Plaster + Paint

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	32.9	kg/m^2
Total environmental component impact	:	11.9	$kg\ CO_2{-}eq/m^2$

Heat capacity
$6.25\ Wh/m^2\ K$

R-value
$0.272\ K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 28$ min | $t_{ch} = 45.5$ min | $t_f = 60$ min | $N_{60} = 265.3$

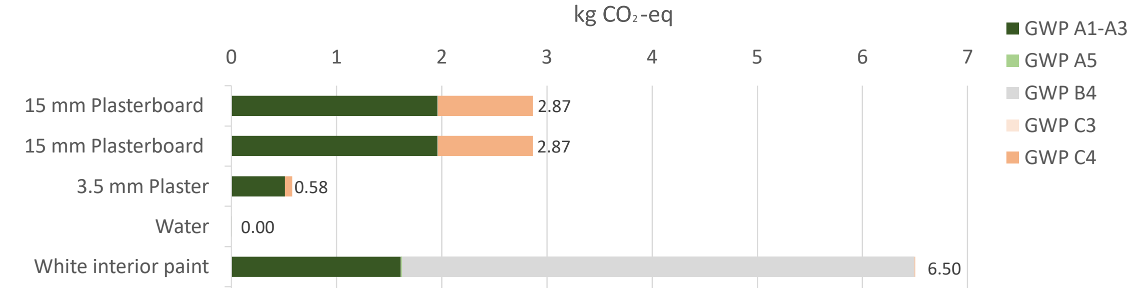
IC 12 - 2 x 15 mm Plasterboard + Plaster + Paint

Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	35 mm
Component plane weight	:	36.9 kg/m^2
Total environmental component impact	:	12.8 kg CO_2-eq/m^2

Heat capacity
7.5 Wh/m^2 K

R-value
0.297 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 33.6$ min | $t_{ch} = 56$ min | $t_f = 80$ min | $N_{60} = 265.3$

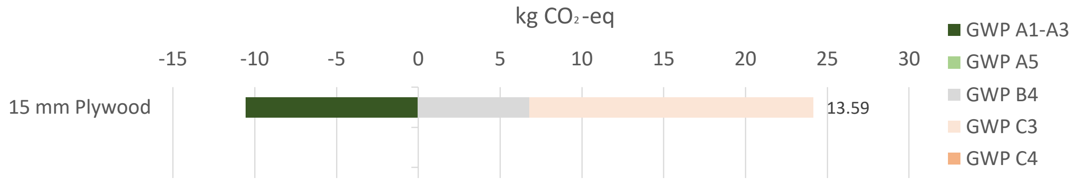
IC 13 - 15 mm Plywood

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	15	mm
Component plane weight	:	7.4	kg/m^2
Total environmental component impact	:	13.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
3.33 $Wh/m^2\ K$

R-value
0.245 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	D-s2,d0	D-s2,d0

Fire technical parameters

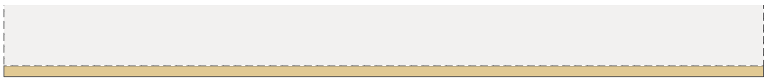
$t_{ins} = 9.6$ min | $t_{ch} = 9$ min | $t_f = 9$ min | $N_{60} = 13.6$

IC 14 - 15 mm OSB

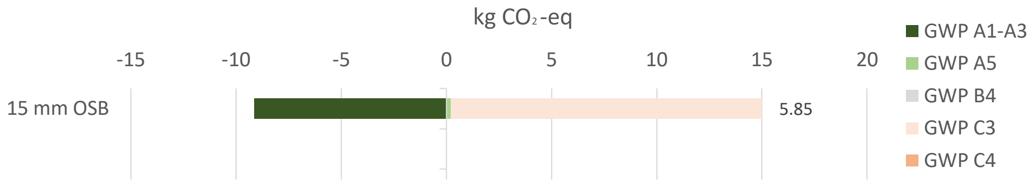
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	15 mm
Component plane weight	:	9 kg/m^2
Total environmental component impact	:	5.9 kg CO_2−eq/m^2

Heat capacity
3.33 Wh/m^2 K

R-value
0.245 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
Test

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 11.1 min

t_{ch} = 10.4 min

t_f = 10.4 min

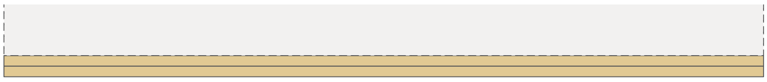
N_{60} = 13.6

IC 15 - 2 x Plywood

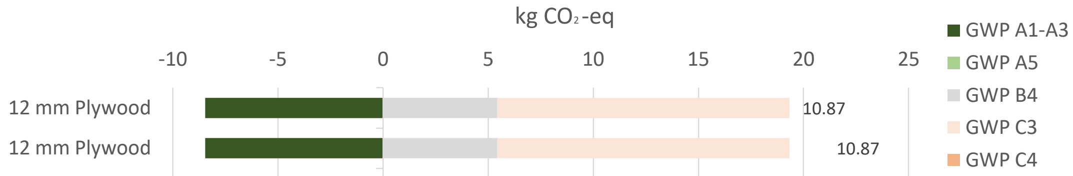
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	24 mm
Component plane weight	:	11.8 kg/m^2
Total environmental component impact	:	21.7 kg CO_2-eq/m^2

Heat capacity
5.33 Wh/m^2 K

R-value
0.315 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

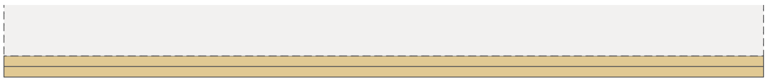
$t_{ins} = 14.8$ min | $t_{ch} = 20$ min | $t_f = 20$ min | $N_{60} = 13.6$

IC 16 - 2 x OSB

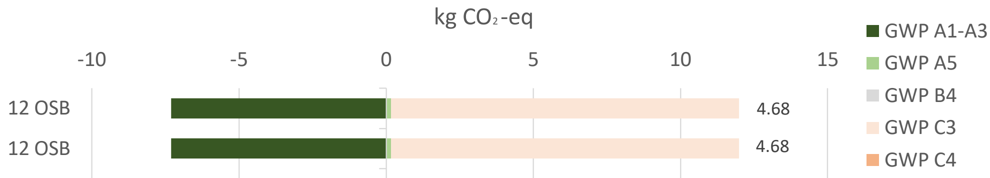
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	24	mm
Component plane weight	:	14.4	kg/m^2
Total environmental component impact	:	9.4	$kg\ CO_2\text{-}eq/m^2$

Heat capacity
5.33 $Wh/m^2\ K$

R-value
0.315 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

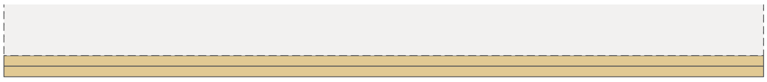
$t_{ins} = 17.8$ min | $t_{ch} = 22.7$ min | $t_f = 22.7$ min | $N_{60} = 13.6$

IC 17 - 2 x 21 mm Plywood

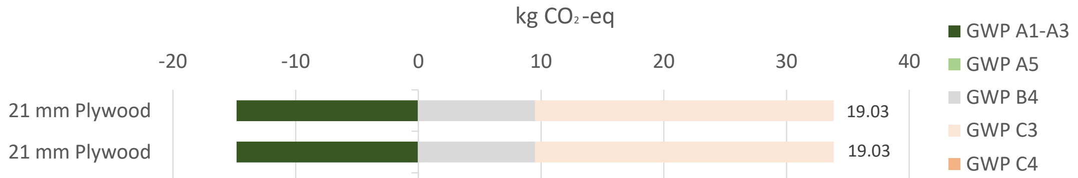
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	20.6	kg/m^2
Total environmental component impact	:	38.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
9.33 $Wh/m^2\ K$

R-value
0.453 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

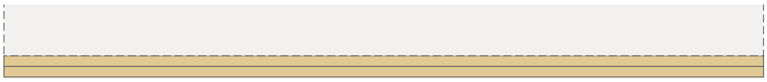
$t_{ins} = 25.9$ min | $t_{ch} = 38$ min | $t_f = 38$ min | $N_{60} = 13.6$

IC 18 - 2 x 21 mm OSB

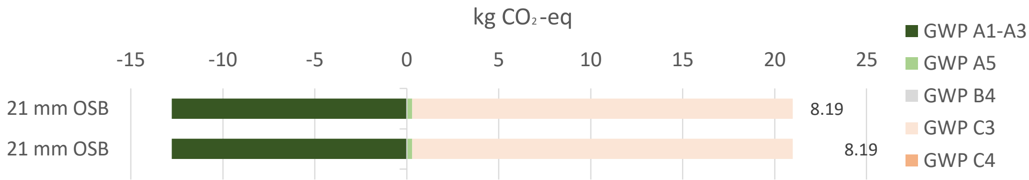
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	25.2	kg/m^2
Total environmental component impact	:	16.4	$kg\ CO_2-eq/m^2$

Heat capacity
$9.33\ Wh/m^2\ K$

R-value
$0.453\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

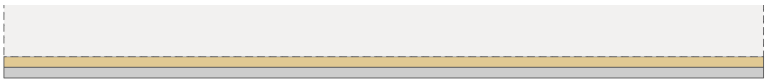
$t_{ins} = 30$ min | $t_{ch} = 42.7$ min | $t_f = 42.7$ min | $N_{60} = 13.6$

IC 19 - 12 mm OSB + 12.5 mm Plasterboard + Plaster + Paint

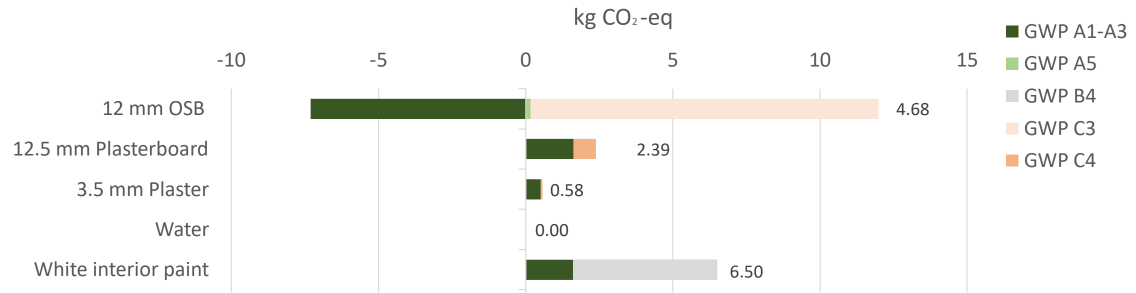
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	29.5	mm
Component plane weight	:	30.1	kg/m^2
Total environmental component impact	:	14.15	$kg\ CO_2{-}eq/m^2$

Heat capacity
$5.8\ Wh/m^2\ K$

R-value
$0.302\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

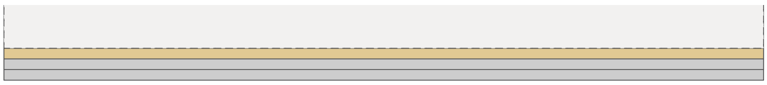
$t_{ins} = 28$ min	$t_{ch} = 18.5$ min	$t_f = 18.8$ min	$N_{60} = 13.6$

IC 20 - 12 mm OSB + 2 x 12.5 mm Plasterboard + Plaster + Paint

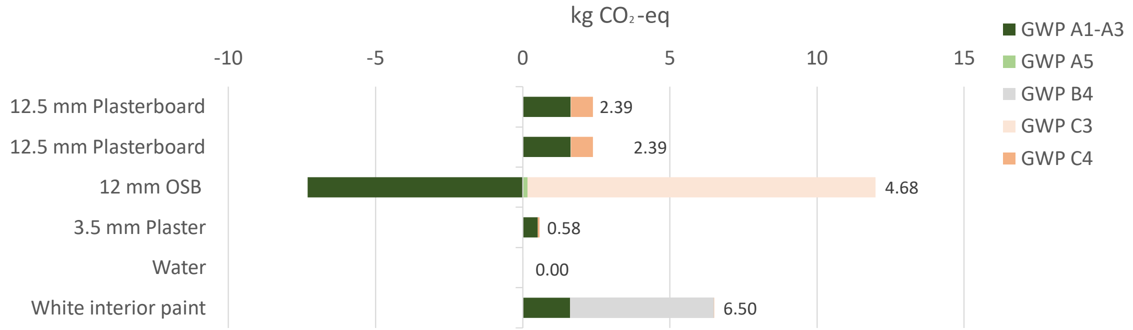
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	40.1	kg/m^2
Total environmental component impact	:	16.5	$kg\ CO_2{-}eq/m^2$

Heat capacity
8.9 Wh/m^2 K

R-value
0.364 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

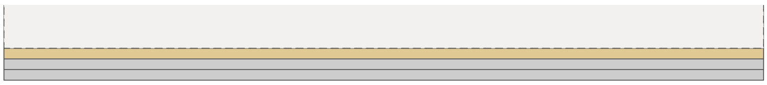
t_{ins} = 38.5 min | t_{ch} = 55 min | t_f = 60 min | N_{60} = 265.3

IC 21 - 15 mm OSB + 2 x 15 mm Plasterboard + Plaster + Paint

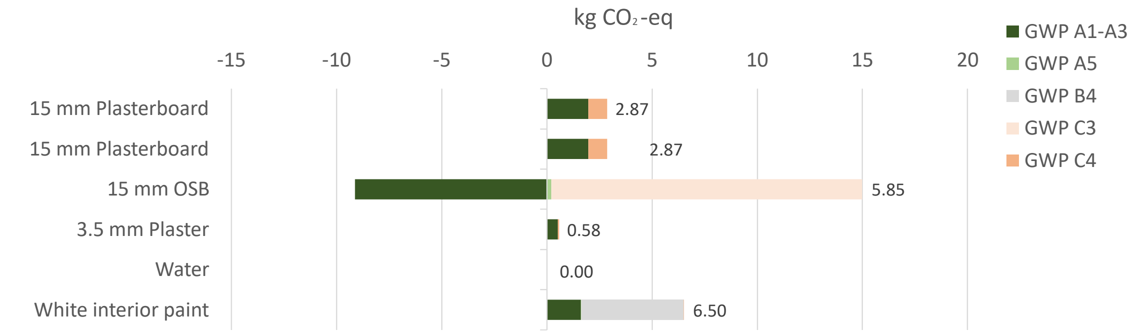
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	50	mm
Component plane weight	:	45.9	kg/m^2
Total environmental component impact	:	18.7	$kg\ CO_2-eq/m^2$

Heat capacity
10.8 $Wh/m^2\ K$

R-value
0.412 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 46.8$ min

$t_{ch} = 71.8$ min

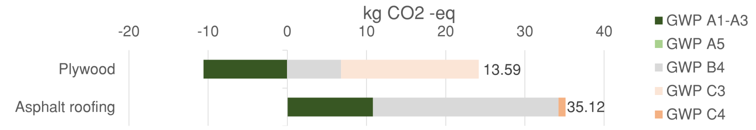
$t_f = 80$ min

$N_{60} = 265.3$

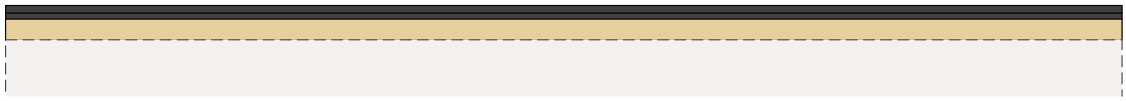
EC 01 - 15 mm Plywood + 2 x 4 mm Asphalt roofing sheet

Component reference	:	AB01	
Component thickness	:	23	mm
Component plane weight	:	17.8	kg/m^2
Total environmental component impact	:	48.7	$kg\ CO_2{-}eq/m^2$

R-value
0 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	$B_{ROOF}(t2)$	D-s2,d0

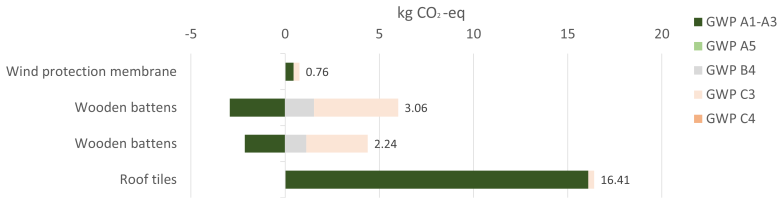
Fire technical parameters

$t_{ins} = 14.3$ min

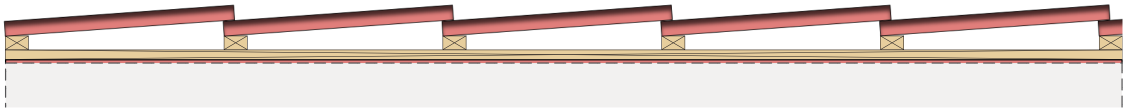
EC 02 - Windmembrane + Wooden battens + Roof tiles

