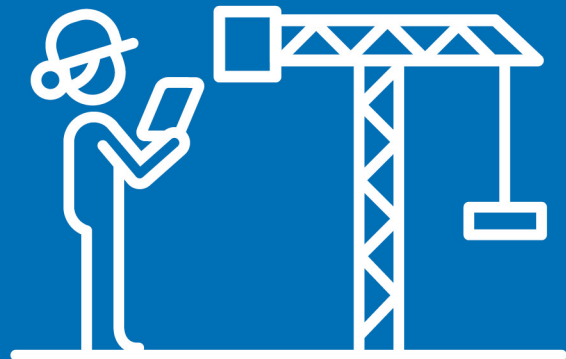




BEST PRACTICE CATALOGUE

Building LCA cases from the Nordic
countries and Estonia



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This publication is also available online in a web-accessible version at:
<https://pub.norden.org/us2024-461/>

PREFACE

This report is a part of the Nordic Sustainable Construction programme initiated by the Nordic Ministers of Construction and Housing and funded by Nordic Innovation. The programme contributes to the Nordic Vision 2030 by supporting the Nordics in becoming the leading region in sustainable and competitive construction and housing with minimised environmental and climate impact.

The programme supports the green transition of the Nordic construction sector by creating and sharing new knowledge, initiating debates in the sector, creating networks, workshops and best practice cases, and facilitating Nordic harmonisation of regulation for buildings' climate impact.

The programme runs from 2021-2024 and consists of the following focus areas:

- Work package 1 – Nordic Harmonisation of Life Cycle Assessment
- Work package 2 – Circular Business Models and Procurement
- Work package 3 – Sustainable Construction Materials and Architecture
- Work package 4 – Emission-free Construction Sites
- Work package 5 – Programme Secretariat and Capacity-Building Activities for Increased Reuse of Construction Materials

This report is a final deliverable for Work Package 1, task 5; an acceleration programme with knowledge sharing clinics and best practice catalogues. Work Package 1 is led by the Finnish Ministry of Environment.

The work has been carried out by SWECO, BUILD – AALBORG UNIVERSITY, LCA Support and EFLA.

All views, interpretations and recommendations are made by the authors and represent no official statements.

For more information on Nordic Sustainable Construction, visit our [website](#)



SUMMARY

This report is a deliverable for Work Package 1, task 5, led by the Finnish Ministry of Environment and carried out by SWECO, BUILD (Aalborg University), LCA Support and EFLA. The project is a part of the Nordic Sustainable Construction programme initiated by the Nordic Ministers of Construction and Housing and funded by Nordic Innovation.

It presents a catalogue of 26 best practice cases of Life Cycle Assessments (LCA) in the Nordic countries and Estonia. The cases have been collected through an open call in the participating countries in 2024. They indicate efforts for either reducing total carbon emissions below a given reference or demonstrating specific carbon mitigation measures.

The cases are presented in a systematic structure providing general information as well as specific carbon assessment and carbon mitigation procedures. Results are given in Global Warming Potential and illustrated from different angles and different forms of aggregation. Key methodological features are given in a transparent manner in order to view the results in their context. A summary of the key mitigation strategies are given in tables 1 and 2.

The results show a wide range of case types, contexts and carbon mitigation strategies. Most cases reflect the current situation in which carbon declarations and mitigation strategies are being applied when committing to voluntary certification schemes or client requirements. These experiences, however, may prove valuable as carbon regulation will become a mandatory requirement in the European Union and other countries.

Among the most-widely reported strategies is an early commitment to sustainability goals and the adoption of innovative, low-carbon materials and techniques. From the use of alternative concrete binders and high-recycled content steel to the extensive use of timber, particularly in innovative applications like CLT slab and walls elements, these projects show how material choices can significantly lower carbon footprints. Early collaboration between designers, contractors, consultants and suppliers have proven essential in achieving ambitious climate targets. Technological strategies include prefabrication, bio-based construction materials as well as efficient and renewable energy.

The reported cases also highlight considerable variation in method, especially scope, rendering direct comparison inappropriate. Until a greater methodological harmonisation is achieved, this report advises to clearly define methodological choices and provide detailed explanations of the underlying assumptions when creating a case database for learning and analysis.

INTRODUCTION

The reduction of carbon emissions in the built environment is a critical component in the global effort to combat climate change. The construction and use of buildings are significant contributors to greenhouse gas emissions, accounting for a substantial portion of the world's carbon footprint. As urbanisation is proceeding, the need for sustainable construction practices becomes increasingly urgent. Implementing low-carbon solutions in the construction sector not only mitigates environmental impact, but also promotes energy efficiency, resource conservation and long-term economic benefits.

In response to these pressing challenges, the Nordic Sustainable Construction programme has been established. This initiative aims to support the Nordic Vision 2030 by promoting sustainable and competitive construction practices with minimal environmental and climate impact. The programme seeks to accelerate the decarbonisation of the building and construction sector through knowledge sharing and the dissemination of best practices.

The Nordic countries and Estonia have made significant strides in establishing carbon regulations for buildings. Mandatory climate declarations for new buildings have either been introduced or are currently under development in all five Nordic countries and Estonia. By the beginning of 2026, all Nordic countries are expected to have a legal framework for disclosing life-cycle greenhouse gas emissions, with or without limit values [1][2]. This harmonisation of regulations is crucial for fair competition and mobilising the market to develop efficient low-carbon solutions.

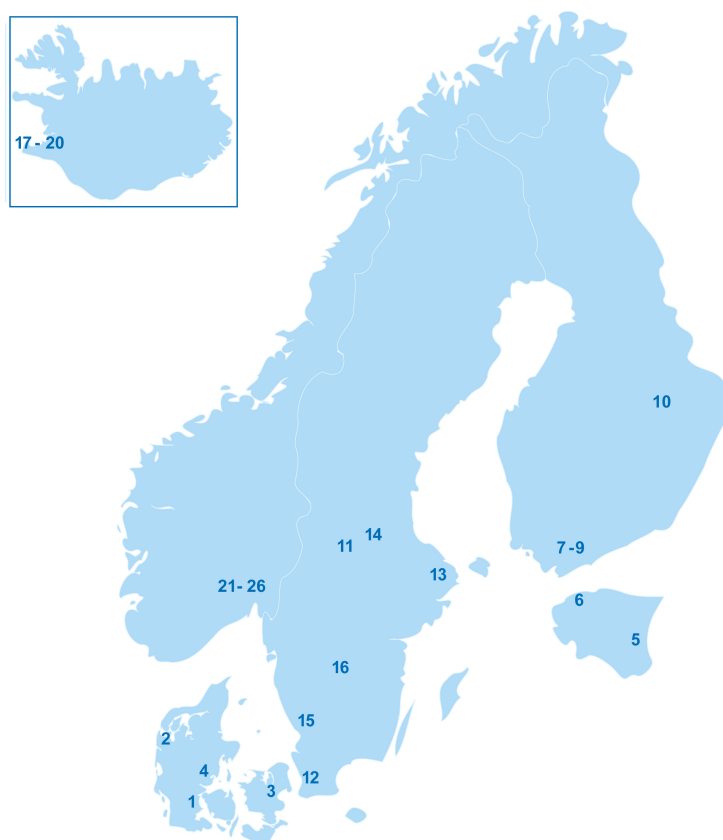
This report is a deliverable of the programme, presenting a comprehensive catalogue of best practices in low-carbon construction from the Nordic countries and Estonia. The catalogue includes detailed case studies of selected construction projects that exemplify low-carbon solutions. These projects serve as benchmarks for the industry, providing valuable insights into effective strategies for reducing carbon footprints and enhancing sustainability.

The report begins with a methodology section outlining the criteria and process used for selecting the projects and the methods employed in analysing their carbon reduction strategies. Following this, the catalogue section presents the 26 detailed case studies of low-carbon buildings from the Nordic countries and Estonia, highlighting approaches and results. The report concludes with a summary of the key findings from the case studies and provides recommendations for future initiatives in low-carbon construction.

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1. Balouktsi, M., Kanafani, K., Francart, N., Langkjær, N., Ryberg, M. (2024): *Decarbonisation Of The Building Stock*. Nordic Innovation. <https://pub.norden.org/us2024-438>
 2. Balouktsi, M., Francart, N., & Kanafani, K. (2024). Harmonised Carbon Limit Values for Buildings in Nordic Countries: Analysis of the Different Regulatory Needs. Nordic Innovation. <https://www.nordicsustainableconstruction.com/knowledge/2024/march/new-report-regulatory-needs-for-harmonising-carbon-limit-values>

METHODOLOGY

This catalogue presents the climate impact of 26 best-practice cases from the Nordic countries and Estonia. It is meant as an inspiration and a collection of examples of measures taken to reduce the climate impact. Cases are modelled with varying Life Cycle Assessment (LCA) methods and tools related to the participating countries and project context. Therefore, result comparison across cases is often not possible. Even at country level, method variation may occur due to varying regulatory requirements and certification systems. Also, methods evolve over time, not at least regarding a more complete and mandatory regime for carbon regulation today compared to a historically dominating voluntary certification schemes. As the Nordic countries are implementing mandatory declarations and limit values, a greater degree of harmonisation is expected in the future. A thorough analysis and comparison of methodological differences in the Nordic countries is available in previously published reports.^[3]



3. Erlandsson, M., Görman, F., Thrysin, Å., Häkkinen, T., Eckerberg, K., Pesu, J., & Dalborg, M. (2024). *Nordic view on data needs and scenario settings for full life cycle building environmental assessment*. Nordic Innovation. <https://pub.norden.org/us2024-428>

To enhance transparency and facilitate result interpretation, Table 1 provides an overview of the choices related to selected influential methodological aspects. These aspects include area definition, included modules, included elements, the Global Warming Potential (GWP) indicator used, emissions data sources for generic materials, decarbonisation scenarios (for energy and materials) and exported energy. Like most countries, the Nordics use a 50-year reference study period. A brief explanation of major methodological differences is provided below.

Area definition: This choice of area definition significantly influences the reported outcomes of climate impact assessments for the cases. For instance, calculating climate impact per gross floor area (GFA) yields different results than assessments based on heated floor area (HFA) or net heated area. Currently, there is a lack of standardisation in the reference units and definitions employed across Nordic nations^[4]. This variability complicates the ability to compare results across countries.

Life cycle stages: Buildings go through various stages throughout their life cycle, which include the product stage, the construction process, the use stage, and the end-of-life stage. The EN 15978 standard provides a modular framework for defining these stages and serves as a reference for current regulations and certifications in the Nordic countries. This standard is also used in the presentation of results in the following section. Carbon emissions from the product stage (A1-A3) and the construction stage (A4-A5) are often combined and referred to as upfront embodied carbon emissions, as they occur before the building is commissioned. Scenario-based embodied carbon emissions include emissions from use (B1), maintenance (B2), repair (B3), product replacements (B4), and refurbishments (B5) that take place during the building's use phase, along with end-of-life processes (C1-C4). Operational emissions are related to energy consumption (B6) and water consumption (B7) during the building's reference study period. Differences in system boundaries in the case assessments are a significant factor that limits the comparability of the presented values. The results are displayed per life cycle module wherever possible to improve transparency.

Building components: System boundaries in best practice cases also vary in this aspect. The biggest discrepancies lie in the partial or full inclusion or exclusion of site preparation, building services, external works and furnishing. Even if two countries may have identical scopes, the included level of detail per component may differ. Another aspect is that standard values may be used for certain components such as building services in some cases, while other cases may have project-specific detailed calculated values. This is not indicated in the results other than the broader included scope of components.

GWP indicator: The Nordic countries currently use different scopes of the Global Warming Potential (GWP) indicator. For instance, Finland and Denmark employ a comprehensive measure called GWP-total, which includes biogenic emissions as well as emissions from land use and fossil fuels. In contrast, Sweden and Norway focus solely on emissions from land use and fossil fuels, using the indicator GWP-GHG, while omitting the biogenic part. Due to these varying indicators, it is not possible to make direct

4. Balouktsi, M., Kanafani, K., Francart, N., Langkjær, N., Ryberg, M. (2024): *Decarbonisation Of The Building Stock*. Nordic Innovation. <https://pub.norden.org/us2024-438>

module-by-module comparisons of carbon calculations across countries; any interpretations should be understood in context.









Climate impact data: In best practice cases, climate impact calculations should ideally use environmental data from product-specific Environmental Product Declarations (EPDs) and EPDs from national industry associations as much as possible^[5]. Using data that is specific to the industry and product minimises uncertainties in climate impact results compared to generic data. Generic environmental data across Nordic countries are commonly representing a conservative, higher level of impacts. However, specific information on the usage of EPDs has not been collected. Additionally, since conservative factor approaches and other aspects of developing generic data vary among Nordic countries, results may be difficult to compare even when the same scope is applied.










Decarbonisation scenarios: One of the most significant variations in calculation methods involves the choice between using current emissions and future emissions from energy use, that account for planned renewable conversion of production for electricity, district heating, and gas. This is particularly relevant for calculating operational energy (B6). Several used methods have scenarios for gradual decarbonisation of the energy supply in this module. However, even if two methods from different countries include such decarbonisation scenarios, they may still be incomparable due to differing national preconditions such as policy, data and methodologies. Regarding decarbonisation scenarios for materials used in future processes, such as replacements (B4), only the FutureBuilt scheme currently incorporate these scenarios.








Exported energy: According to the EU Building Directive (EPBD), "exported energy" refers to the portion of renewable energy generated on a building site that is sent to the energy grid, rather than being utilised on-site for purposes such as self-consumption or electric vehicle charging. The rules governing how renewable energy generated on-site is calculated and distributed for different uses are expected to be a significant focus in the revision of the EPBD as it a critical factor of comparability. However, current approaches vary across different certification systems and regulations. The treatment of exported energy involves not only decisions on how energy savings are allocated, but also considerations of the supply chain impacts, which include the embodied impacts of renewable energy systems.

5. Balouktsi, M., Kanafani, K., Francart, N., Langkjær, N., Ryberg, M. (2024): *Decarbonisation Of The Building Stock*. Nordic Innovation. <https://pub.norden.org/us2024-438>

Table 1: Overview of main methodological aspects behind the sourced climate impact values of the best practice cases. Note: EDW: External doors and windows; IDW: Internal doors and windows; EF: External finishes; IF: Internal finishes; BS: Building services; Fixed furniture: FF; Specialist groundworks and piling: SG.

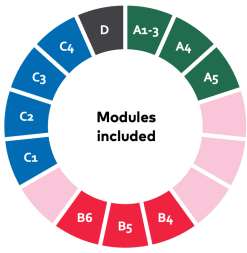
		Type	Stages included	Elements excluded	Area definition	GWP indicator	Generic material emission data	Decarb. scenario (energy)	Decarb. scenario (materials)	Exported energy included
01		School	A1-A3, B4, B6, C3, C4, D	FF, SG	GFA / HFA	GWP-total	Yes, +EPDs	Yes	No	Module D
02		Renovation farm	A1-A3, B4, B6, C3, C4, D	BS, FF, SG	GFA / HFA	GWP-total	Yes, +EPDs	Yes	No	Module D
03		Residential low	A1-A3, B4, B6, C3, C4, D	FF, SG	GFA / HFA	GWP-total	Yes, +EPDs	Yes	No	Module D
04		Residential high	A1-A3, B4, B6, C3, C4, D	FF, SG	GFA / HFA	GWP-total	Yes, +EPDs	Yes	No	Module D
05		Commercial	A1-A5, B4, B4-B6, C2-C4	N/A	HFA	GWP-total	Yes, +EPDs	Yes	No	N/A
06		Residential high	A1-A5, B4, B4-B6, C2 - C4	N/A	GFA	GWP-total	Yes, + EPDs	(probably NO)	No	N/A
07		Residential high	A1-A5, B3, B4, B6, C1-C4, D	FF, SG	HFA	GWP-total	Yes, + EPDs	Yes (benefits-sharing method)	No	Module D
08		Residential high	A1-A5, B4, B6, C1-C4, C	SG	HFA	GWP-total	Yes, +EPDs	Yes, benefits-sharing method	No	No

09		Office	A1-A5, B4, B6, C1-C4, D	FF	GFA	GWP-total	Yes, + EPDs	Yes, benefits-sharing method	No	No
10		Residential high	A1-A5, B3, B4, B6, C1-C4, D	FF, SG	HFA	GWP-total	Yes, + EPDs	Yes, benefits-sharing method (2019)	No	No
11		Residential low	A1-3, A4-A5, B1-B5, B6, B7, C1-4, D	FF, SG	GFA	GWP-GHG	Yes, + EPDs	—	—	Negative value in B6
12		Office	A1-A5, B4-B7	EDW, IDW, BS, FF, SG	GFA	GWP-GHG	No, EPDs	No	No	Negative value in B6
13		Office	A1-A5, B4-B7	BS, IDW, FF, SG	GFA	GWP-GHG	Yes, + EPDs	No	No	Negative value in B6
14		Residential low	A1-A5, B4-B7, C1-C4	BS, FF, SG	GFA	GWP-GHG	Yes, + EPDs	Yes, as per NollCO2 certification method	No	Benefits allocated to B6
15		Logistical building	A1-A5, B4-B6	BS, FF, SG	GFA	GWP-GHG	Yes, + EPDs	No	No	Negative value in B6
16		Logistical building	A1-A5, B4-B7	FF, SG	GFA	GWP-GHG	Yes, + EPDs	No	No	Negative value in B6
17		Residential low	A1-A5, B4-B6, C1-C4, D	BS, FF, SG	GFA	GWP-total	Yes + EPDs	Not relevant	No	Not relevant
18		School	A1-A5, B4-B6, C1-C4, D	BS, FF, SG	GFA	GWP-total	Yes + EPDs	Not relevant	No	Not relevant
19		Nursing home	A1-A5, B4-B6, C1-C4, D	BS, FF, SG	GFA	GWP-total	Yes + EPDs	Not relevant	No	Not relevant

20		Parliament offices	A1-A5, B4-B6, C1-C4, D	BS, FF, SG	GFA	GWP-total	Yes + EPDs	Not relevant	No	Not relevant
21		Residential low	A1-A3, B4	BS, FF, SG	GFA	GWP-GHG	Yes, + EPDs	Not relevant	No	Not relevant
22		Residential high	A1-A5, B4, B6, B7, C3, D	BS, FF	GFA	GWP-GHG	Yes, + EPDs	No	-	-
23		Residential high	A1-3, A4-A5, B4, B6, C2-C4	FF, IDW	GFA	GWP-GHG	Yes, + EPDs	Yes, average 60-year NO + EU28 electricity mix	No	No distinction between self-use/ exported
24		School	A1-A3, B4-B7	BS, FF	GFA	GWP-GHG	Yes, + EPDs	Yes, average 60-year NO + EU28 electricity mix	-	No distinction between self-use/ exported
25		Office	A1-3, A4-A5, B1-B5, B6, C1-C4	BS, FF	GFA	GWP-GHG	Yes, + EPDs	Yes, average 60-year NO + EU28 electricity mix	Yes	No distinction between self-use/ exported
26		Nursing home	A1-A3, B4-B7	BS, FF	HFA	GWP-GHG	Yes, + EPDs	-	-	-

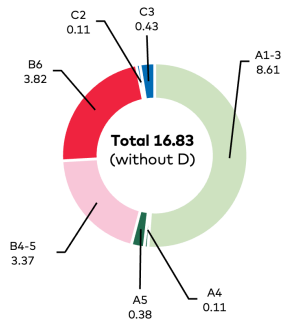
CASE CATALOGUE

The cases are presented on in four pages, each following an identical structure. After a table with key information about the building project, a short description introduces the case with background information on the process and which carbon reduction measures have been adopted. The last three pages contain carbon assessment data in figures and short descriptions according to the overview below.

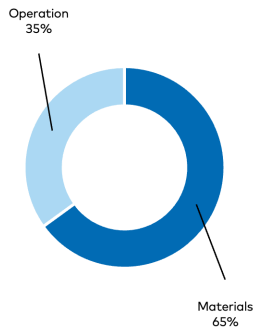


Overview of the included modules compared to a full life cycle according to EN 15978.

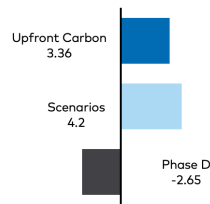
The dark tone indicates that a module is included.



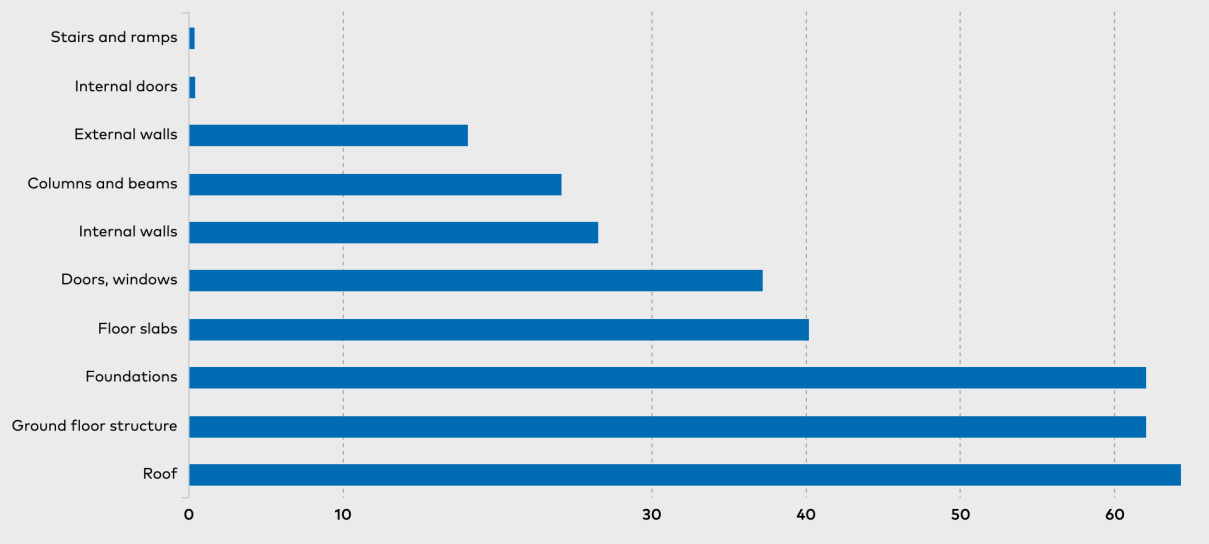
Total Global Warming Potential (GWP) for all included life cycle modules. Note that scenarios for modules might differ from one case to another.



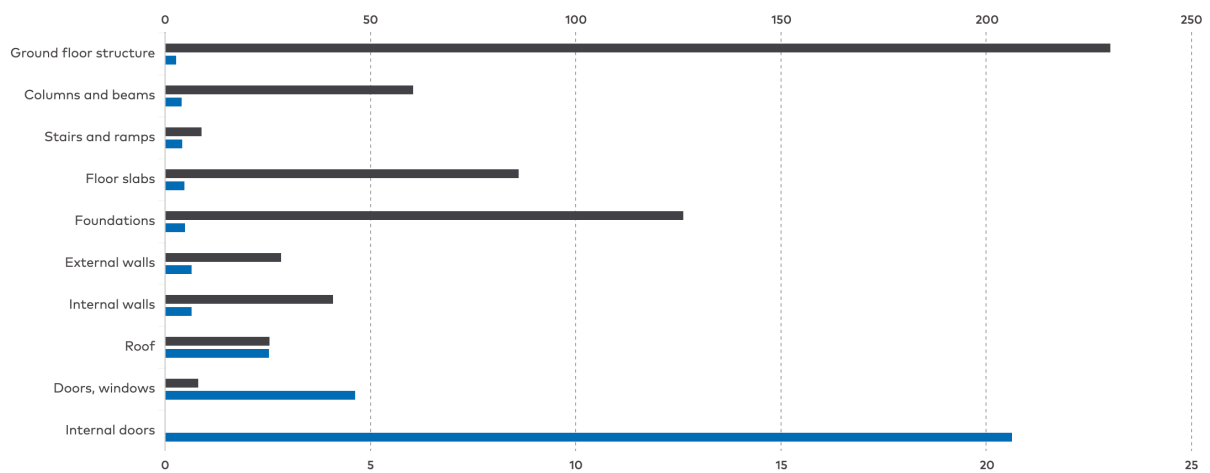
Total GWP divided into operation (B6, B7) and materials (A1-A5, B1-B5, C1-C4).



Total GWP divided into upfront carbon (A1-A5) and future scenarios (B1-B5, C1-C4), while D is shown separately.



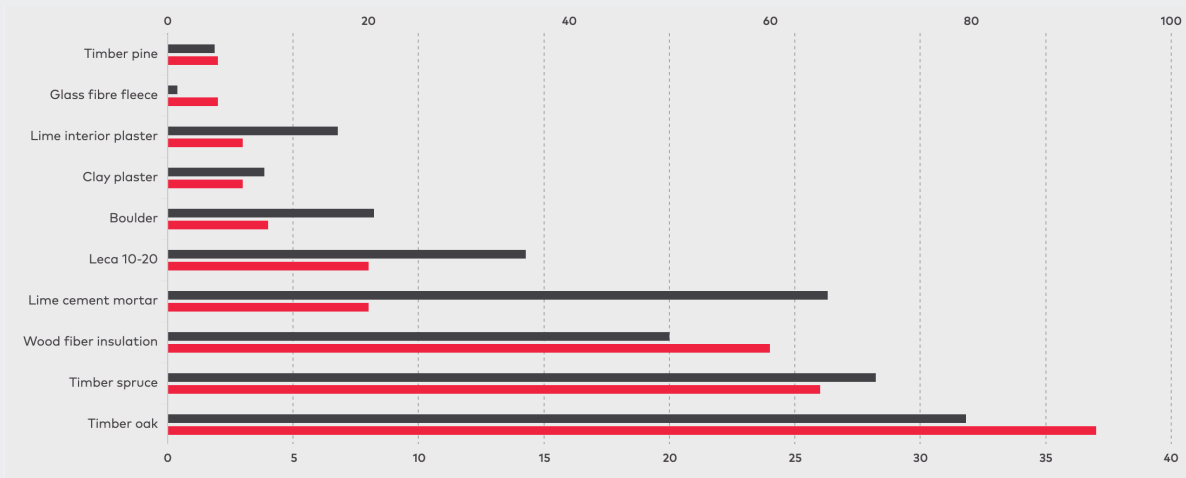
GWP of building elements for all material-related impacts (A1-A5, B1-B5, C1-C4) in the project. Ordered by magnitude. Results cover all material impacts.



Black scale: Element quantity per building reference area, meaning weight per building unit.

Blue scale: GWP per element quantity, meaning carbon intensity of one unit of an element relative to its weight.

Results cover all material-related impacts in the project.



Black scale: Product quantity per building reference area, meaning weight per building unit.

Red scale: GWP per building reference area, meaning carbon intensity of products.

Results are limited to 10 products with the highest GWP.



Photos by Niels Nygaard Photography

01 Erlev Skole

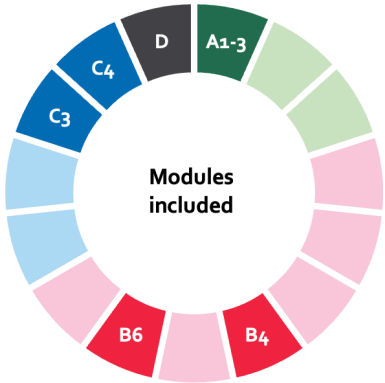
Denmark

Building use	School	Stories above ground	2
Location	Gammel Hørregårdsvej 29, 6100 Haderslev	Basement area	—
Client	Haderslev Municipality	Structural system	Column-beam timber frame
LCA consultant	Arkitema	Facade type	Wood
Year of completion	2021	Roof type	Flat roof
Reference area	6,014 m ² (gross floor area)	Heat demand /source	District heating

The school was designed as timber construction, making it one of the country's first wooden schools in recent times. The school's shape is not optimal in terms of achieving a low climate impact per m², as due to daylight requirements for virtually all rooms there is a need for a large façade area per m² floor area. At the same time, the building is in 1-2 storeys, which significantly impacts the roof and terrain decks per m² of floor area. Therefore, the materials have been optimised considerably with a wood column-beam construction, wood on interior surfaces and wood as façade cladding. To support the pedagogical ideas and learning attitudes, the architecture is designed as a series of simple and open geometries – a tight grid of columns where each part has been designed with different elements together with users in a co-creation process. The school is characterised by a multitude of different types of spaces that support the activity-based teaching method. Large common rooms, typical classrooms, small learning spaces and small niches.

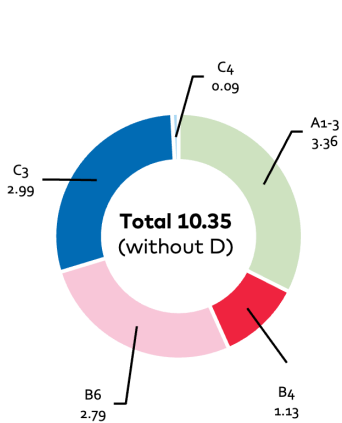
Assessment method

LCA scheme compliance	—
LCA tool version	LCAbyg 5
Life cycle stages included	A1-A3, B4, B6, C3, C4, D
Material emission data	EPD and generic Danish database (from LCAbyg and DGNB)
Material decarbonisation scenario	—
Energy calculation method	According to building regulations
Energy, dynamic scenario	Dynamic development of energy supply according to frozen policy, based on an official national report

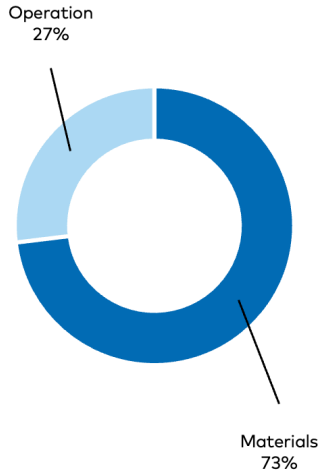


LCA results: Life cycle modules

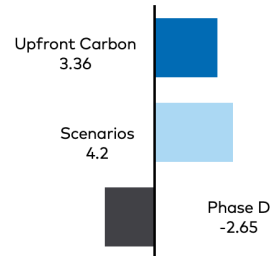
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

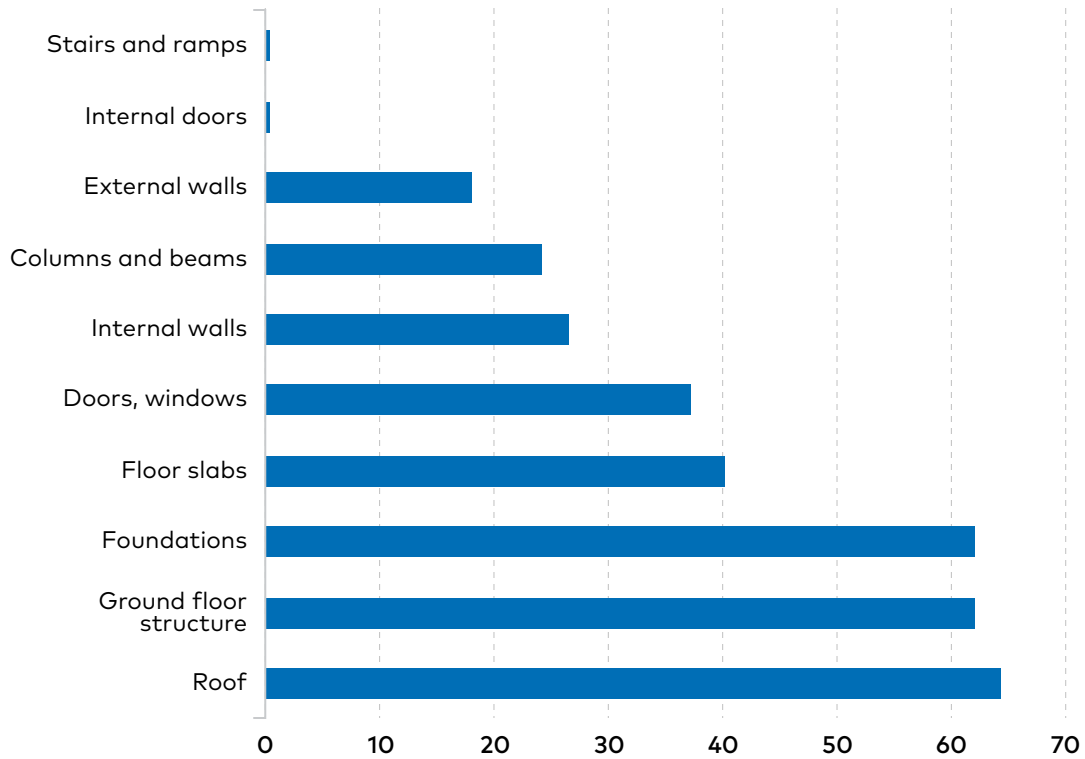


The system includes key modules from the product, use and end-of-life stages according to Danish industry practice by the time. The project lies below the current limit value of 12 kgCO₂e/m²a specified in the building regulations. Generic values for building services are included to complete the inventory.

In the second figure, Operation includes B6, while materials include A1-A3, B4, C3-C4.

In the third figure, Upfront includes A1-A3, scenarios include B4, C3-C4, and D is shown separately. For a timber construction, upfront carbon is low while high in the end-of-life stage due to the biogenic carbon balance.

LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

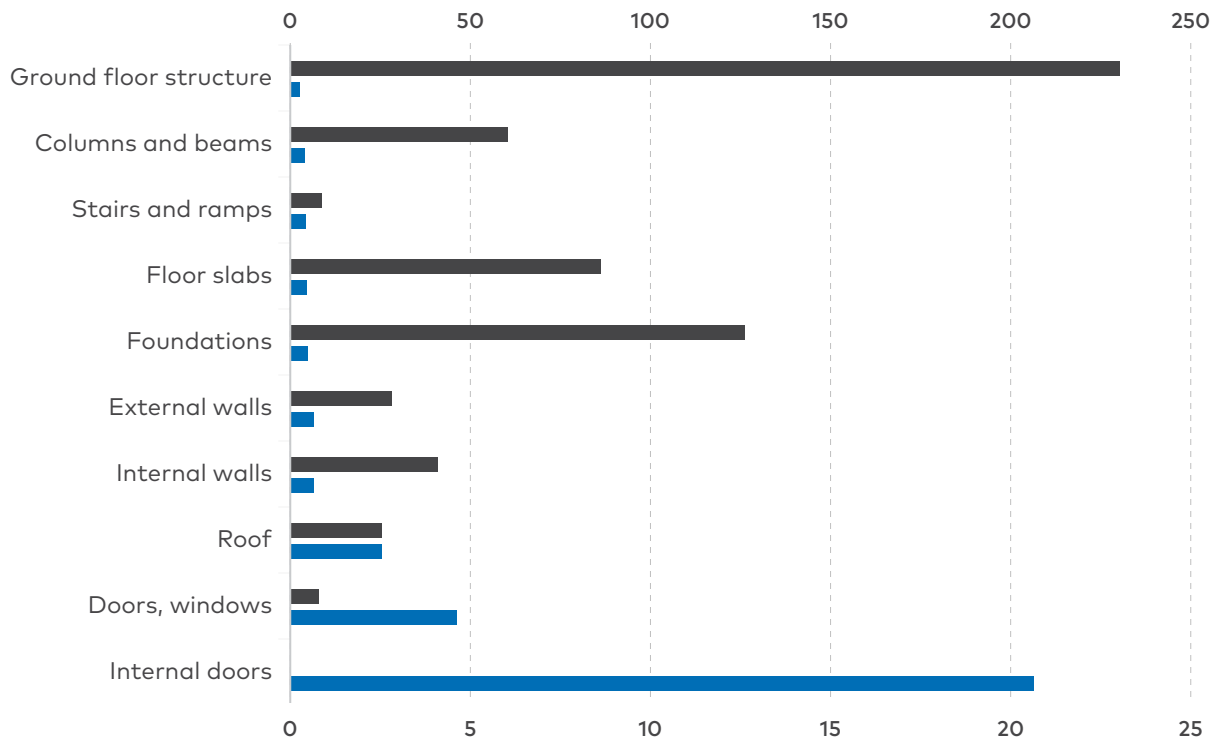
Material inventory: All materials

Life cycle modules: A1-A3, B4, C3-C4

The low-rise structure results in the highest impacts from the roof and the ground floor deck.

The timber column and beam frame are low-carbon optimised.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials

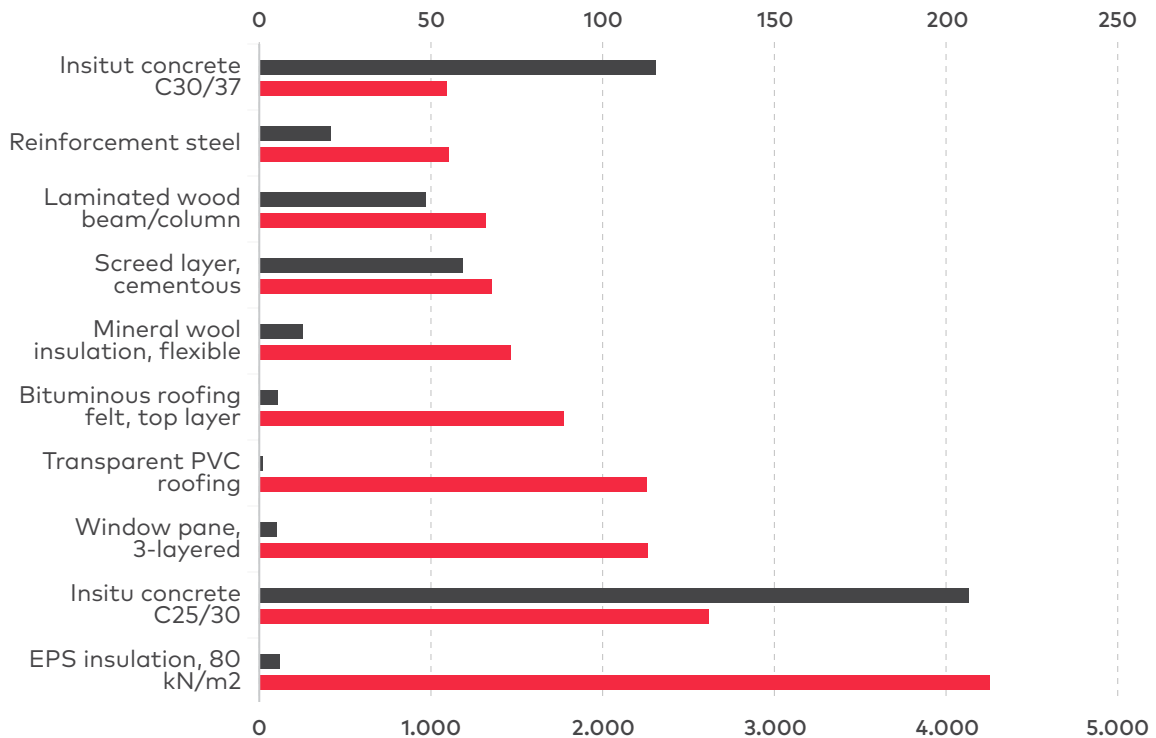
Life cycle modules: A1-A3, B4, C3-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

The ground floor structure and foundation products dominate the GWP ranking due to the low building height.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3, B4, C3-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Also at product level, ground floor structure and foundations rank the highest, followed by roofing material and windows.