Component reference	:	SFH09
Component thickness	:	128 mm
Component plane weight	:	49.4 kg/m^2
Total environmental component impact	:	22.5 $kg\ CO_2{-}eq/m^2$

R-value
0 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	B_{ROOF}(t2)	D-s2,d0

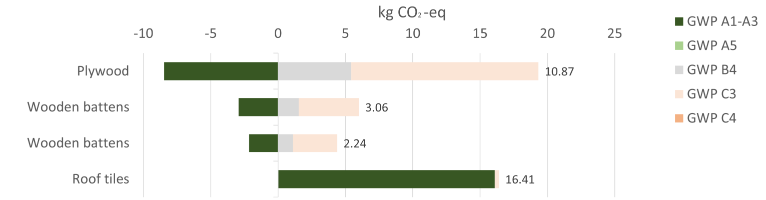
Fire technical parameters

$t_{ins} = 0$ min

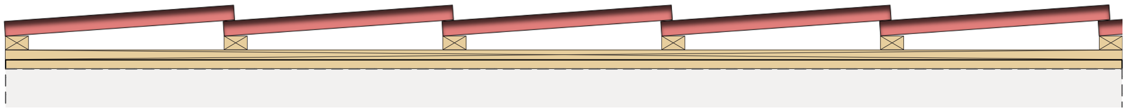
EC 03 - 12 mm Plywood + Wooden battens + Roof tiles

Component reference	:	TRAE	
Component thickness	:	140	mm
Component plane weight	:	55.1	kg/m^2
Total environmental component impact	:	32.6	$kg\ CO_2{-}eq/m^2$

R-value
$0\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	B_{ROOF}(t2)	D-s2,d0

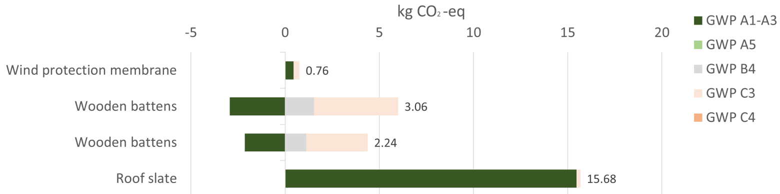
Fire technical parameters

$t_{ins} = 11.4$ min

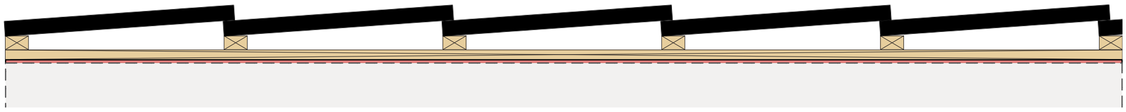
EC 04 - Windmembrane + Wooden battens + Roof Slates

Component reference	:	SFH09	
Component thickness	:	127	mm
Component plane weight	:	34.4	kg/m^2
Total environmental component impact	:	21.7	$kg\ CO_2-eq/m^2$

R-value
$0\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	$B_{ROOF}(t4)$	D-s2,d0

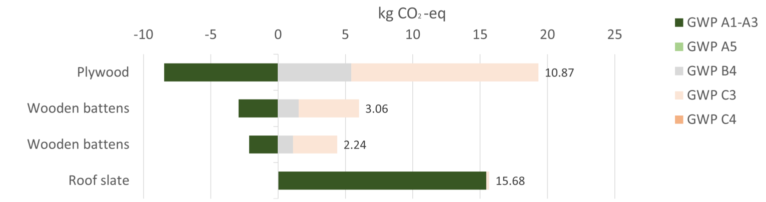
Fire technical parameters

$t_{ins} = 0$ min

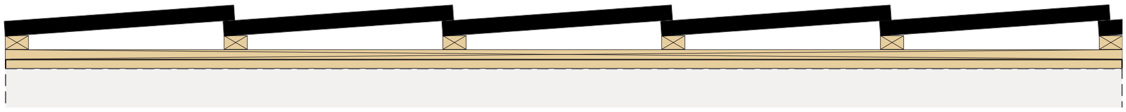
EC 05 - 12 mm Plywood + Wooden battens + Roof slates

Component reference	:	TRAE	
Component thickness	:	139	mm
Component plane weight	:	40.1	kg/m^2
Total environmental component impact	:	32.8	$kg\ CO_2{-}eq/m^2$

R-value
0 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	B_{ROOF}(t4)	D-s2,d0

Fire technical parameters

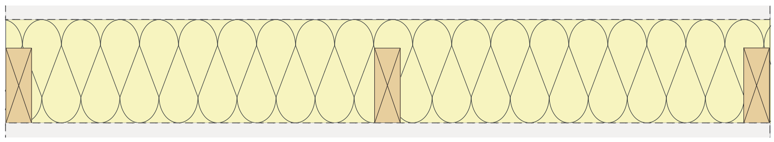
t_{ins} = 11.4 min

S 01 - 390 mm Wooden beams & 340 mm Insulation

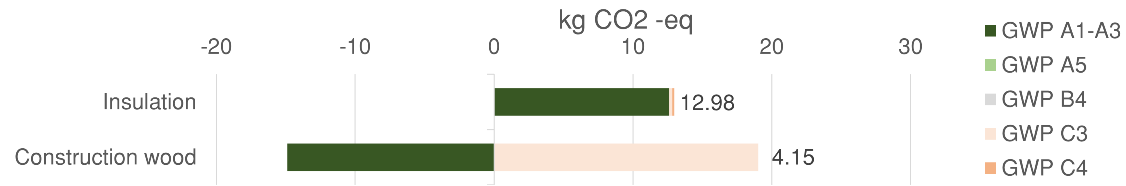
Component reference	:	SFH14
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	390 mm
Component plane weight	:	18.6 kg/m^2
Total environmental component impact	:	17.1 kg CO_2–eq/m^2

Heat capacity
None

R-value
0.34/(0.0095 + 0927 · L) K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

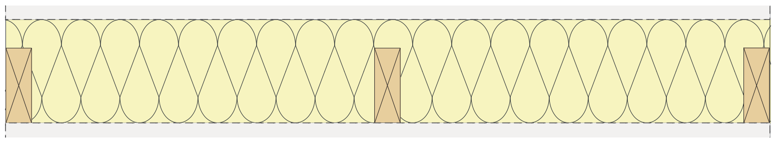
f_k = 30 MPa

S 02 - 245 mm Wooden beams & 240 mm Insulation

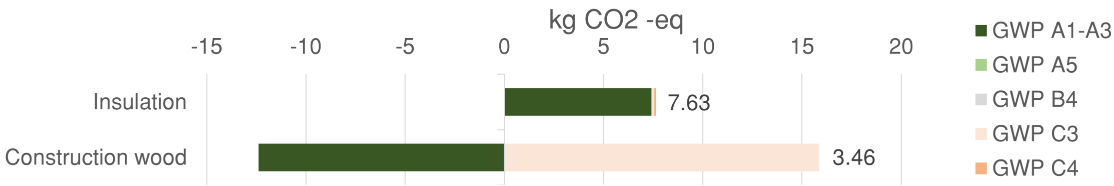
Component reference	:	AB01
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	13.5 kg/m^2
Total environmental component impact	:	11.1 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.24/(0.0095 + 0.927 \cdot L)$
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

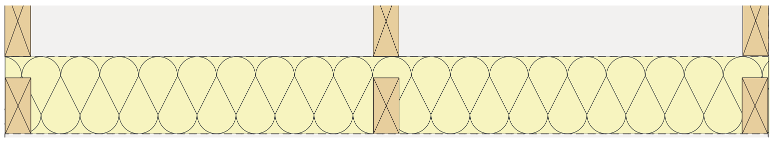
$f_k = 30$ MPa

S 03 - 390 mm Wooden beams truss & 340 mm Insulation

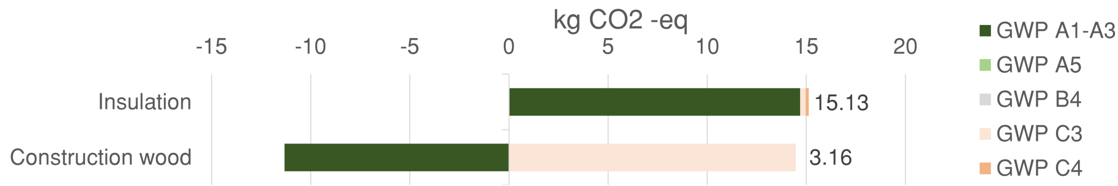
Component reference	:	SFH09
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	390 mm
Component plane weight	:	17.5 kg/m^2
Total environmental component impact	:	18.3 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.34/(0.049 + 0927 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

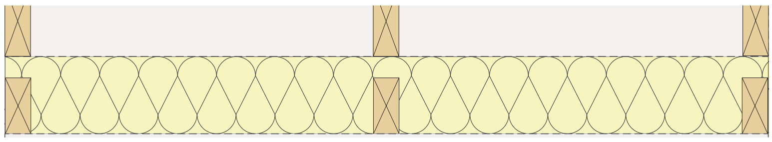
f_k = 30 MPa

S 04 - 145 mm Wooden truss & 395 mm Insulation

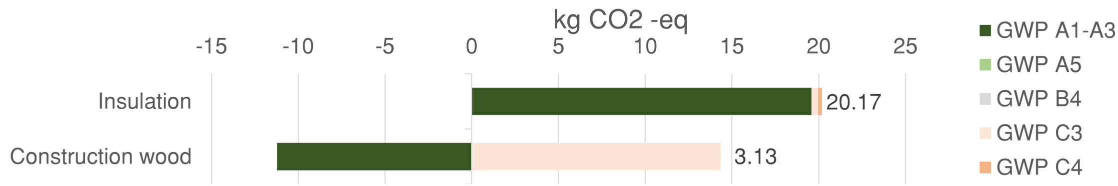
Component reference	:	SFH20	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	495	mm
Component plane weight	:	20.6	kg/m^2
Total environmental component impact	:	23.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

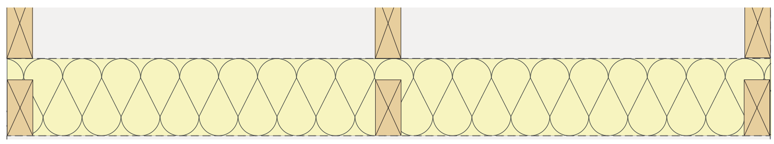
$f_k = 30$ MPa

S 05 - 145 mm Wooden truss & 395 mm Insulation

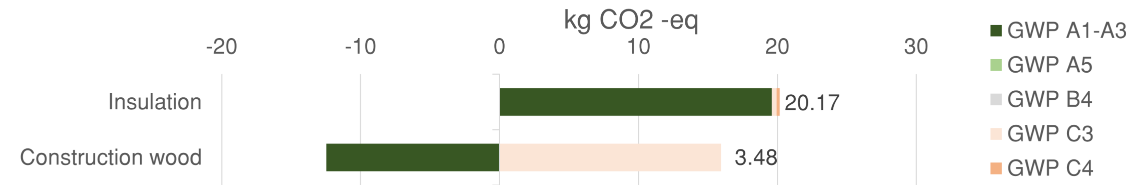
Component reference	:	SFH20	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	495	mm
Component plane weight	:	21.4	kg/m^2
Total environmental component impact	:	23.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

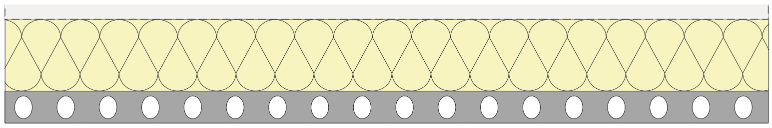
$f_k = 30$ MPa

S 06 - 220 mm Hollow-core slab + 400 mm Insulation

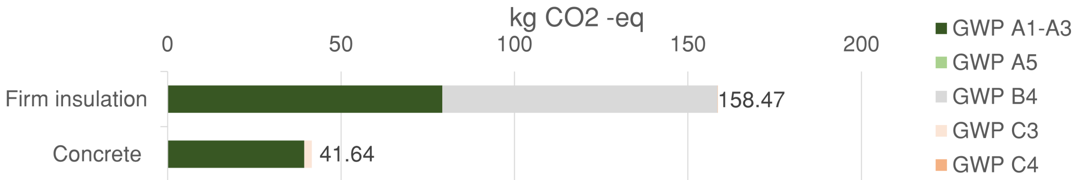
Component reference	:	AB02	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	620	mm
Component plane weight	:	376.9	kg/m^2
Total environmental component impact	:	200	$kg\ CO_2-eq/m^2$

Heat capacity
66.6 $Wh/m^2\ K$

R-value
0.4/L+0.11
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R30

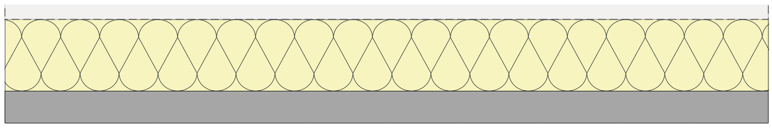
EI30

S 07 - 180 mm Concrete deck + 400 mm Insulation

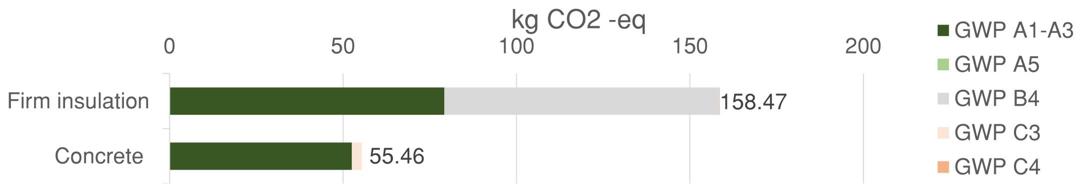
Component reference	:	SFH15	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	580	mm
Component plane weight	:	482.8	kg/m^2
Total environmental component impact	:	213.9	$kg\ CO_2-eq/m^2$

Heat capacity
66.6 $Wh/m^2\ K$

R-value
0.4/L+0.09
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R240

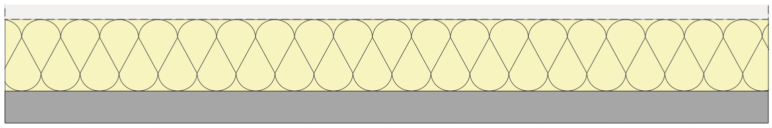
EI240

S 08 - 200 mm Concrete deck + 400 mm Insulation

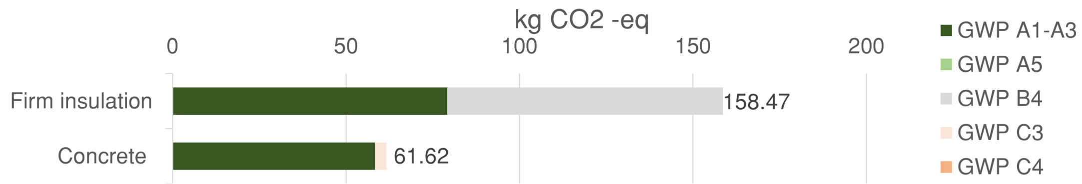
Component reference	:	OB05	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	600	mm
Component plane weight	:	530	kg/m^2
Total environmental component impact	:	220	$kg\ CO_2{-}eq/m^2$

Heat capacity
66.6 $Wh/m^2\ K$

R-value
0.4/L+0.1
$K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R240

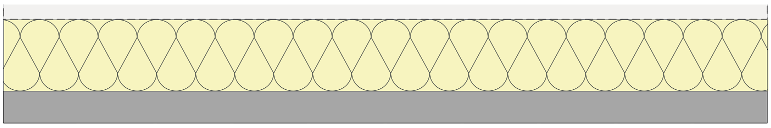
EI240

S 09 - 220 mm Concrete deck + 400 mm Insulation

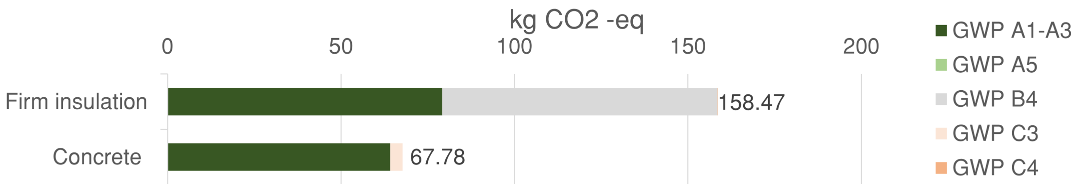
Component reference	:	OB05
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	620 mm
Component plane weight	:	577.2 kg/m^2
Total environmental component impact	:	226.3 kg CO_2-eq/m^2

Heat capacity
66.6 Wh/m^2 K

R-value
0.4/L+0.11
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R240

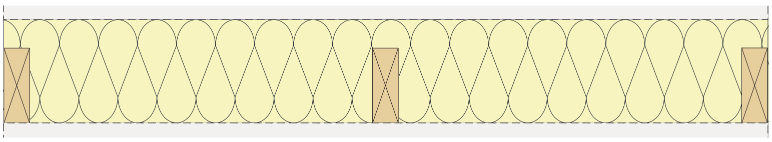
EI240

S 10 - 390 mm Wooden beams & 340 mm Insulation

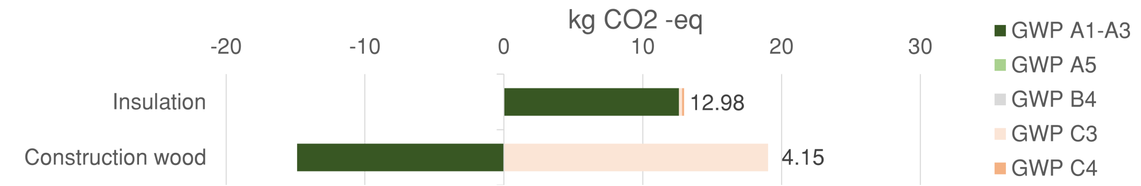
Component reference	:	SFH14
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	390 mm
Component plane weight	:	18.6 kg/m^2
Total environmental component impact	:	17.1 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.34/(0.0095 + 0.927 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

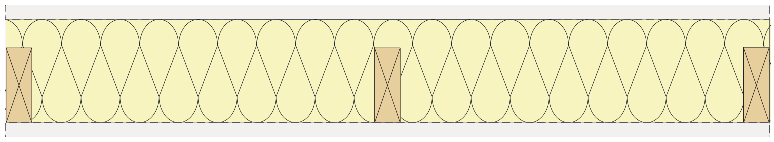
f_k = 24 MPa

S 11 - 245 mm Wooden beams & 240 mm Insulation

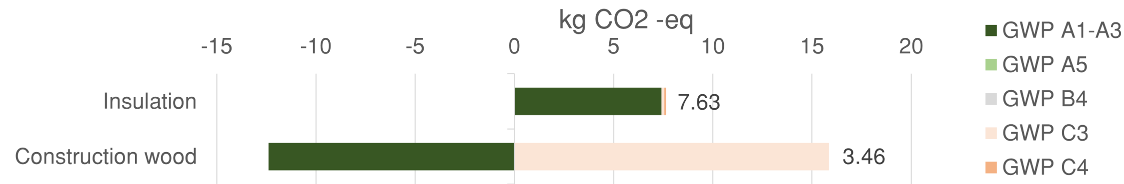
Component reference	:	AB01
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	13.5 kg/m^2
Total environmental component impact	:	11.1 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.24/(0.0095 + 0.927 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

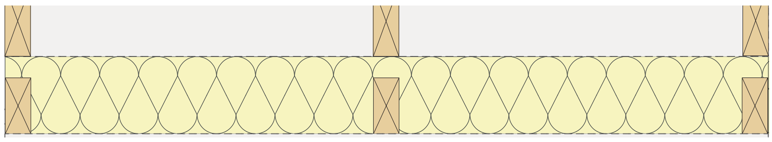
$f_k = 24$ MPa

S 12 - 390 mm Wooden beams truss & 340 mm Insulation

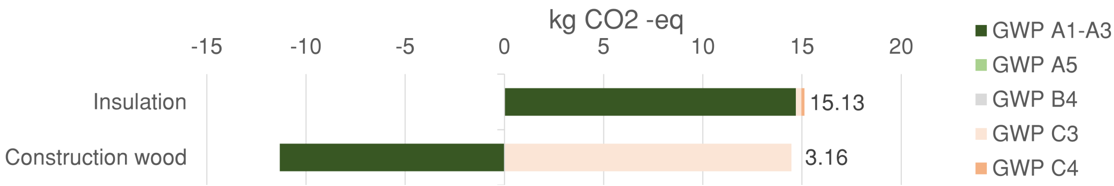
Component reference	:	SFH09	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	390	mm
Component plane weight	:	17.5	kg/m^2
Total environmental component impact	:	18.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.34/(0.049 + 0.927 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

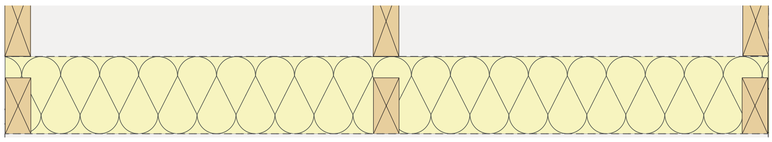
f_k = 24 MPa

S 13 - 145 mm Wooden truss & 395 mm Insulation

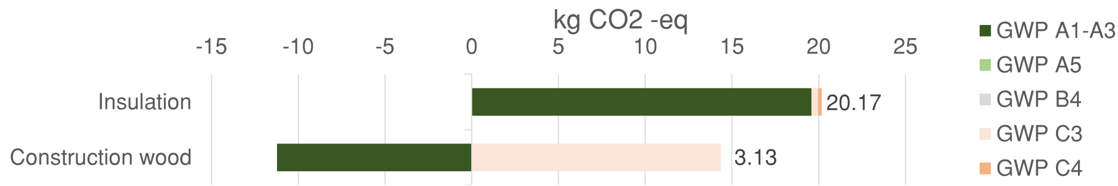
Component reference	:	SFH20
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	495 mm
Component plane weight	:	20.6 kg/m^2
Total environmental component impact	:	23.3 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

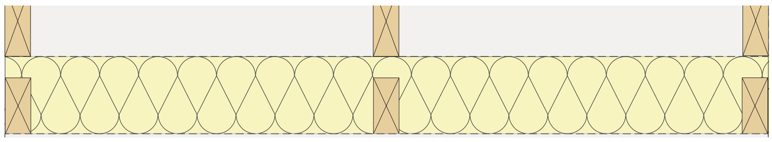
f_k = 24 MPa

S 14 - 145 mm Wooden truss & 395 mm Insulation

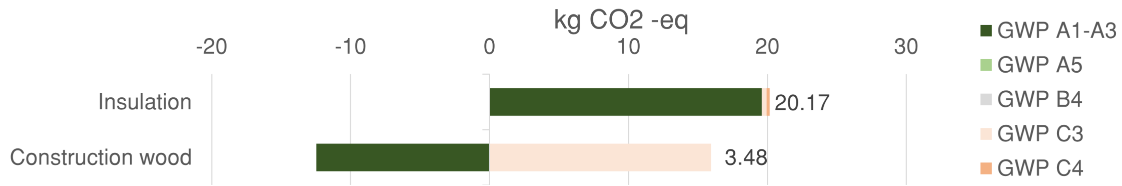
Component reference	:	SFH20	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	495	mm
Component plane weight	:	21.4	kg/m^2
Total environmental component impact	:	23.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

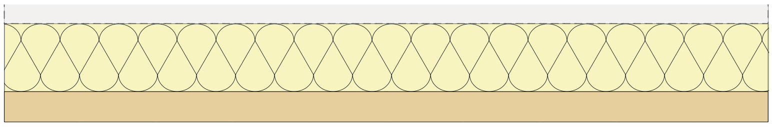
$f_k = 24$ MPa

S 15 - 200 mm CLT deck + 400 mm Insulation

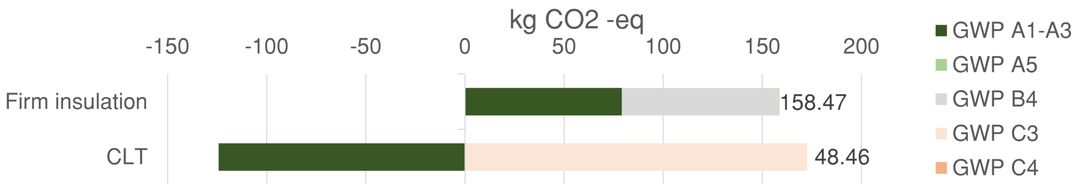
Component reference	:	Lilleheden	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	600	mm
Component plane weight	:	152.4	kg/m^2
Total environmental component impact	:	206.9	kg CO_2−eq/m^2

Heat capacity
22.2 Wh/m^2 K

R-value
0.4/L+0.2/0.13
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

R60

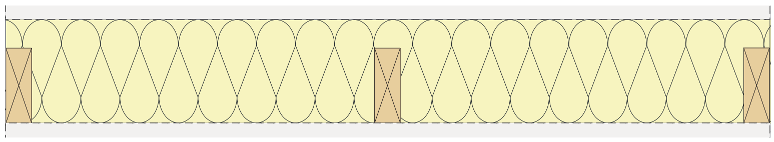
EI60

S 16 - 390 mm GLT beams & 340 mm Insulation

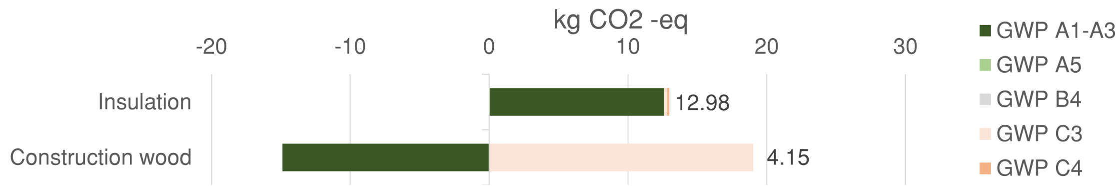
Component reference	:	SFH14	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	390	mm
Component plane weight	:	18.6	kg/m^2
Total environmental component impact	:	17.1	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.34/(0.0095 + 0.927 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

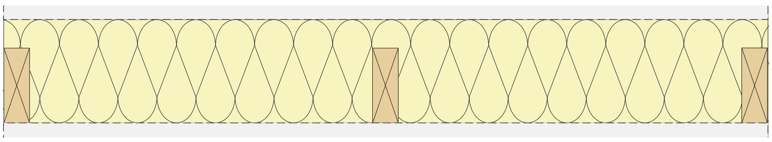
$f_k = 24$ MPa

S 17 - 245 mm GLT beams & 240 mm Insulation

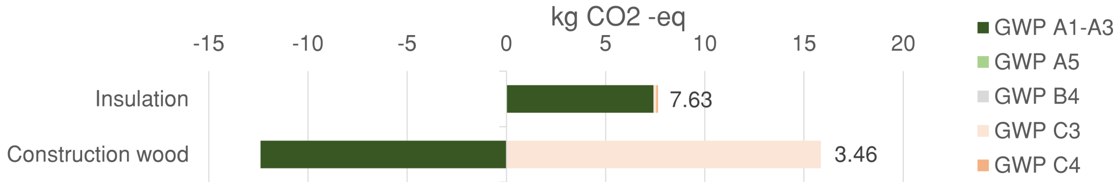
Component reference	:	AB01
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	245 mm
Component plane weight	:	13.5 kg/m^2
Total environmental component impact	:	11.1 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.24/(0.0095 + 0.927 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

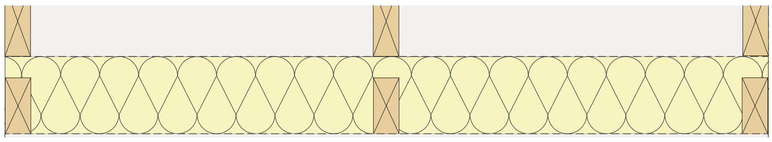
$f_k = 24$ MPa

S 18 - 390 mm GLT beams truss & 340 mm Insulation

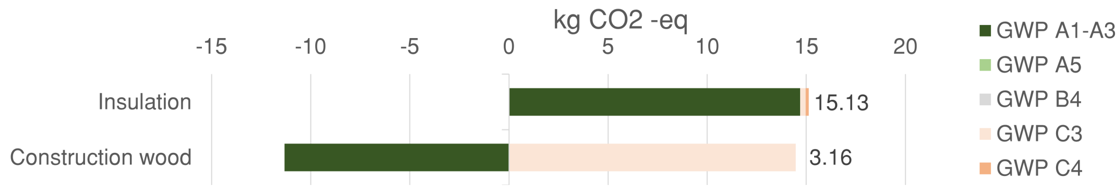
Component reference	:	SFH09
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	390 mm
Component plane weight	:	17.5 kg/m^2
Total environmental component impact	:	18.3 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.34/(0.049 + 0.927 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 40.8$ min

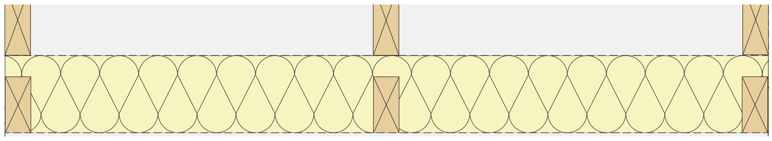
$f_k = 24$ MPa

S 19 - 145 mm GLT truss & 395 mm Insulation

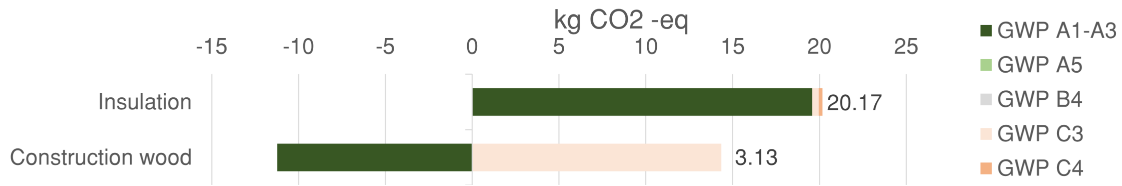
Component reference	:	SFH20
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	495 mm
Component plane weight	:	20.6 kg/m^2
Total environmental component impact	:	23.3 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

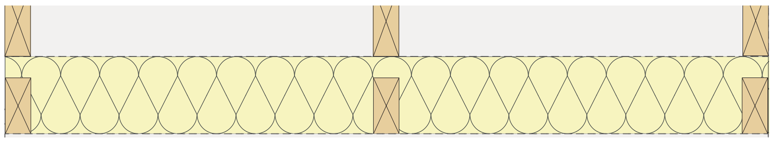
f_k = 24 MPa

S 20 - 145 mm GLT truss & 395 mm Insulation

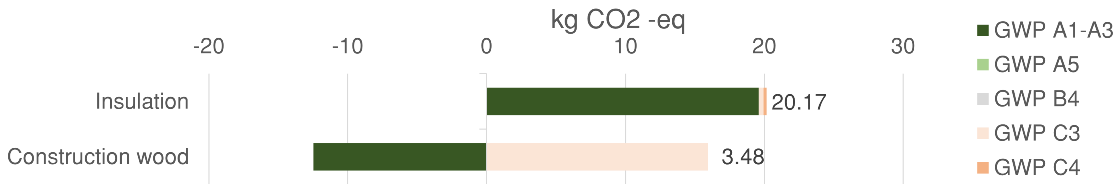
Component reference	:	SFH20
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	495 mm
Component plane weight	:	21.4 kg/m^2
Total environmental component impact	:	23.7 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.12/(0.0059 + 0.96 \cdot L) + 0.375/L$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 40.8 min

f_k = 24 MPa

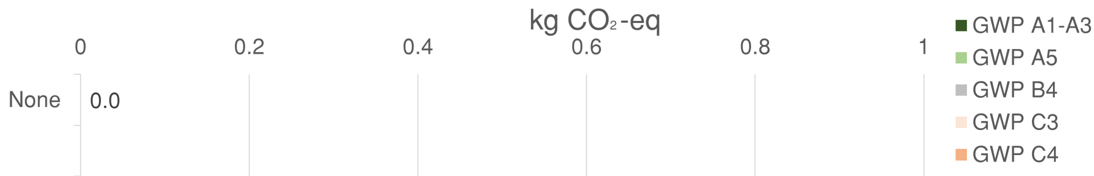
IL 01 - None

Component reference	:	SFH01
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 $kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
0 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