Photo by Henning Larsen Architects

02 Kirkehøjgaard

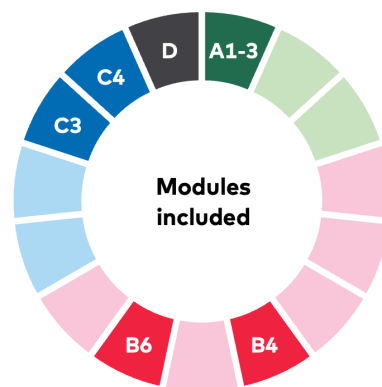
Denmark

Building use	Detached home	Stories above ground	1
Location	Kirkevej, 5600 Faaborg	Basement area	0 m ²
Client	The Agency for Culture and Palaces	Structural system	Half-timbered
LCA consultant	Henning Larsen Architects	Façade type	Half-timbered
Year of completion	2023	Roof type	Pitched roof
Reference area	219 m ² (heated floor area)	Heat demand /source	Heat pump

In collaboration with Henning Larsen Architects, the Danish Agency for Culture and Palaces has worked on the restoration of the listed four-long farm Kirkehøjgaard. It is part of a pilot project to save distressed listed buildings. The analysis compares the completed restoration with a hypothetical conventional restoration. The purpose is to measure the effect of using biogenic materials and low-carbon emission materials for restoration. Three different LCA methods for building renovations are also explored. In the assessment shown here, only new added materials are considered. The farm consists of the detached farmhouse, three connected outbuildings and one detached outbuilding, constructed between 1178 and 1853. The condition of the farm was such that the decay was accelerating and there was a danger of collapse. The project can also shed light on whether reusing local building materials rather than replacing them with new ones can help strengthen the conservation values of a restoration project. Especially a restoration as extensive as this one, where up to 80% of the original materials are replaced. The project focuses on, amongst others, ensuring the following aspect craftsmanship, traditions, processing and moisture (incorporation of permeable materials that contribute to more stable moisture conditions for preservation and for increased comfort).

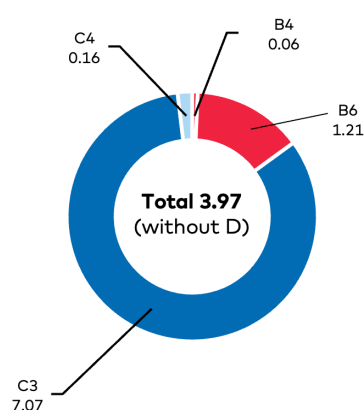
Assessment method

LCA scheme compliance	Industry guidance in LCA for renovation 2017
LCA tool version	LCAbyg 2023 (version 5.4.0.5)
Life cycle stages included	A1-A3, B4, B6, C3, C4, D
Material emission data	Generic Danish database according to Danish building regulations and EPDs
Material decarbonisation scenario	—
Energy calculation method	According to building regulations
Energy, dynamic scenario	Dynamic development of energy supply according to frozen policy, based on an official national report from 2020

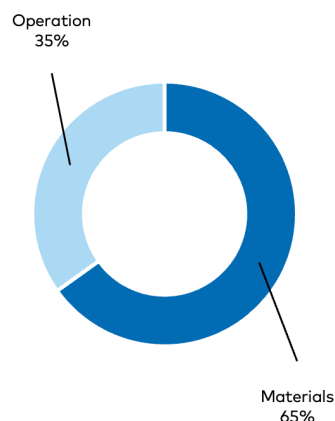


LCA results: Life cycle modules

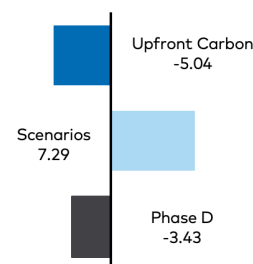
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

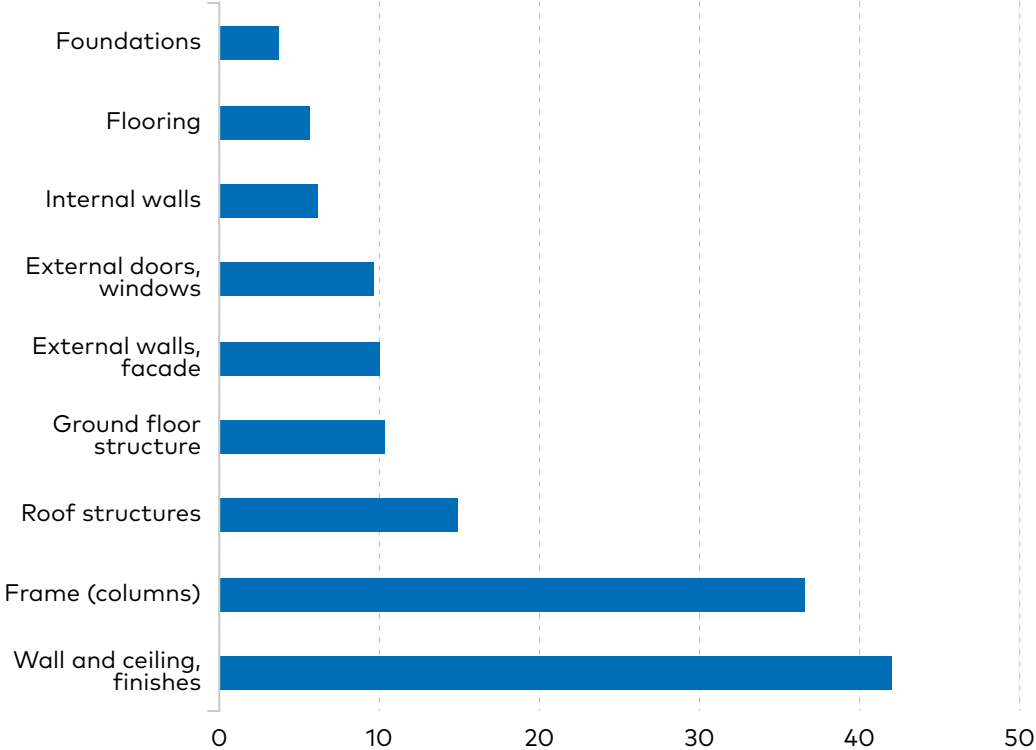


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



Material impacts only include new added materials. The remaining life cycle of existing materials is not included. Modules A1-3 have negative emissions of 5.04 [kgCO₂e/m² reference area * year] due to the dominating biogenic materials used, while the effect is reversed in C3. This should also be seen in light of the fact that this is a project to restore the building, not completely transform it, which means that a relatively small amount of materials have been used. In the second figure, *Operation* includes B6, while materials include A1-A3, B4, C3-C4. Despite the historic character of the building, impacts from energy use are very low, because of the after insulation of the outer constructions and change to heat pump. In the third figure, *Upfront* includes A1-A3, scenarios include B4, C3-C4, and D is shown separately. Upfront impacts are negative due to the biogenic content of the added materials.

LCA results: Building elements

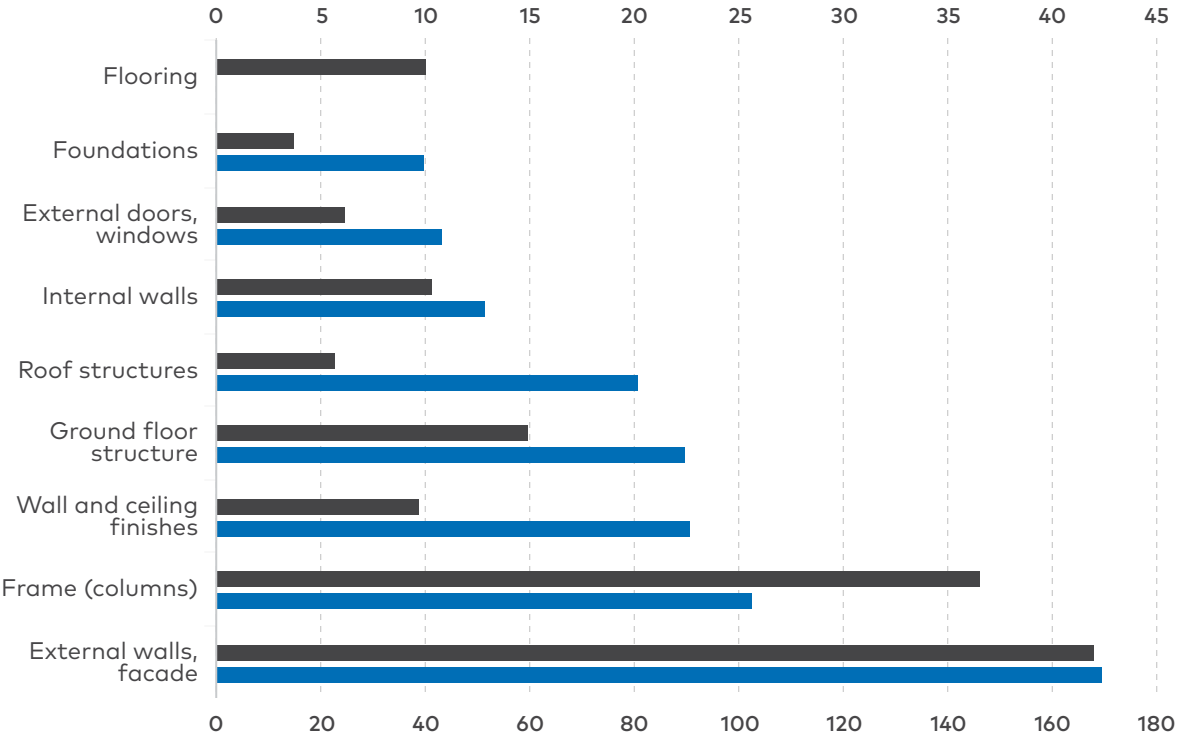


GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials
Life cycle modules: A1-A3, B4, C3-C4

The high amount of GWP in wall and ceiling is a result of outer wall insulation being allocated to the inner wall finishes.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

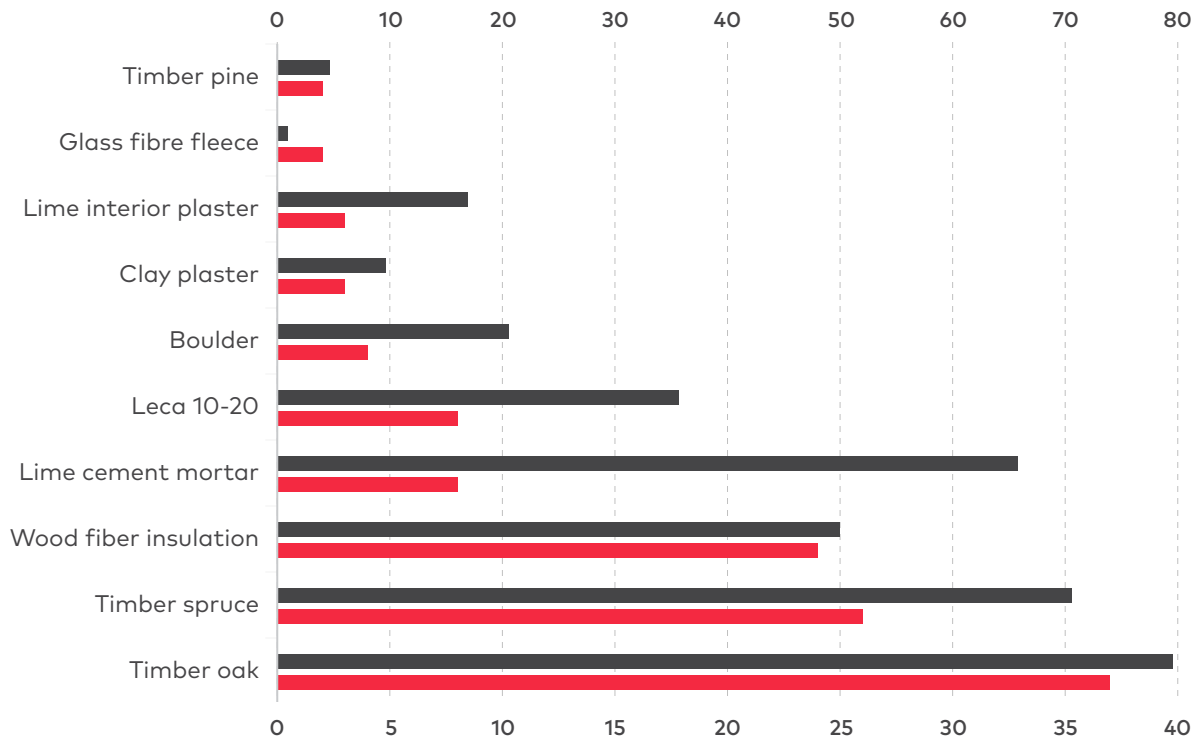
Material inventory: All materials
Life cycle modules: A1-A3, B4, C3-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

The Frame shows high density and smaller GWP/quantity do to the biobased materials. Areas where the insulation materials have a higher QWP/ quantity compared to quantity/ area in the building.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3, B4, C3-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Both in quantity and impacts, the added timber frame members have the highest share, followed by wood fibre insulation and lime mortar.



Photos by Adam Mørk

03 Living places Copenhagen

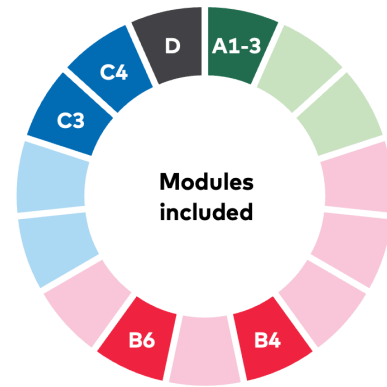
Denmark

Building use	Detached home	Stories above ground	3
Location	Otto Busses Vej 29A, 2450 København SV	Basement area	—
Client	Velux Group	Structural system	Cross-laminated timber
LCA consultant	Artelia	Façade type	Wood
Year of completion	2023	Roof type	Pitched roof
Reference area	147 m ² (gross floor area)	Heat demand /source	Heat pump and solar cells

With Living Places, we are exploring how far we can go with existing solutions for housing construction, and the results are promising. Living Places demonstrates scalable solutions that can ensure healthy and good housing for future citizens with radical reduction of emissions and resource consumption in the buildings' life cycle. The buildings will be a temporary 1:1 exhibition model in the centre of Copenhagen. It will show how to build with a low-carbon footprint and focus on health. The one-family home shown here is one of two completed houses that are part of a larger exhibition showcasing a total of seven new building prototypes to promote healthier and lower-impact homes. The building design and material choices have been optimised for minimal carbon emissions and improved indoor climate. The building has been constructed using cross-laminated timber (CLT), both in the walls and the roof, and with a ground screw foundation to ensure minimal disruption to the building plot. The building has been designed towards utilising natural ventilation as much as possible. This was achieved through placing windows and openings in the interior structure to allow for an undisrupted flow of air and light through the building and by using windows with motors for automatic opening.

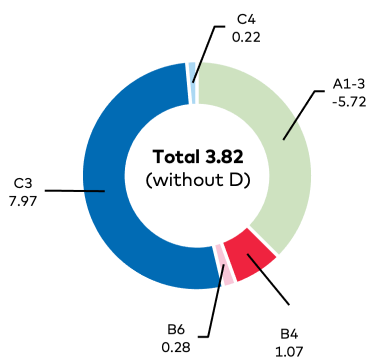
Assessment method

LCA scheme compliance	—
LCA tool version	LCAbyg 5
Life cycle stages included	A1-A3, B4, B6, C3, C4, D
Material emission data	Generic Danish database used in LCAbyg and DGNB and EPD
Material decarbonisation scenario	—
Energy calculation method	According to building regulations
Energy, dynamic scenario	Dynamic development of energy supply according to frozen policy, based on an official national report from 2020

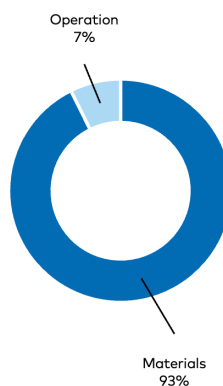


LCA results: Life cycle modules

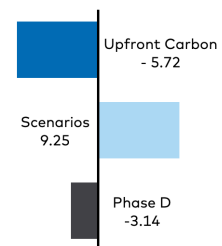
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

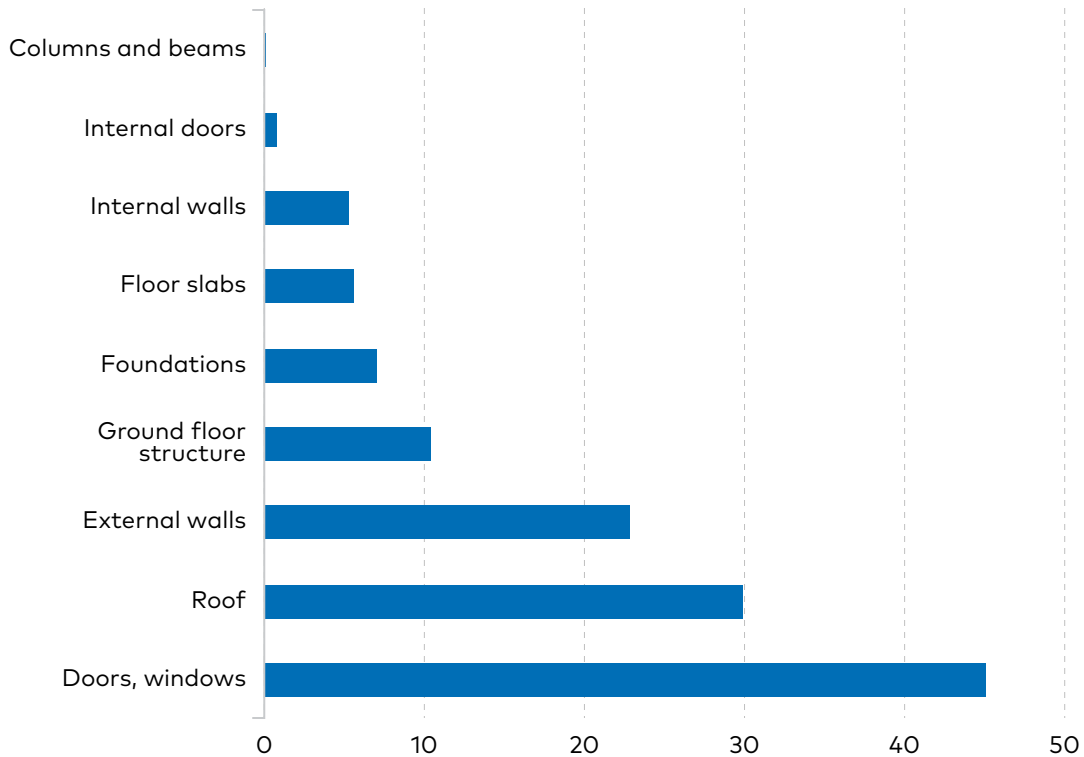


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The life-cycle modules follow Danish practice in voluntary schemes and the carbon regulations of that time. Modules A1-3 have negative emissions due to the dominating biogenic materials used, while the effect is reversed in C3. In the second figure, *Operation* includes B6, while materials include A1-A3, B4, C3-C4. The project is highly energy efficient and uses heat pumps and solar cells, combined with low emissions in the electricity mix. In the third figure, *Upfront* includes A1-A3, scenarios include B4, C3-C4, and D is shown separately. Upfront impacts are negative due to the biogenic content of the added materials.

LCA results: Building elements



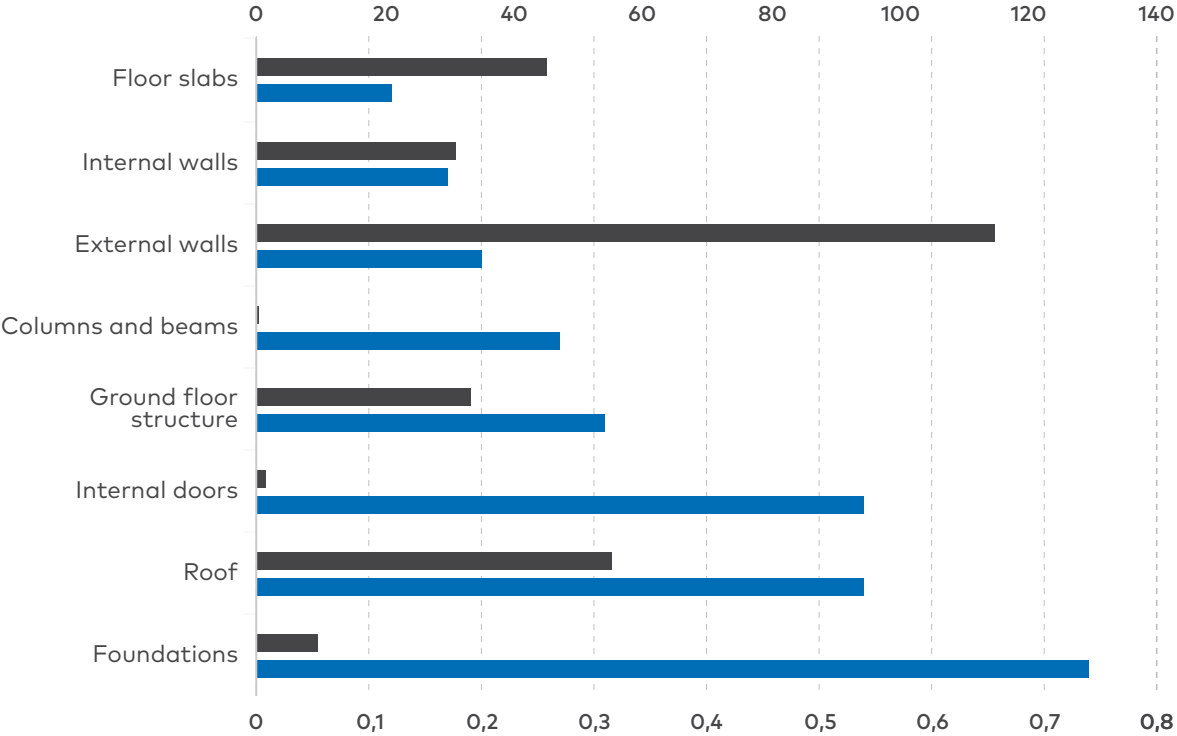
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A3, B4, C3-C4

External doors and windows dominate the element GWP ranking, which in parts is due to the low impacts of the remaining elements. The roof has a relative high impact due to its large dimension relative to the building geometry. Foundations and ground floor deck have a reduced impact due to screw technology.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

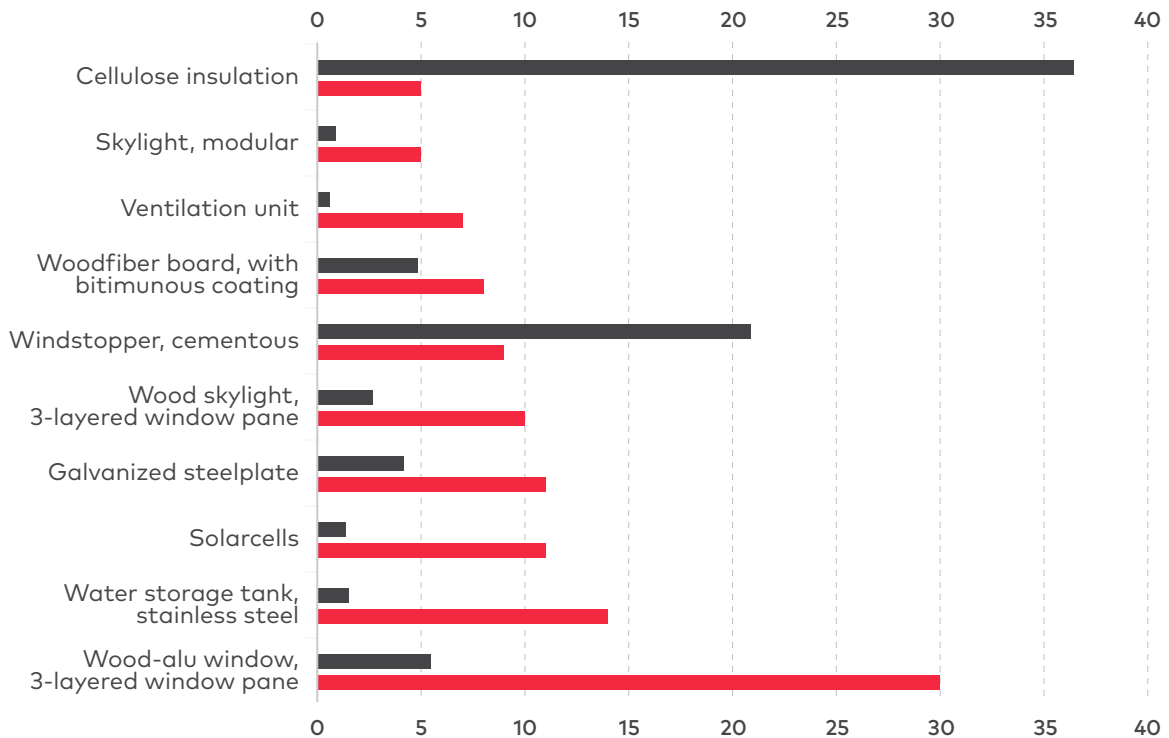
Material inventory: All materials
Life cycle modules: A1-A3, B4, C3-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

The steel screw foundations show a low weight, but a relatively high carbon intensity. Due to the lightweight structure, the roof has a rather large carbon intensity per weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3, B4, C3-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Façade windows dominate the product GWP ranking, especially when also including the skylight windows and panes. Note that windows are modelled with a series of products.

Other high impacts are in the heating system and solar cells.



Photos by Helene Høyer Mikkelsen, Realdania By og Byg

04 MiniCO₂ Etagehus TRÆ

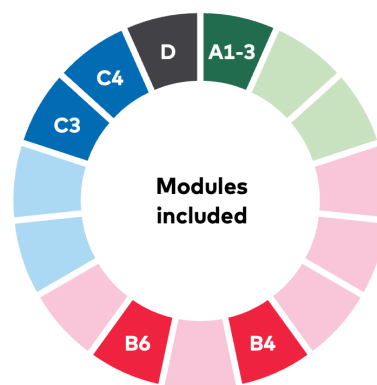
Denmark

Building use	Apartment building	Stories above ground	5
Location	Kongens Stræde 90, 7000 Fredericia, Kanalbyen	Basement area	—
Client	Realdania By og Byg	Structural system	Column-beam timber frame
LCA consultant	Artelia A/S	Façade type	Wood
Year of completion	2024	Roof type	Pitched roof
Reference area	576.7 m ² (gross floor area)	Heat demand /source	District heating

The building is part of an experimental project by Realdania By og Byg that includes several buildings, each in its own primary material. The project included stakeholders and contributors; JAJA Arkitekter, Egil Rasmussen, Blumer-Lehmann and Artelia A/S. The purpose of MiniCO₂ has been to construct the buildings primarily in wood and then compare them with similar buildings in other materials such as concrete and brick. The project sets requirements for the experimental buildings that enable them to be compared in terms of carbon footprint and strength. The test building will function as a residential building and is designed with one dwelling per floor. The five-storey building stands on a pile foundation and a reinforced concrete foundation slab. The ground floor is made of concrete, with EPS as insulating material. The building's load-bearing structures consist of CLT, glulam and steel. The insulating materials are primarily wood fibre and mineral wool in select places. The lightweight exterior walls are built as a timber frame, primarily insulated with wood fibre. The façades are clad with cedar, and the interior surfaces are clad with fibre plaster. The lightweight inner walls are timber frame structures with fibre plaster. The floor decks are constructed as ribbed decks with CLT and glulam and are insulated with paper wool. Special attention has been paid to meeting acoustic requirements between floors, which can be a challenge without the use of concrete. The roof is a timber beam and rafter structure.

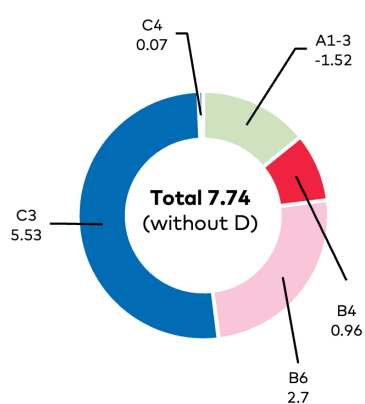
Assessment method

LCA scheme compliance	—
LCA tool version	LCAbyg 5
Life cycle stages included	A1-A3, B4, B6, C3, C4, D
Material emission data	Generic Danish database used in LCAbyg and DGNB and EPD
Material decarbonisation scenario	—
Energy calculation method	According to building regulations
Energy, dynamic scenario	Dynamic development of energy supply according to frozen policy, based on an official national report from 2020

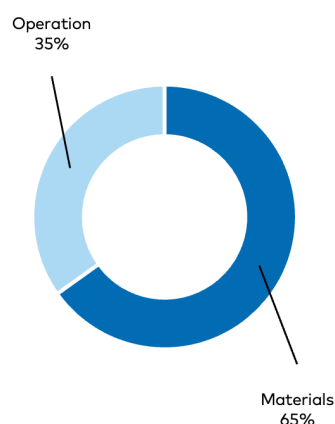


LCA results: Life cycle modules

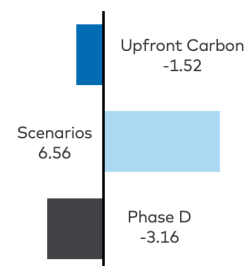
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

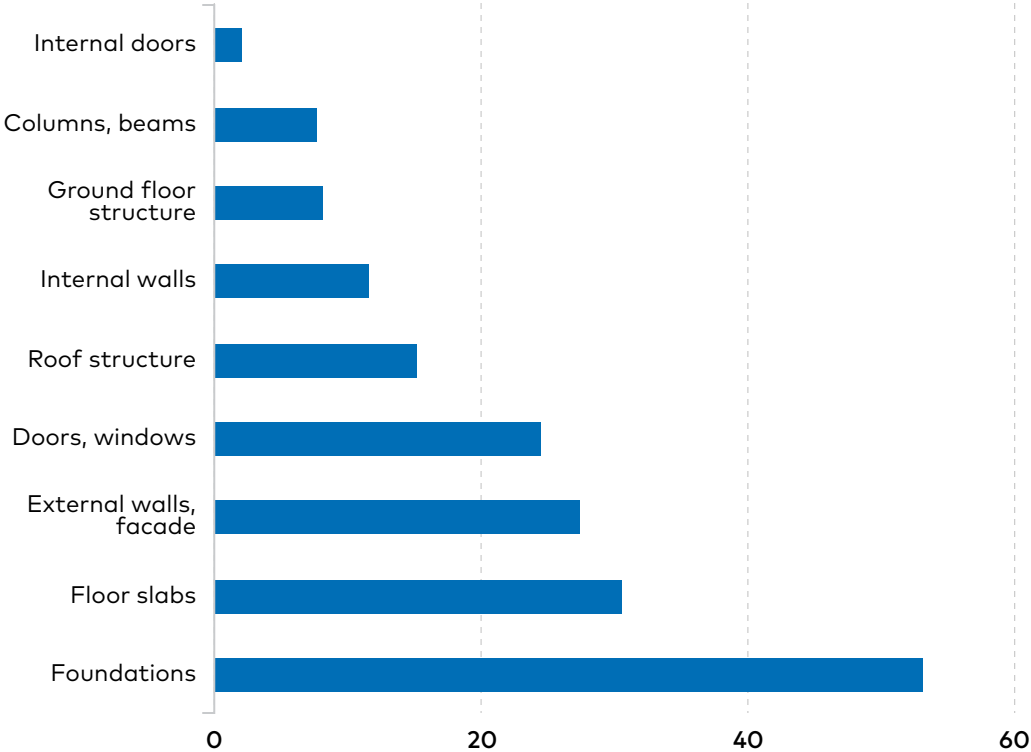


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary reflects the current Danish practice, including a minimum number of modules of all stages. Impacts are below the current limit value of 12.0 and the low-emission level of 8.0 kgCO₂e/m²a. In the second figure, Operation includes B6, while materials include A1-A3, B4, C3-C4. In the third figure, Upfront includes A1-A3, scenarios include B4, C3-C4, and D is shown separately. Upfront impacts are negative due to the large share of biogenic materials.

LCA results: Building elements



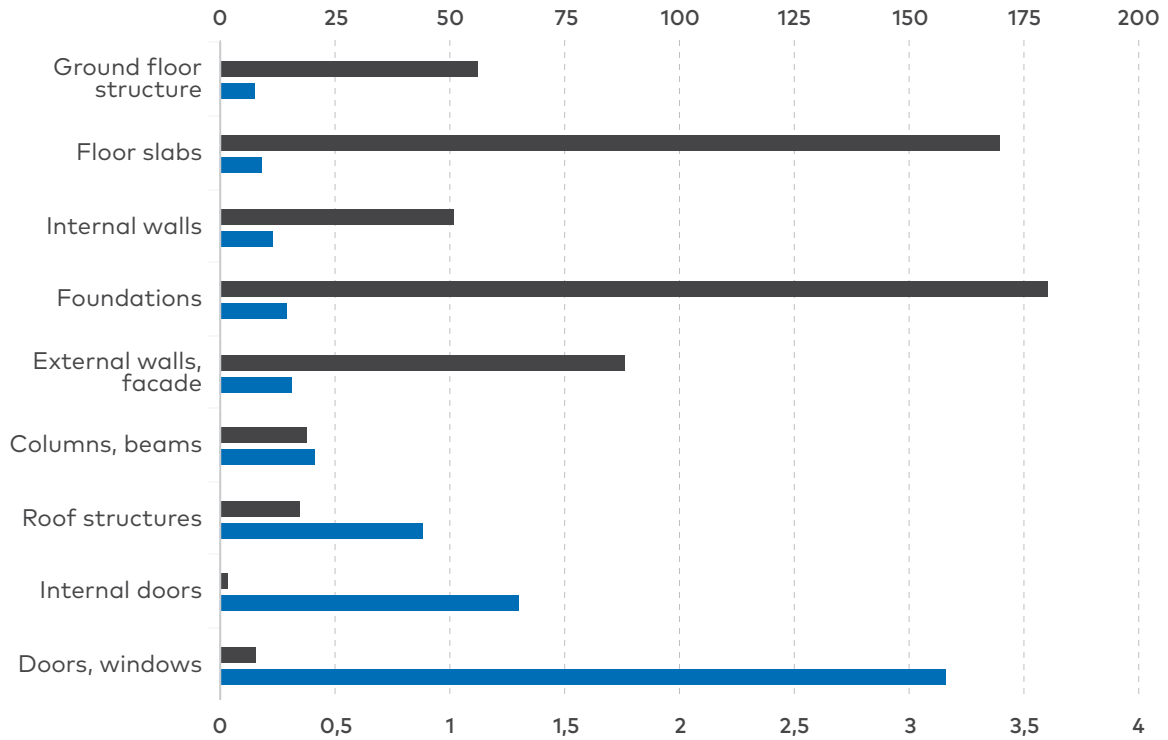
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A3, B4, B6, C3-C4

Foundations include deep-rammed concrete piles and have the largest relative impacts. In a multi-storey building, floor slabs are relevant too, even though the building has been optimised for balancing both acoustic and fire performance.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

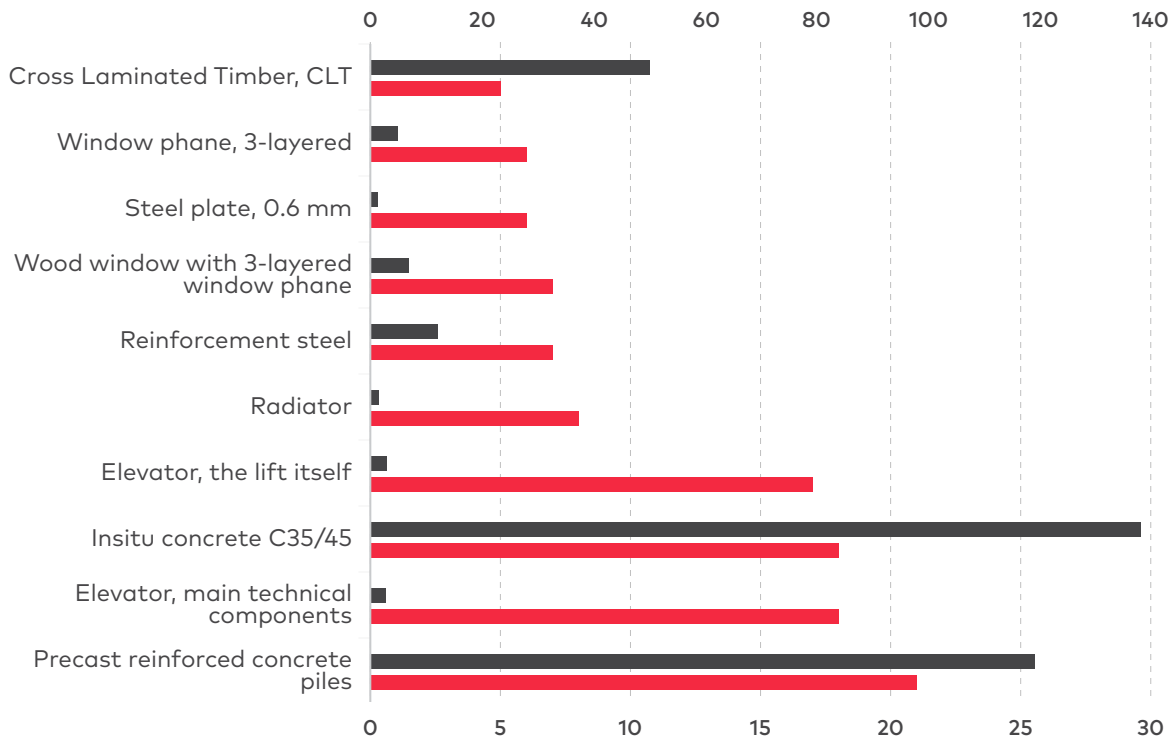
Material inventory: All materials

Life cycle modules: A1-A3, B4, B6, C3-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3, B4, B6, C3-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Based on its coastal location, rammed concrete piles are the single highest impact products, followed by the elevator and concrete for foundations. In non-test conditions, two instead apartments instead of one would share an elevator, halving its relative emissions.



Photo ssby Lõunakeskus OÜ

05 Lõunakeskus Commercial Building

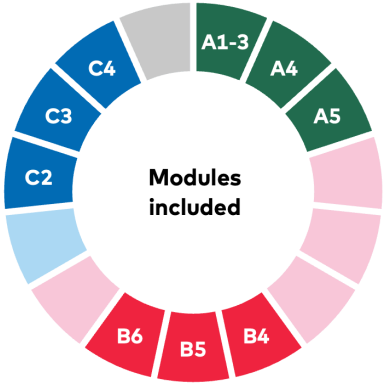
Estonia

Building use	Retail and restaurant / Office	Stories above ground	2
Location	Ränirahnu tee 21 Räni, 61708, Estonia	Basement area	—
Client	Lõunakeskus OÜ	Structural system	Steel beams, columns and concrete slabs
LCA consultant	LCA Support	Façade type	Wood composite, aluminium panels
Year of completion	2024	Roof type	Flat roof
Reference area	4043.5 m ² (heated floor area)	Heat demand /source	District heating and solar cells

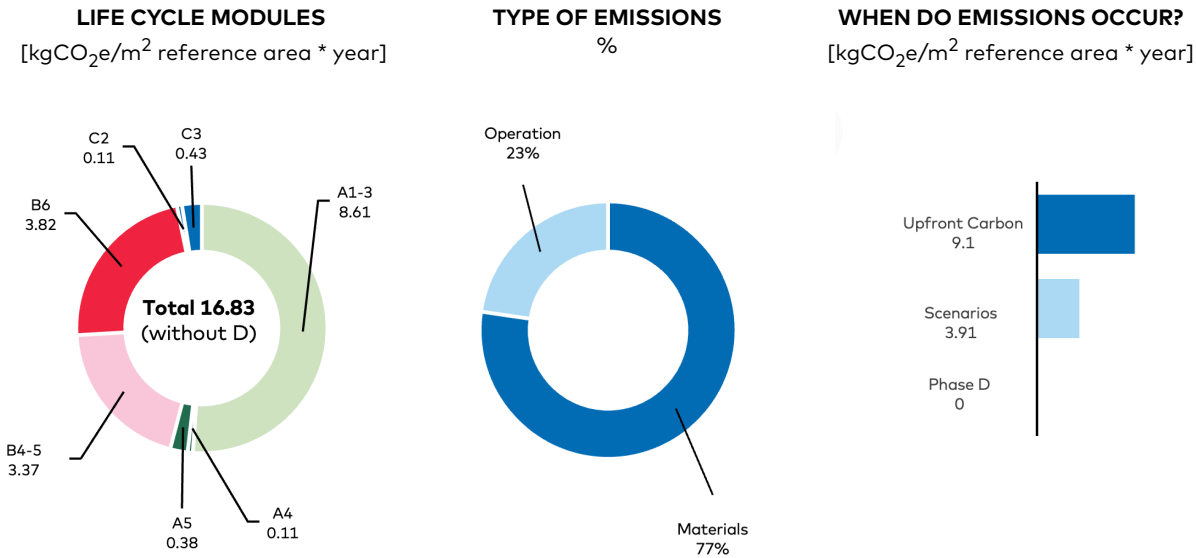
Estonian retail property developer Astri Group built a new standalone building Ränirahnu tee 21 in the Lõunakeskus retail park for an IKEA plan and order point, the Masku furniture store, the Tartu University Clinic radiology clinic and laboratory and a Pristis office. As Estonians' residual energy mix is one of the dirtiest in Europe, the most effective way to lower CO₂ emissions for new buildings, is to invest in energy generation and savings. For energy generation, Astri Group's energy company Roheline Astri OÜ built a 350-kW solar park on the roof of a building, which will produce more electricity than the building consumes. The surplus electricity will be directed to the Lõunakeskus shopping park via a local distribution grid. Ränirahnu tee 21 is hooked up to Gren's district heating and cooling network in order to lower emissions. The new building also uses Estonian-based R8 software, which uses AI to lower overall energy consumption and provide grid services via virtual power plant. The building has received an energy rating of A, with an energy efficiency rating of 33 kWh/m²a, which is several times better than the required level. Astri Group was one of the first in Estonia to voluntarily calculate the life cycle assessment (LCA) of climate impact for new buildings, and a similar analysis was also done for Ränirahnu tee 21. The parking lot is prepared for up to 30 electric vehicle charging stations, with two 50 kW and 2,150 kW chargers installed in the first phase.

Assessment method

LCA scheme compliance	—
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4, B4-B6, C2-C4
Material emission data	OneClick LCA database 7.6
Material decarbonisation scenario	—
Energy calculation method	—
Energy, dynamic scenario	Dynamic development of energy supply. Ministry of the Environment of Estonia 2020-2070 CO ₂ values.

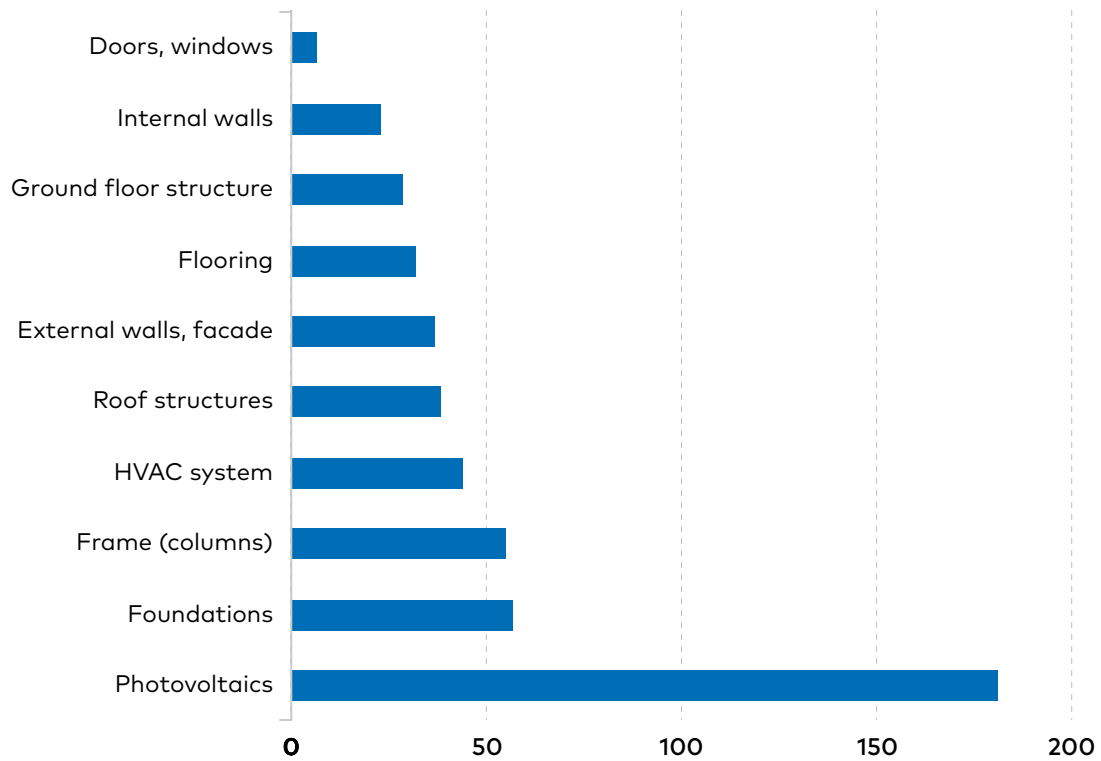


LCA results: Life cycle modules



The LCA includes a range of modules from all life cycle stages. The product stage is slightly higher than the use stage. In the second figure, Operation includes B6, while materials include A1-A5, B4-B5, C2-C4. In the third figure, Upfront includes A1-A5, scenarios include B4-B5, C2-C4, and D is shown separately. Upfront and scenarios are relatively balanced due to the inclusion of future replacements and refurbishment.

LCA results: Building elements



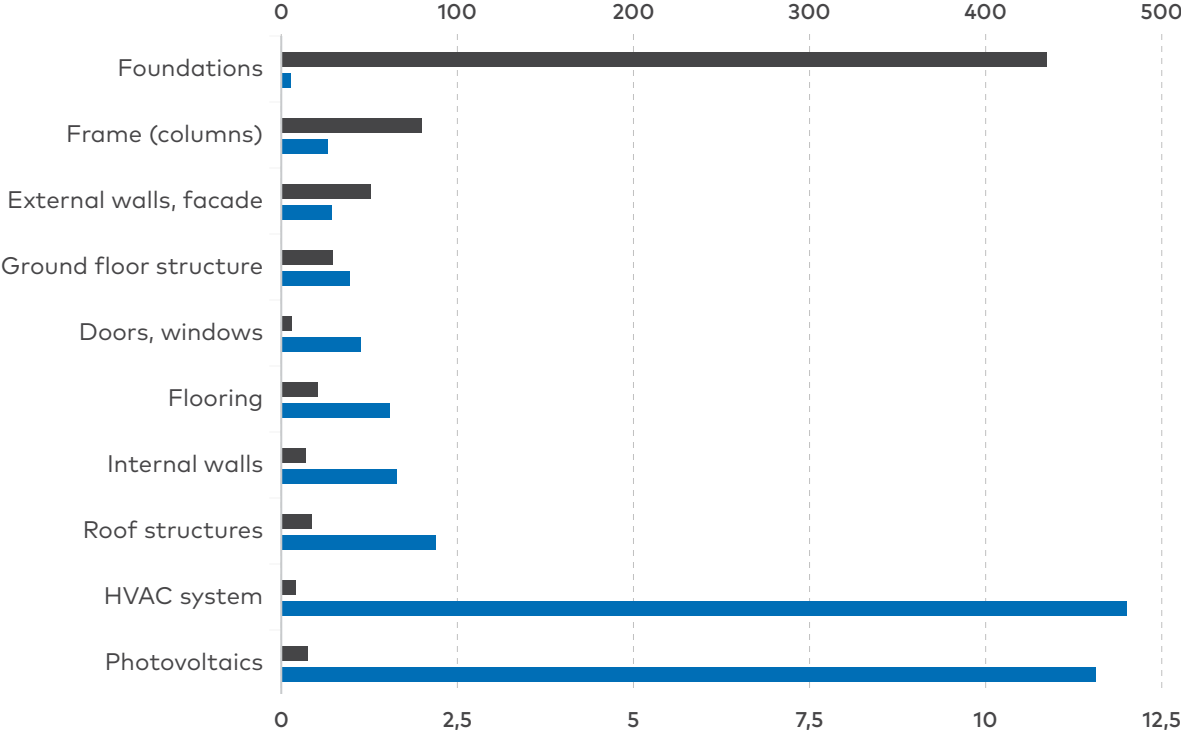
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B1-B5, C1-C4

The dominating impacts stem from the extensive photovoltaic system on the flat roof of this department store. Other characteristic impacts relate to foundations and the structural frame, followed by the roof.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

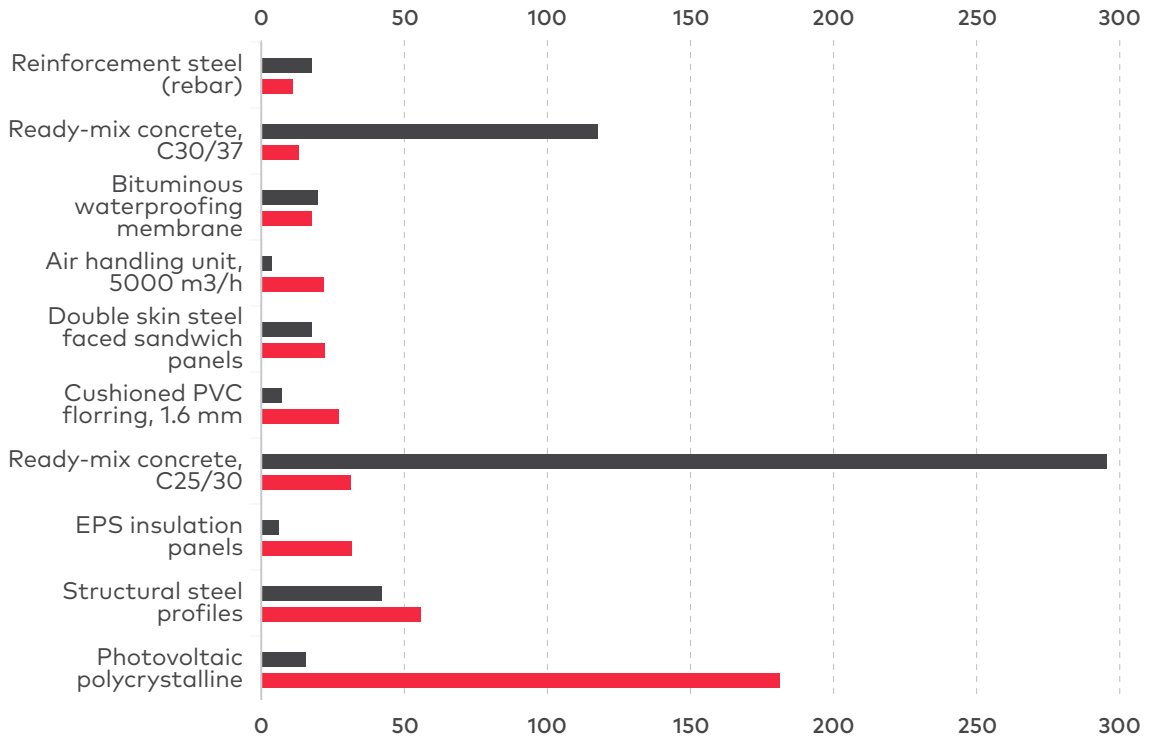
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A3, B4, C3-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for material intensity, while product impacts per building reference area are a measure for carbon intensity.

Solar cells are the dominating product due to the size of the photovoltaic roof system. The structural steel members have a high recycled content, reducing impacts of this potential hot spot.



Photos by Bonava Estonia OÜ

06 Aiandi street 11 Mustamäe Tallinn

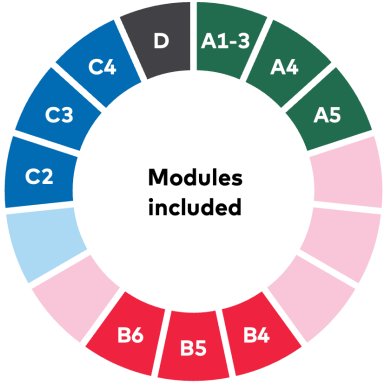
Estonia

Building use	Apartment building	Stories above ground	8
Location	Aiandi tn 11/1 Mustamäe LO Tallinn 12915, Estonia	Basement area	—
Client	Bonava Estonia OÜ	Structural system	hollow core panels+ load bearing walls
LCA consultant	Bonava Latvia (tbc)	Façade type	EPS+ plaster
Year of completion	2024	Roof type	Flat roof
Reference area	2305 m ² (gross floor area)	Heat demand /source	District heating and solar cells

The Aiandi 11/1 residential building is located in the Mustamäe area of Tallinn, which was previously occupied by greenhouses and a flea market. This particular plot consists of three different houses varying in size and number of floors. An LCA (Life Cycle Assessment) calculation has been conducted as a pilot project for the 8-floor building. The project marks Bonava Estonia's first endeavour into calculating the CO₂ footprint. The CO₂ calculation was performed in the late phase of the project, so no direct measures were implemented to reduce the footprint. However, several measures have been incorporated into the building. Solar panels are installed on the roof to generate electricity for common areas and electric cars. Bicycle spaces and charging options for electric devices were added to encourage the use of light scooters and low-emission vehicles, reducing CO₂ emissions. Faucets with limited flow were used to reduce water consumption. We explored energy-efficient designs and included features such as heat retention, air tightness, efficient district heating and ventilation with heat recovery. Green roofs were used to mitigate the heat island effect caused by asphalt surfaces. The project was undertaken to understand the content and methodology of CO₂ calculation and to explore the principles of its implementation, aiming to make smarter decisions in the early phases of future projects. Currently, we are also pursuing BREEAM certification and are achieving the 'Excellent' level. However, the certification application is still in progress and has not yet been issued.

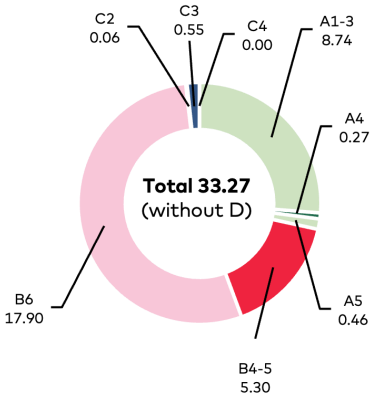
Assessment method

LCA scheme compliance	—
LCA tool version	One click LCA
Life cycle stages included	A1-A5, B4-B5, B6, C2-C4
Material emission data	OneClick LCA database and EPD's
Material decarbonisation scenario	—
Energy calculation method	—
Energy, dynamic scenario	Dynamic development of energy supply. For district heat, LCA study for country-specific district heating based on IEA, OneClick LCA 2023. For electricity, Ministry of the Environment of Estonia 2020-2070 CO ₂ values

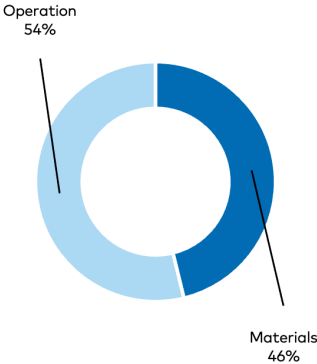


LCA results: Building elements

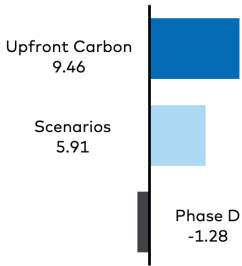
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

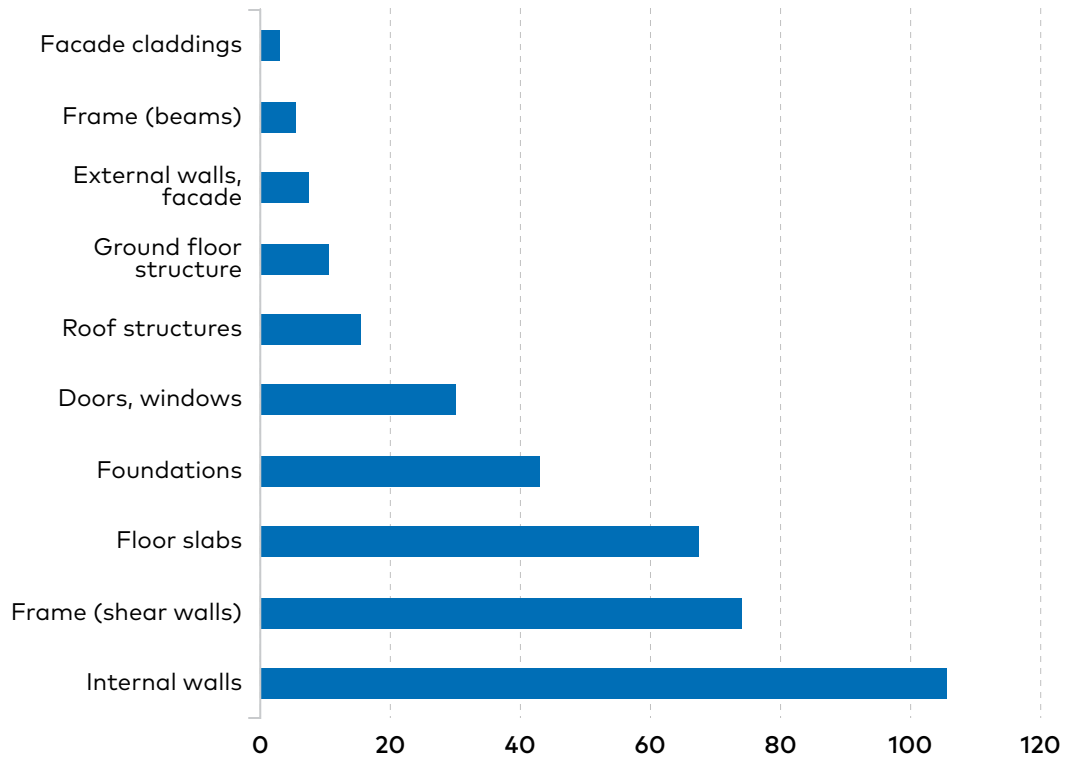


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes a share of all life cycle stages. In the second figure, *Operation* includes B6, while materials include A1-A5, B4-B5, C2-C4. In the third figure, *Upfront* includes A1-A5, scenarios include B4,-B5, C2-C4 and D is shown separately.

LCA results: Building elements



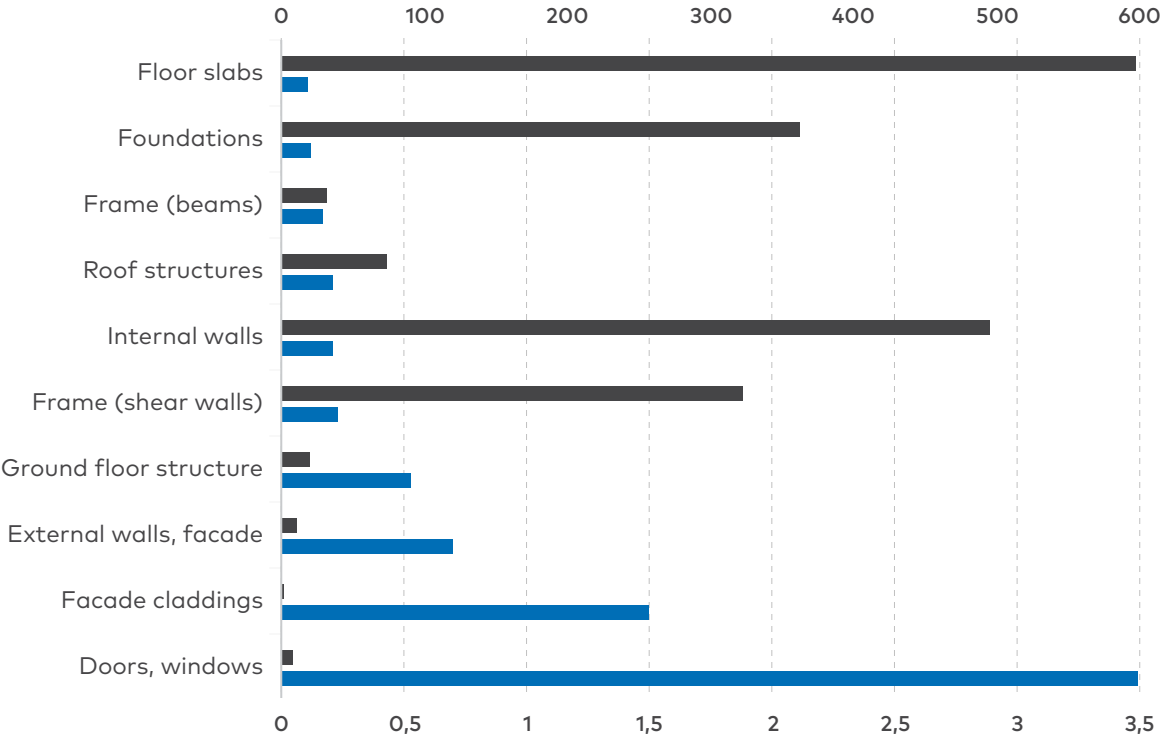
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4-B5, C2-C4

The structural system including load-bearing walls, floor slabs and foundations have the highest impacts.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

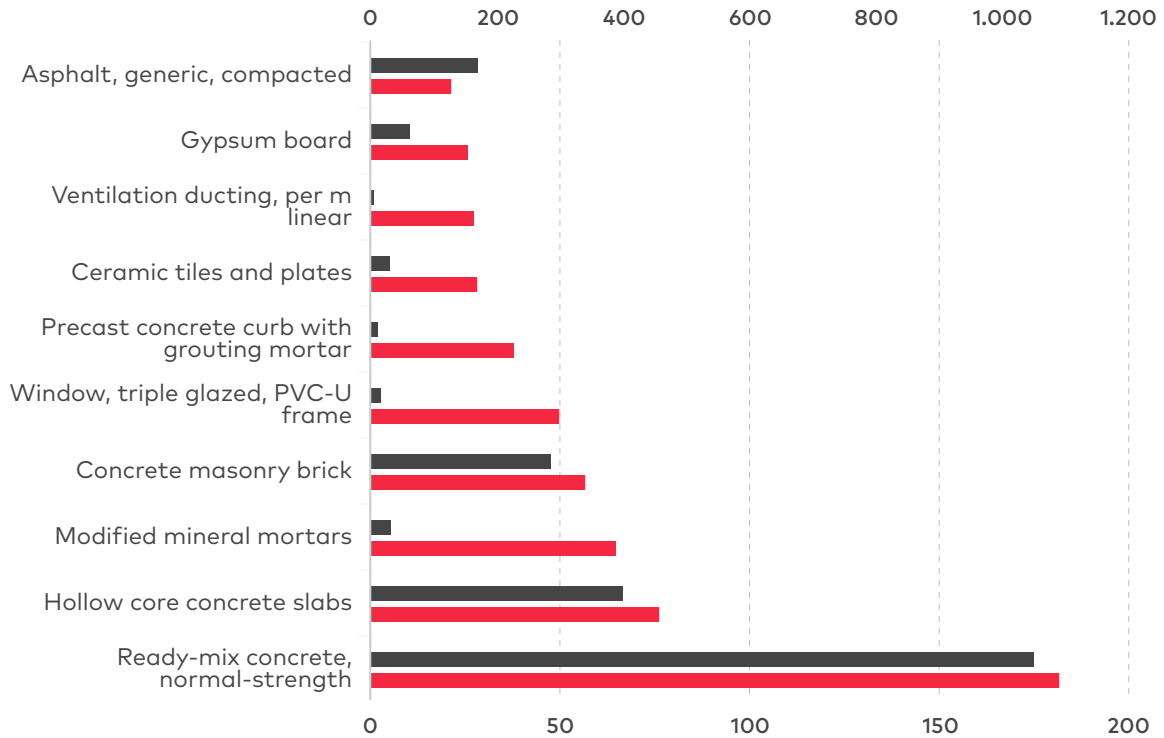
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A5, B4-B5, C2-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

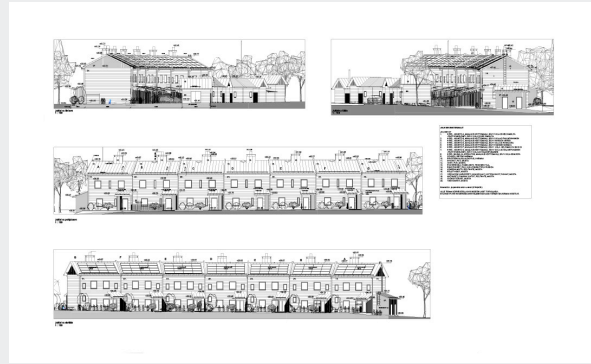
Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Also at product level, the structural system including concrete for the foundations and prefabricated floor slabs are dominating.



Photo by Asunto Oy Haapaperhosen Aarre



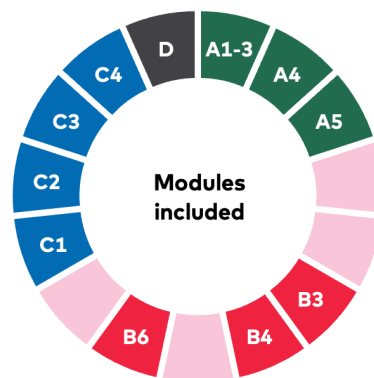
07 Honkasuon Aarraitat Finland

Building use	Terraced house	Stories above ground	2
Location	Haapaperhosentie 27, Helsinki	Basement area	—
Client	Asunto Oy Haapaperhosen Aarre	Structural system	Massive log construction
LCA consultant	GreenCons Oy	Façade type	Massive log façade
Year of completion	2023	Roof type	Gable roof
Reference area	830 m ² (Heated floor area)	Heat demand /source	Heat pumps

The project consists of seven terraced two-storey homes, located in Helsinki, Finland. The main goal was to build a project that has a Carbon Handprint that is bigger than its carbon footprint. This was achieved better than expected, the CO₂ handprint is almost double compared to the CO₂ footprint. The second sustainability goal was cultural: we wanted to show the advantages of the traditional Nordic massive log construction in finding solutions to the urgent problems of modern day building and sustainable forest use. The specific sustainability measures implemented in this project were maximising the carbon storage, minimising technology and energy use and maximising photovoltaic power and heat pumps. The whole project is based on circularity principles: the bearing log frames, floors, ceilings, insulations, clay renderings, windows, doors, fixtures etc. are all designed and built for deconstruction and reuse. The spaces are multifunctional, and the log frames can be converted to other uses or relocated whole or in parts if necessary. The innovations in this project are based on local materials and ancient local tradition and handcrafts and applying those in innovative ways. The project's LCA was first conducted in the concept phase, then in the design phase and a third time after construction. It gave an insight to how the ambitious sustainability goals were met and facilitated discussions with the building officials. The most significant result was that it is possible to build regeneratively. We are in close contact with the end users/residents and monitor how everything works and how satisfied the users are with their homes.

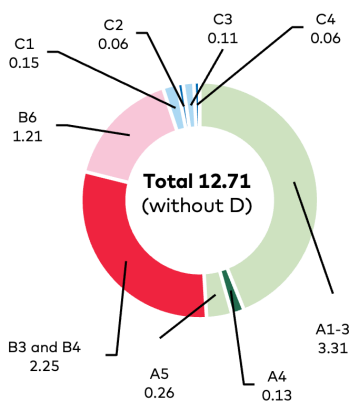
Assessment method

LCA scheme compliance	Method for the whole-life carbon assessment of buildings (Finnish Ministry of the Environment)
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B3, B4, B6, C1-C4, D
Material emission data	Generic Finnish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy Performance Certificate (Finnish)
Energy, dynamic scenario	Energy decarbonisation scenario according to the Finnish method; (most likely) benefit-sharing method

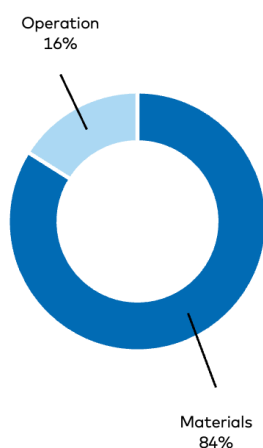


LCA results: Life cycle modules

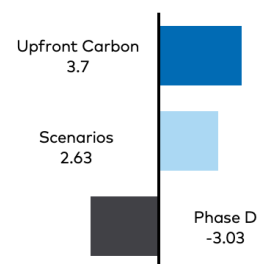
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

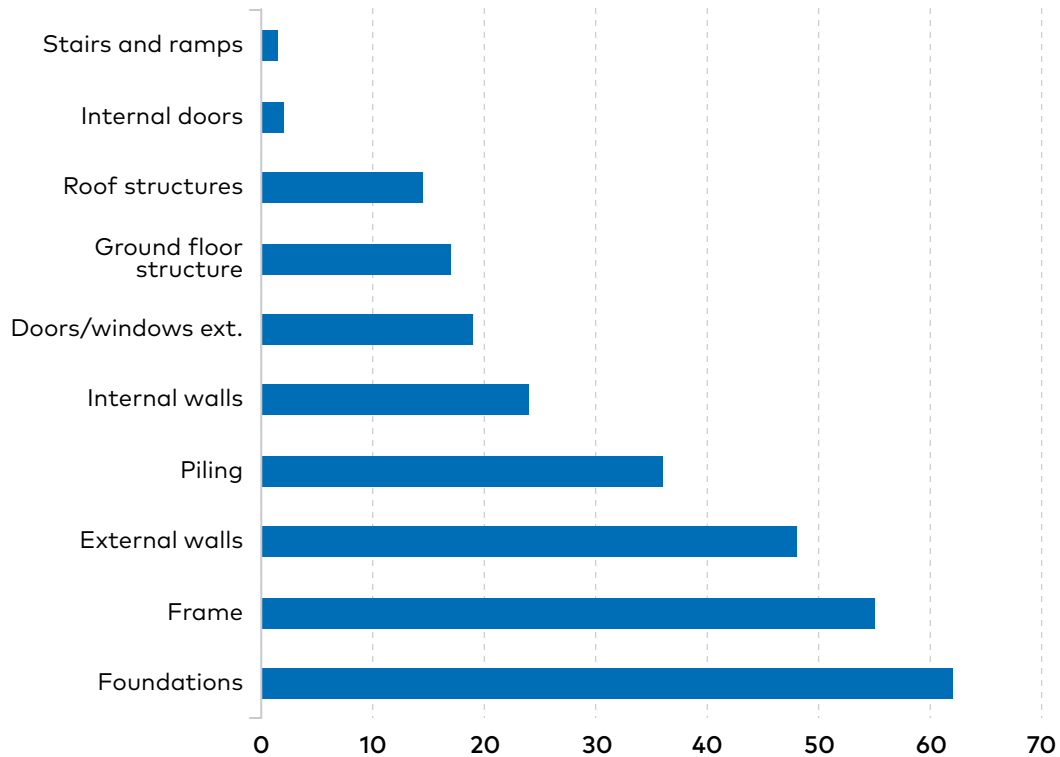


The system boundary covers almost all life cycle modules, where the product stage is dominating the overall impacts, followed by repairs and replacements. Beyond the building materials, the assessment also includes building energy systems/installations such as electrical cables, HVAC, water pipes, sewage pipes, heating systems (heat pump) as well as solar PV panels.

In the second figure, *Operation* includes B6, while materials include A1-A5, B3-B4, C1-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B3-B4, C1-C4, and D is shown separately.

LCA results: Building elements



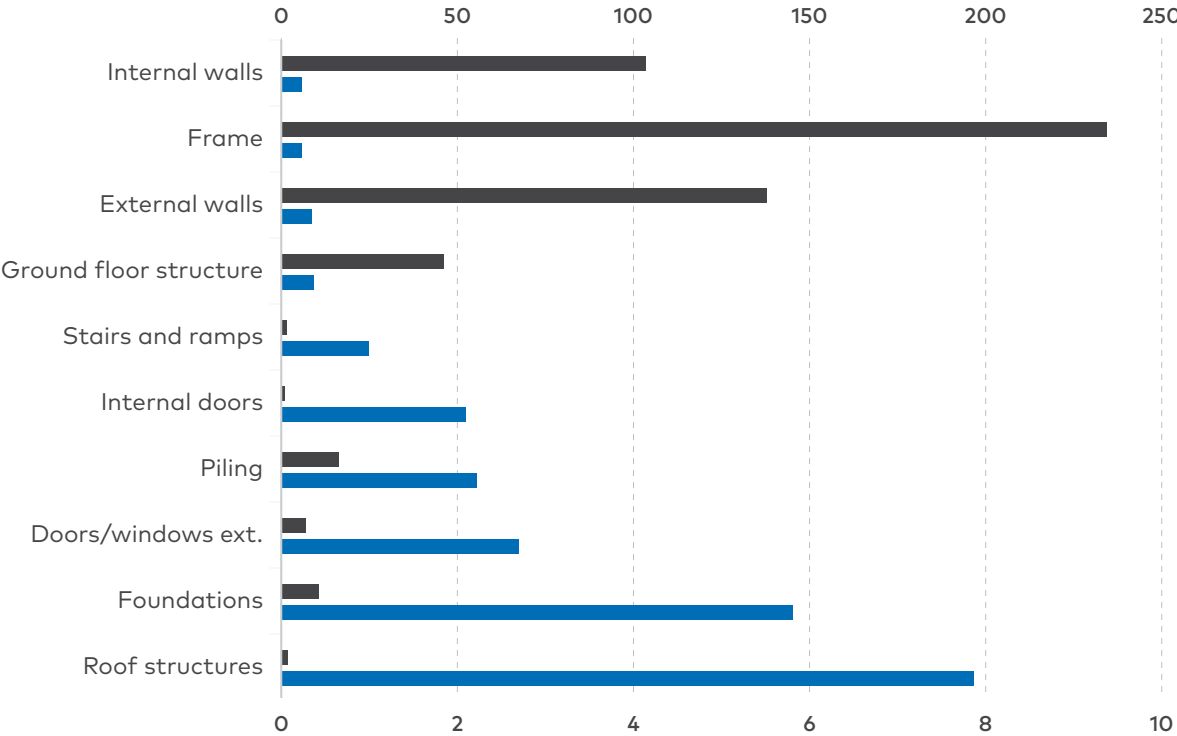
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B3-B5, C1-C4

Strip foundations and massive wood log frame dominate the building element GWP. External and internal walls as well as piling are also relevant, while the roof has a relatively low impact for low-rise constructions. All the technical components and piping for electricity, water etc. were included in the estimation, with a combined impact of 115 kgCO₂e/m² reference area (not included in the figure).