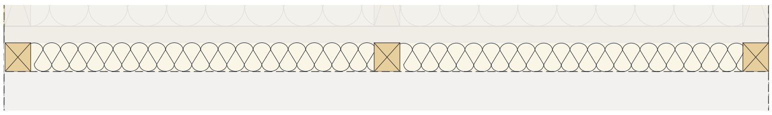
Component material class
None

IL 02 - 45 mm Wooden studs & insulation

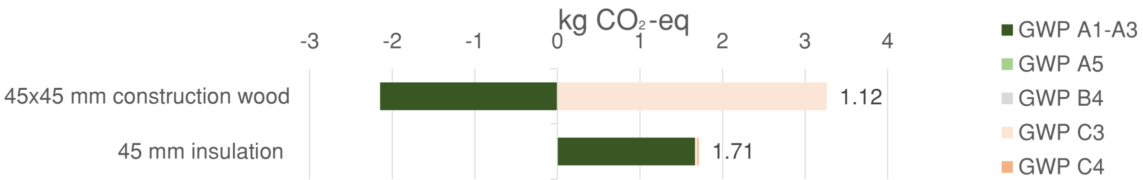
Component reference	:	SFH01	
Construction type	:	Frame construction	
Exterior side compatible with	:	Frame construction cladding	
Interior side compatible with	:	Frame construction cladding	
Component thickness	:	45	mm
Component plane weight	:	2.9	kg/m^2
Total environmental component impact	:	2.8	$kg\ CO_2{-}eq/m^2$

Heat capacity
None

R-value
$0.045/(0.00975 + 0.925 \cdot L)\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

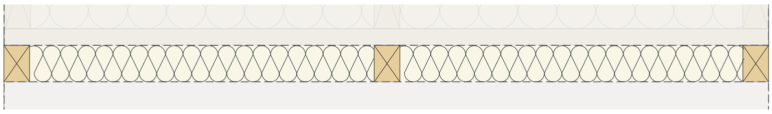
Component material class
D-s2,d0

IL 03 - 70 mm Wooden studs & insulation

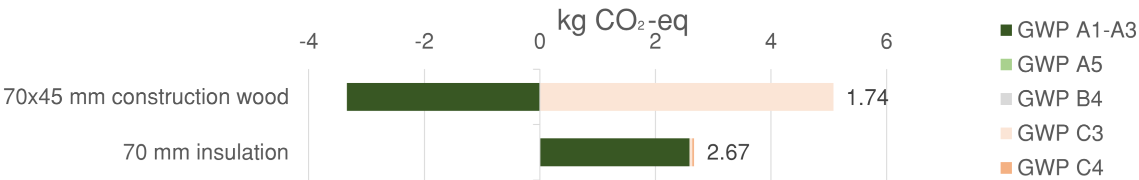
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	70 mm
Component plane weight	:	4.5 kg/m^2
Total environmental component impact	:	4.4 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.07/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

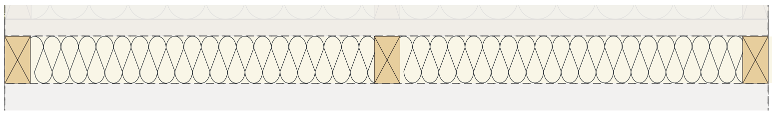
Component material class
D-s2,d0

IL 04 - 95 mm Wooden studs & insulation

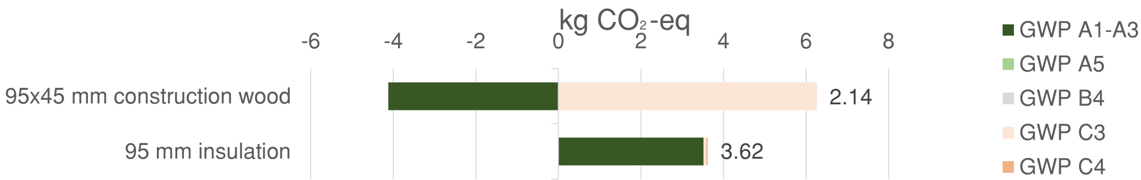
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	5.7 kg/m^2
Total environmental component impact	:	5.8 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

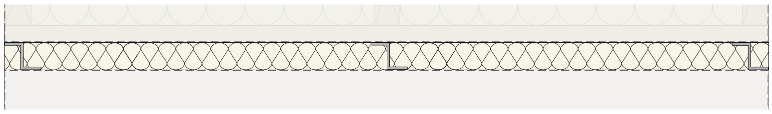
Component material class
D-s2,d0

IL 05 - 70 mm Z steel frame & insulation

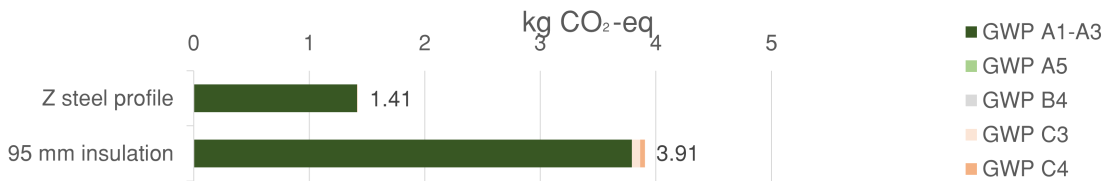
Component reference	:	Knauf
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	3.9 kg/m^2
Total environmental component impact	:	5.3 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot$ L
K m^2/W



Environmental impact per m^2 component



Fire technical classification

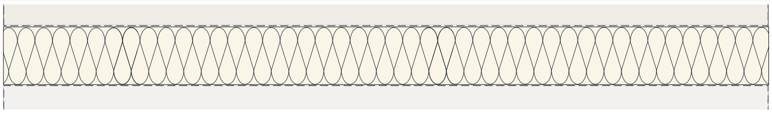
Surface Material Class
None

Component material class
A1

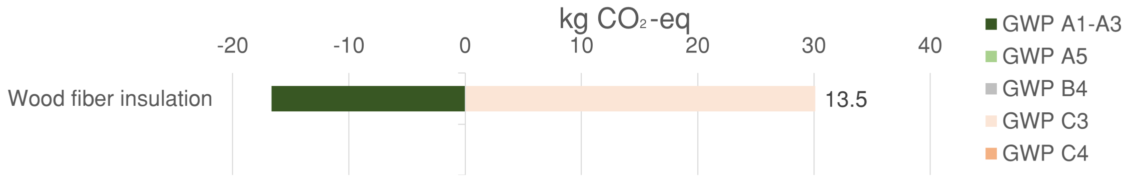
INS 01 - Wood fiber insulation

Component thickness	:	0.1	m
Component plane weight	:	16	kg/m^2
Total environmental component impact	:	13.5	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.038



Environmental impact per m^2 component



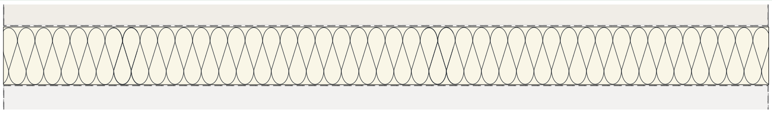
Fire technical classification

Surface Material Class	Component material class
None	E

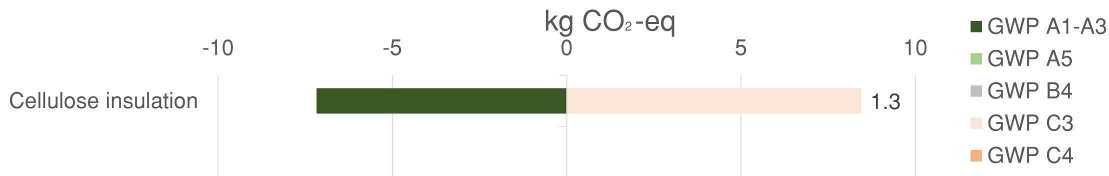
INS 02 - Cellulose insulation

Component thickness	:	0.1	m
Component plane weight	:	4.5	kg/m^2
Total environmental component impact	:	1.3	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.04



Environmental impact per m^2 component



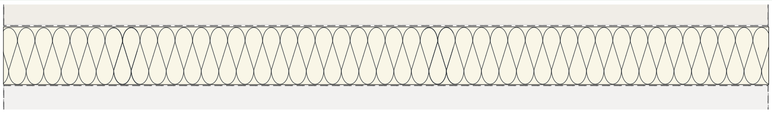
Fire technical classification

Surface Material Class	Component material class
None	D

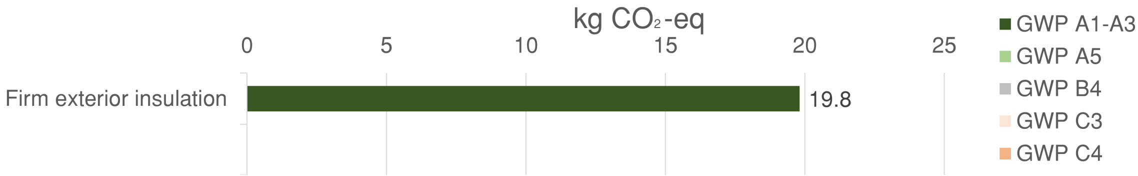
INS 03 - Firm exterior insulation

Component thickness	:	0.1	m
Component plane weight	:	14.6	kg/m^2
Total environmental component impact	:	19.8	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



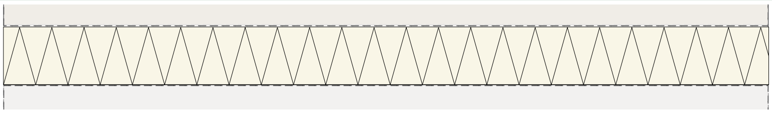
Fire technical classification

Surface Material Class	Component material class
None	A

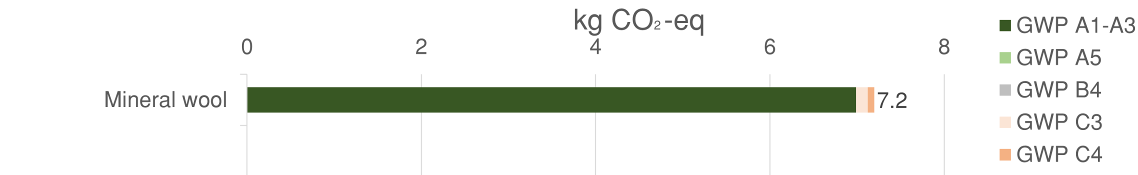
INS 04 - Mineral wool

Component thickness	:	0.1	m
Component plane weight	:	4.6	kg/m^2
Total environmental component impact	:	7.2	$kg\ CO_2{-}eq/m^2$

λ_{dry}
0.034



Environmental impact per m^2 component



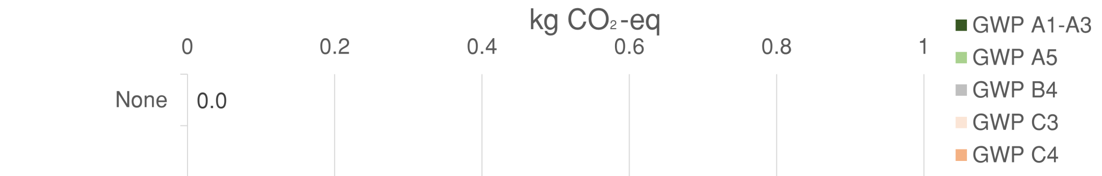
Fire technical classification

Surface Material Class	Component material class
None	A

VB 01 - None

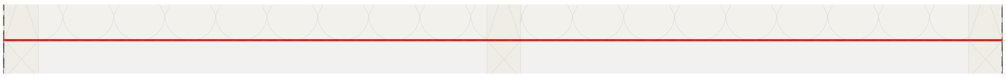
Component reference	:	None
Compatible with	:	Solid constructions
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 kg CO_2−eq/m^2

Environmental impact per m^2 component

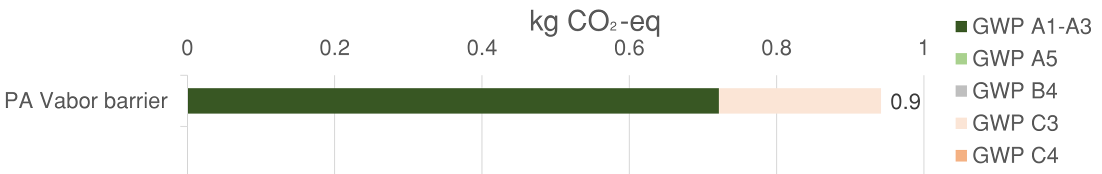


VB 02 - PA Vapor barrier

Component reference	:	None
Compatible with	:	Frame constructions
Component thickness	:	1 mm
Component plane weight	:	0.08 kg/m^2
Total environmental component impact	:	0.9 kg CO_2−eq/m^2



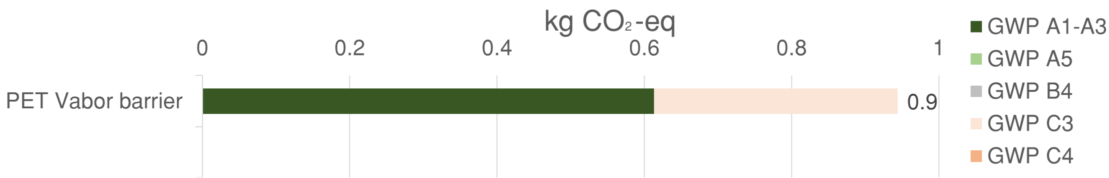
Environmental impact per m^2 component



VB 03 - PET Vapor barrier

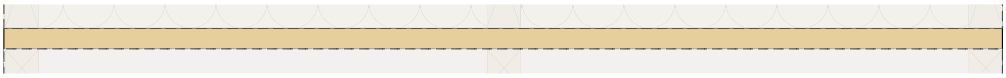
Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	1	mm
Component plane weight	:	0.12	kg/m^2
Total environmental component impact	:	0.9	$kg\ CO_2{-}eq/m^2$

Environmental impact per m^2 component

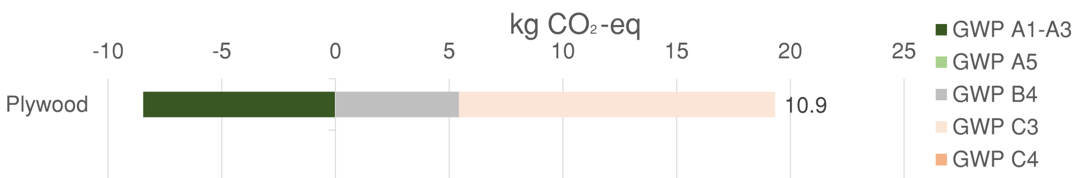


VB 04 - 12 mm plywood

Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	12	mm
Component plane weight	:	5.9	kg/m^2
Total environmental component impact	:	10.9	$kg\ CO_2{-}eq/m^2$



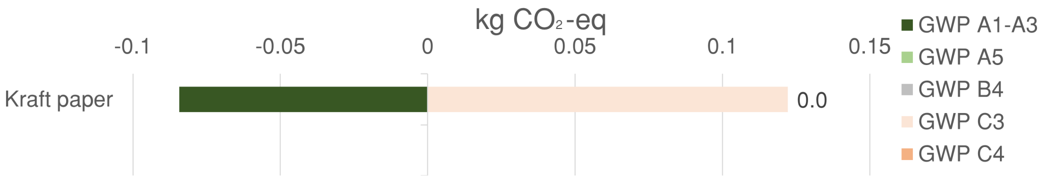
Environmental impact per m^2 component



VB 05 - Kraft paper

Component reference	:	None	
Compatible with	:	Frame constructions	
Component thickness	:	1	mm
Component plane weight	:	0.08	kg/m^2
Total environmental component impact	:	0.04	$kg\ CO_2{-}eq/m^2$

Environmental impact per m^2 component



M.4 Horizontal divisions

The Horizontal divisions have five different micro components, these are:

- IC - Interior cladding
- FL - Exterior cladding
- S - Structure & insulation
- IL - Installation layer
- INS - Insulation

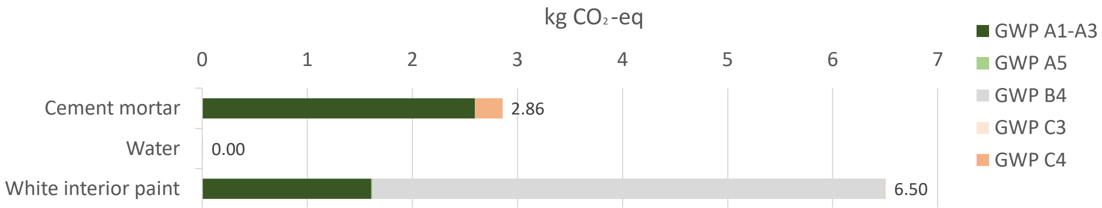
IC 01 - 10 mm mortar + Paint

Component reference	:	AB02	
Compatible with	:	Solid constructions	
Component thickness	:	10	mm
Component plane weight	:	18.7	kg/m^2
Total environmental component impact	:	9.4	$kg\ CO_2{-}eq/m^2$