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

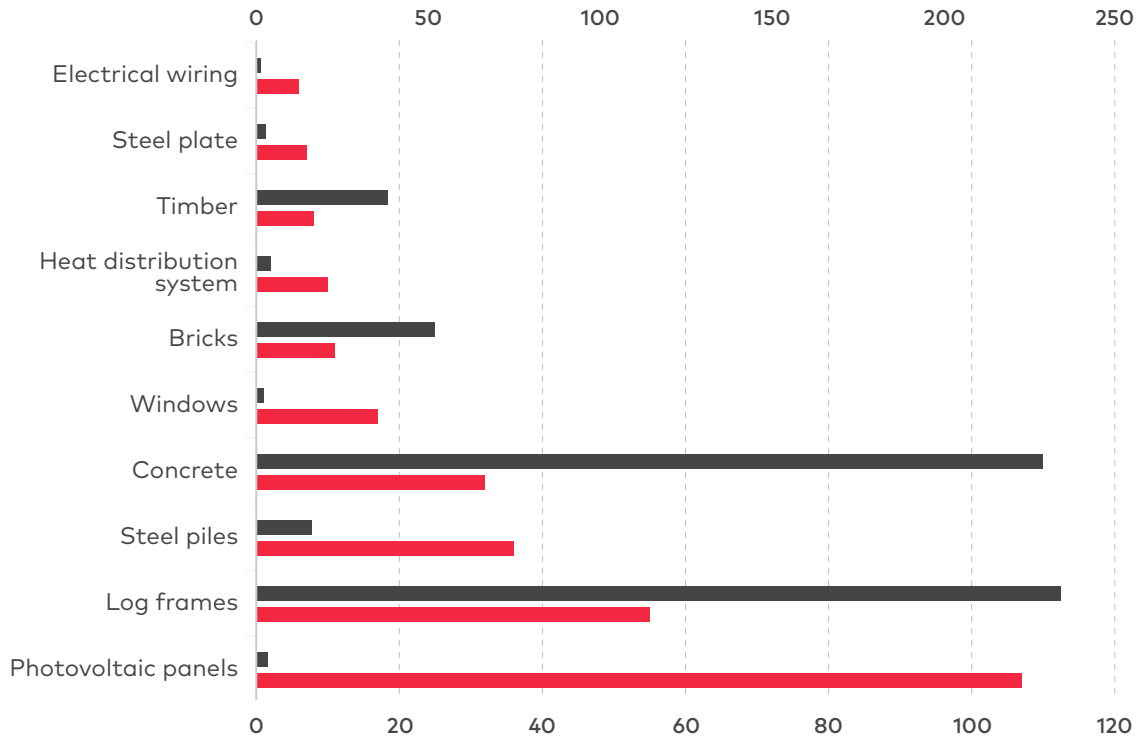
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A5, B3-4, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B3-5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The use of solar cells is also reflected in the material impacts, while most other products are ranging well below. Here, the timber logs used for the walls are followed by the steel pile foundations and concrete for the foundation.



Photo by Jesper Arvidsson, Jespers Foto & Repro



Photo by Alexander Fallahi, Dachser Sweden AB

08 Wooden closed apartment block

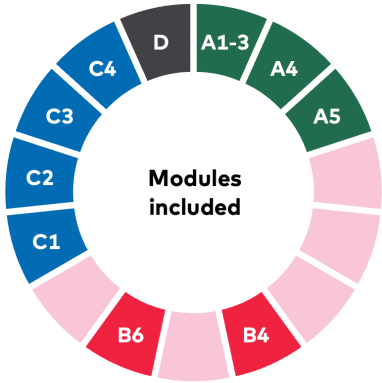
Finland

Building use	Apartment building	Stories above ground	6
Location	Lavakatu 9 A & B, 00120 Helsinki	Basement area	—
Client	A-Kruunu Oy	Structural system	Wood
LCA consultant	Insinööri (AMK)	Façade type	Wood panelling
Year of completion	2024	Roof type	Flat roof – wood-framed with bitumen felt
Reference area	6,465 m ² (heated floor area)	Heat demand /source	District heating and solar panel

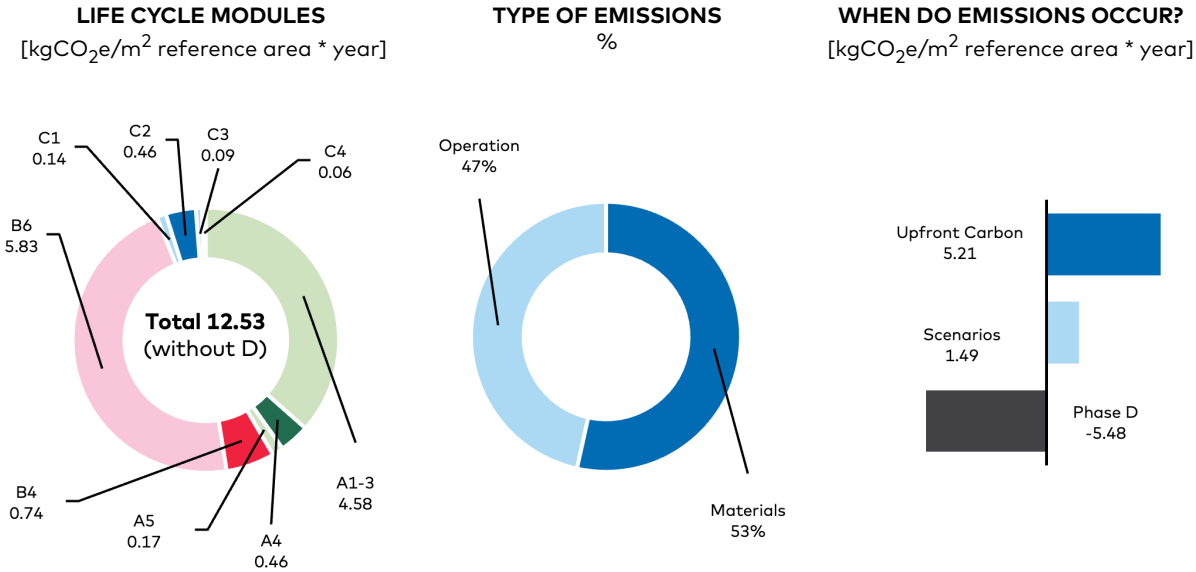
The wood apartment block in Postipuisto, Helsinki won the City of Helsinki's Asuntoreformi architecture competition, aiming at exploring urban wood construction. This was the first project for A-Kruunu implementing CLT for the frame in a large urban residential block. The architectural design optimises the use of daylight for the interior and common areas and a greenhouse was provided in the exterior. According to the LCA calculation, the project has a reduced carbon footprint of approximately 20% over its life cycle compared to an average concrete building. To make sure the life cycle emissions stay low, the houses were built with a class A energy level target, which currently is best in class in Finland. In addition, A-Kruunu only uses green energy sources for heating and electricity. In addition to the reduced carbon footprint, A-Kruunu uses wood to create visibility and piloting opportunities for the wood construction industry in Finland. Crucial for the success of the project was the collaboration partner JVR-Rakenne with their wood construction and project management expertise. That also helped to stay within budget, which is especially important for A-Kruunu working the social housing field. The apartment rents are lower than market rents in the area, as targeted. At the same time, no compromises were made in the standard of living.

Assessment method

LCA scheme compliance	Method for the whole-life carbon assessment of buildings (Finnish Ministry of the Environment)
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4, B6, C1-C4, C
Material emission data	Generic Finnish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy Performance Certificate (Finnish)
Energy, dynamic scenario	Energy decarbonisation scenario according to the Finnish method; (most likely) benefit-sharing method

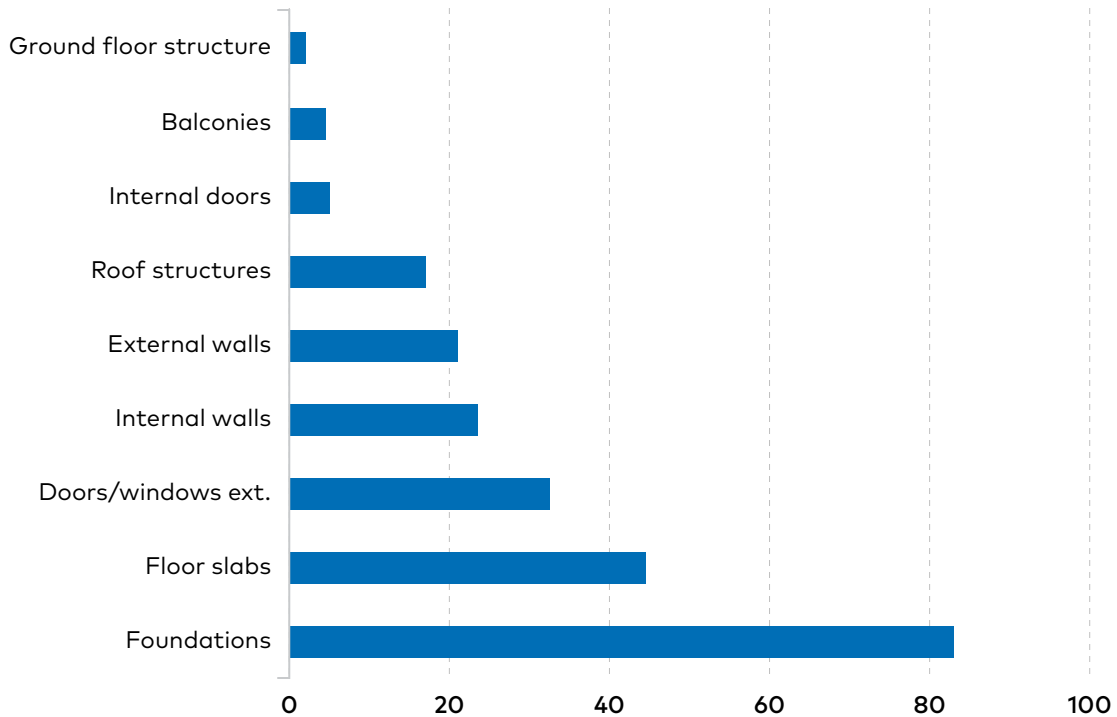


LCA results: Life cycle modules



The system boundary covers almost all life cycle modules, where the product stage is dominating the overall impacts, followed by repairs and replacements. Beyond the building materials, the assessment also includes a detailed inventory of building services (lifts and escalators, electricity system, renewable energy systems). In the second figure, *Operation* includes B6, while materials include A1-A5, B4, C1-C4. In the third figure, *Upfront* includes A1-A5, scenarios include B4, C1-C4, and D is shown separately.

LCA results: Building elements



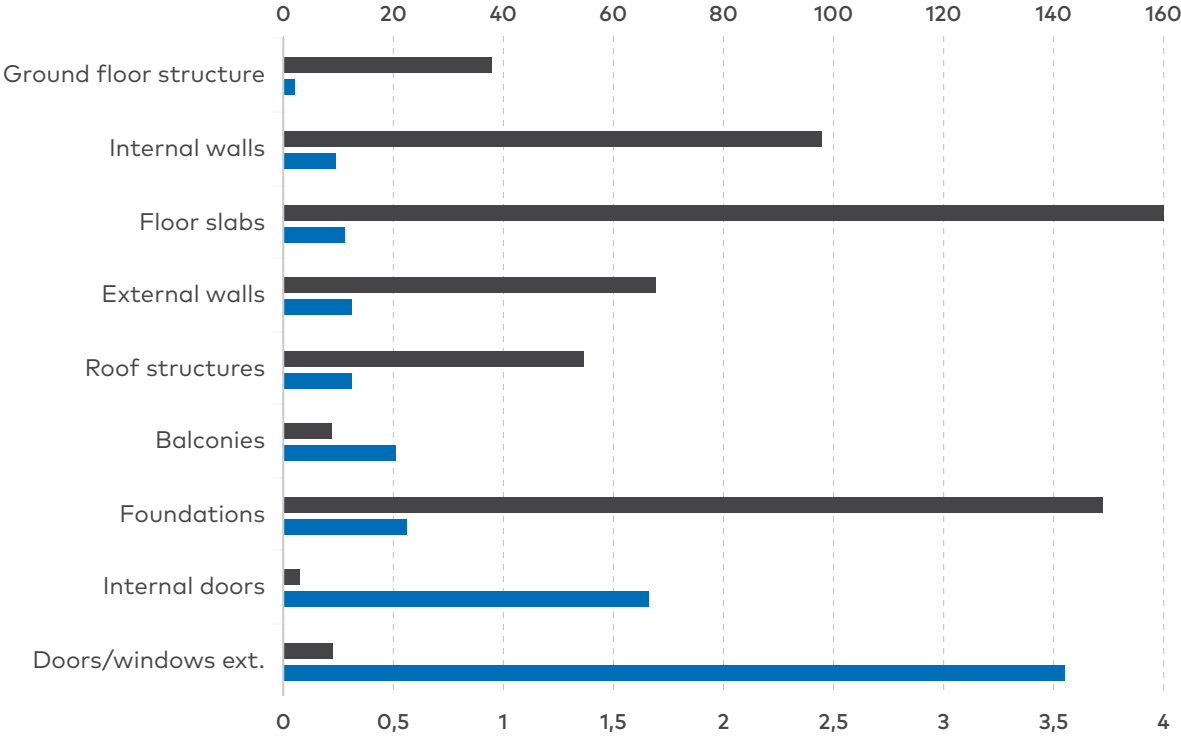
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4-B5, C1-C4

Waterproofing is included in the ground floor structure, finishes and coverings are included in walls, flooring is included in floor slabs, exterior cladding is included for the exterior walls and roof structure. The technical components included in this assessment have a total impact of 71.5 kgCO₂e/m² reference area (not included in the figure).

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

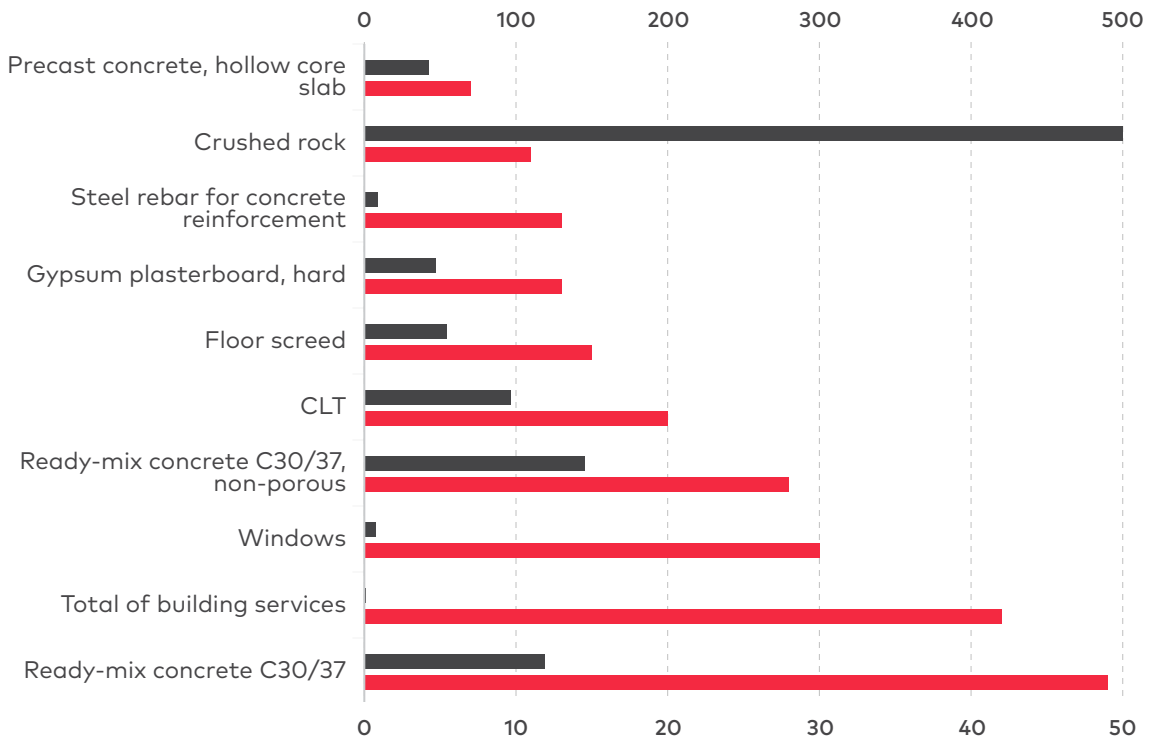


Material inventory: All materials
Life cycle modules: A1-A5, B4-B5, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B4-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos by Union Investment

09 Wood city Office II

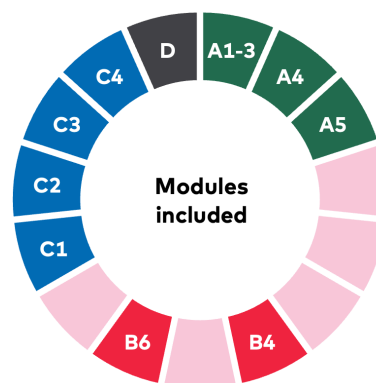
Finland

Building use	Office	Stories above ground	7
Location	Jätkäsaarenlaituri 1, 00180 Helsinki	Basement area	900 m ²
Client	WithSecure Oyj	Structural system	Steel
LCA consultant	Sustera, Vantaa, Finland	Façade type	Column-beam system (GLT) - CLT-hybrid slab (CLT + concrete)
Year of completion	2024	Roof type	Bituminous roofing felt on mineral wool insulation
Reference area	18,327 m ² (gross floor area)	Heat demand /source	District heating

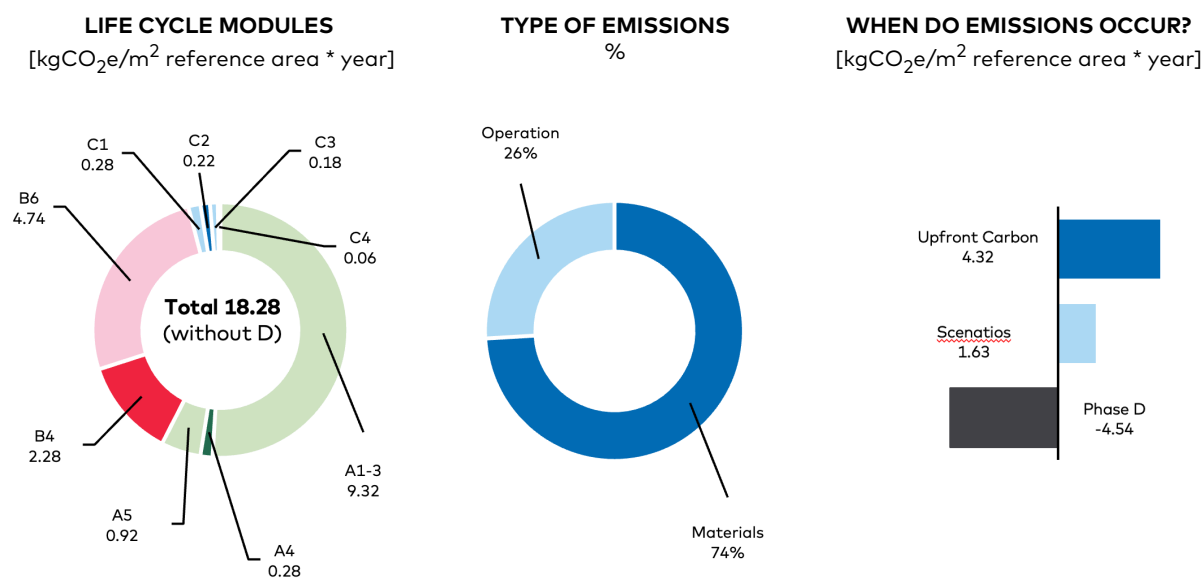
The 8-story wooden office building in Jätkäsaari, Helsinki, completed in 2024, is a low-carbon pioneer in Finnish office construction. It features 1,200 m³ structural timber, including a CLT intermediate floor plan and wooden façades, which are rare for office buildings. Besides the timber solutions, which have been innovated for this project, one of the remaining carbon hot spots are the steel structures with particularly high emissions, for which alternative solutions had to be found. Additional efforts include achieving low energy consumption during operation as well as low-emission product solutions, documented by environmental product declarations. Effective cooperation with the customer has enabled an accurate calculation result. Based on a preliminary calculation, the carbon footprint of the site was presented to the Client during the construction phase during the site visit.

Assessment method

LCA scheme compliance	Method for the whole-life carbon assessment of buildings (Finnish Ministry of the Environment), LEED Platinum
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4, B6, C1-C4, D
Material emission data	Generic Finnish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy Performance Certificate (Finnish)
Energy, dynamic scenario	Energy decarbonisation scenario according to the Finnish method; (most likely) benefit-sharing method



LCA results: Life cycle modules

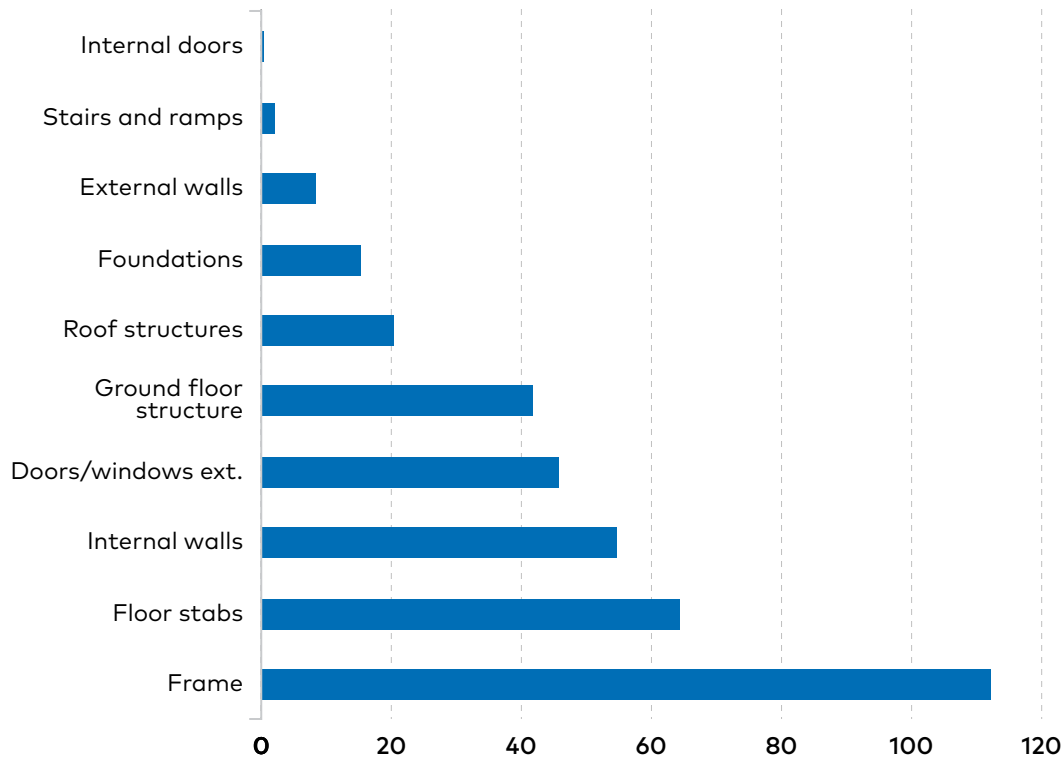


The system boundary covers almost all life cycle modules, where the product stage is dominating the overall impacts, followed by energy use. Building services are modelled in detail (lifts and escalators, electricity system, HVAC system, renewable energy systems, water system).

In the second figure, *Operation* includes B6, while materials include A1-A5, B4, C1-C4

In the third figure, *Upfront* includes A1-A5, scenarios include B4, C1-C4, and D is shown separately.

LCA results: Building elements



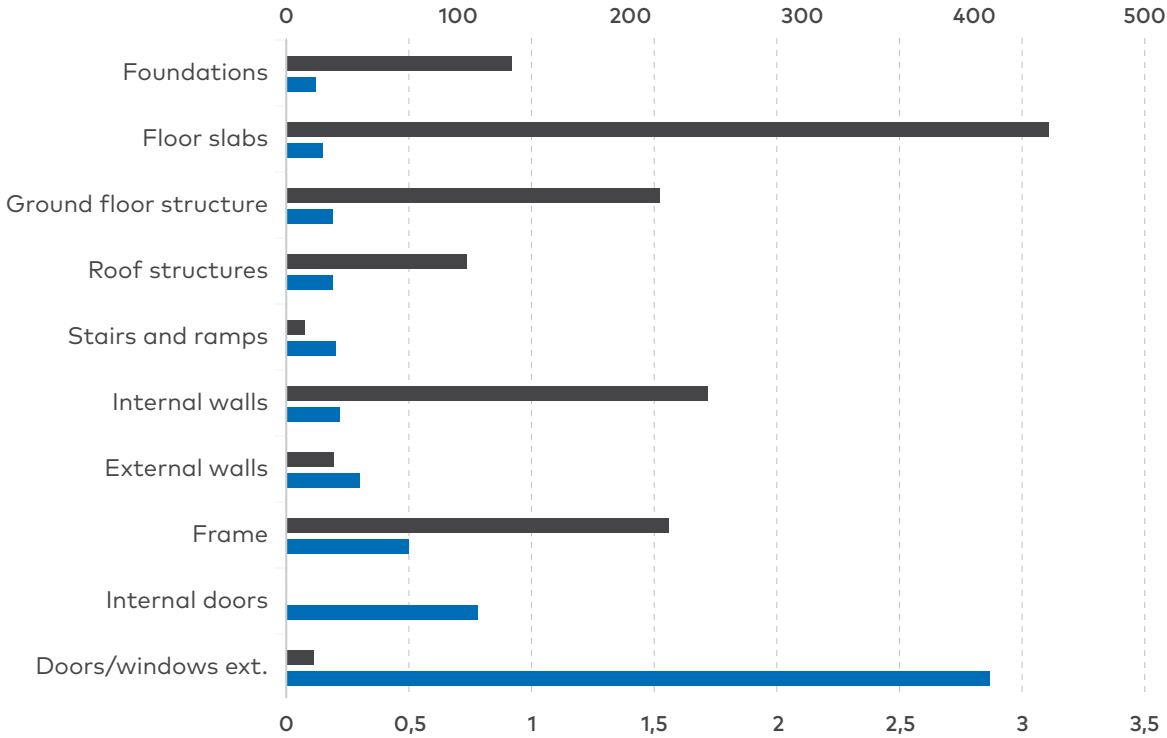
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4, C1-C4

Basement walls are included in the frame. Floor slabs include flooring and ceiling. Interior walls include finishes and coverings. Both the roof structure and exterior walls include exterior cladding. All the technical components and piping for electricity, water etc. were included in the estimation. Combined, they have an impact of 95 kg CO₂e/m² reference area (not included in the figure).

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO2e / kg building element]

■ Quantity/Area ■ GWP/Quantity

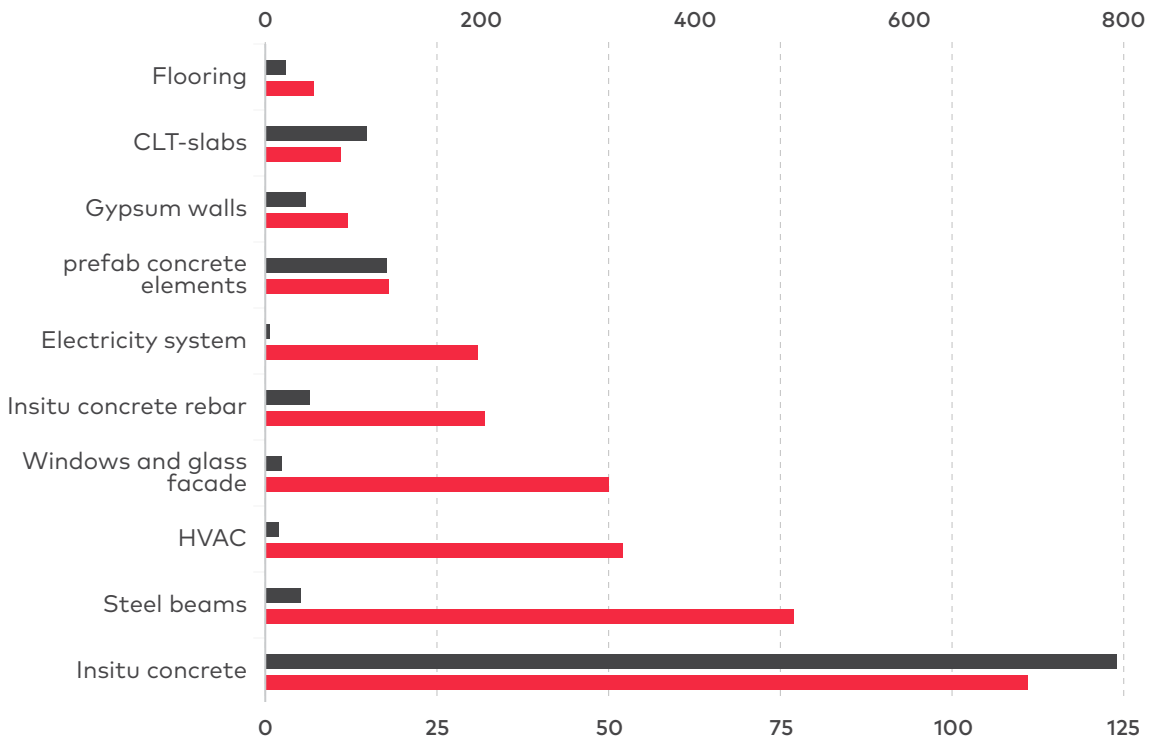
Material inventory: All materials
Life cycle modules: A1-A5, B4, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

The curtain wall façade is dominating the product list with the highest impacts, likely due to the large glazing area. Internal doors are likely a large number of glass doors with large dimensions.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The highest-ranking product is in-situ concrete, including all subtypes. This is followed by steel beams, HVAC systems and the curtain wall façade, reflecting a classic urban office building.



Photos by Y-Foundation, M2-Kodit Oy

10 Wood social housing

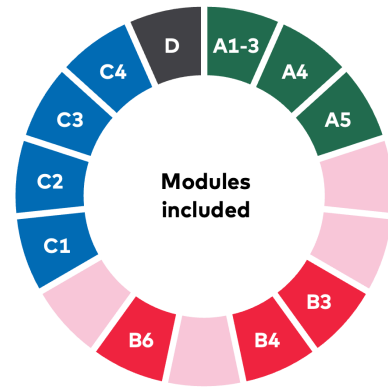
Finland

Building use	Apartment building	Stories above ground	4
Location	Vanhankallionkatu 5	Basement area	1 floor
Client	Y-Foundation, M2-Kodit Oy	Structural system	CLT sheets and volumetric elements
LCA consultant	Vesitaito	Façade type	Cladding
Year of completion	2021	Roof type	Tin roof
Reference area	1,490 m ² (heated floor area)	Heat demand /source	Central district heating

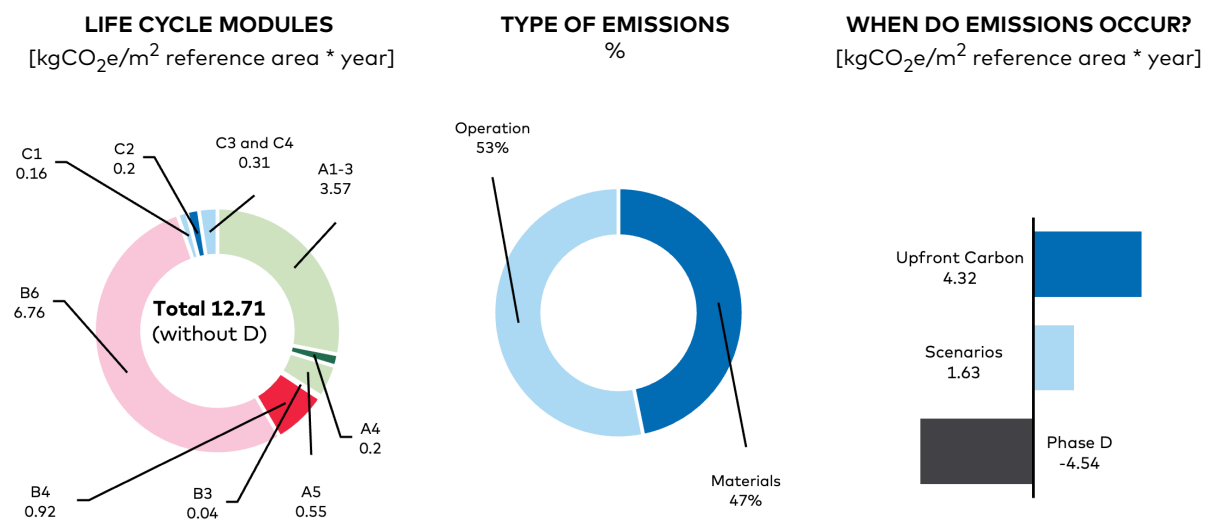
The project consists of two separate buildings and 48 apartments. Other facilities include outdoor equipment storage, space for storing baby carriages and a drying room. Building B also has a laundry room, sauna and a communal club room for use by the residents of both buildings. The load-bearing structure is wood and cross-laminated timber (CLT), resulting in a low carbon footprint. The 31.5 m² and 36 m² studios and 48 m² two room apartments are made with individual volumetric elements and the 64 m² three room apartments use two volumetric elements. The glazed balconies are also part of the volumetric elements. The elevator shafts and stairs are made of CLT sheets. Together with the façade cladding, they make the use of wood visible. The city plan specifies the roof shape and colour effects allowed in the area, which guided the design. The entire building has sprinklers, and the interior walls are clad with drywall. Rubber insulation between the volumetric elements cuts off the lateral displacement of sound. Work on site progressed as planned. Special effort was paid to the weather protection. The roof sections were assembled on site, leaving only the surface membrane uninstalled, and then put up for weather protection as element installation progressed. In both buildings, it took two months to build the ground floors and other concrete structures. Volumetric elements were prefabricated from CLT in Kuhmo and lifted into place on site under the protection of pre-assembled roof sections. On-site wood element installation took two weeks in both buildings, and the roofs were built on site in three weeks. It can be concluded that prefabrication has shortened the construction process, prevented damage from moisture and improved quality.

Assessment method

LCA scheme compliance	Method for the whole-life carbon assessment of buildings (Finnish Ministry of the Environment)
LCA tool version	OneClickLCA
Life cycle stages included	A1-A5, B4-B5, B6, C2-C4, D
Material emission data	Generic Finnish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy Performance Certificate (Finnish)
Energy, dynamic scenario	Energy decarbonisation scenario according to the Finnish method; (most likely) benefit-sharing method



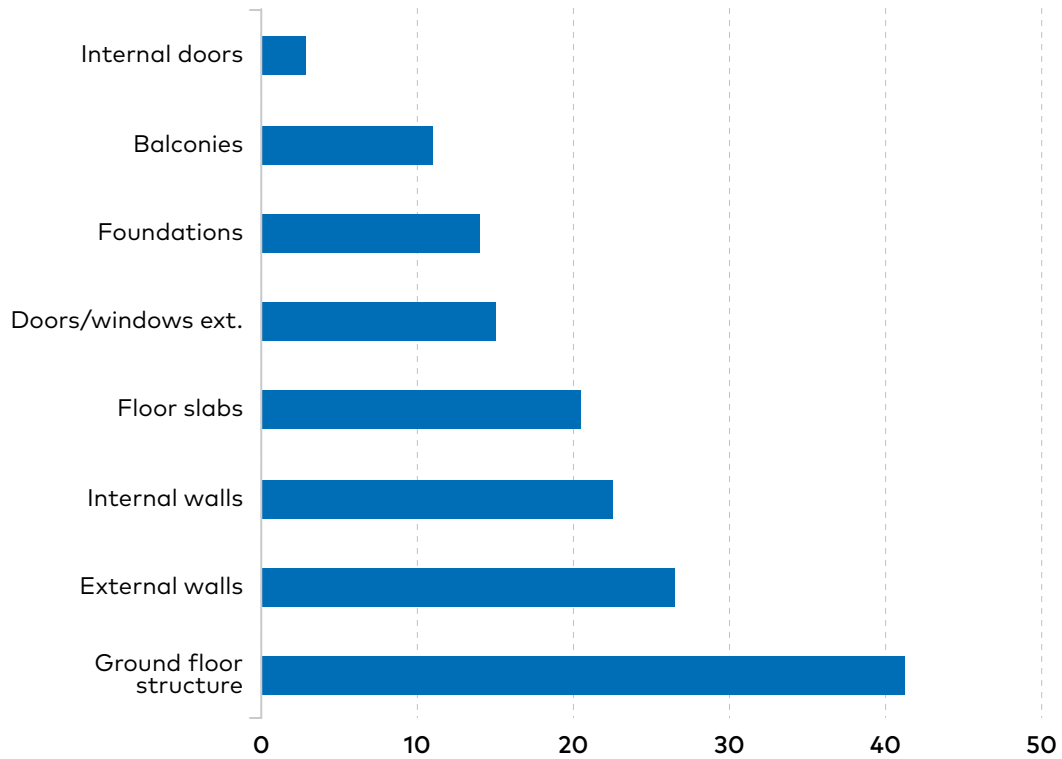
LCA results: Life cycle modules



The system boundary covers almost all life cycle modules, where the energy consumption is dominating the overall impacts, followed by the product stage. Building services are modelled in detail (lifts and escalators, electricity system, HVAC system, renewable energy systems, water system, heating system).

In the second figure, Operation includes B6, while materials include A1-A5, B3-B4, C1-C4. In the third figure, Upfront includes A1-A5, scenarios include B3-B4, C1-C4, and D is shown separately.

LCA results: Building elements



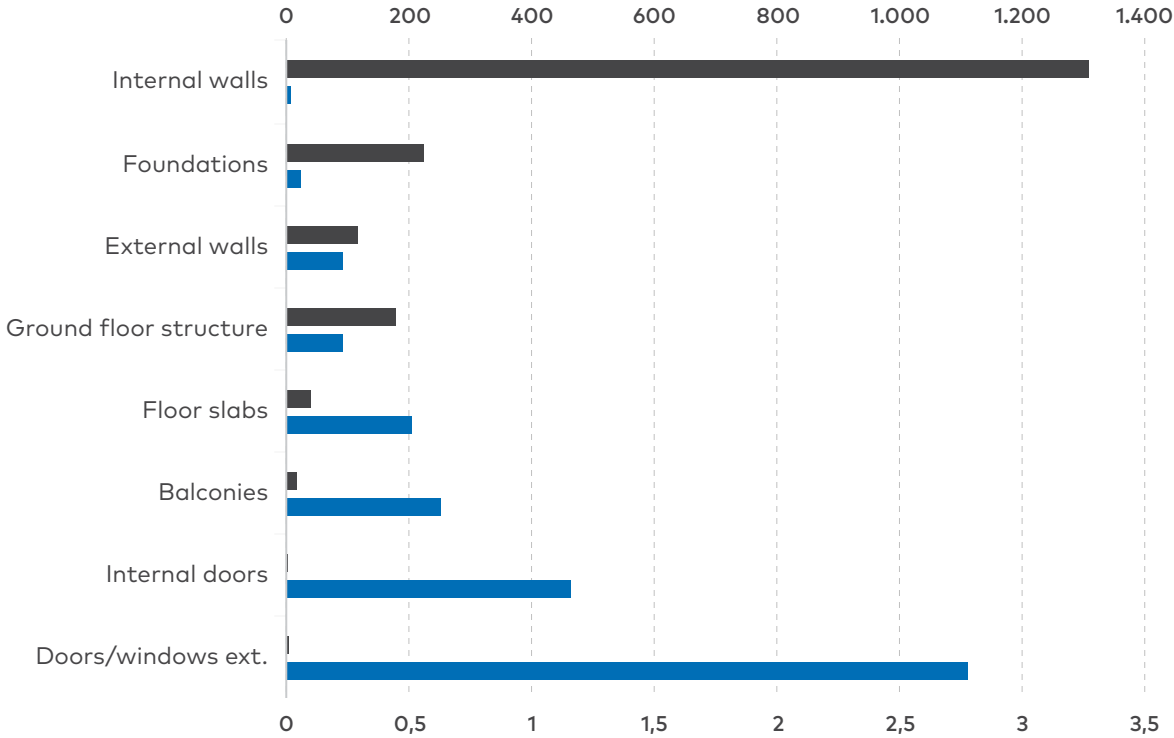
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B3-B4, C1-C4

The building is made with prefabricated space elements and is thus difficult to separate into individual elements. The roofing is most likely included in floor slabs. Internal walls include surfaces and finishes.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

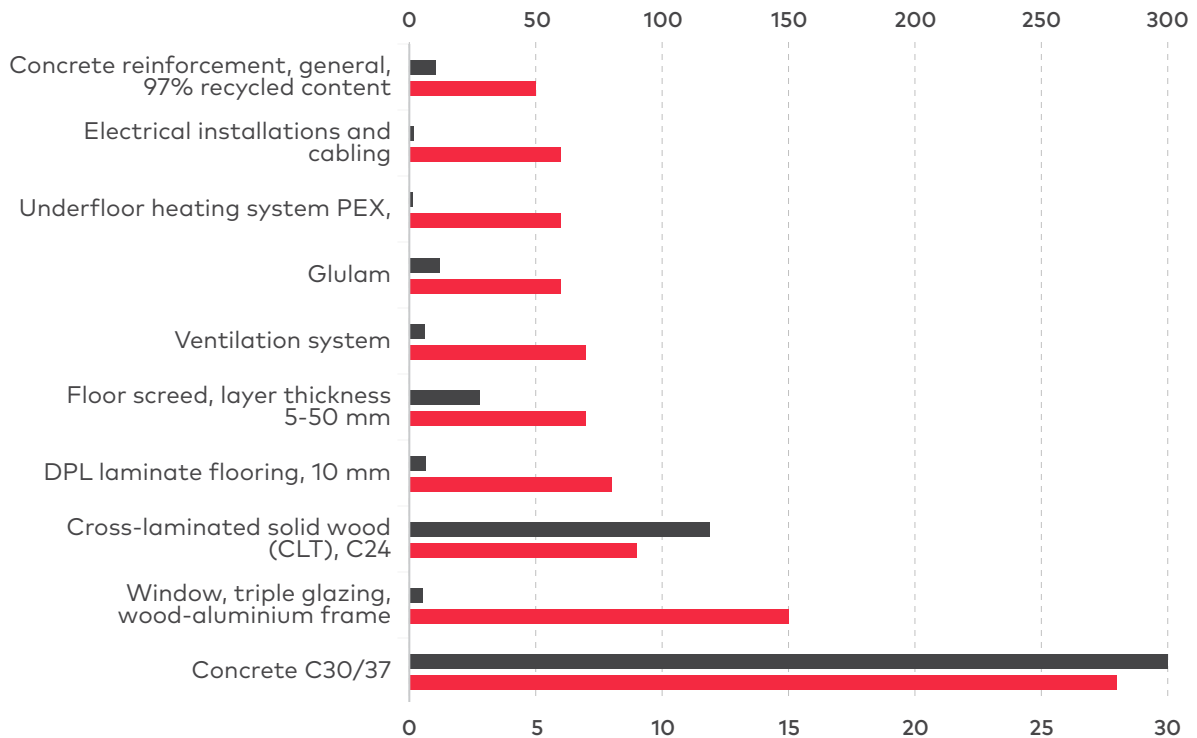
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A5, B3-B4, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

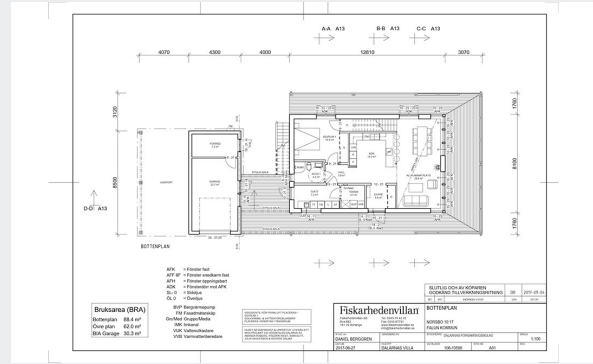
Life cycle modules: A1-A5, B3-B4, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

In this lightweight prefabricated structure, concrete for the ground floor deck is dominating the individual product impacts, followed by the triple-glazed windows and CLT.



Photo by Dalarnas Försäkringsbolag



Drawing by Fiskarhedenvillan AB

11 Dalarnas Villa

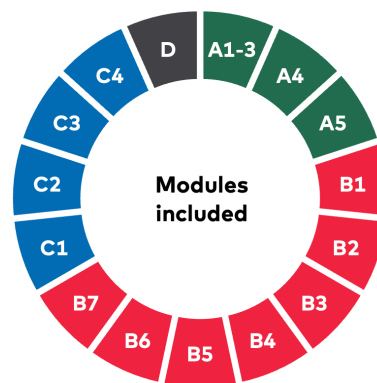
Sweden

Building use	Detached home	Stories above ground	2
Location	Dalarna, Sweden	Basement area	0 m ²
Client	Dalarnas Försäkringsbolag	Structural system	Column-beam timber frame
LCA consultant	Researcher: Bojana Petrovic, PhD project	Façade type	Wood cladding
Year of completion	2019	Roof type	Pitched roof
Reference area	180 m ² (Gross floor area)	Heat demand /source	Heat pump

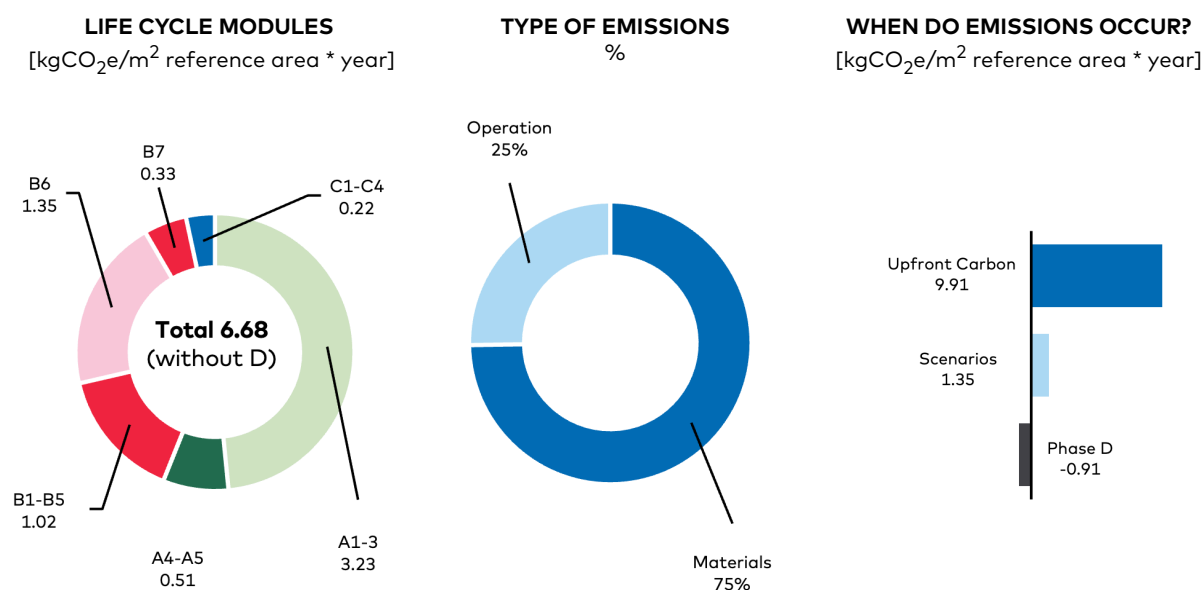
Dalarnas Villa was financed by the insurance company Dalarnas Försäkringsbolag, and was built in collaboration with stakeholders such as Dalarna University, Fiskarhedenvillan AB (house manufacturer and supplier of building materials) as well as other entrepreneurs specialising in building energy systems. This was among the first Swan-labelled single-family homes and many resources were invested into certifying the project. The main purpose of this project was to test, compare and evaluate sustainable solutions dominated by wood-based building materials and energy-efficient systems. The building's envelope consists of a wooden framework and wood panel façades, while concrete was only used in the foundation. Instead of using conventional insulation materials such as glass and rock wool, the idea was to install cellulose insulation for the external walls and for the ceiling, and wood fibre insulation was used for the internal walls' insulation. The roof is made of steel, while the doors and windows are a combination of glass and wood. Moreover, a major focus was on replaceable components; if any installation breaks, it should be easy to replace. In accordance with the forthcoming Boverket regulations for single-family residential buildings, entering into force on 1 July 2025, the proposed carbon emissions threshold for building materials (including phases A1-A5) is set at 180 kg CO₂e/m². The Dalarnas Villa home reported emissions of 130 kg CO₂e/m², representing a reduction of nearly 30% below the established reference limit. This outcome underscores the project's alignment with progressive sustainability targets and demonstrates the potential for carbon reduction in residential construction.

Assessment method

LCA scheme compliance	Svanen
LCA tool version	One Click LCA
Life cycle stages included	A1-3, A4-A5, B1-B5, B6, B7, C1-4, D
Material emission data	Mainly included EPDs with minor data based on Generic Swedish database
Material decarbonisation scenario	-
Energy calculation method	TMF energy programme
Energy, dynamic scenario	Non

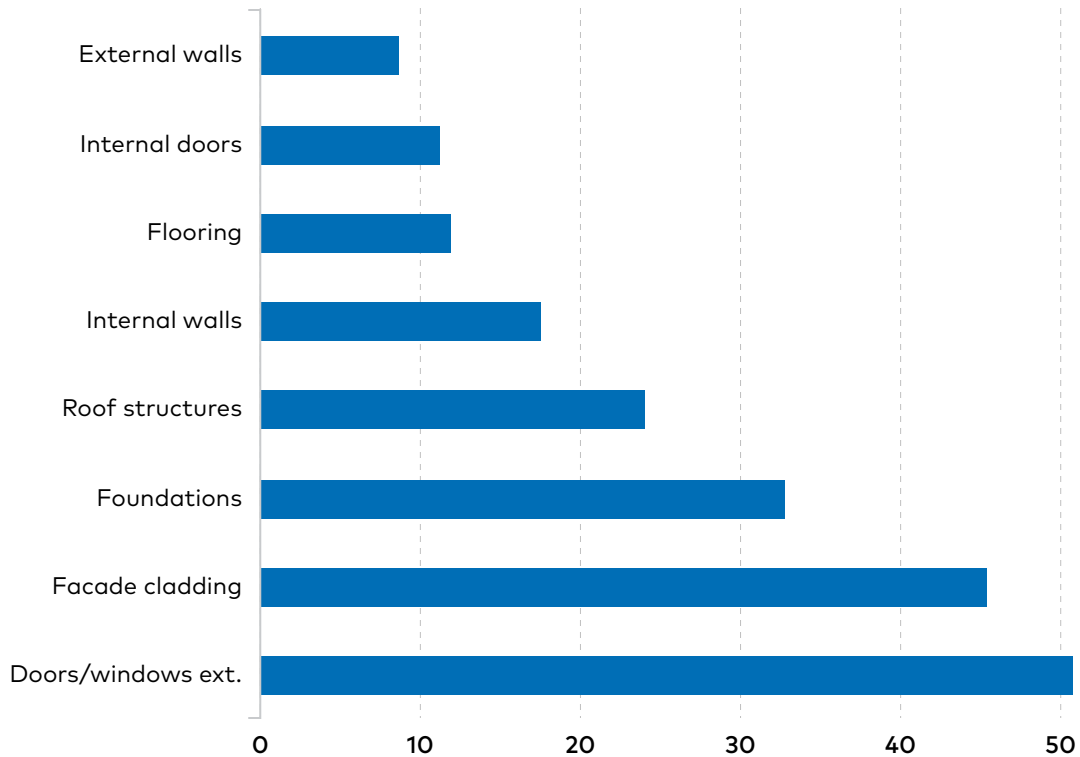


LCA results: Life cycle modules



The LCA includes all life cycle stages. The product stage is dominating, followed by the impacts released during the building's use stage, while the lowest amount of impacts are found during the construction, water use and end-of-life phases. The product stage is modelled with a detailed building model, including all building materials and building energy systems/installations: Electrical cables, HVAC, water pipes, sewage pipes, heating systems (heat pump) as well as solar PV panels. Despite the completeness, a relatively low total climate impact is achieved. Biogenic carbon was assessed separately and is not included in these results. In the second figure, *Operation* includes B6, B7, while materials include A1-A5, B1-B5, C1-C4. Even though the materials' share of impacts includes all modules, operations make up 25% of the total GWP, which related to the cold climate in the Dalarna region, located north of Stockholm. In the third figure, *Upfront* includes A1-A5, scenarios include B1-B5, C1-C4, and D is shown separately. Upfront and future scenarios are relatively balanced due to the complete modelling of the use stage and the considerable energy demand, while D is relatively small.

LCA results: Building elements



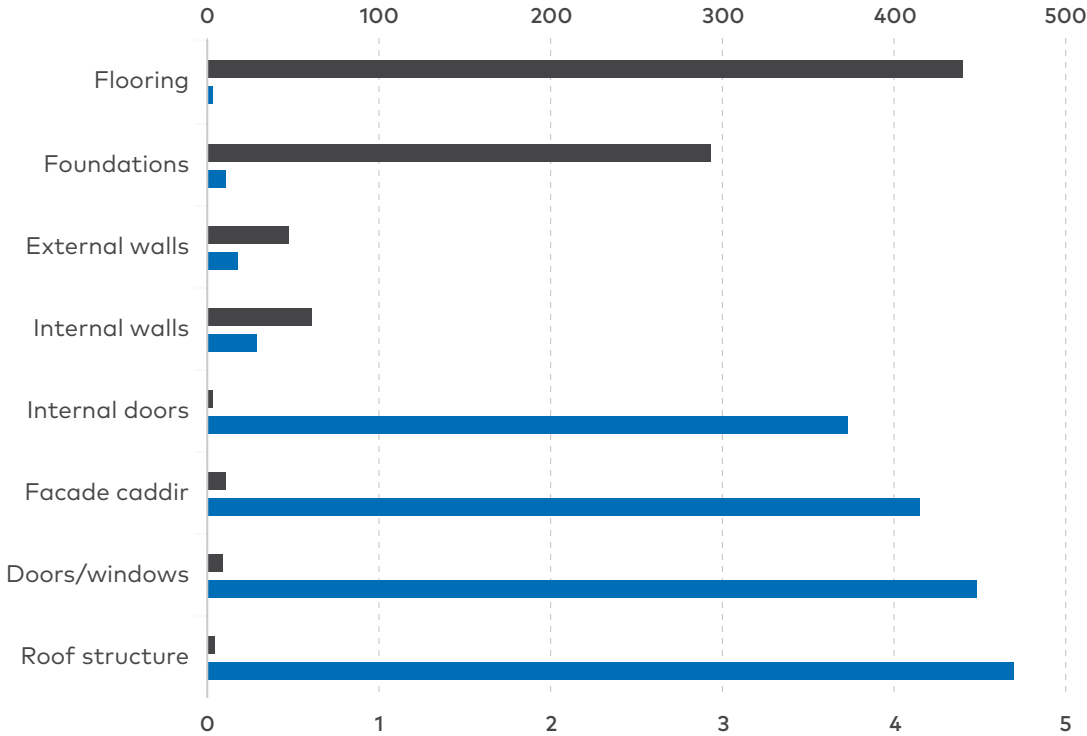
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B1-B5, C1-C4

The external openings have the highest impacts followed by the façade cladding. If the external walls were added to the façade cladding, they would dominate the results. All the technical components and piping, for electricity, water etc. were included in the estimation. Combined, they have an impact of 192 kgCO₂e/m² reference area (not included in the figure).

Building element quantity / reference rea [kg building element / m² reference area]



Building element GWP / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A5, B1-B5, C1-C4

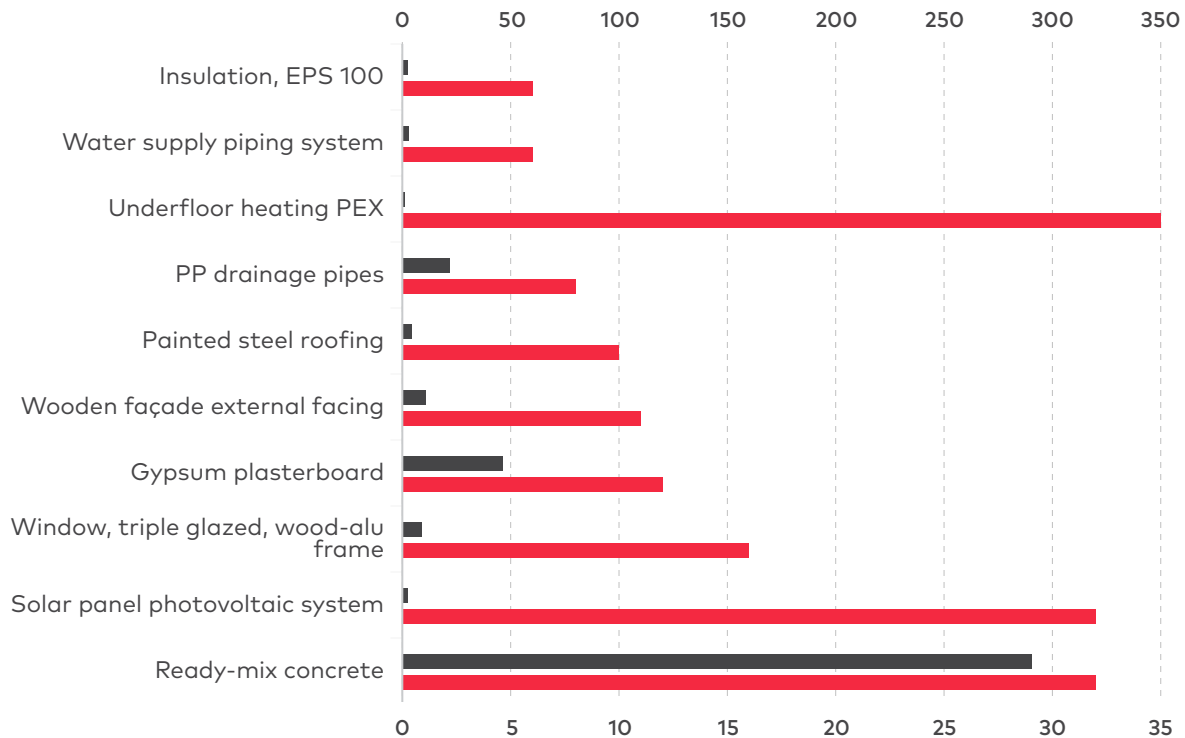
Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

Even though the roof structure with overhang covers a large area, its lightweight build-up exhibits a low material intensity. Due to this light weight, a high carbon intensity occurs. The opposite is true for flooring and foundations, which include the ground floor deck and strip foundations dominated by reinforced concrete.

Windows and doors also have a significant carbon intensity.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Concrete, gypsum boards and drainage pipes are dominating the material weight in the building.

The carbon impacts are also dominated by concrete, however followed by solar cells and the triple-glazed windows and doors.



Photos by Wihlborgs Fastigheter AB

12 Kvartetten

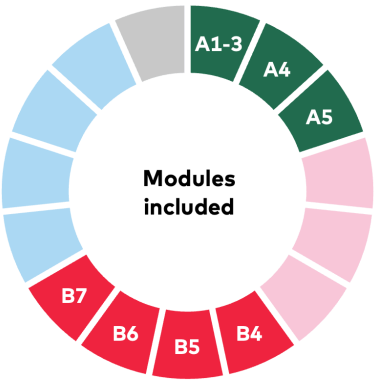
Sweden

Building use	Office	Stories above ground	9
Location	Skrivaregatan 21, Malmö	Basement area	3,140m ²
Client	Wihlborgs Fastigheter AB	Structural system	Prefabricated concrete walls/ slabs and steel beams/columns
LCA consultant	Projekt Engagemang (PE) and PEAB	Façade type	Several; Brick, metal, corrugated sheet, ceramics, flint
Year of completion	2023	Roof type	Flat roof
Reference area	23,247 m ² (gross floor area)	Heat demand /source	District heating

From the outset, the project had high climate targets: in addition to certification according to Miljöbyggnad Gold and WELL Gold, Kvartetten is also part of the LFM30, a local initiative to drive climate-neutral construction. Prior to the detailed design, the decision was made to see if it was possible to certify the project according to the NollCO2 certification scheme, since then the work on this has been a central part of the design and production of all parties involved. Collaboration between all stakeholders and dialogue with suppliers were a standard procedure in the project. The building is very flexible for the office tenants. For example, by utilising modular dimensions that control the layout of installations and having a wall screen above the suspended ceiling, tenants can easily expand or contract their operations or change from an open landscape to cell offices or meeting rooms. To reduce the project's climate impact, the choice of materials and products has been reviewed, the structure has been slimmed down and recycled materials have been compared. For example, this resulted in the use of concrete with alternative binders to cement, dividing the slab into sections to reduce local thickness, using bricks produced with renewable energy and the drainage board on the exterior basement walls consisting of recycled material. A major change was to raise the atrium roof, which allowed the building to have less external walls and thus significantly reduce its climate impact.

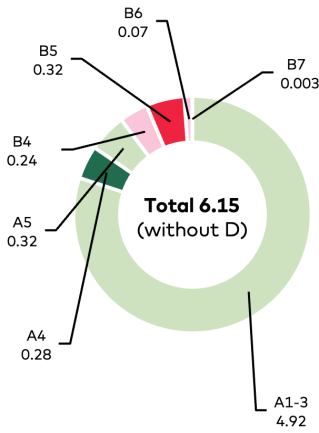
Assessment method

LCA scheme compliance	Miljöbyggnad, WELL, and Noll CO2 certification
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4-B7
Material emission data	EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy simulation method for Noll CO2 certification
Energy, dynamic scenario	Noll CO2 certification

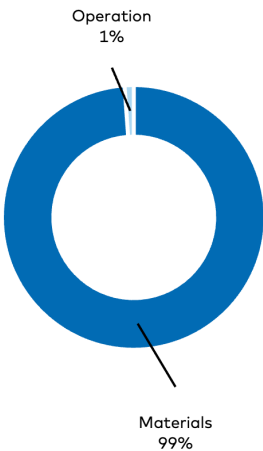


LCA results: Life cycle modules

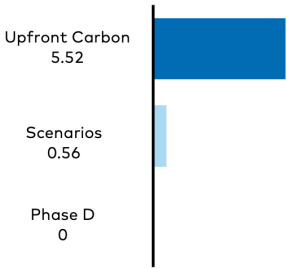
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

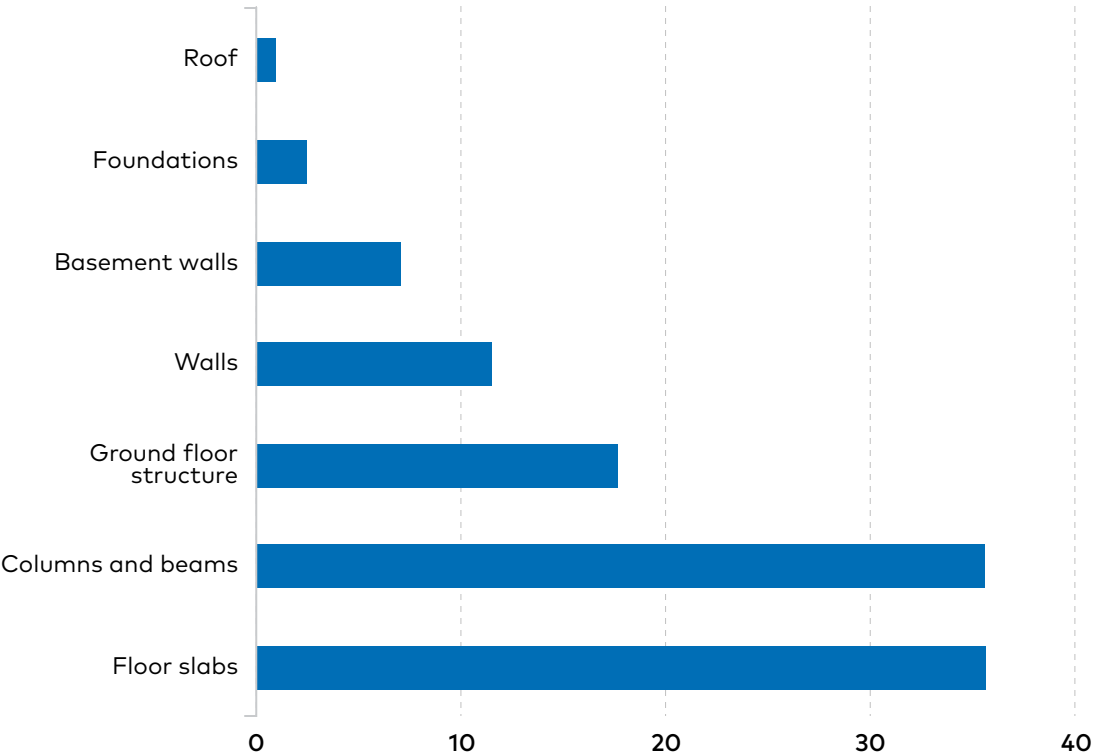


The results shown here are from the NollCO2 certification. The system boundary covers almost all life cycle modules, where the product stage is dominating followed by energy consumption. All materials are reported, including building energy systems/installations such as electrical cables, HVAC, water pipes, sewage pipes, heating systems, lifts and solar PV panels. The NollCO2 report states that end-of-life stages, C1-C4, are included in the assessment. However, the impacts are all set to zero.

In the second figure, *Operation* includes B6 and B7, while materials include A1-A5, B4-B5. B6 and B7 have very low impacts, mainly because in the used version of the NollCO2 certification the impact from energy use is reduced annually until assumed zero in 2050.

In the third on the right, *Upfront* includes A1-A5, scenarios include B4-B5, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

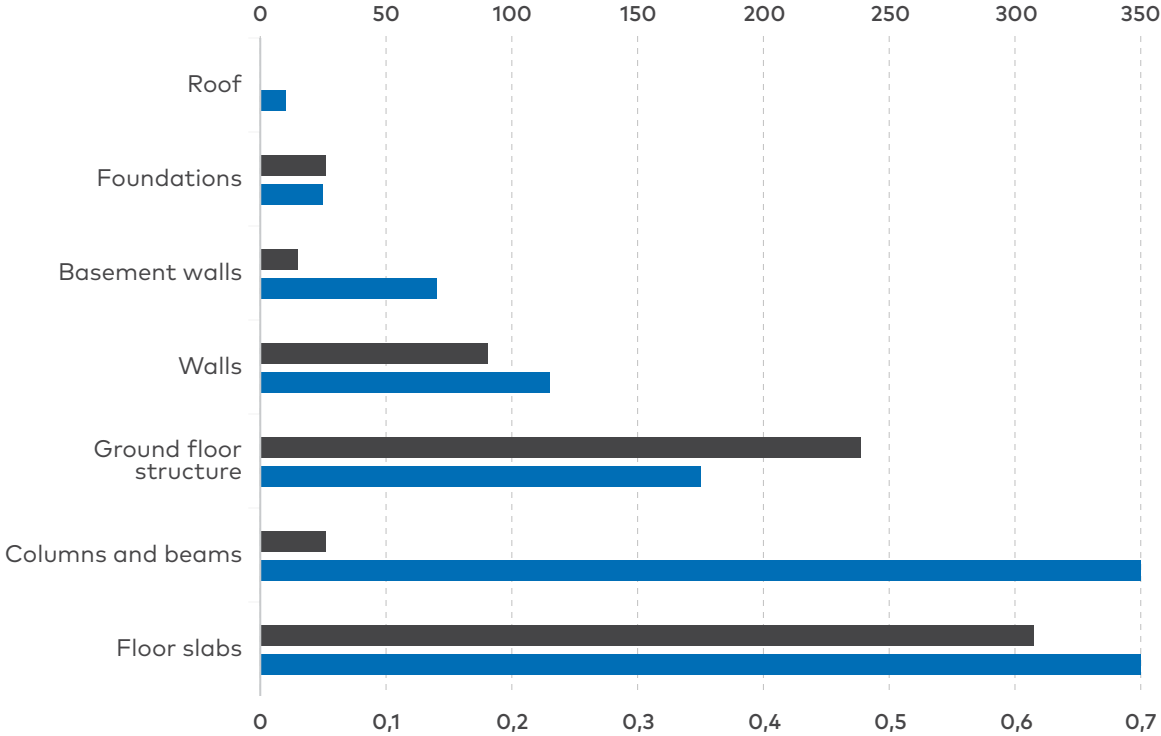


The results shown here are based on the Miljöbyggnad certification.

Material inventory: Materials used for the building frame and underground structure (foundation, ground floor down to the drainage layer, and basement walls).

Life cycle modules: A1-A3.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity



The results shown here are based on the Miljöbyggnad certification.

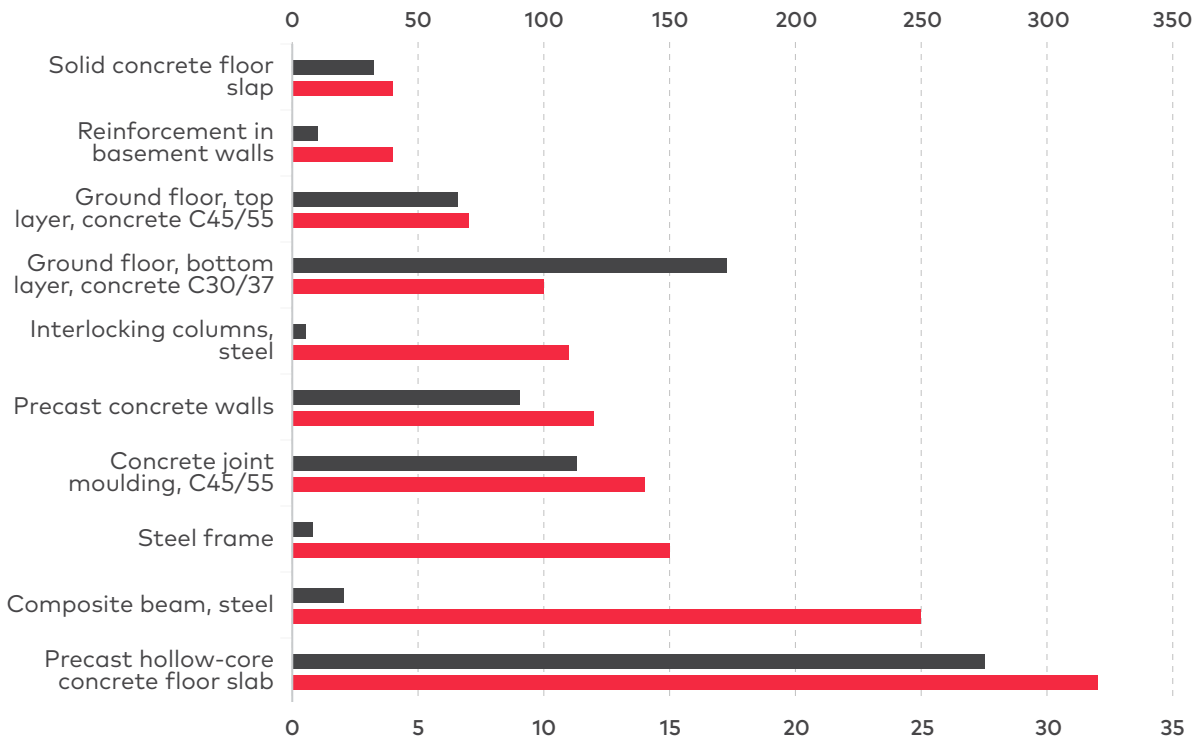
Material inventory: Materials used for the building frame and underground structure (foundation, ground floor down to the drainage layer, and basement walls).

Life cycle modules: A1-A3

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

The results shown here are based on the Miljöbyggnad certification. This means that only materials used for the building frame and underground structure (foundation, ground floor down to the drainage layer, and basement walls) are included.

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The listed products for the structural system are dominated by concrete and steel materials, led by the floor slabs.



Photos by Wihlborgs Fastigheter AB

13 Space

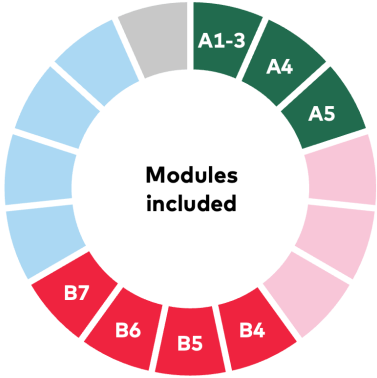
Sweden

Building use	Office	Stories above ground	5
Location	Rydbergs torg 11, Lund	Basement area	—
Client	Wihlborgs Fastigheter AB	Structural system	Prefabricated concrete beams, with wood and steel pillars
LCA consultant	Projekt Engagemang (PE) and Solenco AB	Façade type	Glass and wood
Year of completion	2023	Roof type	Flat roof
Reference area	7,400 m ² (gross floor area)	Heat demand /source	District heating

Space is an innovation centre with offices and lab activities. It has achieved NollCO₂, Miljöbyggnad GOLD and WELL certifications. Reducing the climate impact of phase A1-A3 has been pursued at various levels throughout the project. Such efforts include using steel with a high recycled content, using of climate-enhanced concrete, constructing the façade in-situ with cantilever walls instead of installing a material-intensive façade system, and using a glulam and steel combination for the frame system. In general materials have been chosen based on a thorough comparison focusing on climate impact and costs. Steps were taken to reduce climate impacts during the construction phase (A4-A5), for example, using prefabricated solutions for the HDF joists to reduce waste and spillage, ensuring that the building was airtight before starting the dehydration process thereby reducing energy consumption, purchasing renewable electricity from hydropower and district, and raising project stakeholder awareness of the energy, water and waste generated by the project. Space is built with modular dimensions that provide flexibility for future floor plan changes in connection with tenant adaptations. The building layout and the building's ventilation system design enhance this flexibility. The protection and durability of materials have also been considered, for example by protecting the wooden façade structure with a double façade and using durable and high-quality surface finishes.

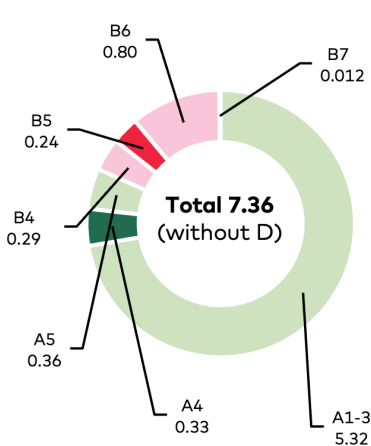
Assessment method

LCA scheme compliance	Miljöbyggnad, WELL, and Noll CO2 certification
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4-B7
Material emission data	Generic Swedish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy simulation method for Noll CO2 certification
Energy, dynamic scenario	Noll CO2 certification

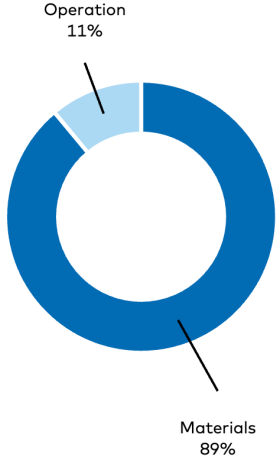


LCA results: Life cycle modules

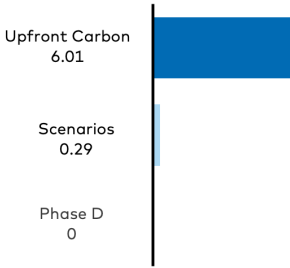
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

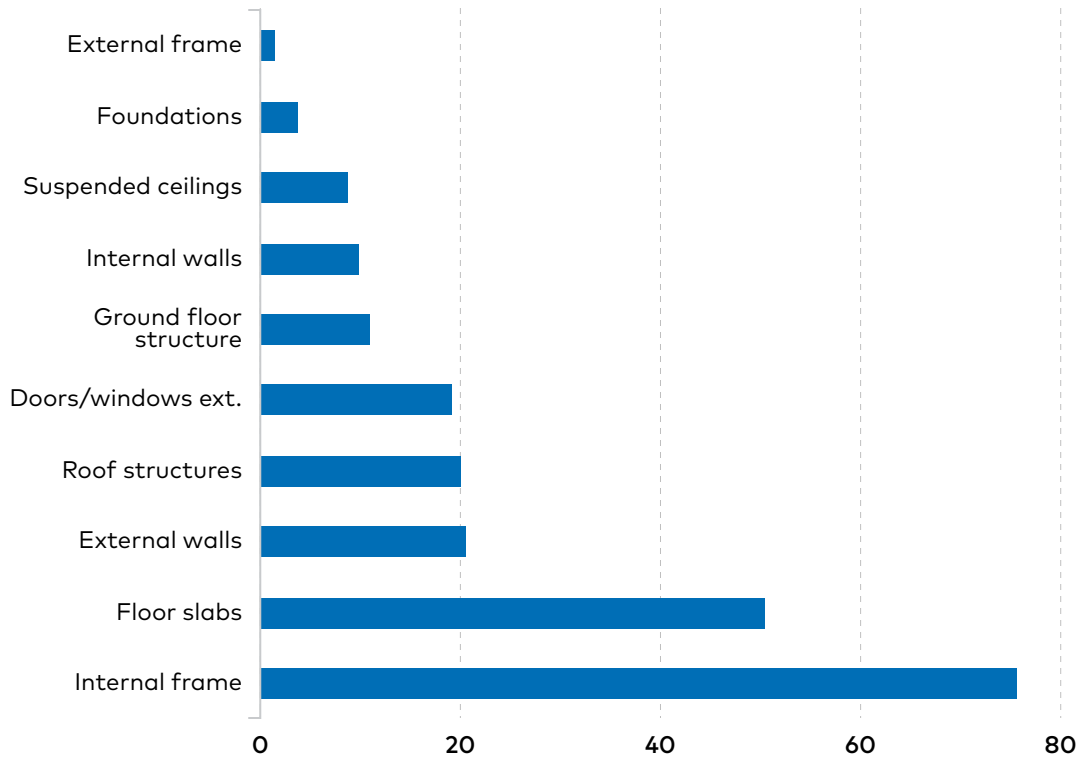


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The results shown here are from the NollCO2 certification. The system boundary covers almost all life cycle modules, where the product stage is dominating followed by energy consumption. All materials are reported, including building energy systems/installations such as electrical cables, HVAC, water pipes, sewage pipes, heating systems, lifts and solar PV panels. The NollCO2 report states that end-of-life stages, C1-C4, are included in the assessment. However, the impacts are all set to zero. In the second figure, *Operation* includes B6 and B7, while materials include A1-A5, B4-B5. B6 and B7 have very low impacts, mainly because in the used version of the NollCO2 certification the impact from energy use is reduced annually until assumed zero in 2050. In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, and D is shown separately had it been included in the assessment.

LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

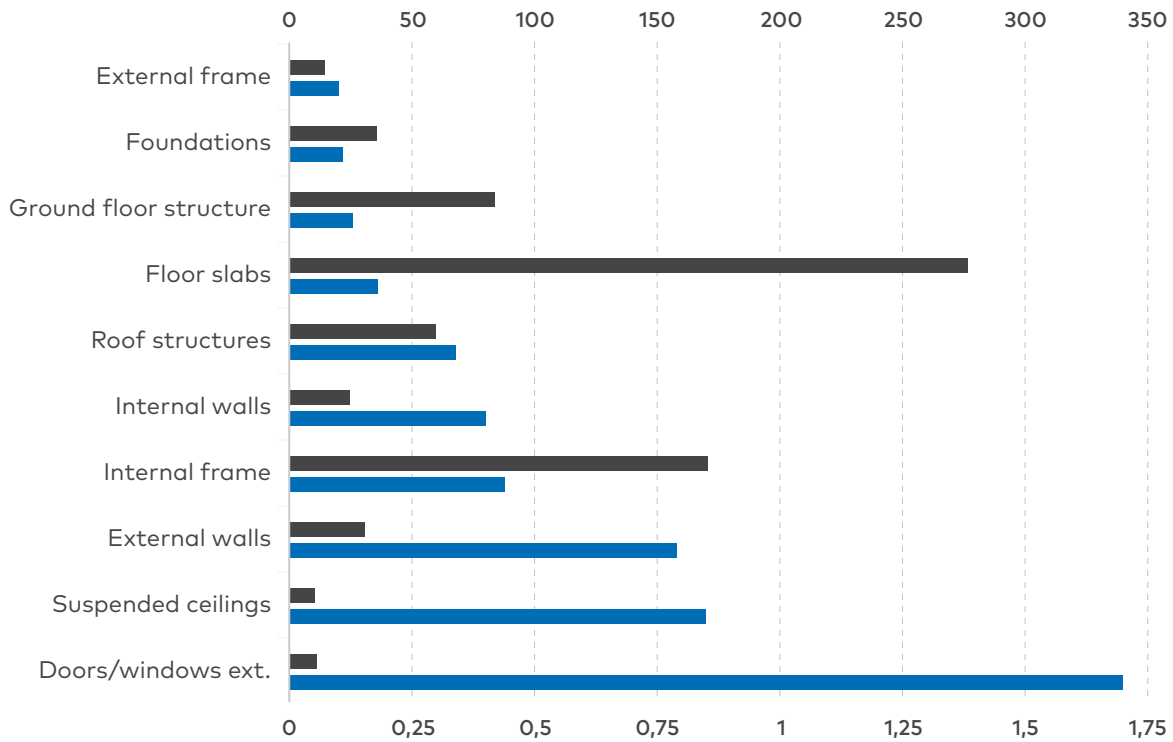
The results shown here are based on the Miljöbyggnad certification. All materials are included, but technical components and piping for heat, water etc. are not included

Material inventory: All materials

Life cycle modules: A1-A3

The internal frame also contains internal balconies in the atrium.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

The results shown here are based on the Miljöbyggnad certification. All materials are included, but technical components and piping for heat, water etc. are not included.

Material inventory: All materials

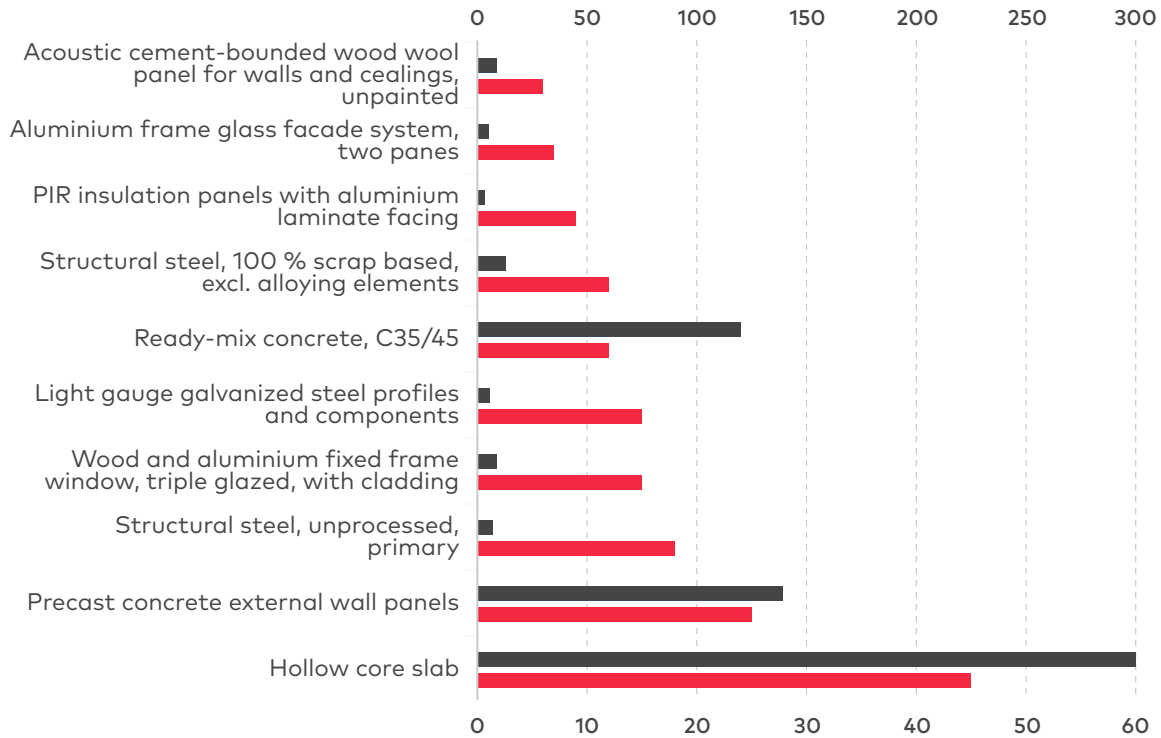
Life cycle modules: A1-A3

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

The internal frame also contains internal balconies in the atrium.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

The results shown here are based on the Miljöbyggnad certification. All materials are included, but technical components and piping for heat, water etc. are not included.

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A3

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos by Fiskarhedenvillan

14 Villazero

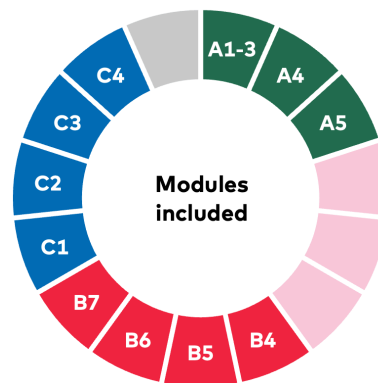
Sweden

Building use	Detached home	Stories above ground	1
Location	Furustigen 6, 78450 Borlänge	Basement area	—
Client	Fiskarhedenvillan AB, Borlänge Sweden	Structural system	Wooden framework
LCA consultant	—	Façade type	Pressure treated wood
Year of completion	2022	Roof type	Asymmetrical gable roof
Reference area	136 m ² (gross floor area)	Heat demand /source	Heat pump

To build and construct a detached single-family home with reduced CO₂ emissions while also developing our knowledge about sustainability, the decision to aim for the NollCO₂ certification was made early on. Among the first tasks to be completed was the identification of building materials with a high CO₂ impact in a standardised detached single-family home, and decide what materials needed to be replaced. One material that stood out as very versatile and in most cases with a low CO₂ impact was wood. That insight inspired the project to use wood extensively. The most innovative area of use was probably the replacement of concrete with CLT (cross-laminated timber) in the foundation. Instead of casting a concrete slab on top of EPS and reinforcing bar, six prefabricated CLT elements were mounted on top of 400 mm of EPS. Another area where the project chose wood instead of the conventional solution was the roof covering. Instead of using concrete tiles, a pressure-treated wooden cladding combined with building integrated PV-panels forms the roof of the southern side of the building. To make the house both energy-efficient and reduce CO₂ impact, insulation made from wood fibres was chosen for external walls and roof. While innovation is important, it is also crucial to be sensible which is why several sensors have been installed in various parts of the foundation, external walls and roof. The sensors measure dampness, temperature and relative humidity (RH) during their approximate five-year lifespan.

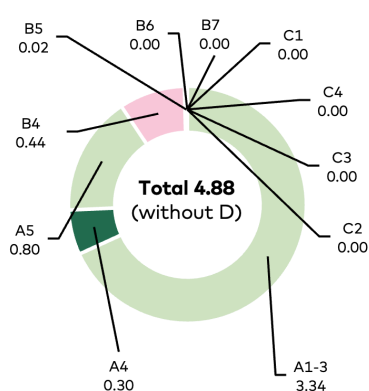
Assessment method

LCA scheme compliance	Noll CO2, Nordic Swan Ecolabel
LCA tool version	NollCO2
Life cycle stages included	A1-A5, B4-B7, C1-C4
Material emission data	Generic Swedish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy simulation method for Noll CO2 certification
Energy, dynamic scenario	Noll CO2 certification

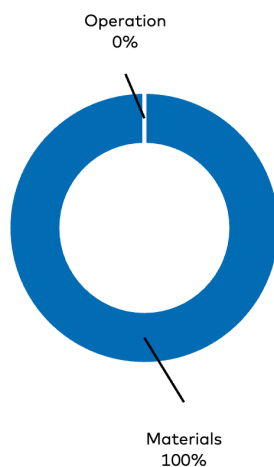


LCA results: Life cycle modules

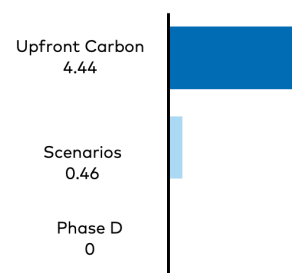
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

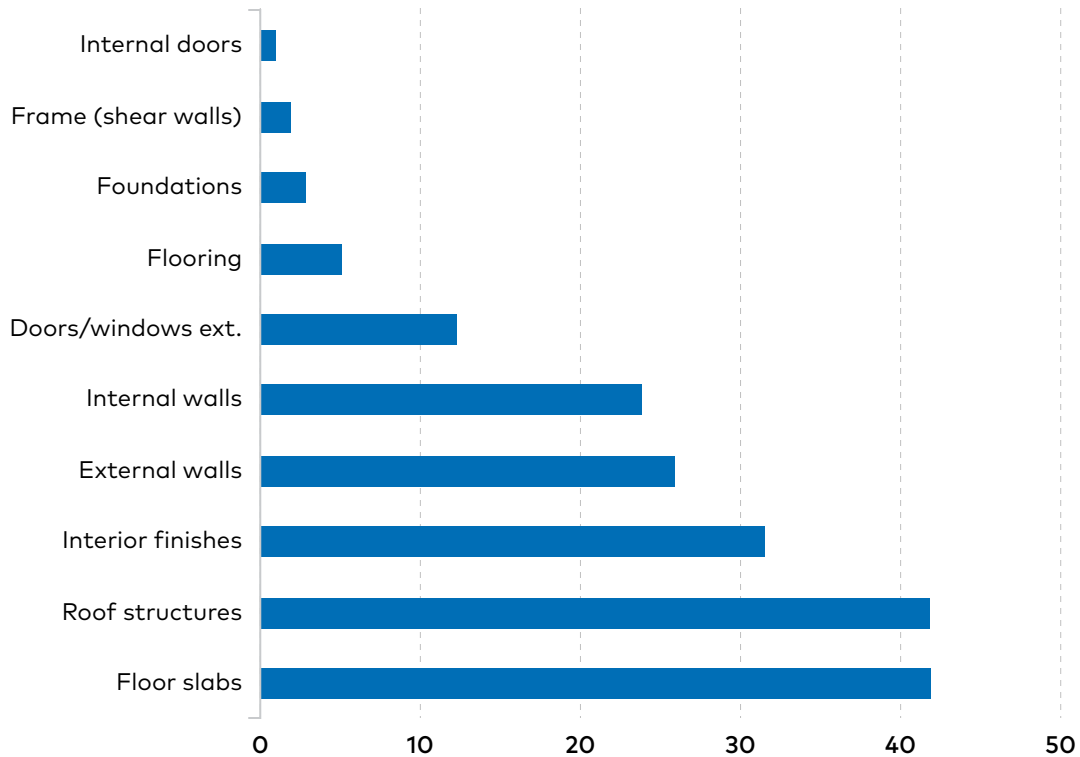


The results shown here are from the NollCO2 certification. The system boundary covers almost all life cycle modules where the product stage is dominating followed by energy consumption. All materials are reported, including building energy systems/installations such as electrical cables, HVAC, water pipes, sewage pipes, heating systems, lifts and solar PV panels. B6 becomes a negative climate value according to the certification, as solar power displaces coal power in the electricity networks covered by Nord Pool. A total of -114.10 tons of CO₂-e by 2050 when all electricity produced in the electricity grid is assumed to have no climate impact. The impact is for B6 is shown to be zero in the figures.

In the second figure, *Operation* includes B6 and B7, while materials include A1-A5, B4-B5, C1-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, C1-C4, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



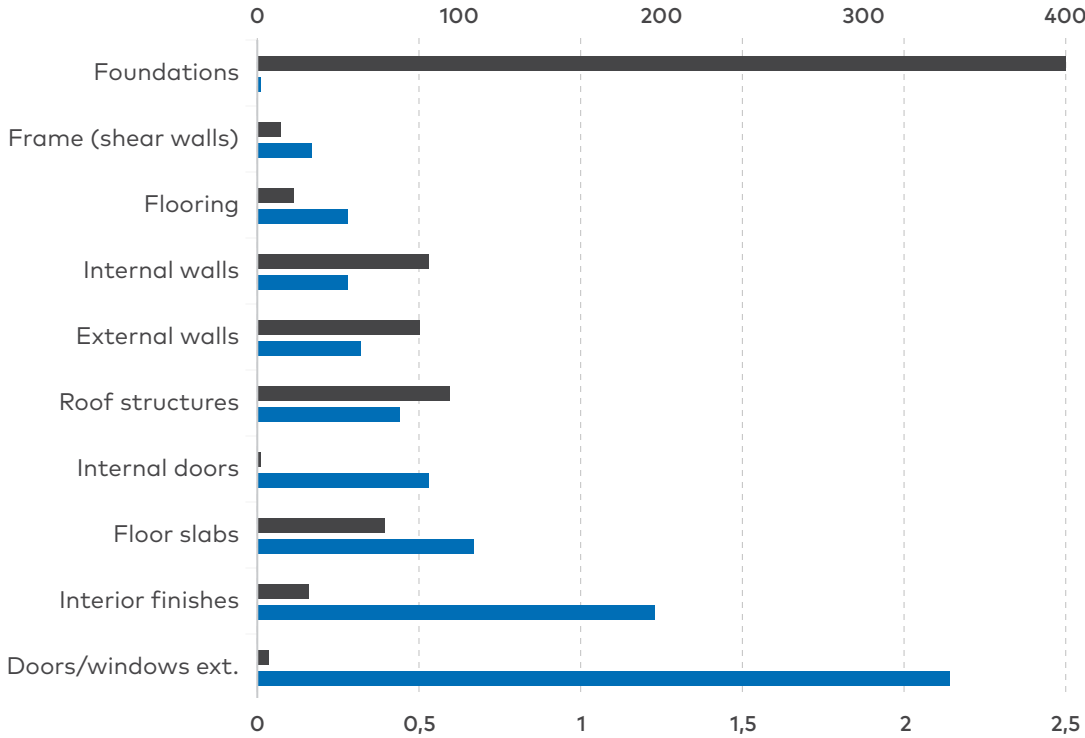
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4, B5

Exterior walls and roofing are included exterior cladding. Interior finishes are for walls and ceilings. All the technical components and piping for electricity, water etc. were included in the estimation. Combined, they have an impact of 33 kgCO₂e/m² reference area (not included in the figure).

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity



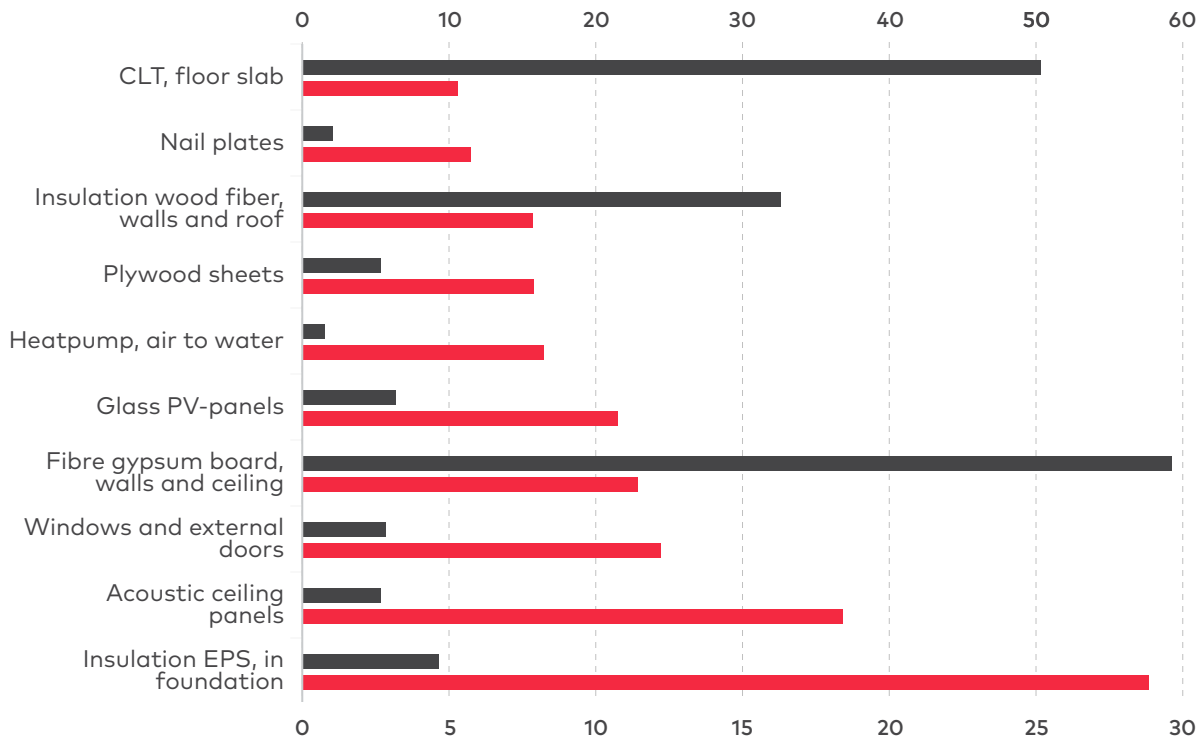
Material inventory: All materials

Life cycle modules: A1-A5, B4, B5

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photo by Jesper Arvidsson, Jespers Foto & Repro



Photo by Filip Persson, SLP

15 Fyllinge

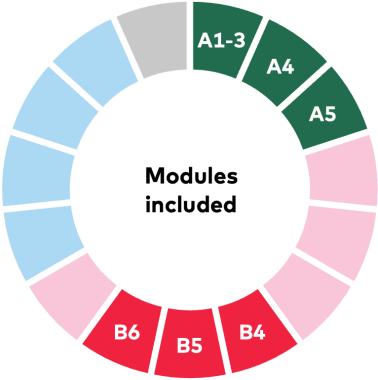
Sweden

Building use	Logistical building	Stories above ground	2
Location	Kistingevägen 6; 302 62 Fyllinge	Basement area	—
Client	SLP Halmstad Fyllinge 20:434 AB	Structural system	Steel
LCA consultant	Solenco AB	Façade type	Steel sandwich panels (mineral wool core)
Year of completion	2023	Roof type	Steel sheet roof
Reference area	6,042 m ² (gross floor area)	Heat demand /source	District heating

From the start of the project, climate and sustainability goals were at the top of the agenda. At a later stage, it was decided to certify the building with Miljöbyggnad Silver and NollCO₂. Collaboration between the LCA consultant, the tenant, the contractor and the building owner made it possible to realise this project which is the first logistics building in Sweden certified according to NollCO₂ and the first building within the NollCO₂ certification to balance its carbon impact to net zero on site, using the photo-voltaic system installed on the building's roof. In the early project stages, it was decided to opt out of EPS and polyurethane insulation as much as possible. Investigation of the best construction for the concrete slab on the ground in the warehouse showed that the Teqbase plan, executed without joints and without reinforcement, would be a very climate-smart and time-efficient solution and accelerate construction time. It was decided to make the wall elements for warehouses and offices as sheet metal sandwich elements with a stone wool core. Different suppliers were compared based on the climate impact per square metre of façade. Due to difficulties sourcing steel with a sufficiently low climate impact, the designers have worked towards minimising the amount of steel purchased. Through smart division of fire zones and other measures, the fire consultant was able to establish that no sprinkler system was required for the building, which represents a large saving in embodied carbon emissions. The window and door supplier undertook to produce project-specific EPDs for all supplied windows and doors.

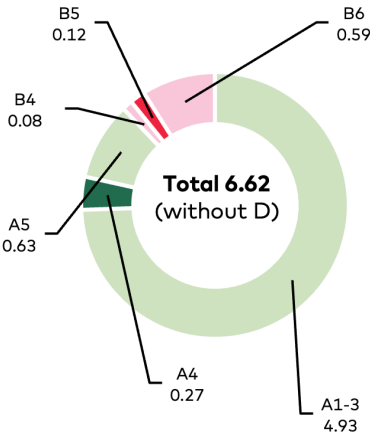
Assessment method

LCA scheme compliance	Miljöbyggnad and NollCO2 certification
LCA tool version	One Click LCA, NollCO2
Life cycle stages included	A1-A5, B4-B6
Material emission data	Generic Swedish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy simulation method for Noll CO2 certification
Energy, dynamic scenario	Noll CO2 certification

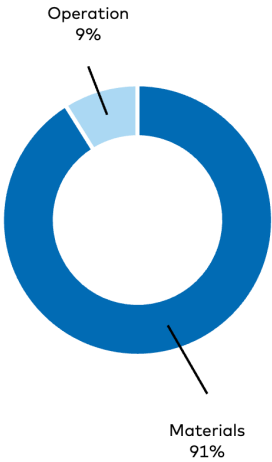


LCA results: Life cycle modules

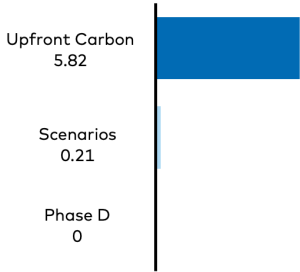
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

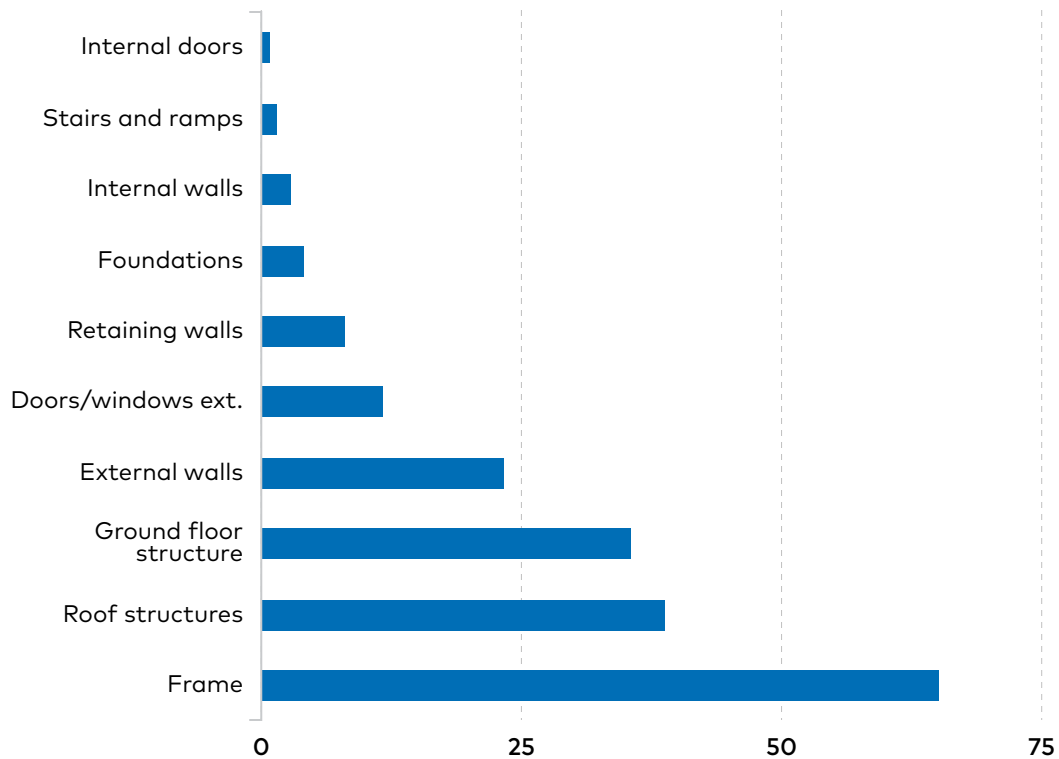


The results shown here are from the NollCO2 certification. The system boundary includes the product and use stages. All materials are reported, including building energy systems/installations such as electrical cables, HVAC, water pipes, sewage pipes, heating systems, lifts and solar PV panels. Impacts from energy use are reduced by district heating and solar power generation.

In the second figure, Operation includes B6, while materials include A1-A5, B4-B5.

In the third figure, Upfront includes A1-A5, scenarios include B4-B5, and D is shown separately, had it been included in this assessment.

LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

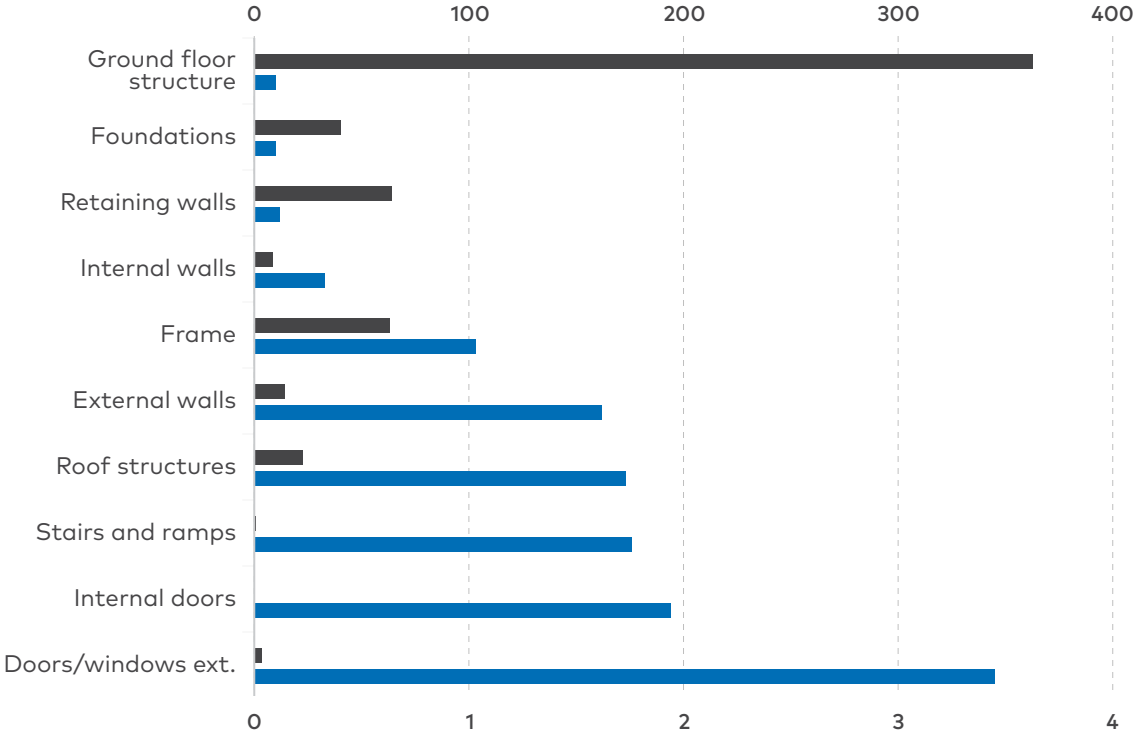
The results shown here are from the NollCO2 certification.

Material inventory: All materials

Life cycle modules: A1-A5, B4-B5

All the technical components and piping for electricity water etc. were included in the estimation. Combined, they have an impact of 10 kgCO₂e/m² reference area (not included in the figure). The suspended ceiling is allocated to the roof.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity



The results shown here are from the NollCO2 certification.

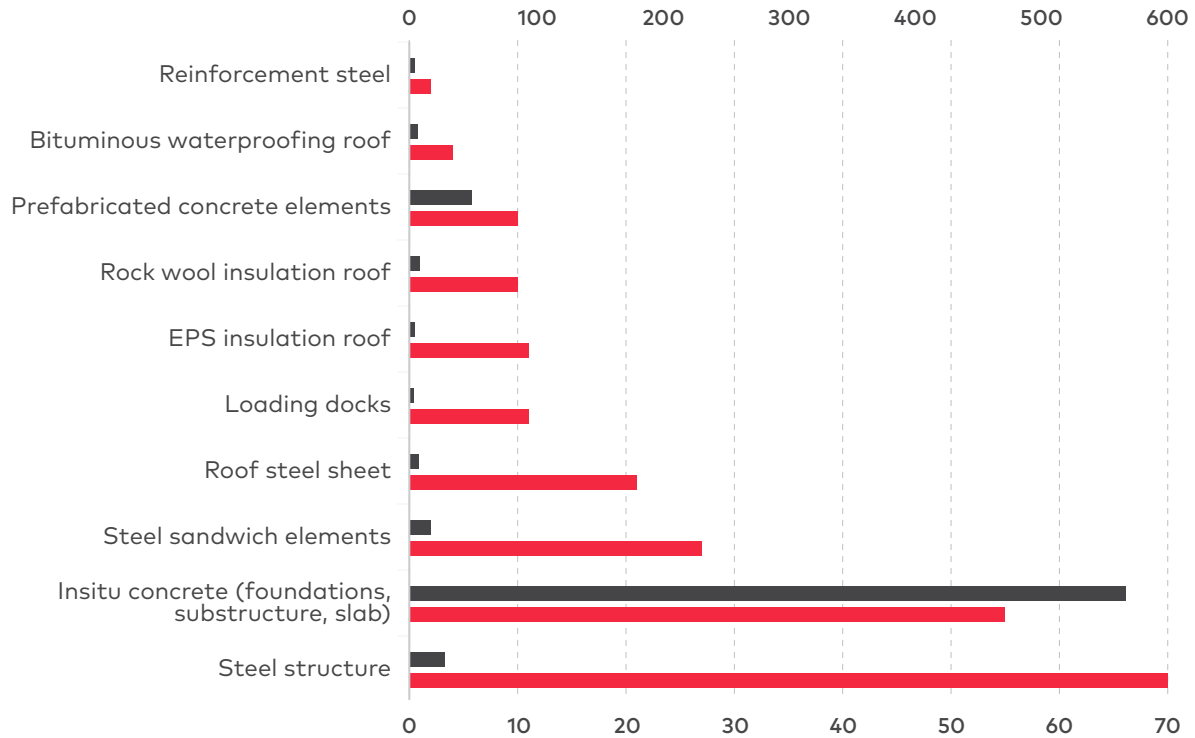
Material inventory: All materials

Life cycle modules: A1-A5, B4-B5

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

The results shown here are from the NollCO2 certification.

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photo by Jesper Arvidsson, Jespers Foto & Repro



Photo by Alexander Fallahi, Dachser Sweden AB

16 Stigamo Södra

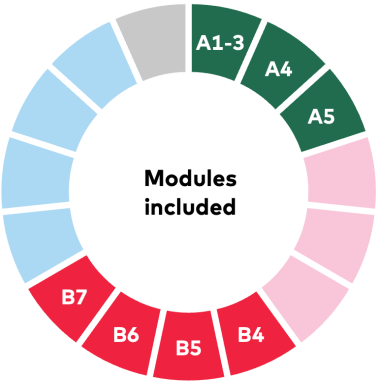
Sweden

Building use	Logistical building	Stories above ground	2
Location	Södra Stigamovägen 15A, 555 92 Vaggeryd	Basement area	—
Client	SLP Vaggeryd Stödorp 2:22 AB	Structural system	Steel
LCA consultant	Greenshape AB	Façade type	Steel sandwich panels (mineral wool core)
Year of completion	2024	Roof type	Flat roof
Reference area	18,327 m ² (gross floor area)	Heat demand /source	District heating

The project is planned and built for a single tenant who rents the entire facility including one storage facility, one cross dock facility and office functions. According to the sustainability goals of the property owner Swedish Logistic Properties, the project is certified according to Miljöbyggnad Silver and NollCO₂. NollCO₂ sets a building-specific baseline and reduction threshold for the life-cycle stages A1-A3 and a general threshold for the life cycle stages A4-A5. Embodied carbon emissions are balanced to net zero by compensation measures, in this project composing of the photovoltaic system installed on the building's roof. The main goal of the project was to reduce material and in the next step select smart materials with low embodied carbon to reduce the buildings carbon impact. The LCA was conducted according to the NollCO₂ principles and an early calculation pinpointed carbon-intensive materials and resulting improvement potentials. Elements with a high carbon impact were improved by choosing materials with low embodied carbon. The main stakeholders in the LCA calculation and improvements were the contractor and the LCA consultant. The biggest improvements were found in the early stages and when dimensioning systems as well as choosing subcontractors and materials. The project will follow up the carbon intensity after three years, where the building energy use intensity and carbon impact from energy use will be analysed.

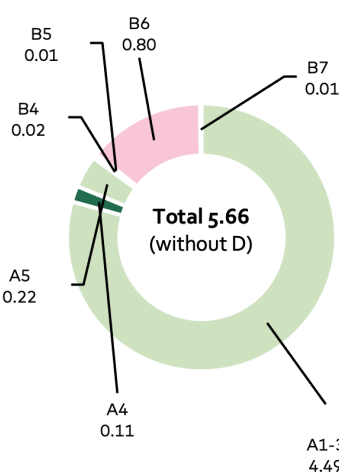
Assessment method

LCA scheme compliance	Miljöbyggnad and NollCO2 certification
LCA tool version	One Click LCA, NollCO2
Life cycle stages included	A1-A5, B4-B7
Material emission data	Generic Swedish database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Energy simulation method for Noll CO2 certification
Energy, dynamic scenario	Noll CO2 certification

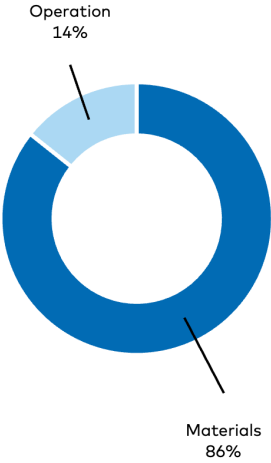


LCA results: Life cycle modules

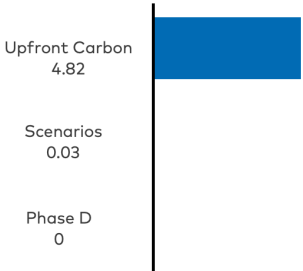
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



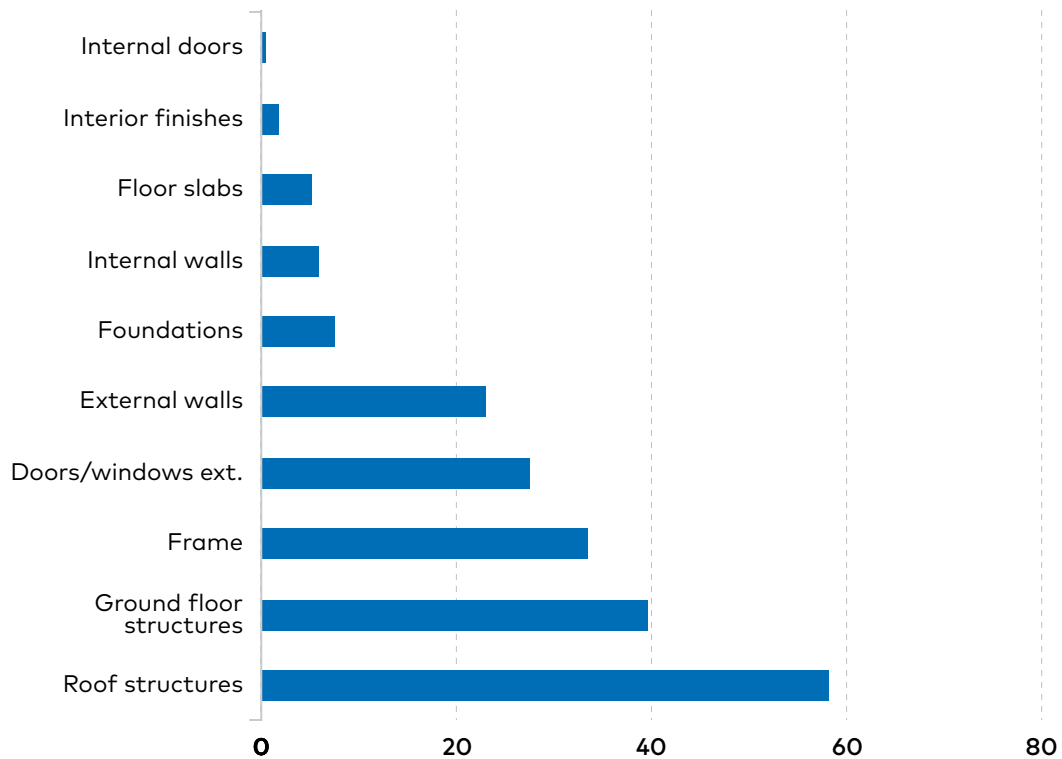
WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The results shown here are from the NollCO2 certification. The system boundary includes the product and use stages. Building services are modelled in detail (lifts and escalators, electricity system, HVAC system, renewable energy systems, water system, sewage system).