Heat capacity
0 $Wh/m^2\ K$

R-value
0.141 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

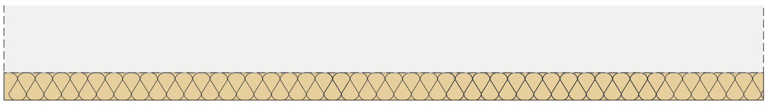
Fire protecting ability	Surface Material Class	Component material class
None	None	None

IC 02 - 60 mm Insulation panel cladding (Skalflex)

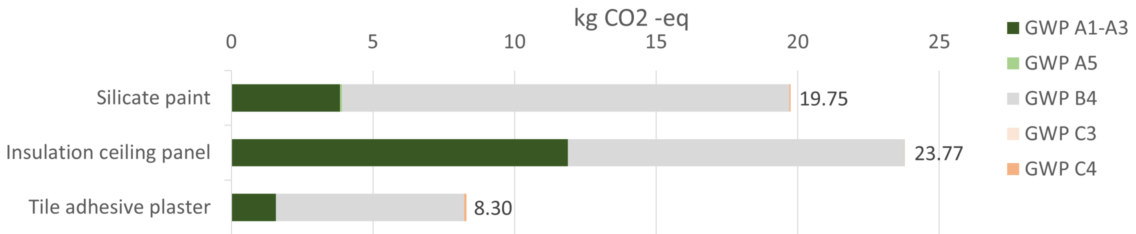
Component reference	:	Self
Compatible with	:	Solid constructions
Component thickness	:	63 mm
Component plane weight	:	15.7 kg/m^2
Total environmental component impact	:	51.8 kg CO_2–eq/m^2

Heat capacity
0 Wh/m^2 K

R-value
1.9 K m^2/W



Environmental impact per m^2 component



Fire technical classification

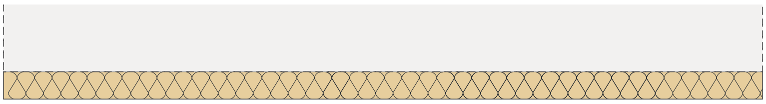
Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

IC 03 - 80 mm Insulation panel cladding (Skalflex)

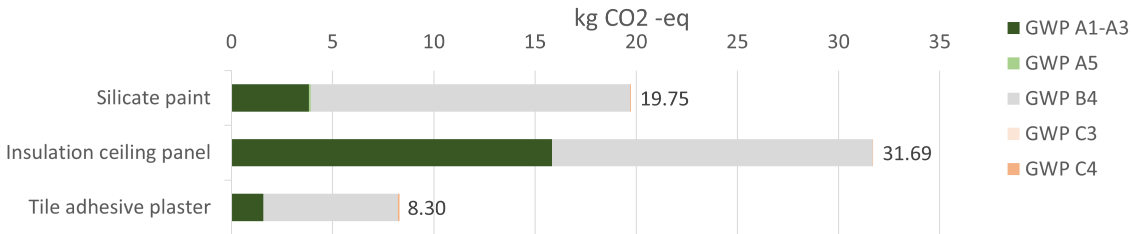
Component reference	:	Self
Compatible with	:	Solid constructions
Component thickness	:	83 mm
Component plane weight	:	18.6 kg/m^2
Total environmental component impact	:	59.7 $kg\ CO_2-eq/m^2$

Heat capacity
0 $Wh/m^2\ K$

R-value
1.9 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

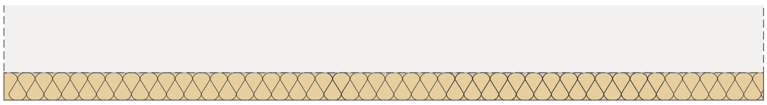
Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

IC 04 - 100 mm Insulation panel cladding (Skalflex)

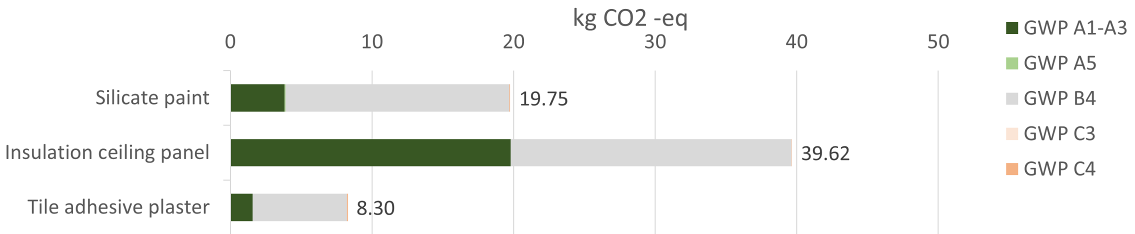
Component reference	:	Self	
Compatible with	:	Solid constructions	
Component thickness	:	103	mm
Component plane weight	:	21.5	kg/m^2
Total environmental component impact	:	67.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
0 Wh/m^2 K

R-value
1.9 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

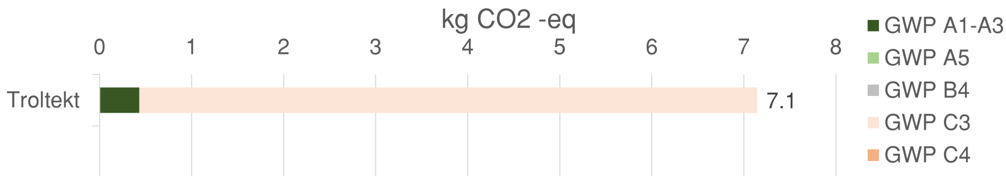
IC 05 - 25 mm Troldtekt

Component reference	:	Self
Compatible with	:	Frame constructions
Component thickness	:	25 mm
Component plane weight	:	9 kg/m^2
Total environmental component impact	:	7.1 $kg\ CO_2{-}eq/m^2$

Heat capacity
4.8 $Wh/m^2\ K$

R-value
0.125 $K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	B-s1,d0	B-s1,0

Fire technical parameters

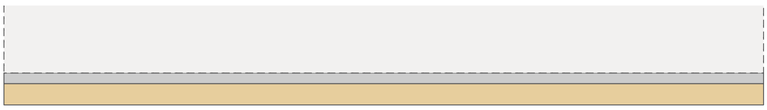
$t_{ins} = 27.5$ min $t_{ch} = 23.8$ min $t_f = 23.8$ min

IC 06 - 12.5 mm Plasterboard, F + 25 mm Troldtekt

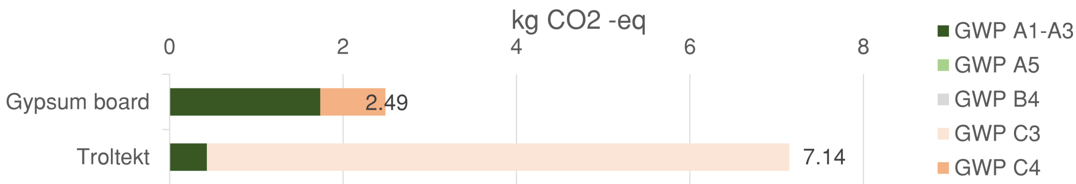
Component reference	:	Self	
Compatible with	:	Frame constructions	
Component thickness	:	37.5	mm
Component plane weight	:	19	kg/m^2
Total environmental component impact	:	9.6	$kg\ CO_2{-}eq/m^2$

Heat capacity
7.9 $Wh/m^2\ K$

R-value
0.188 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
B-s1,d0

Component material class
B-s1,0

Fire technical parameters

$t_{ins} = 38$ min

$t_{ch} = 33.9$ min

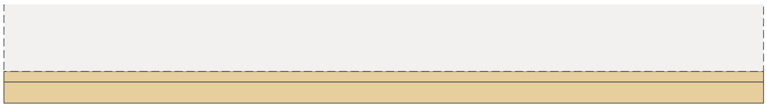
$t_f = 42.5$ min

IC 07 - 12 mm Plywood, F + 25 mm Troldtekt

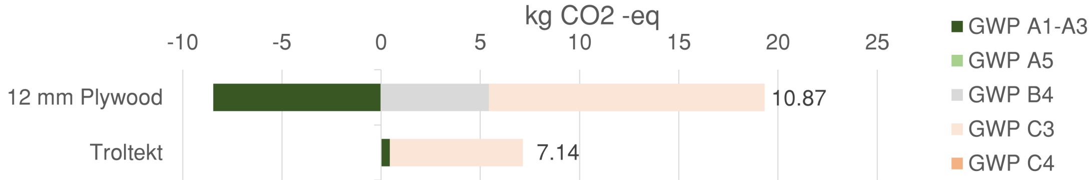
Component reference	:	Self	
Compatible with	:	Frame constructions	
Component thickness	:	37	mm
Component plane weight	:	14.9	kg/m^2
Total environmental component impact	:	18	$kg\ CO_2{-}eq/m^2$

Heat capacity
$8.9\ Wh/m^2\ K$

R-value
$0.217\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	B-s1,d0	D-s2,0

Fire technical parameters

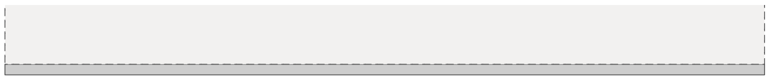
$t_{ins} = 29.8$ min | $t_{ch} = 29.1$ min | $t_f = 29.1$ min

IC 08 - 9.5 mm Plasterboard + Plaster + Paint

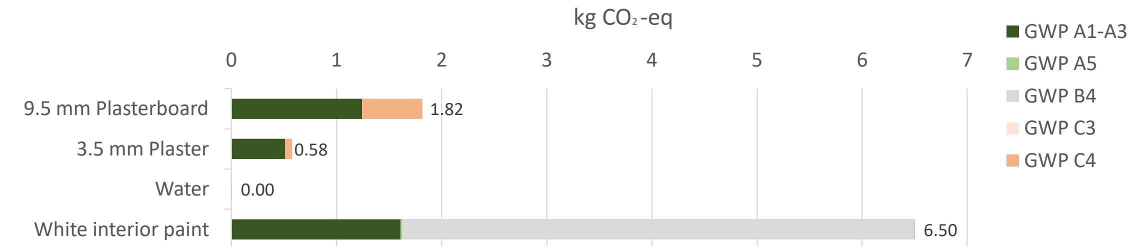
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	14.5 mm
Component plane weight	:	20.5 kg/m^2
Total environmental component impact	:	8.9 kg CO_2-eq/m^2

Heat capacity
2.4 Wh/m^2 K

R-value
0.194 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 13.3 min

t_{ch} = 10.1 min

t_f = 18.8 min

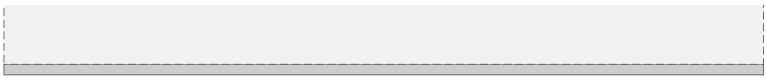
N_{60} = 13.6

IC 09 - 12.5 mm Plasterboard + Plaster + Paint

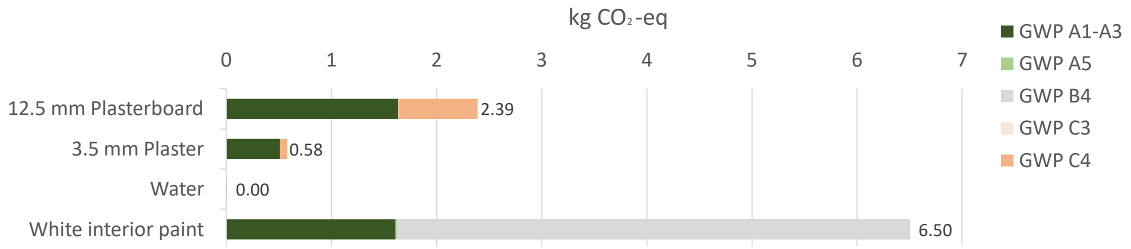
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	17.5	mm
Component plane weight	:	22.9	kg/m^2
Total environmental component impact	:	9.5	$kg\ CO_2{-}eq/m^2$

Heat capacity
$3.13\ Wh/m^2\ K$

R-value
$0.209\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

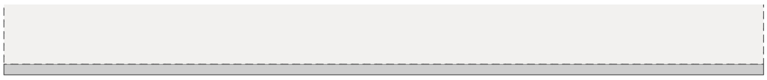
$t_{ins} = 17.5$ min | $t_{ch} = 15.5$ min | $t_f = 32.25$ min | $N_{60} = 13.6$

IC 10 - 15 mm Plasterboard + Plaster + Paint

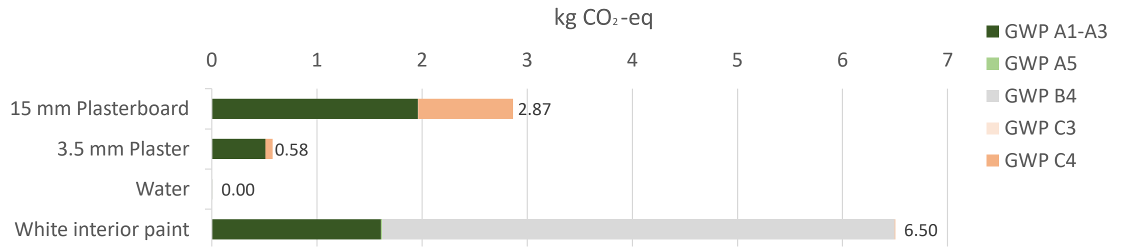
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	20	mm
Component plane weight	:	24.9	kg/m^2
Total environmental component impact	:	10	$kg\ CO_2{-}eq/m^2$

Heat capacity
3.75 $Wh/m^2\ K$

R-value
0.222 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	A2-s1,d0	A2-s1,d0

Fire technical parameters

$t_{ins} = 21$ min | $t_{ch} = 20$ min | $t_f = 43.5$ min | $N_{60} = 13.6$

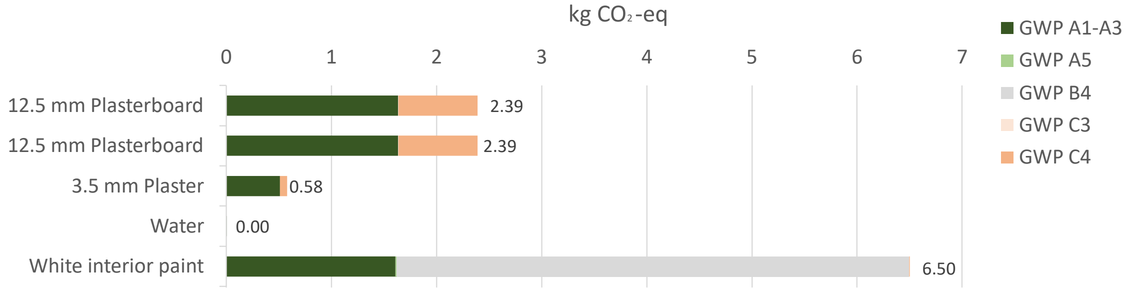
IC 11 - 2 x 12.5 mm Plasterboard + Plaster + Paint

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	30	mm
Component plane weight	:	32.9	kg/m^2
Total environmental component impact	:	11.9	kg CO_2−eq/m^2

Heat capacity
6.25 Wh/m^2 K

R-value
0.272 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

t_{ins} = 28 min | t_{ch} = 45.5 min | t_f = 60 min | N_{60} = 265.3

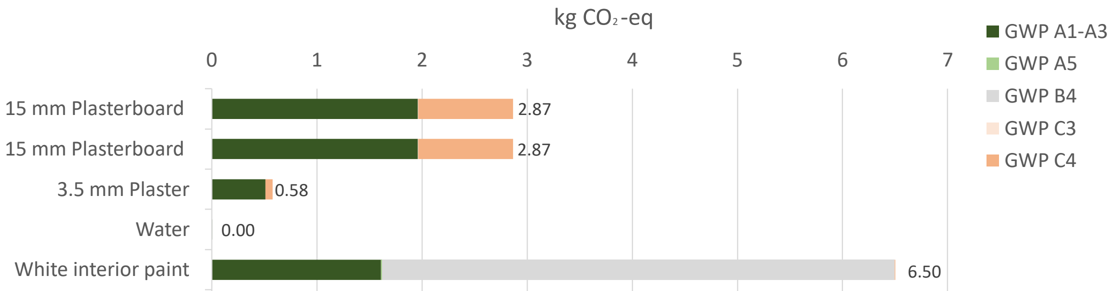
IC 12 - 2 x 15 mm Plasterboard + Plaster + Paint

Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	35	mm
Component plane weight	:	36.9	kg/m^2
Total environmental component impact	:	12.8	$kg\ CO_2-eq/m^2$

Heat capacity
$7.5\ Wh/m^2\ K$

R-value
$0.297\ K\ m^2/W$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	A2-s1,d0

Fire technical parameters

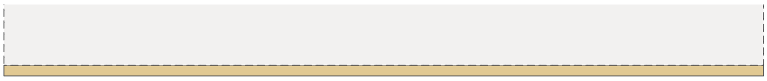
$t_{ins} = 33.6$ min | $t_{ch} = 56$ min | $t_f = 80$ min | $N_{60} = 265.3$

IC 13 - 15 mm Plywood

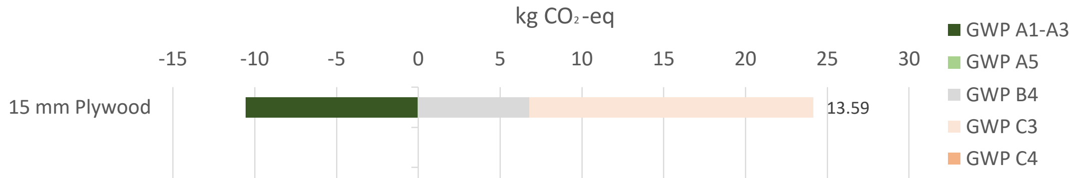
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	15 mm
Component plane weight	:	7.4 kg/m^2
Total environmental component impact	:	13.6 kg CO_2-eq/m^2

Heat capacity
3.33 Wh/m^2 K

R-value
0.245 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
Test

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 9.6 min

t_{ch} = 9 min

t_f = 9 min

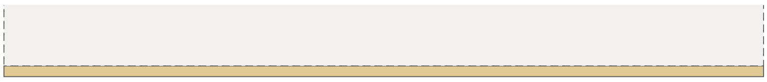
N_{60} = 13.6

IC 14 - 15 mm OSB

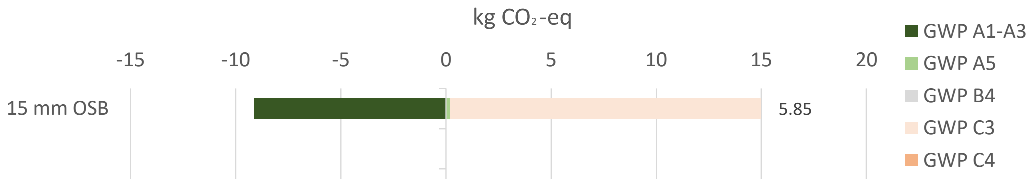
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	15	mm
Component plane weight	:	9	kg/m^2
Total environmental component impact	:	5.9	$kg\ CO_2{-}eq/m^2$

Heat capacity
$3.33\ Wh/m^2\ K$

R-value
$0.245\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
Test	D-s2,d0	D-s2,d0

Fire technical parameters

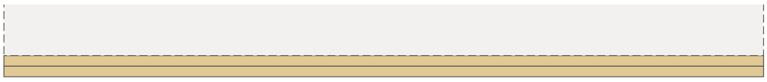
$t_{ins} = 11.1$ min | $t_{ch} = 10.4$ min | $t_f = 10.4$ min | $N_{60} = 13.6$

IC 15 - 2 x Plywood

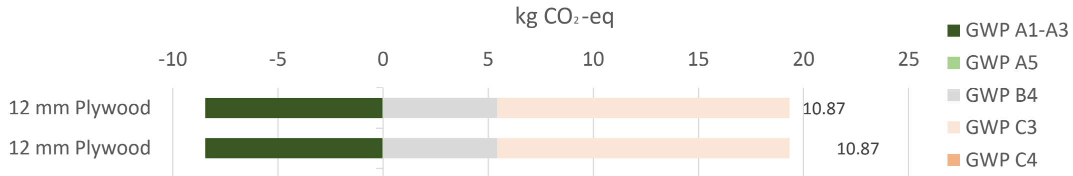
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	24	mm
Component plane weight	:	11.8	kg/m^2
Total environmental component impact	:	21.7	$kg\ CO_2-eq/m^2$

Heat capacity
5.33 $Wh/m^2\ K$

R-value
0.315 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

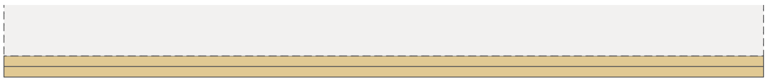
$t_{ins} = 14.8$ min | $t_{ch} = 20$ min | $t_f = 20$ min | $N_{60} = 13.6$

IC 16 - 2 x OSB

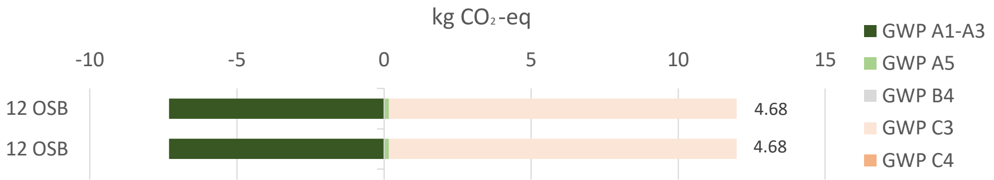
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	24	mm
Component plane weight	:	14.4	kg/m^2
Total environmental component impact	:	9.4	$kg\ CO_2-eq/m^2$

Heat capacity
$5.33\ Wh/m^2\ K$

R-value
$0.315\ K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
D-s2,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 17.8$ min

$t_{ch} = 22.7$ min

$t_f = 22.7$ min

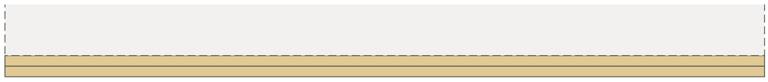
$N_{60} = 13.6$

IC 17 - 2 x 21 mm Plywood

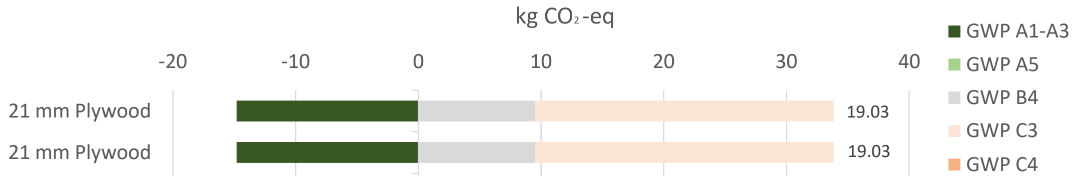
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	42 mm
Component plane weight	:	20.6 kg/m^2
Total environmental component impact	:	38.1 kg CO_2-eq/m^2

Heat capacity
9.33 Wh/m^2 K

R-value
0.453 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

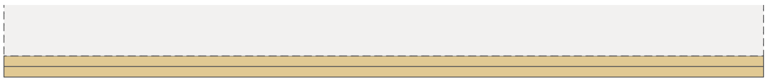
t_{ins} = 25.9 min | t_{ch} = 38 min | t_f = 38 min | N_{60} = 13.6

IC 18 - 2 x 21 mm OSB

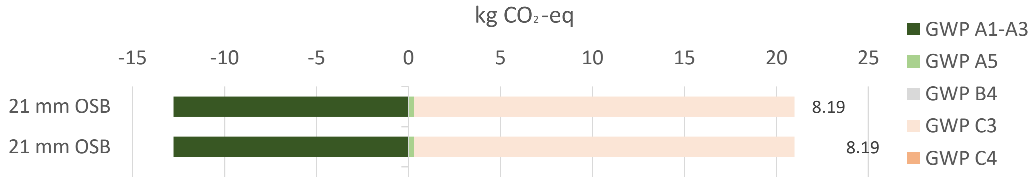
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	42 mm
Component plane weight	:	25.2 kg/m^2
Total environmental component impact	:	16.4 kg CO_2-eq/m^2

Heat capacity
9.33 Wh/m^2 K

R-value
0.453 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	D-s2,d0	D-s2,d0

Fire technical parameters

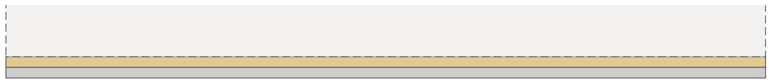
t_{ins} = 30 min | t_{ch} = 42.7 min | t_f = 42.7 min | N_{60} = 13.6

IC 19 - 12 mm OSB + 12.5 mm Plasterboard + Plaster + Paint

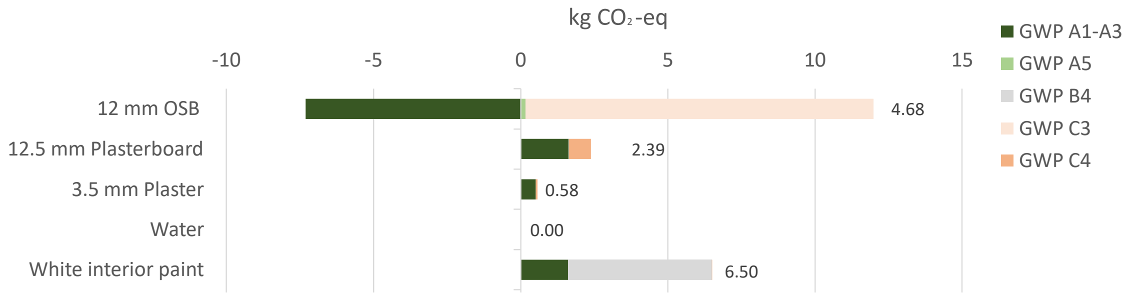
Component reference	:	TRAE
Compatible with	:	Frame constructions
Component thickness	:	29.5 mm
Component plane weight	:	30.1 kg/m^2
Total environmental component impact	:	14.15 kg CO_2-eq/m^2

Heat capacity
5.8 Wh/m^2 K

R-value
0.302 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

t_{ins} = 28 min

t_{ch} = 18.5 min

t_f = 18.8 min

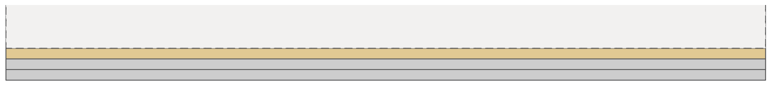
N_{60} = 13.6

IC 20 - 12 mm OSB + 2 x 12.5 mm Plasterboard + Plaster + Paint

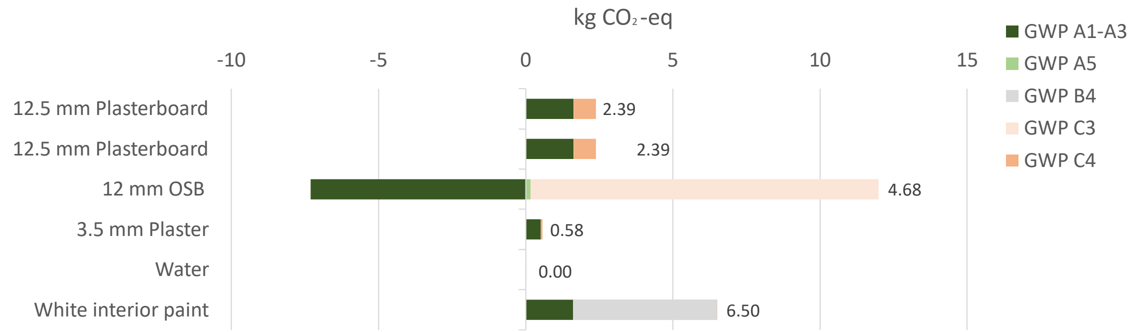
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	40.1	kg/m^2
Total environmental component impact	:	16.5	$kg\ CO_2{-}eq/m^2$

Heat capacity
8.9 Wh/m^2 K

R-value
0.364 K m^2/W



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
K_1 10	A2-s1,d0	D-s2,d0

Fire technical parameters

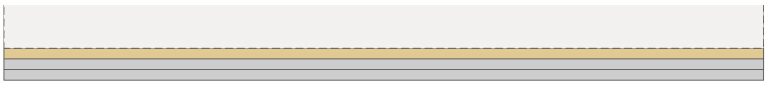
t_{ins} = 38.5 min | t_{ch} = 55 min | t_f = 60 min | N_{60} = 265.3

IC 21 - 15 mm OSB + 2 x 15 mm Plasterboard + Plaster + Paint

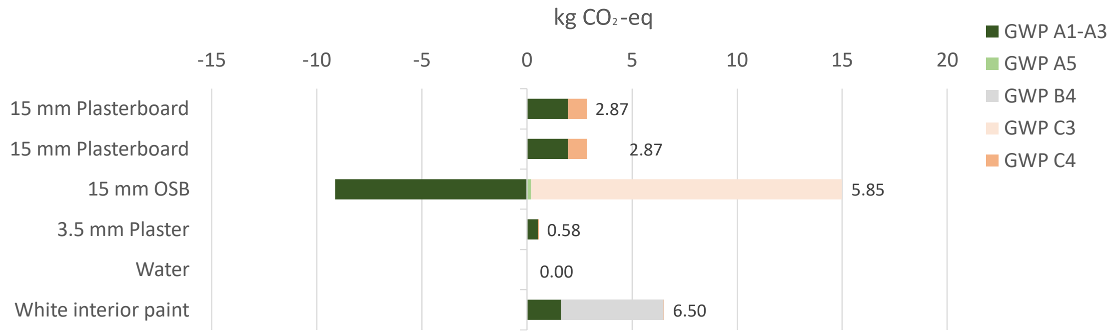
Component reference	:	TRAE	
Compatible with	:	Frame constructions	
Component thickness	:	50	mm
Component plane weight	:	45.9	kg/m^2
Total environmental component impact	:	18.7	$kg\ CO_2{-}eq/m^2$

Heat capacity
10.8 $Wh/m^2\ K$

R-value
0.412 $K\ m^2/W$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
K_1 10

Surface Material Class
A2-s1,d0

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 46.8$ min

$t_{ch} = 71.8$ min

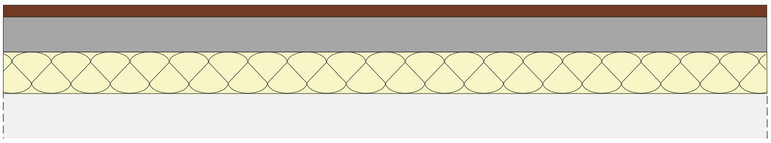
$t_f = 80$ min

$N_{60} = 265.3$

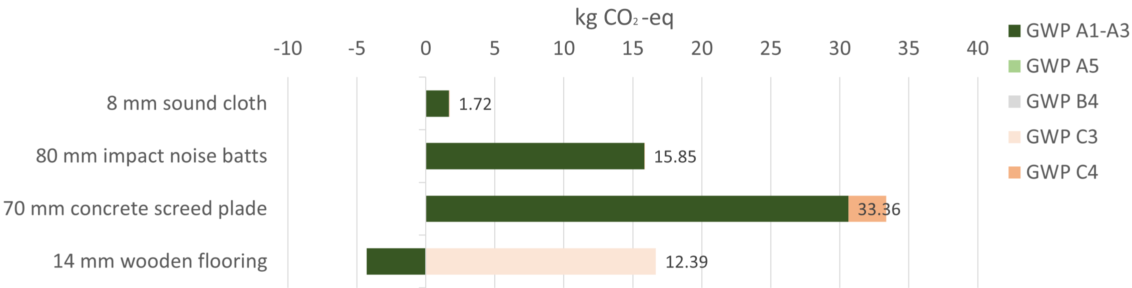
FL 1 - 88 mm Soundreduction + 70 mm concrete +14 mm Parquet floor

Component reference	:	AB02
Compatible with	:	Solid constructions
Component thickness	:	175 mm
Component plane weight	:	190 kg/m^2
Total environmental component impact	:	63.3 kg CO_2-eq/m^2

Heat capacity
49.8 Wh/m^2 K



Environmental impact per m^2 component



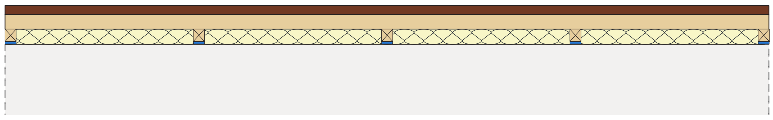
Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D_{fl}-s1	D-s2,d0