In the second figure, *Operation* includes B6 and B7, while materials include A1-A5, B4-B5. In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



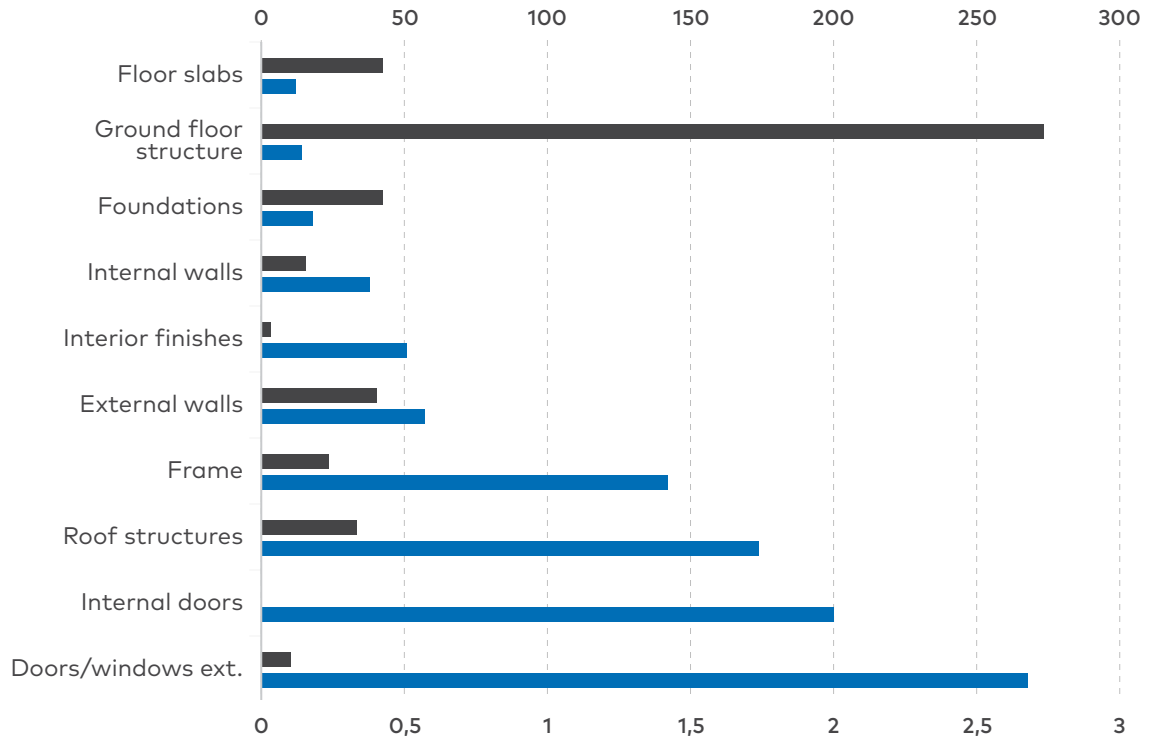
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4-B5

It is not specified if the frame (beams and columns) is interior or exterior. There are also stairs in the model, but they are not included in the figure because their impacts are smaller than internal doors. Interior finishes include floors, walls finishes and coverings and ceilings.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

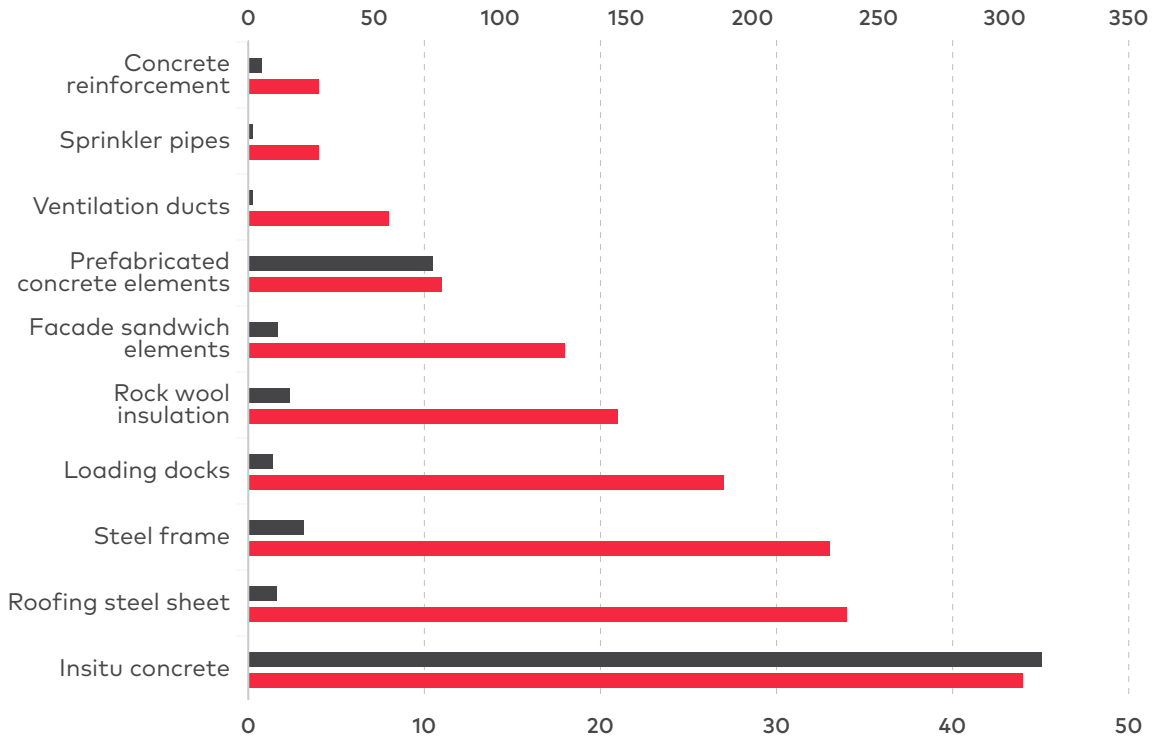
Material inventory: All materials

Life cycle modules: A1-A5, B4-B5

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B4-B5

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos by Vistbyggð ehf.

17 Urriðaholtsstræti 44-74

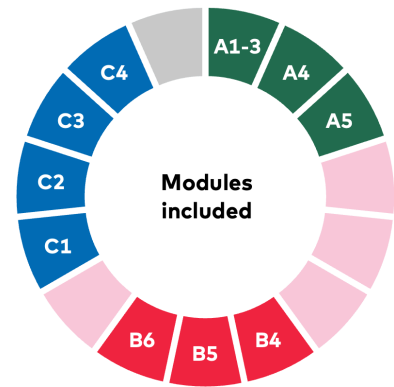
Iceland

Building use	Terraced house	Stories above ground	2
Location	Urriðaholtsstræti 44-74, 210 Garðabær	Basement area	—
Client	Vistbyggð ehf.	Structural system	Cross-laminated timber
LCA consultant	EFLA	Façade type	Wood and aluminium
Year of completion	2021	Roof type	Flat roof
Reference area	2,753 m ² (gross floor area)	Heat demand /source	District heating

Urriðaholtsstræti 44-74 is a terraced housing, consisting of two rows of eight two-story homes. The houses are certified with the Nordic Swan Ecolabel and are situated in the sustainable Urriðaholt neighbourhood, which has also achieved BREEAM Communities certification. The design process focused on careful selection of materials, interior layout, acoustics, natural lighting, and energy saving solutions. The houses are constructed using cross-laminated timber as the load-bearing structure, enhancing sustainability and reducing emissions. All materials are non-toxic and come with the necessary certificates of origin required for the Swan Ecolabel. Each apartment is also equipped with a local ventilation system and air nozzles in every room, contributing to greater energy efficiency. The life cycle assessment was conducted for the following building components over a 60-year lifetime: Exterior walls, windows, flooring, floor slabs, interior walls, partition walls, roofs, plinths, structural frame, ground slab, ceiling, stairs, interior doors and exterior doors. The life cycle assessment shows that the carbon footprint of these houses is 40% lower than that of a typical Icelandic concrete house. The use of cross-laminated timber instead of concrete for the load-bearing structure significantly reduced the carbon footprint, and the energy-saving measures implemented, further contribute to this reduction.

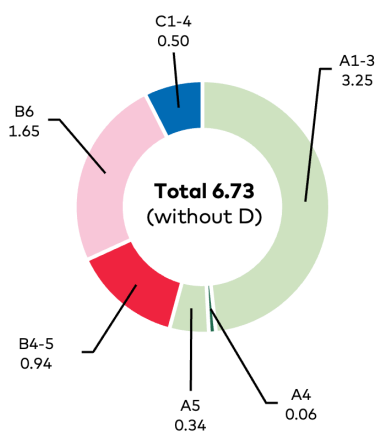
Assessment method

LCA scheme compliance	Nordic Swan Ecolabel, BREEAM neighbourhood
LCA tool version	One Click LCA v 0.33.0
Life cycle stages included	A1-A5, B4-B6, C1-C4,
Material emission data	Generic data and EPDs
Material decarbonization scenario	—
Energy calculation method	SIMIEN energy calculations
Energy, dynamic scenario	LCA study for country specific electricity and district heat mixes based on Orkustofnun, OneClickLCA 2017

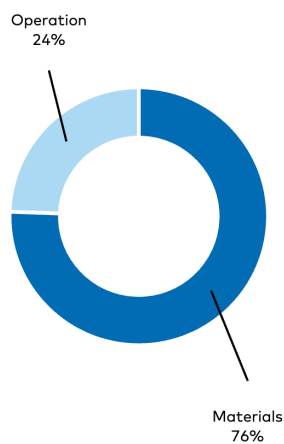


LCA results: Life cycle modules

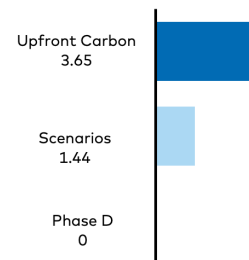
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

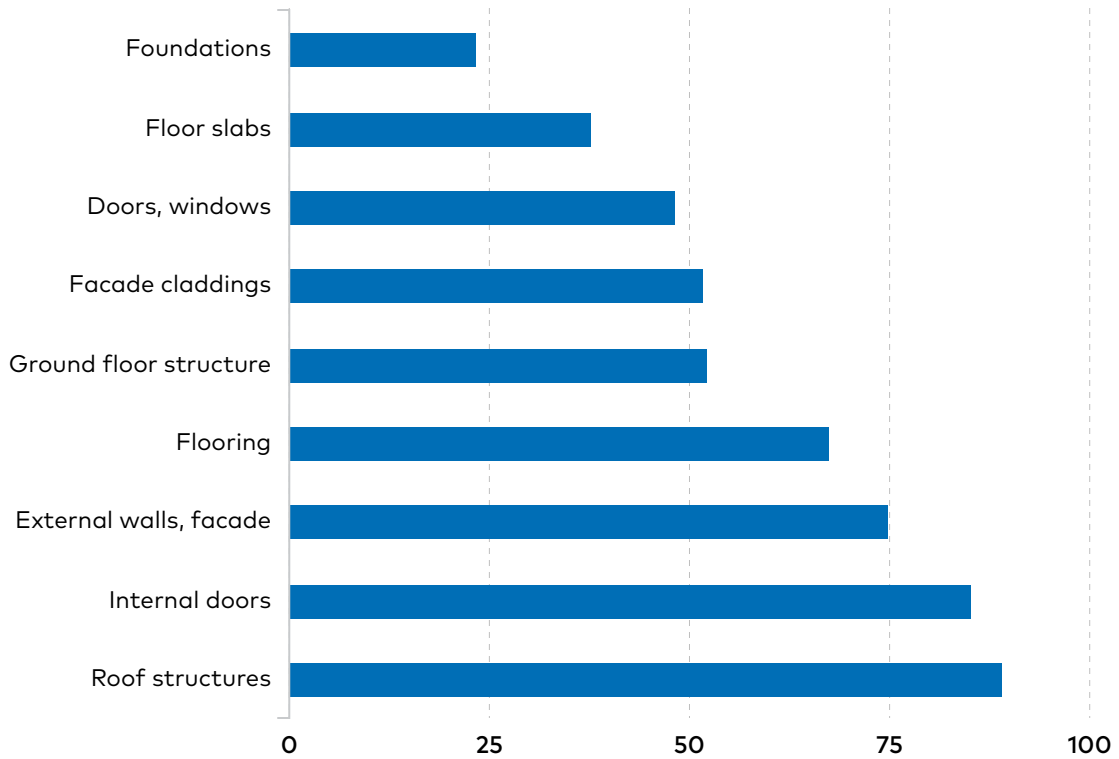


The system boundary includes a share of all life cycle stages.

In the second figure, *Operation* includes B6, while materials include A1-A5, B4-B5, C1-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, C1-C4.

LCA results: Building elements



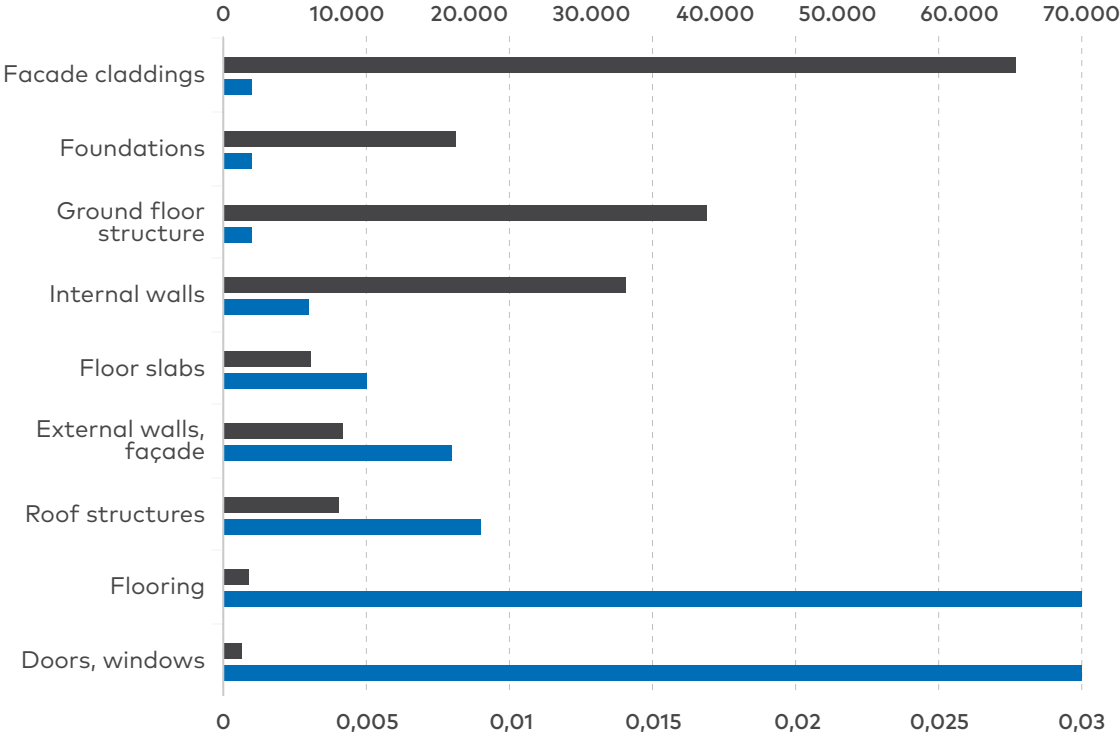
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4, C1-C4

Carbon emissions are distributed quite evenly in this project. Typical for a low-rise structure, roof and ground floor deck, including flooring, top the list.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

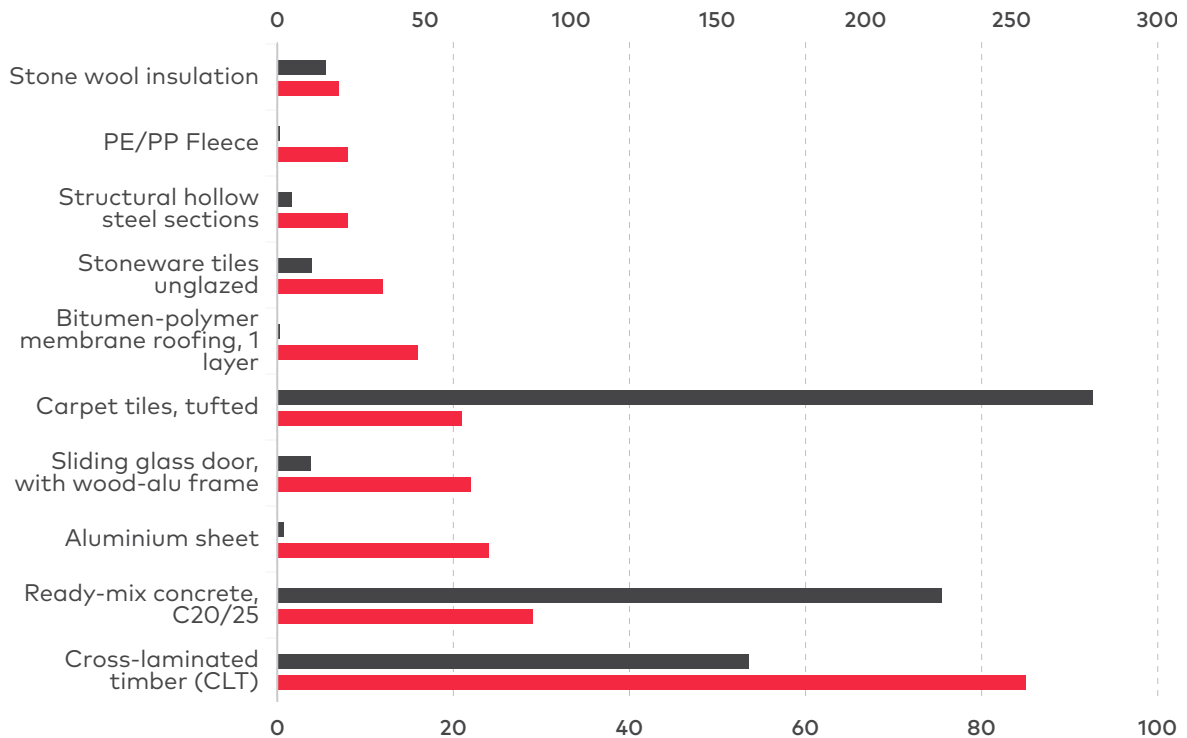


Material inventory: All materials
Life cycle modules: A1-A5, B4, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B1-B5, C1-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The CLT elements in walls and slabs are dominating the product hot spot list. Further down, the concrete for foundations, the aluminium façade cladding and internal glass doors are shown.



Photo by Garðabær

18 Urriðaholtsskóli

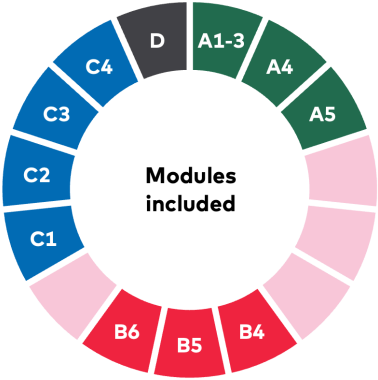
Iceland

Building use	School and children daycare	Stories above ground	2
Location	Vinastræti 1-3, 210 Garðabær	Basement area	1336,8 m ²
Client	Garðabær	Structural system	Reinforced concrete
LCA consultant	EFLA	Façade type	Wood and aluminium
Year of completion	2024	Roof type	Flat roof
Reference area	4,689.4 m ² (gross floor area)	Heat demand /source	District heating

Urriðaholtsskóli is a school that serves two educational levels, kindergarten and elementary school, and is for children aged 1 to 15 years. The school is located in the sustainable Urriðaholt neighbourhood, which has the BREEAM Community certification. The goal of the school building structure is to achieve BREEAM certification. The school building features two stories and a basement. It is constructed from reinforced concrete, is externally insulated, clad in aluminium, and the roof is covered with turf. The life cycle assessment was conducted as part of the BREEAM certification process. The assessment was performed over a 60-year lifetime for the following building components: Ground slab, plinths, floor slabs, flooring, ceiling, roof, exterior walls, interior walls, windows, columns, basement walls and retaining walls.

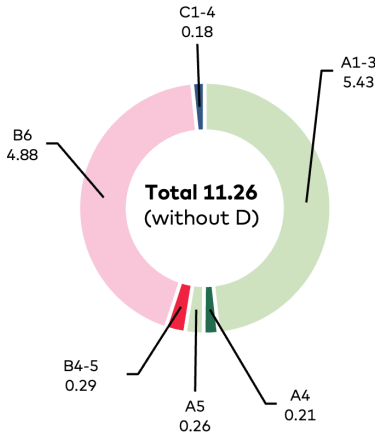
Assessment method

LCA scheme compliance	—
LCA tool version	One Click LCA v 0.33.0
Life cycle stages included	A1-A5, B4-B6, C1-C4, D
Material emission data	Generic data and EPDs
Material decarbonisation scenario	—
Energy calculation method	—
Energy, dynamic scenario	LCA study for country specific electricity and district heat mixes based on Orkustofnun, OneClickLCA 2017

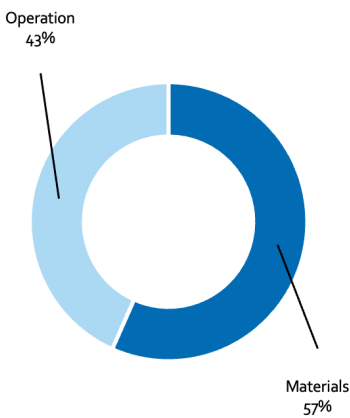


LCA results: Life cycle modules

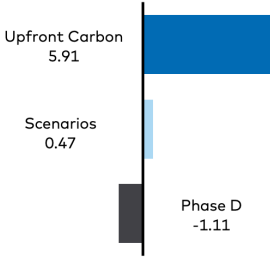
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]

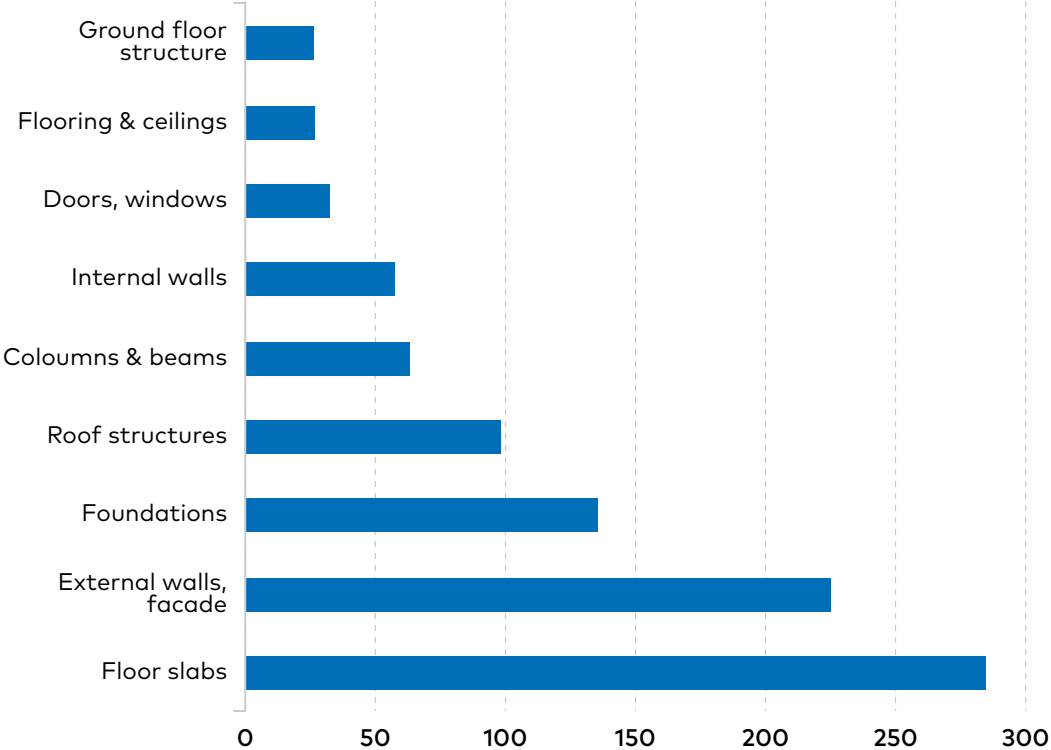


The system boundary includes major modules from the product, use and end-of-life stages.

In the second figure, *Operation* includes B6, while materials include A1-A5, B4-B5, C1-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, C1-C4, and D is shown separately.

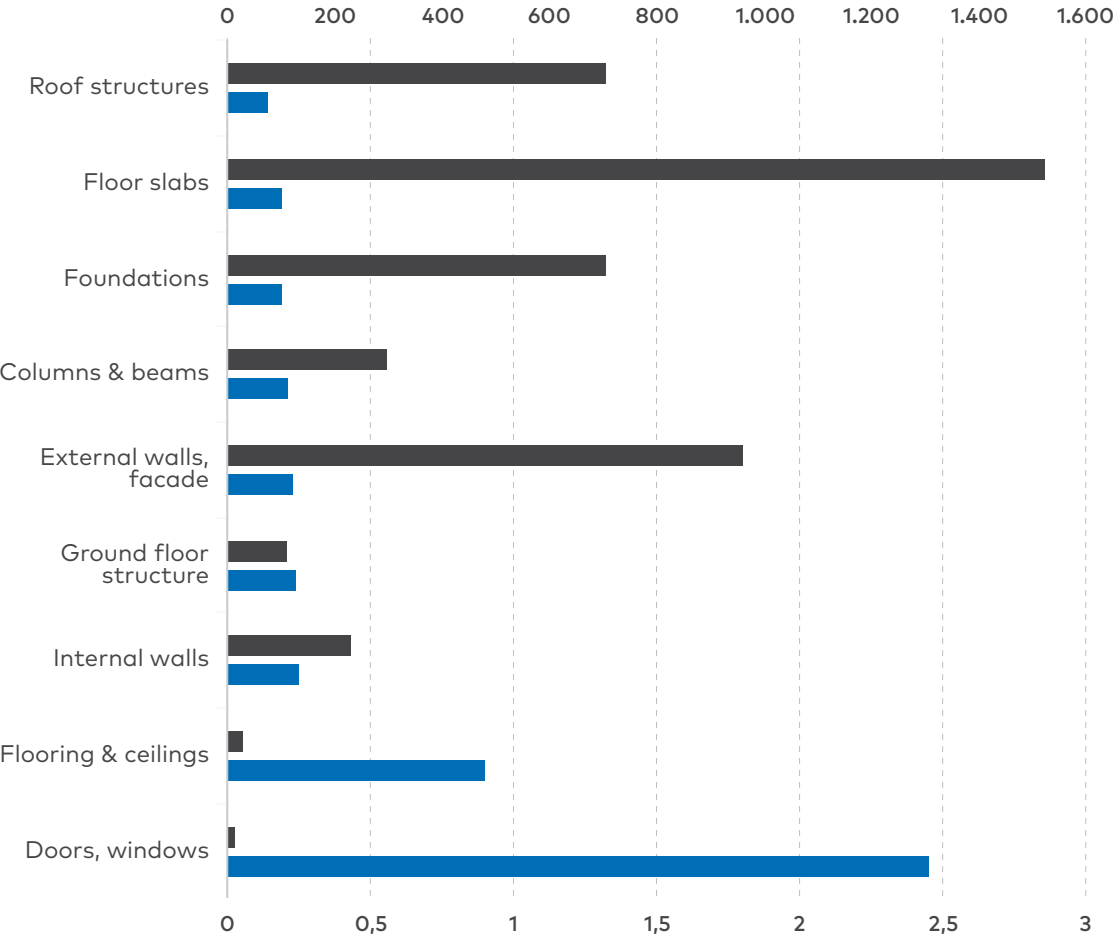
LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials
Life cycle modules: A1-3, B4-5, C1-4

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

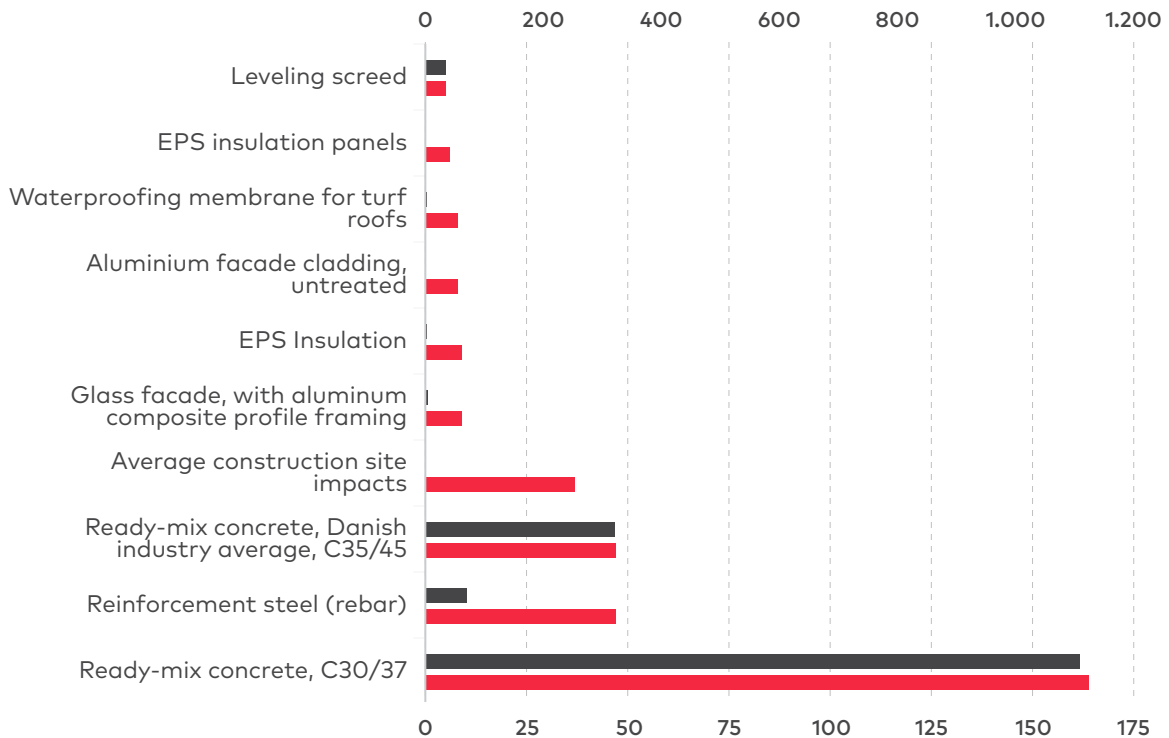
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-3, B4-5, C1-4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kg product / m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-3, B4-5, C1-4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The dominating concrete and reinforcement steel are used in walls and slabs.



Photo by Loop Architects



Photo by Urban Arkitektar

19 Moberg hjúkrunarheimili í Árborg

Iceland

Building use	Nursing home	Stories above ground	2
Location	Árvegur 3, 800 Selfoss	Basement area	—
Client	Framkvæmdasýslan - Ríkiseignir	Structural system	Reinforced concrete
LCA consultant	EFLA	Façade type	Wood
Year of completion	2024	Roof type	Flat roof
Reference area	4369,3 m ² (gross floor area)	Heat demand /source	District heating

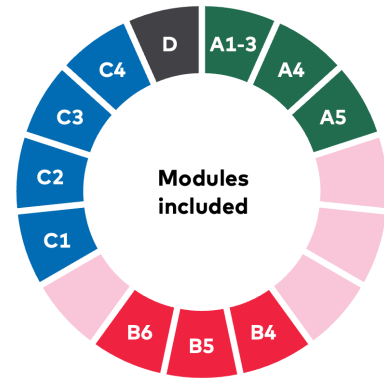
The Moberg nursing home is a two-story circular building featuring an inner courtyard at its centre. It includes 60 nursing rooms divided into five residential units, with the nursing spaces situated around the exterior and service areas and corridors positioned within the circle. The building is mainly constructed from reinforced concrete, externally insulated and clad in timber cladding. The roof is made from insulated concrete, covered with roofing felt and topped with turf and gravel.

From the start, the design prioritised sustainability in both construction and operation. Careful attention was given to material selection, interior design, energy efficiency and effective environmental management. Due to its location in an earthquake-prone area, concrete was selected for the structure, but all external walls were made from wood. To lower concrete emissions, the concrete was mixed with ash from the Eyjafjallajökull volcano eruption, significantly reducing carbon emissions. All wood used in the building was sourced from sustainably managed and legally harvested forests.

The life-cycle assessment influenced the selection of materials for the building. The analysis was carried out for the following building elements over a 60-year lifetime: Ground slab and plinths, floor slabs, flooring, ceiling, roof, exterior walls, interior walls, doors, windows, columns, stairs and interior painting. The measures implemented to reduce the building's carbon footprint resulted in a 4% reduction in carbon emissions.

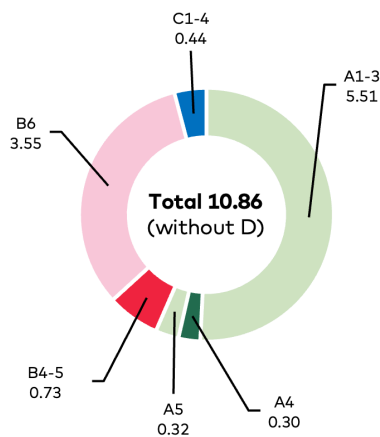
Assessment method

LCA scheme compliance	BREEAM
LCA tool version	One Click LCA v 0.33.0
Life cycle stages included	A1-A5, B4-B6, C1-C4, D
Material emission data	OneClick LCA database and EPD's
Material decarbonisation scenario	—
Energy calculation method	—
Energy, dynamic scenario	LCA study for country specific electricity and district heat mixes based on Orkustofnun, OneClickLCA 2017

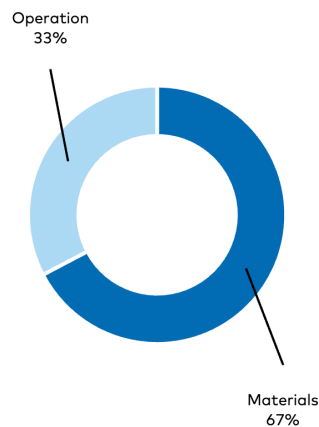


LCA results: Life cycle modules

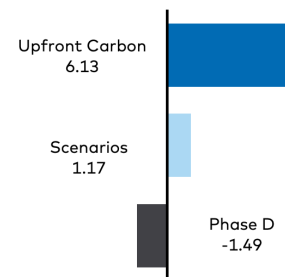
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

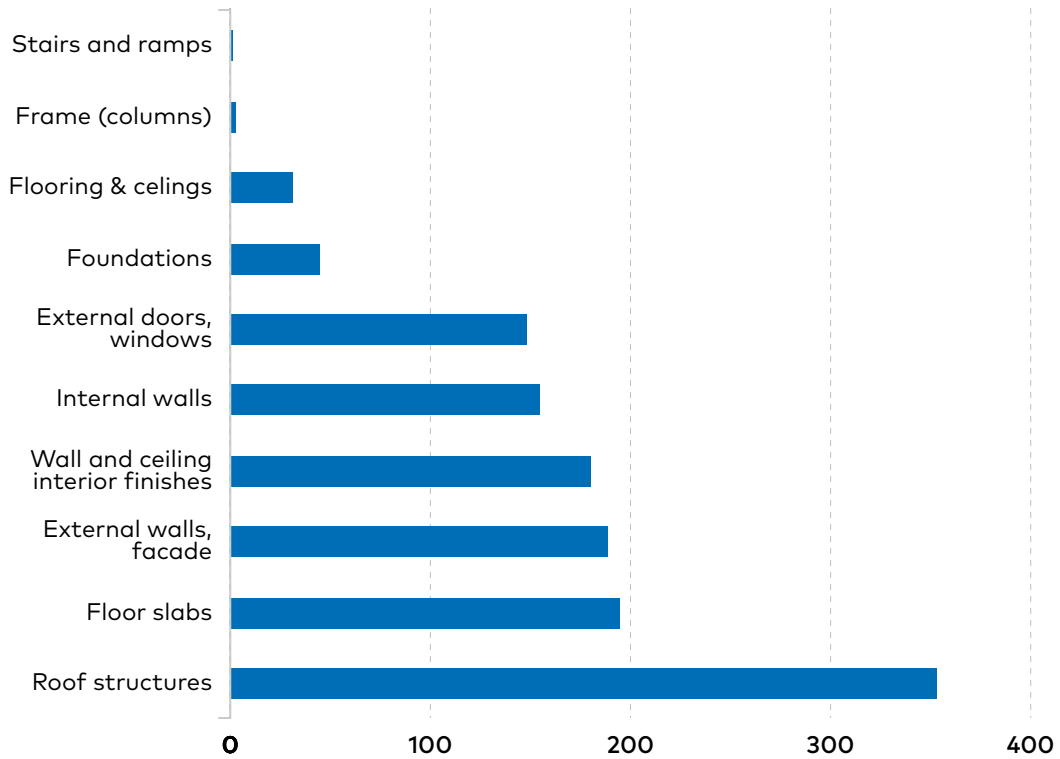


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes key modules from product, use and end-of-life stages. In the second figure, *Operation* includes B6, while materials include A1-A5, B4-B5, C1-C4. In the third figure, *Upfront* includes A1-A5, scenarios include B4-B5, C1-C4, and D is shown separately.