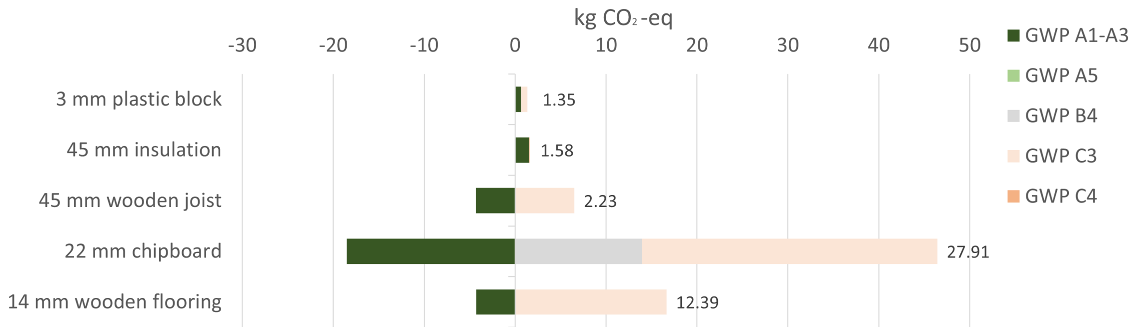
FL 2 - Wooden joist + 22 mm chipboard + 14 mm Parquet floor

Component reference	:	AB05	
Compatible with	:	Solid constructions	
Component thickness	:	87	mm
Component plane weight	:	29.3	kg/m^2
Total environmental component impact	:	45.5	$kg\ CO_2-eq/m^2$

Heat capacity
8 Wh/m^2 K



Environmental impact per m^2 component



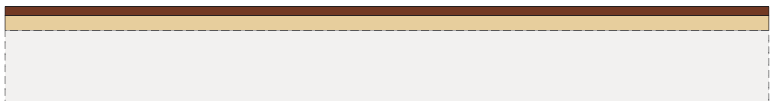
Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D_{fl}-s1	D-s2,d0

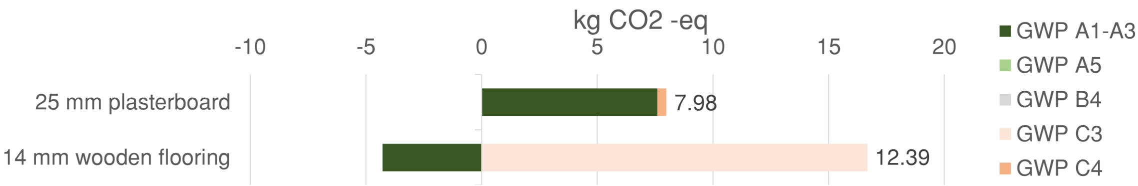
FL 3 - 25 mm Fiber plasterboard + 14 mm Parquet flooring

Component reference	:	AB05	
Compatible with	:	Frame constructions	
Component thickness	:	42	mm
Component plane weight	:	33.1	kg/m^2
Total environmental component impact	:	20.4	$kg\ CO_2-eq/m^2$

Heat capacity
$9.4\ Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
D_{fl}-s1

Component material class
D-s2,d0

Fire technical parameters

$t_{ins} = 28$ min

$t_{ch} = 45.5$ min

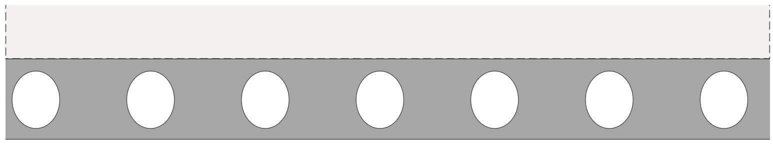
$t_f = 60$ min

$N_{60} = 45$

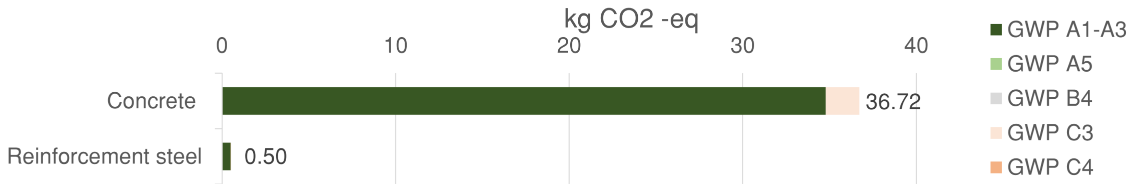
S 01 - 180 mm Hollow-core slab

Component reference	:	AB04	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	180	mm
Component plane weight	:	282.1	kg/m^2
Total environmental component impact	:	37.2	$kg\ CO_2{-}eq/m^2$

Heat capacity
66.6 $Wh/m^2\ K$



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

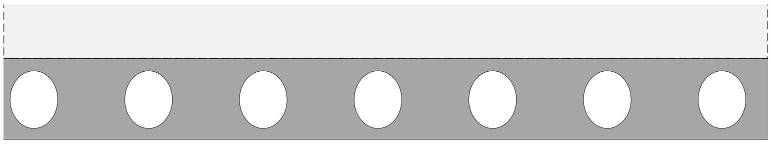
R90

EI90

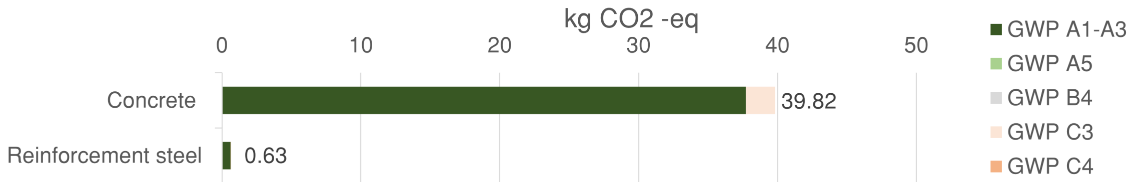
S 02 - 220 mm Hollow-core slab

Component reference	:	AB04
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	220 mm
Component plane weight	:	306 kg/m^2
Total environmental component impact	:	40.4 kg CO_2−eq/m^2

Heat capacity
66.6 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

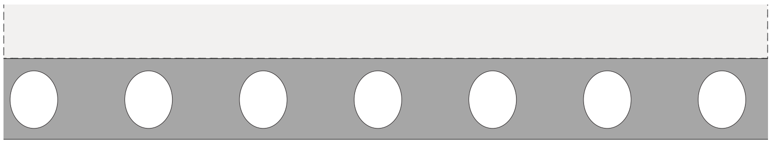
Fire technical parameters

R90 EI90

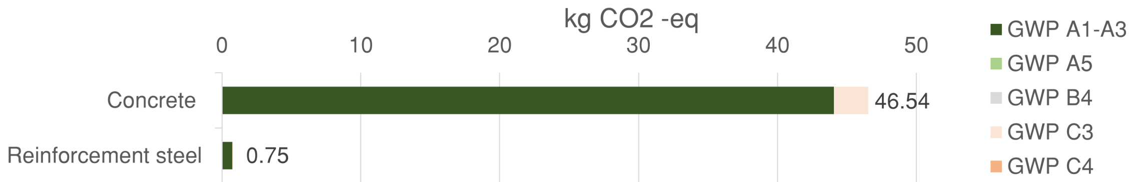
S 03 - 270 mm Hollow-core slab

Component reference	:	AB04	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	270	mm
Component plane weight	:	357.7	kg/m^2
Total environmental component impact	:	47.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
66.6 Wh/m^2 K



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
A1

Component material class
A1

Fire technical parameters

R120

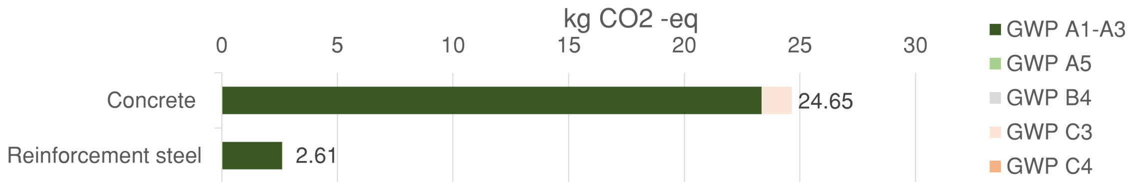
EI120

S 04 - 80 mm In situ concrete

Component reference	:	AB05	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	80	mm
Component plane weight	:	192.9	kg/m^2
Total environmental component impact	:	27.3	$kg\ CO_2-eq/m^2$

Heat capacity
53.3 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

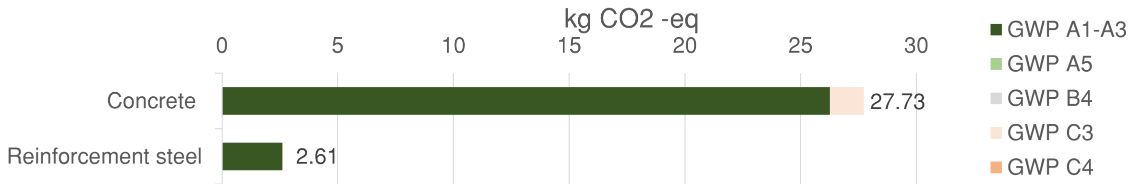
R60 EI60

S 05 - 90 mm In situ concrete

Component reference	:	AB05	
Construction type	:	Solid construction	
Sides compatible with	:	Solid construction cladding	
Component thickness	:	90	mm
Component plane weight	:	216.5	kg/m^2
Total environmental component impact	:	30.3	$kg\ CO_2{-}eq/m^2$

Heat capacity
60 Wh/m^2 K

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

Fire technical parameters

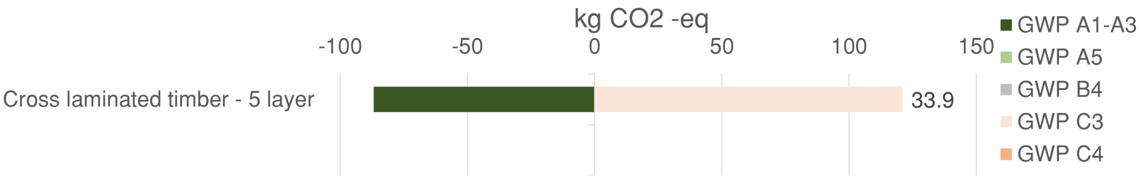
R60 EI60

S 06 - 140 mm CLT - 5 layers

Component reference	:	AB05
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	140 mm
Component plane weight	:	66.1 kg/m^2
Total environmental component impact	:	33.9 $kg\ CO_2{-}eq/m^2$

Heat capacity
22.2 $Wh/m^2\ K$

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	D-s2,d0	D-s2,d0

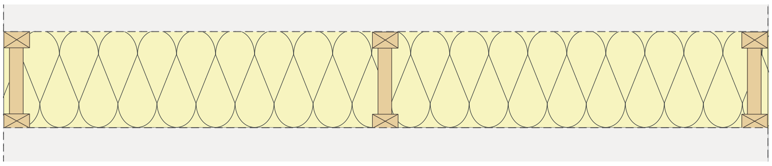
Fire technical parameters

R60 EI60

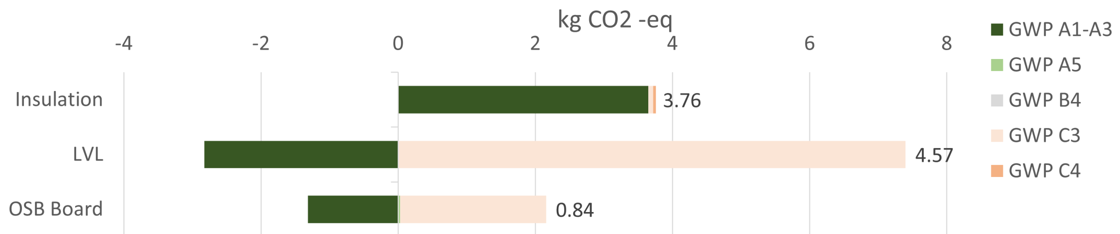
S 07 - 360 mm LVL I-beam & 95 mm Insulation

Component reference	:	AB07
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	360 mm
Component plane weight	:	6.8 kg/m^2
Total environmental component impact	:	9.2 kg CO_2-eq/m^2

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

$t_{ins} = 11.4$ min

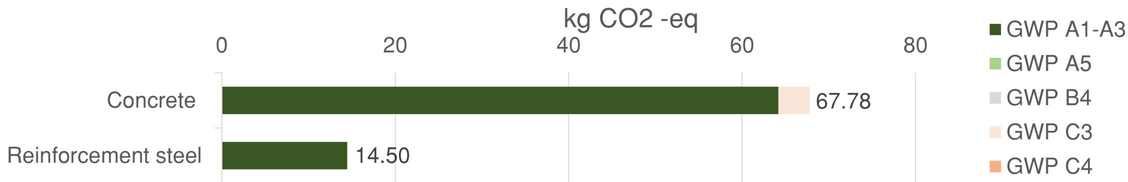
$f_k = 44$ MPa

S 08 - 220 mm concrete

Component reference	:	OB03
Construction type	:	Solid construction
Sides compatible with	:	Solid construction cladding
Component thickness	:	220 mm
Component plane weight	:	542 kg/m^2
Total environmental component impact	:	82.3 kg CO_2-eq/m^2

Heat capacity
66.6 Wh/m^2 K

Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	A1	A1

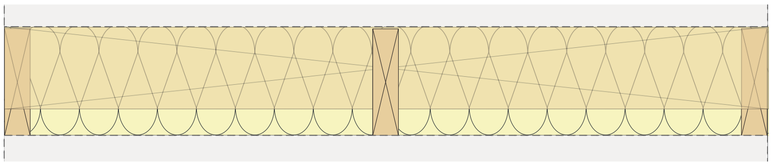
Fire technical parameters

R240 EI240

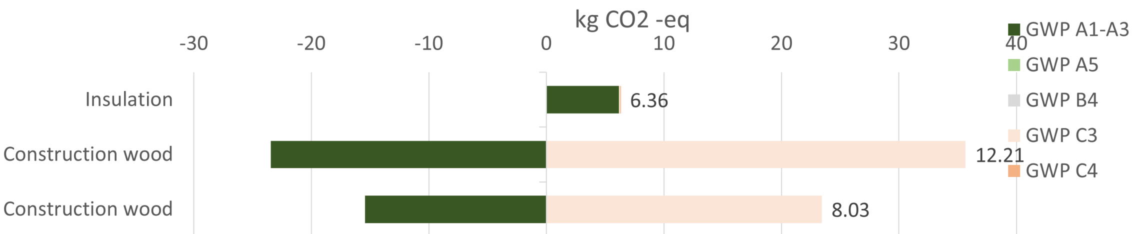
S 09 - 295 mm Wooden beams & 195 mm Wooden beams & 95 mm Insulation

Component reference	:	AB03
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	295 mm
Component plane weight	:	36.3 kg/m^2
Total environmental component impact	:	26.6 kg CO_2−eq/m^2

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

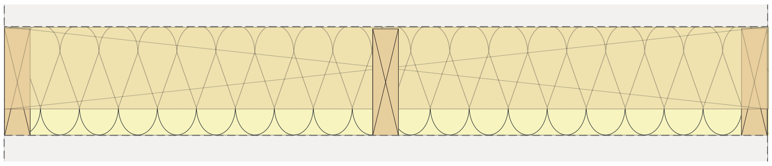
t_{ins} = 22.8 min

f_k = 30 MPa

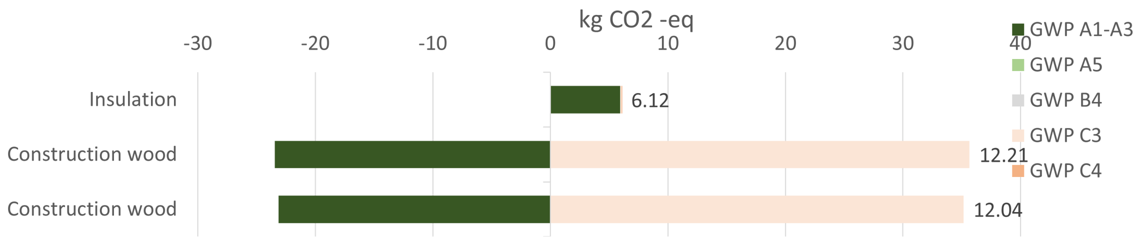
S 10 - 295 mm Wooden beams & 195 mm Wooden beams & 95 mm Insulation

Component reference	:	AB03
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	295 mm
Component plane weight	:	42.4 kg/m^2
Total environmental component impact	:	30.4 $kg\ CO_2{-}eq/m^2$

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

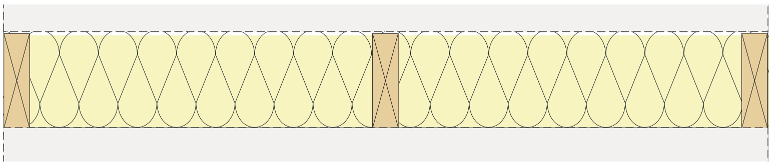
$t_{ins} = 22.8$ min

$f_k = 30$ MPa

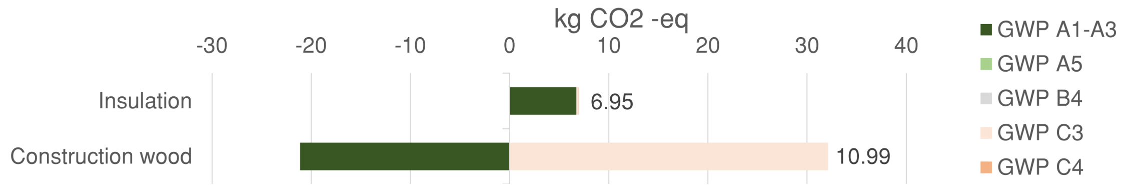
S 11 - 295 mm Wooden beams & 95 mm Insulation

Component reference	:	TH02
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	295 mm
Component plane weight	:	21.94 kg/m^2
Total environmental component impact	:	17.9 $kg\ CO_2{-}eq/m^2$

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	D-s2,d0

Fire technical parameters

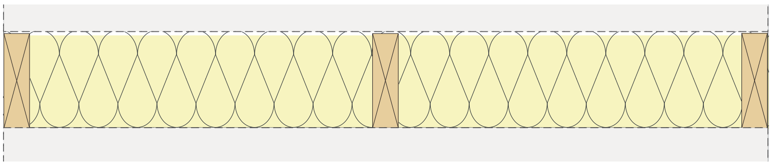
$t_{ins} = 22.8$ min

$f_k = 30$ MPa

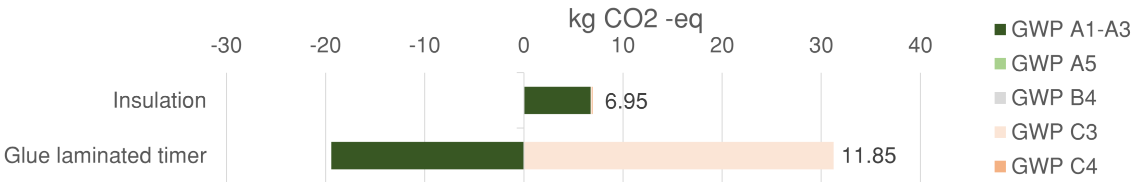
S 12 - 295 mm GLT beams & 95 mm Insulation

Component reference	:	TH02	
Construction type	:	Frame construction	
Sides compatible with	:	Frame construction cladding	
Component thickness	:	295	mm
Component plane weight	:	21.94	kg/m^2
Total environmental component impact	:	17.9	$kg\ CO_2{-}eq/m^2$

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability
None

Surface Material Class
None

Component material class
D-s2,d0

Fire technical parameters

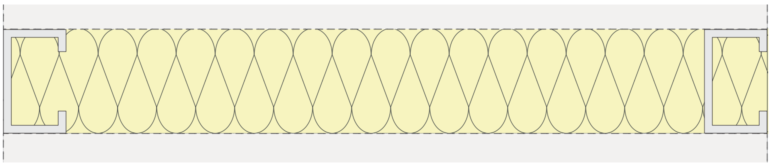
t_{ins} = 22.8 min

f_k = 30 MPa

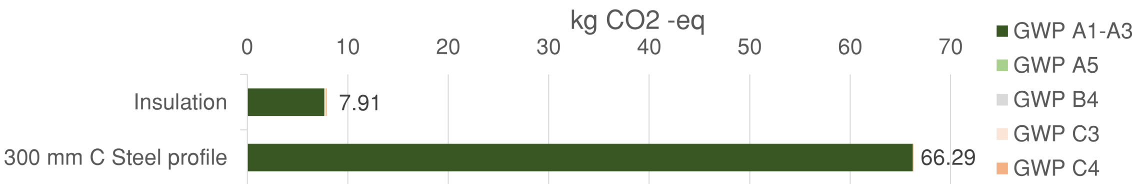
S 13 - 300 mm Steel C-profile & 95 mm Insulation

Component reference	:	Knauf
Construction type	:	Frame construction
Sides compatible with	:	Frame construction cladding
Component thickness	:	300 mm
Component plane weight	:	73.7 kg/m^2
Total environmental component impact	:	74.2 kg CO_2−eq/m^2

Heat capacity
None



Environmental impact per m^2 component



Fire technical classification

Fire protecting ability	Surface Material Class	Component material class
None	None	A1

Fire technical parameters

t_{ins} = 40 min

f_k = 30 MPa

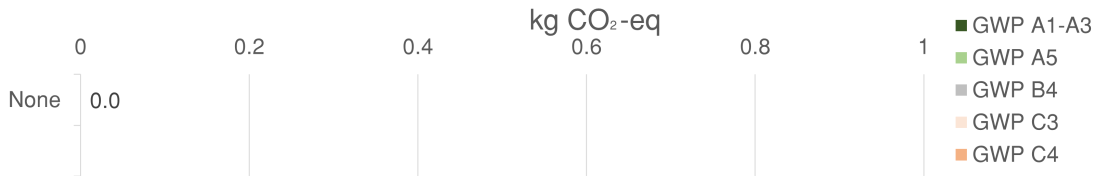
IL 01 - None

Component reference	:	SFH01
Component thickness	:	0 mm
Component plane weight	:	0 kg/m^2
Total environmental component impact	:	0 kg CO_2−eq/m^2

Heat capacity
None

R-value
0 K m^2/W

Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

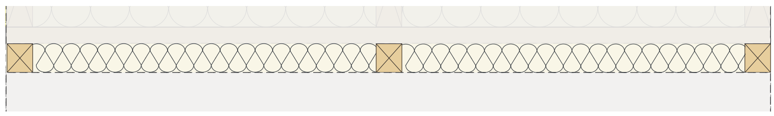
Component material class
None

IL 02 - 45 mm Wooden studs & insulation

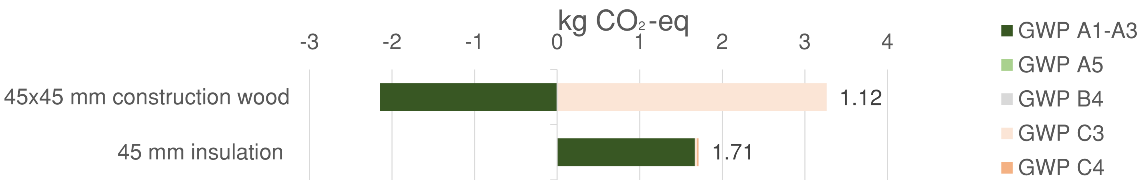
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	45 mm
Component plane weight	:	2.9 kg/m^2
Total environmental component impact	:	2.8 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.045/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

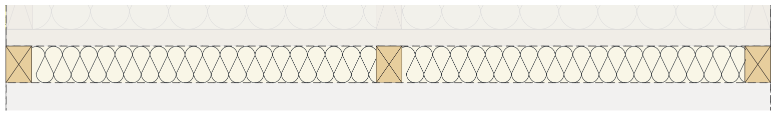
Surface Material Class	Component material class
None	D-s2,d0

IL 03 - 70 mm Wooden studs & insulation

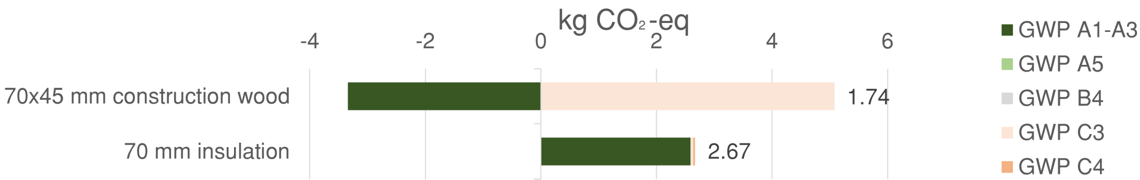
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	70 mm
Component plane weight	:	4.5 kg/m^2
Total environmental component impact	:	4.4 kg CO_2−eq/m^2

Heat capacity
None

R-value
$0.07/(0.00975 + 0.925 \cdot L)$
K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

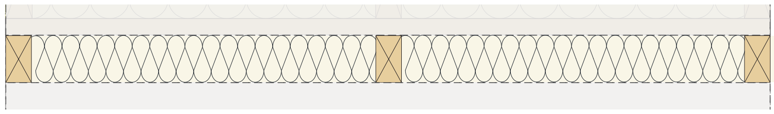
Component material class
D-s2,d0

IL 04 - 95 mm Wooden studs & insulation

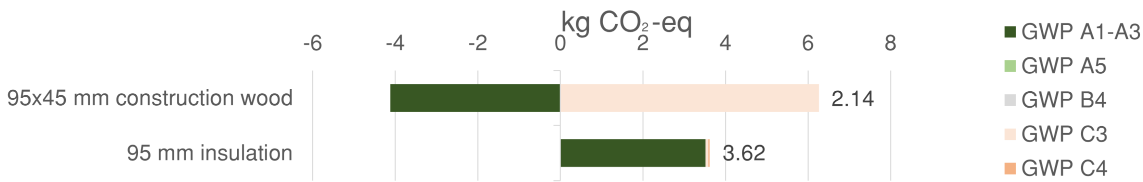
Component reference	:	SFH01
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	5.7 kg/m^2
Total environmental component impact	:	5.8 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

Surface Material Class
None

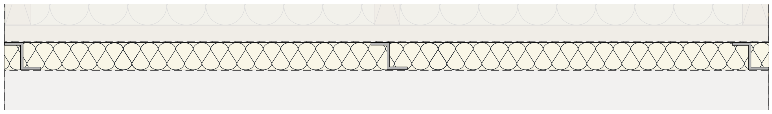
Component material class
D-s2,d0

IL 05 - 70 mm Z steel frame & insulation

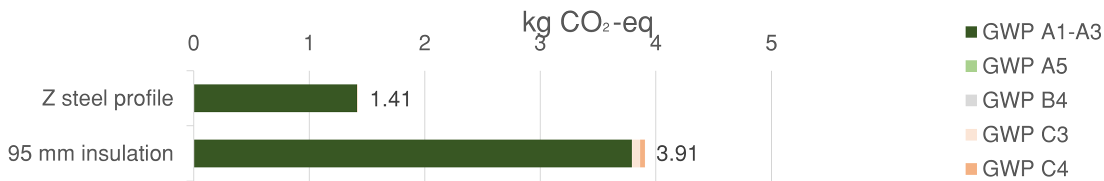
Component reference	:	Knauf
Construction type	:	Frame construction
Exterior side compatible with	:	Frame construction cladding
Interior side compatible with	:	Frame construction cladding
Component thickness	:	95 mm
Component plane weight	:	3.9 kg/m^2
Total environmental component impact	:	5.3 kg CO_2-eq/m^2

Heat capacity
None

R-value
$0.095/(0.00975 + 0.925 \cdot L)$ K m^2/W



Environmental impact per m^2 component



Fire technical classification

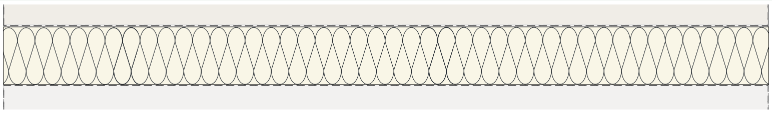
Surface Material Class
None

Component material class
A1

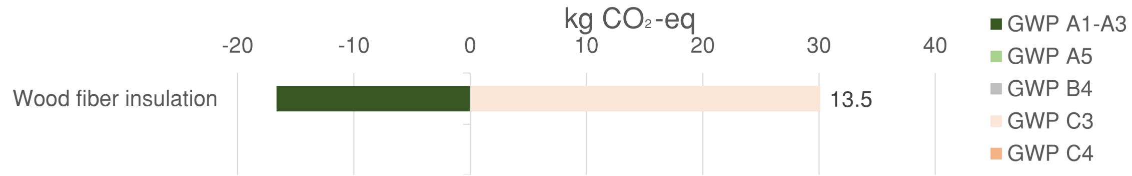
INS 01 - Wood fiber insulation

Component thickness	:	0.1	m
Component plane weight	:	16	kg/m^2
Total environmental component impact	:	13.5	$kg\ CO_2-eq/m^2$

λ_{dry}
0.038



Environmental impact per m^2 component



Fire technical classification

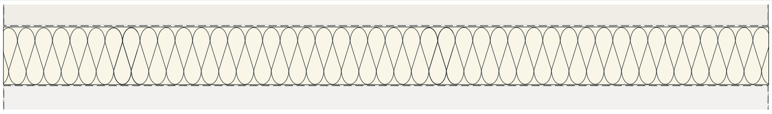
Surface Material Class
None

Component material class
E

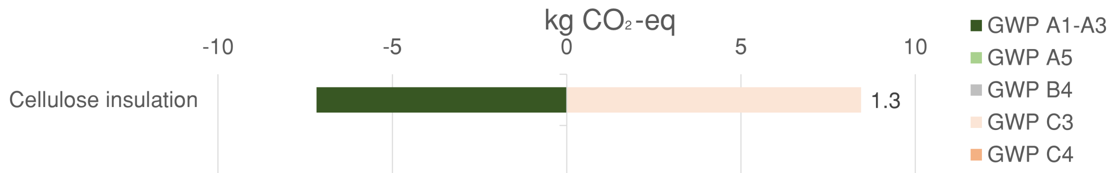
INS 02 - Cellulose insulation

Component thickness	:	0.1	m
Component plane weight	:	4.5	kg/m^2
Total environmental component impact	:	1.3	$kg\ CO_2-eq/m^2$

λ_{dry}
0.04



Environmental impact per m^2 component



Fire technical classification

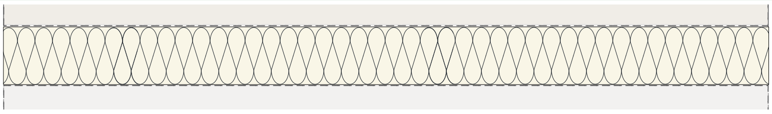
Surface Material Class
None

Component material class
D

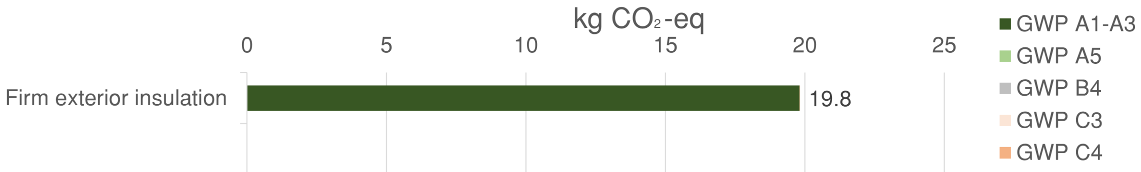
INS 03 - Firm exterior insulation

Component thickness	:	0.1	m
Component plane weight	:	14.6	kg/m^2
Total environmental component impact	:	19.8	kg CO_2−eq/m^2

λ_{dry}
0.034



Environmental impact per m^2 component



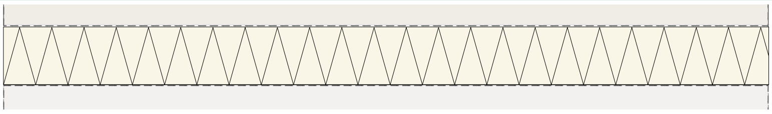
Fire technical classification

Surface Material Class	Component material class
None	A

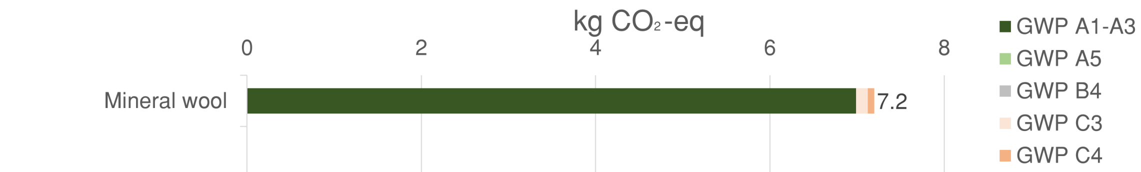
INS 04 - Mineral wool

Component thickness	:	0.1	m
Component plane weight	:	4.6	kg/m^2
Total environmental component impact	:	7.2	kg CO_2−eq/m^2

λ_{dry}
0.034



Environmental impact per m^2 component



Fire technical classification

Surface Material Class	Component material class
None	A