LCA results: Building elements

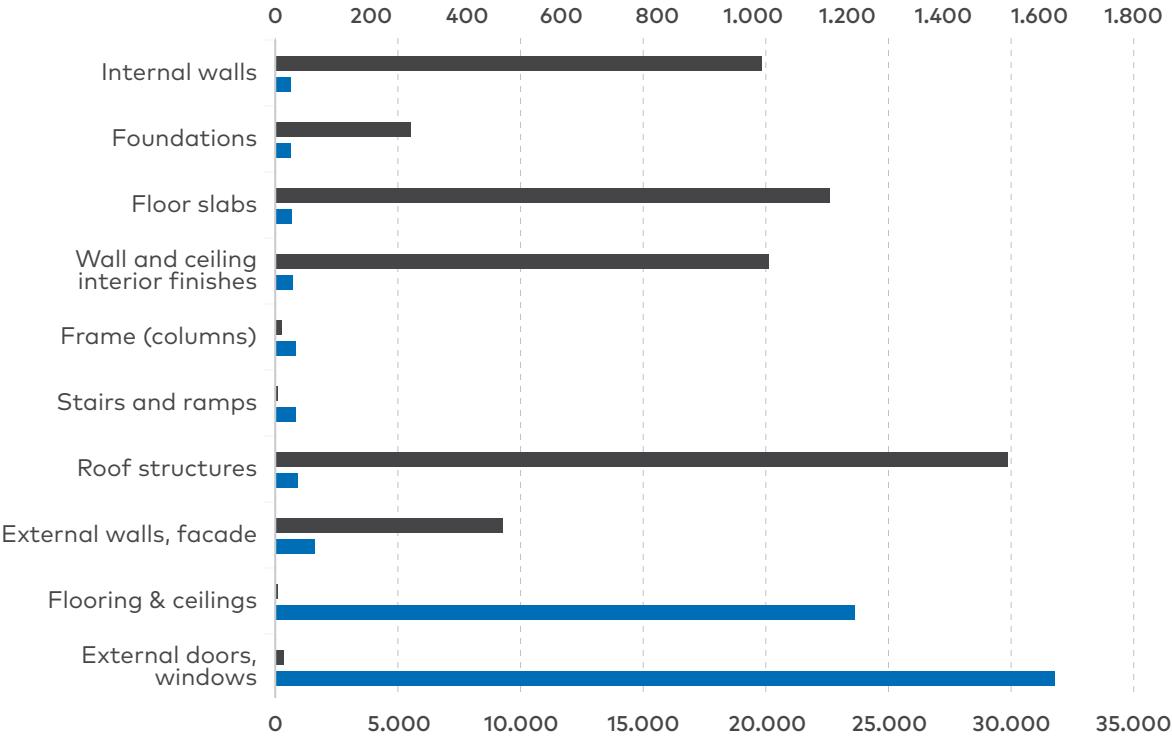


GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-3, B4-5, C1-4

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

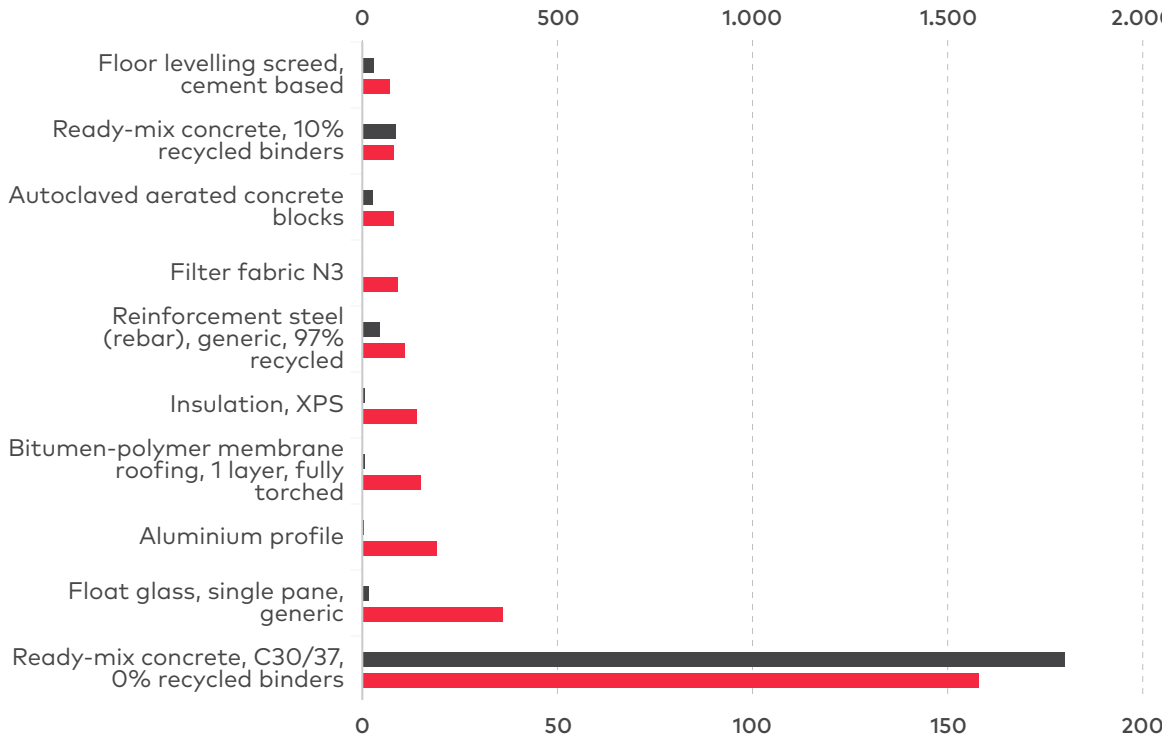


Material inventory: All materials
Life cycle modules: A1-3, B4-5, C1-4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m2 reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-3, B4-5, C1-4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos by Studio Grandi

20 Nýbygging Alþingis: Smiðja

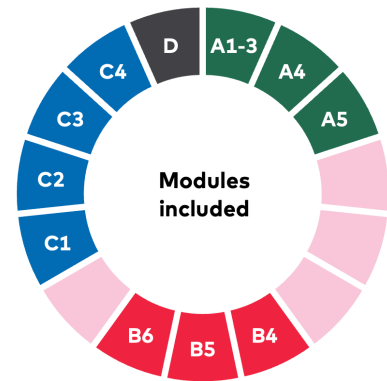
Iceland

Building use	Office	Stories above ground	5
Location	Tjarnargata 9, 101 Reykjavík	Basement area	1307 m ²
Client	Framkvæmdasýslan - Ríkiseignir	Structural system	Reinforced concrete
LCA consultant	EFLA	Façade type	Stone
Year of completion	2023	Roof type	Flat roof
Reference area	5962 m ² (gross floor area)	Heat demand /source	District heating

Smiðja is the new office building for Alþingi, Iceland's parliament. It has five stories and includes a parking basement. During the design and construction of the building, various sustainability metrics were considered, including energy consumption, waste management, land use, and transportation to and from the site. The building is constructed from reinforced concrete, is externally insulated and clad in natural stone. In order to increase its sustainability, the stones used in the construction, blue ore, grey ore, gabbro and liparite, were responsibly sourced from the foundations of previous construction projects, minimising the need for new materials and reducing the environmental footprint. The life cycle assessment was conducted as a part of the BREEAM certification process.

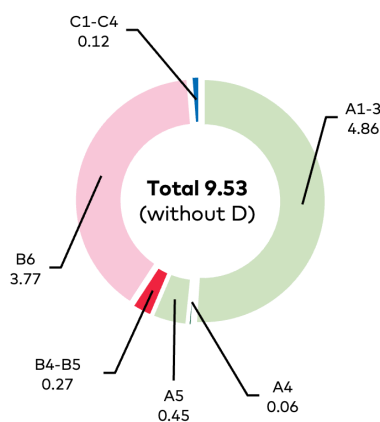
Assessment method

LCA scheme compliance	BREEAM
LCA tool version	One Click LCA v 0.33.0
Life cycle stages included	A1-A5, B4-B6, C1-C4, D
Material emission data	Generic and EPDs
Material decarbonisation scenario	—
Energy calculation method	—
Energy, dynamic scenario	LCA study for country specific district heat mixes based on Orkustofnun, OneClickLCA 2017. country specific electricity mixes based on IEA, OneClickLCA 2016

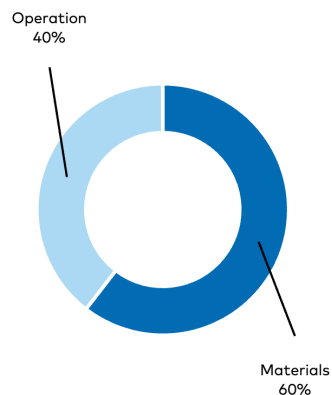


LCA results: Life cycle modules

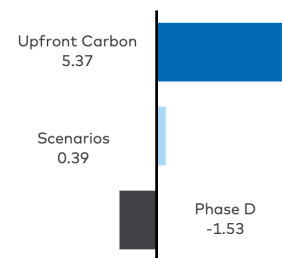
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

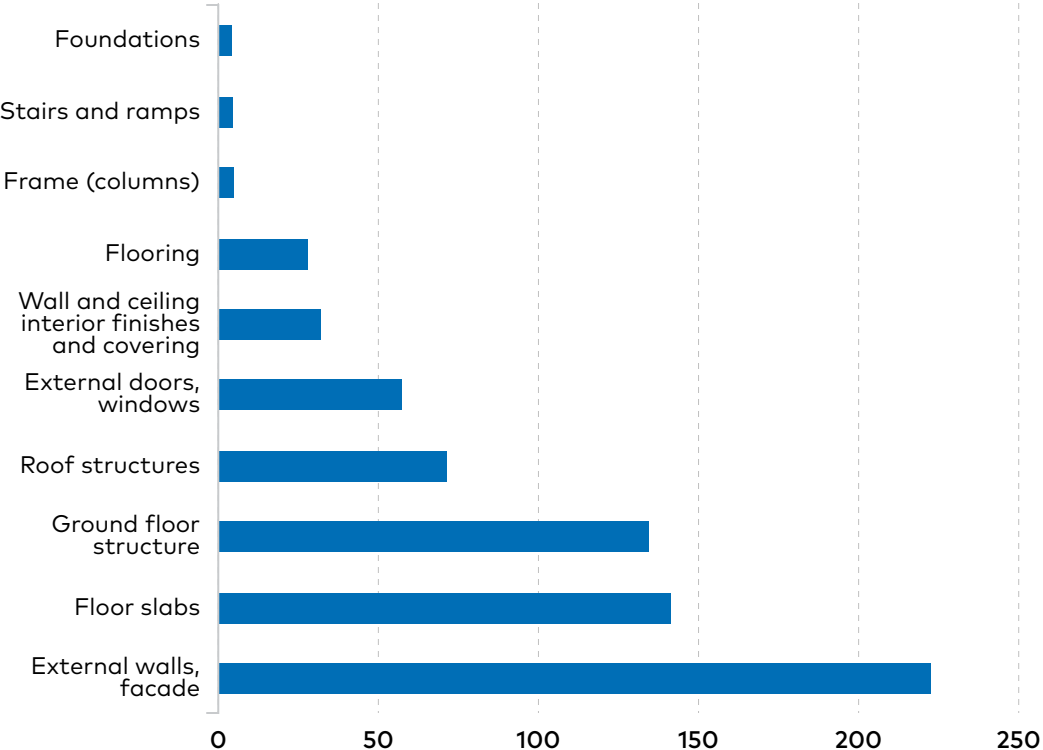


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes key modules from product, use and end-of-life stages. In the second figure, Operation includes B6, while materials include A1-A5, B4-B5, C1-C4. In the third figure, Upfront includes A1-A5, scenarios include B4-B5, C1-C4, and D is shown separately.

LCA results: Building elements

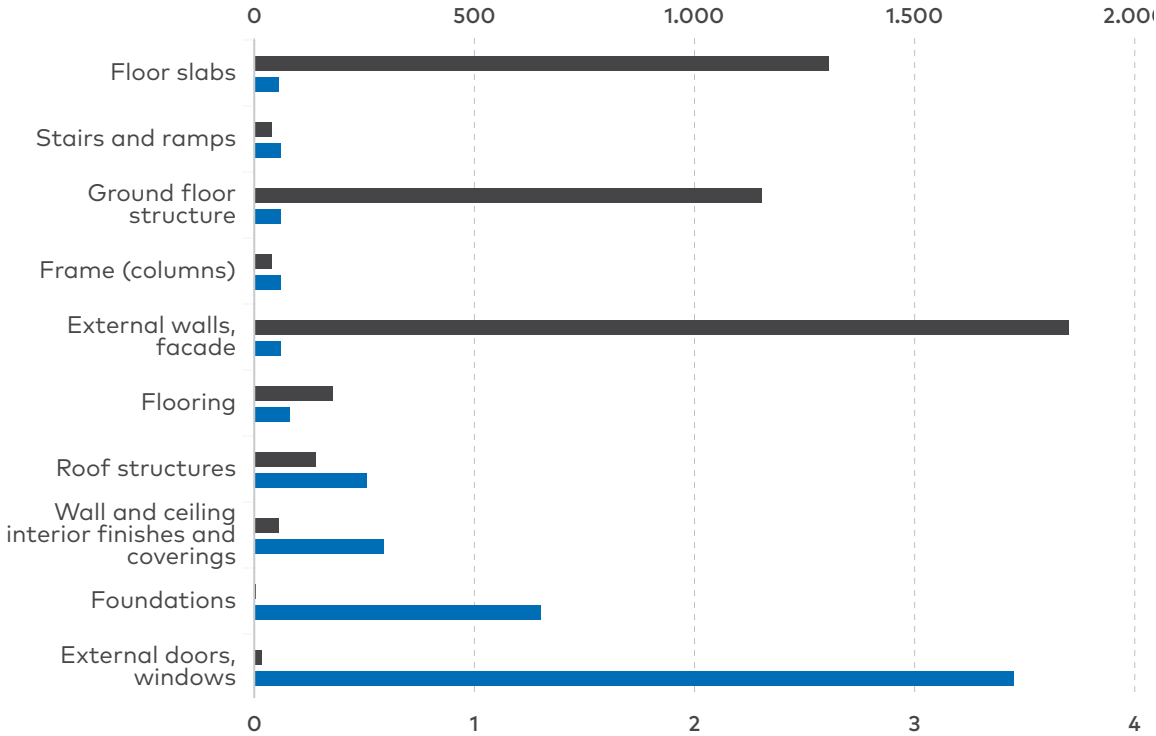


GWP / reference area [kgCO₂e/m² reference area]



Material inventory: All materials
Life cycle modules: A1-3, B4-5, C1-4

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

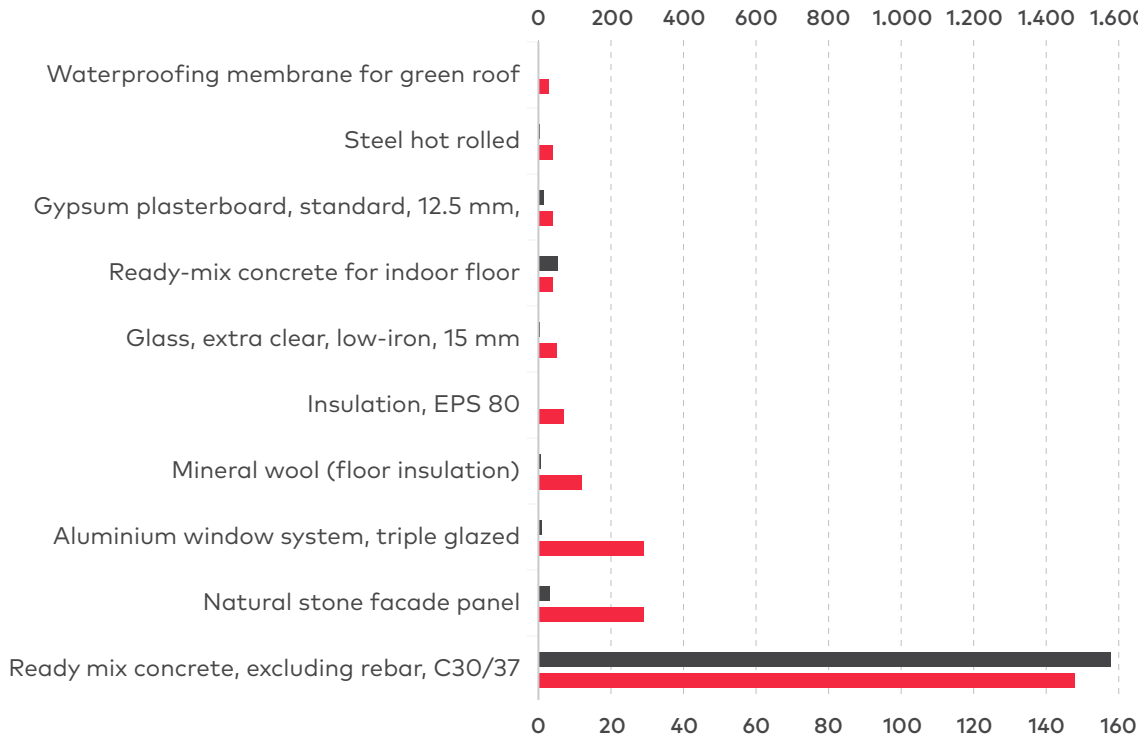
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-3, B4-5, C1-4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-3, B4-5, C1-4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos by Norgeshus AS

21 Norgeshus Nupen

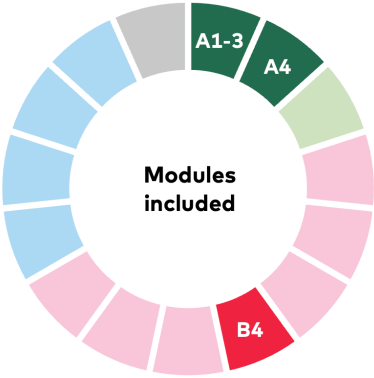
Norway

Building use	Detached home	Stories above ground	2
Location	Oppdal kommune	Basement area	—
Client	Norgeshus AS	Structural system	Column-beam timber frame
LCA consultant	Norgeshus Ingeniør og Arkitekt Kontor (NIAK)	Façade type	Wood cladding
Year of completion	—	Roof type	Gable roof with cement tiles
Reference area	208 m ² (Gross floor area)	Heat demand /source	Electricity

Norgeshus AS is the developer of the Norgeshus franchise concept in Norway, which consists of approximately 155 independent dealers/contractors around Norway, who market and build the houses in our housing catalogues. Nupen is one of our best-selling models in our housing catalogue. To achieve lower CO₂ emissions when a customer works with one of our franchisees to build Nupen, we have selected building materials with documented lower greenhouse gas emissions than other market alternatives. We used EPDs to verify the emissions data for these materials. Material categories for which we have been able to make such choices are EPS, XPS, cross-laminated timber, mortar and moisture barriers. Although the calculation of LCAs is not a requirement for detached houses, our own engineer and architect office has calculated the LCA according to the guidelines and requirements in the Norwegian building code (TEK17).

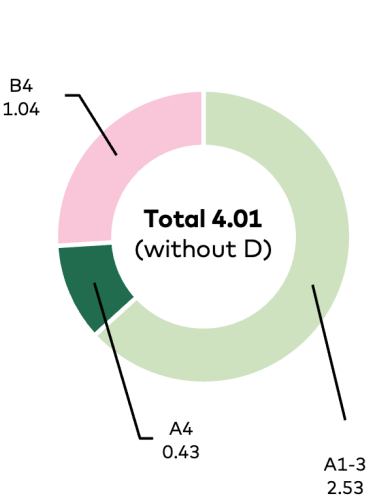
Assessment method

LCA scheme compliance	—
LCA tool version	Reduzer
Life cycle stages included	A1-3, A4, B4
Material emission data	Generic Norwegian database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Phase B6 is not included in assessment
Energy, dynamic scenario	Phase B6 is not included in assessment

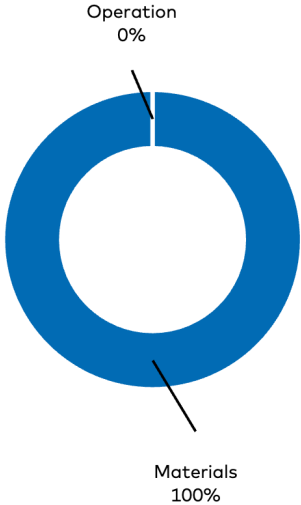


LCA results: Life cycle modules

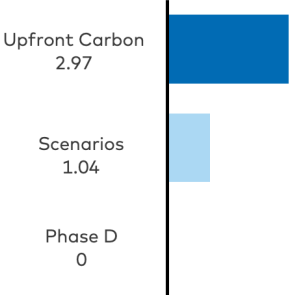
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

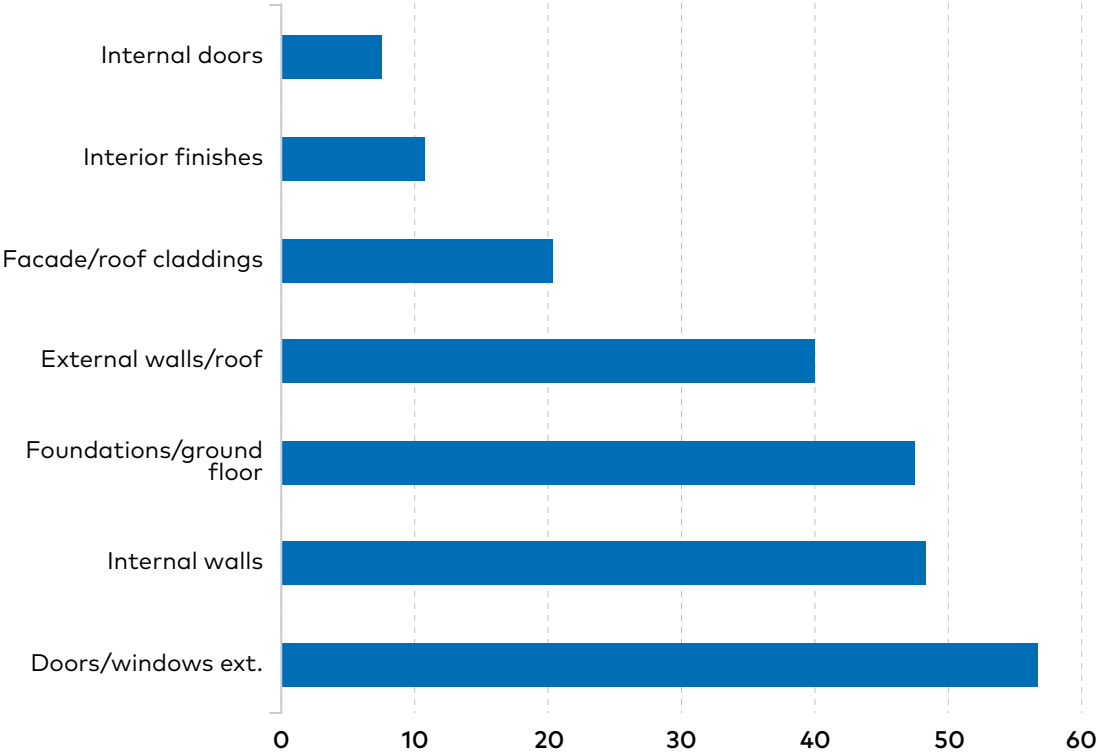


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes the products stage and replacements. Since neither B6 or B7 are included in the assessment, the second figure only shows impacts from the materials, phases A1-A4, and B4. In the third figure, *Upfront* includes A1-A4, scenarios include B4, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



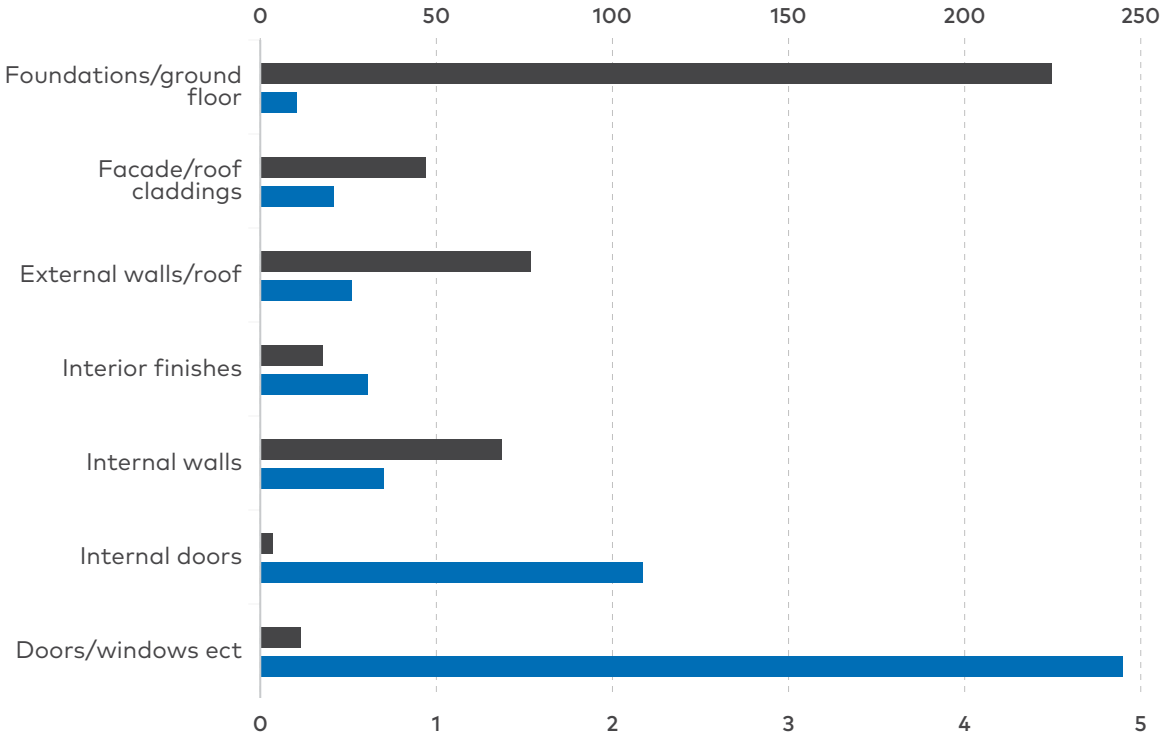
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A4, B4

Foundations include the ground floor structure, internal walls include floor slaps, and interior finishes include walls finishes/coverings, flooring and ceilings.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

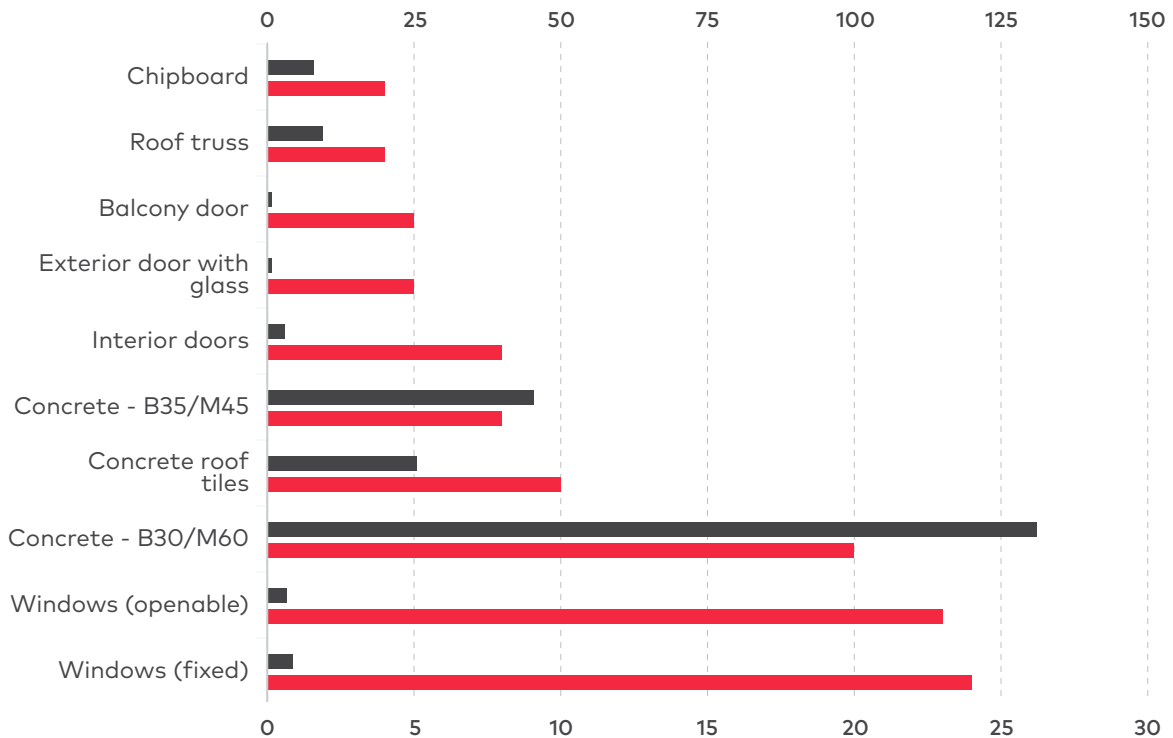
Material inventory: All materials

Life cycle modules: A1-A4, B4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A4, B4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Note from Norgehus: Although we are able to use product-specific emissions factors from EPDs for approximately two thirds of the unique building supplies in our catalogues, we have used generic emissions factors from Boverkets database for all of these hotspots.



Photos by AFE Boligprosjekt 2020 AS

22 Fyrstikkbakken

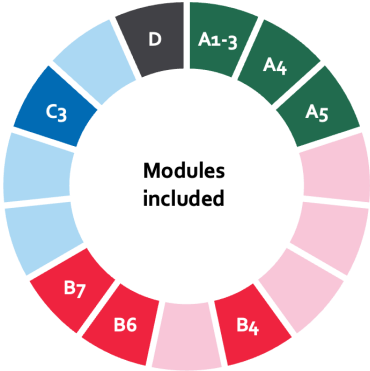
Norway

Building use	Residential	Stories above ground	4 buildings, 8,9,10 and 9 floors
Location	-	Basement area	2476 m ²
Client	AFE Boligprosjekt 2020 AS, Birk & co and AF Eiendom	Structural system	CLT, Concrete and steel
LCA consultant	LINK Arkitektur	Façade type	Painted wood
Year of completion	2024	Roof type	Flat roof, CLT slab, Roof terrace
Reference area	12,699 m ² (useable floor area)	Heat demand /source	District heating and solar cells

The project is part of the FutureBuilt program, which has the goal to reduce CO₂ from energy use, materials and transportation with 50%. It was designed to be an eco-friendly residential densification near public transport hubs, with sharing and joint use as guiding principles. The location of the project was central to the low CO₂ emissions. The main building materials are cross laminated wood (structural system) and low carbon concrete (basement and first floor). The energy use of the buildings is low due to the insulation in the outer walls, decentralized ventilation, and use of coal filters in the kitchen ventilation (requires less extraction of air). The project has proved to be a model project in terms of shared use, sustainability, future living forms and green mobility. The homebuyers range from 22 to 82 years old and have in common is that they support the idea of sharing and community. The project hopes to show one can achieve lower CO₂ emissions by living in a smaller individual space and sharing common spaces with neighbours, but at the same time increase the quality of living. The project has used LCA analysis from the beginning in planning and choice of materials.

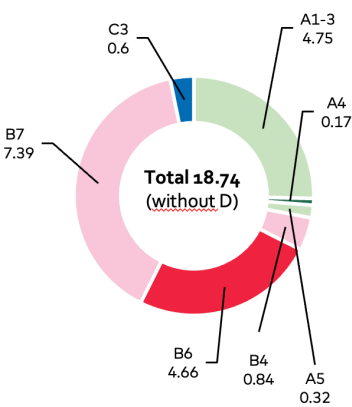
Assessment method

LCA scheme compliance	FutureBuilt
LCA tool version	One Click LCA
Life cycle stages included	A1-A5, B4, B6, B7, C3, D
Material emission data	EPDs
Material decarbonization scenario	-
Energy calculation method	Energy simulation method for the TEK building code
Energy, dynamic scenario	-

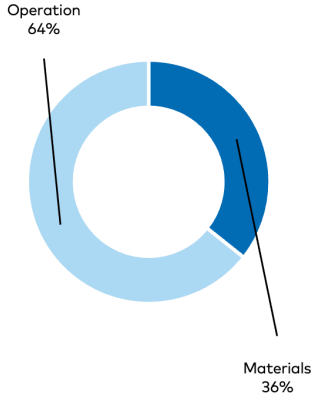


LCA results: Building elements

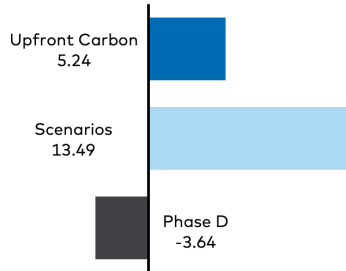
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

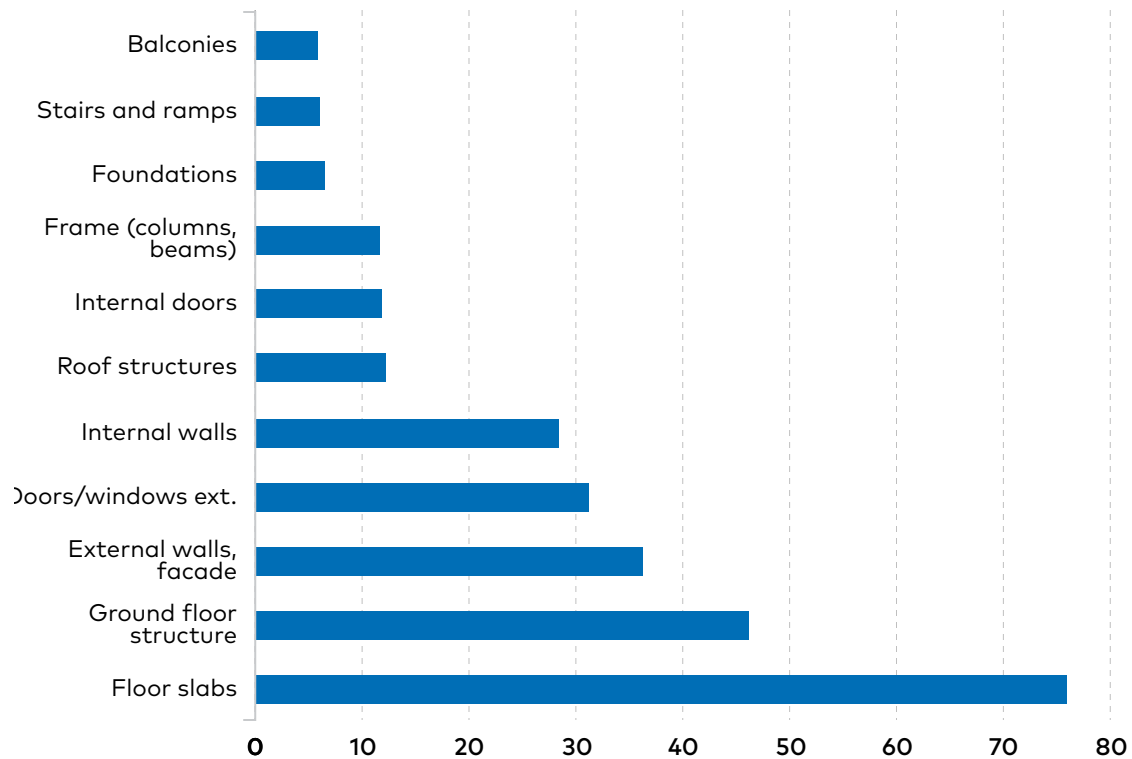


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes the product, use and end-of-life stages. The material inventory also includes solar cells. In the second figure, *Operation* includes B6, while materials include A1-A5, B4, C2-C4. Be aware that B6 contain electricity, district heating and solar power. In the third figure, *Upfront* includes A1-A5, scenarios include B4, C2-C4, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



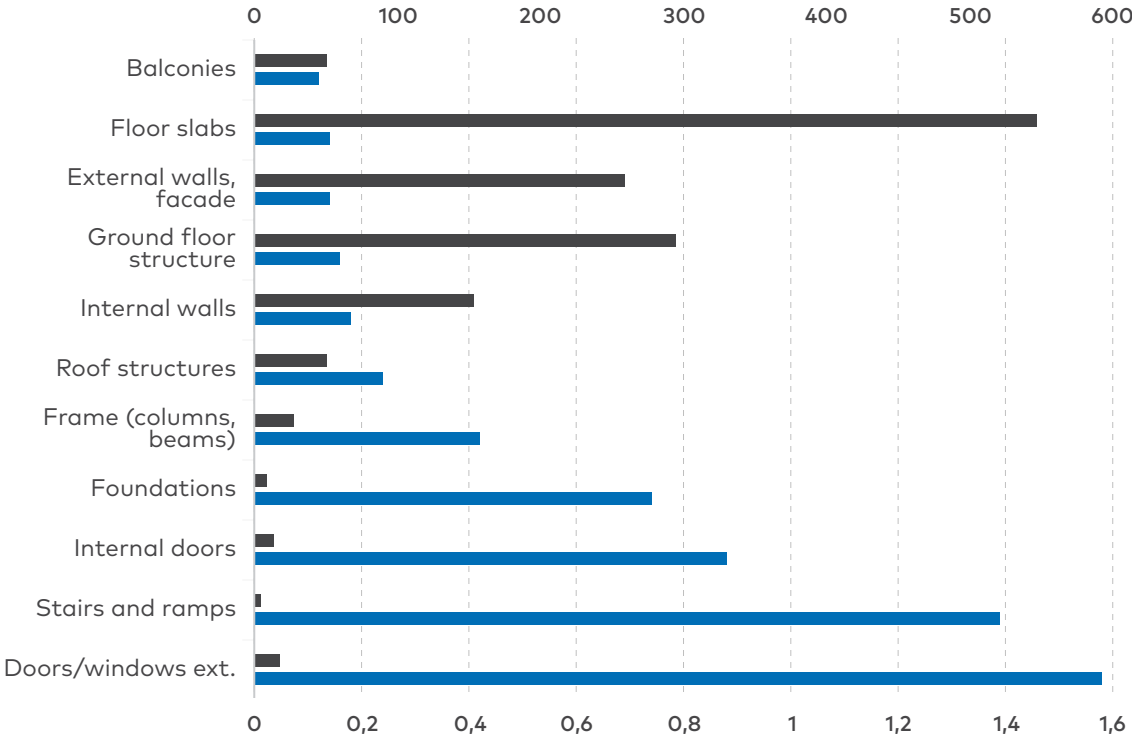
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4, C3

Interior walls are included finishes, Floor slabs include everything from flooring to ceilings, External walls, include the facade cladding, roof structure include external cladding. Solar cells were also calculated (A1-A5, C3), but they are not shown in figure, there impact is 614 kgCO₂eq./m².

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

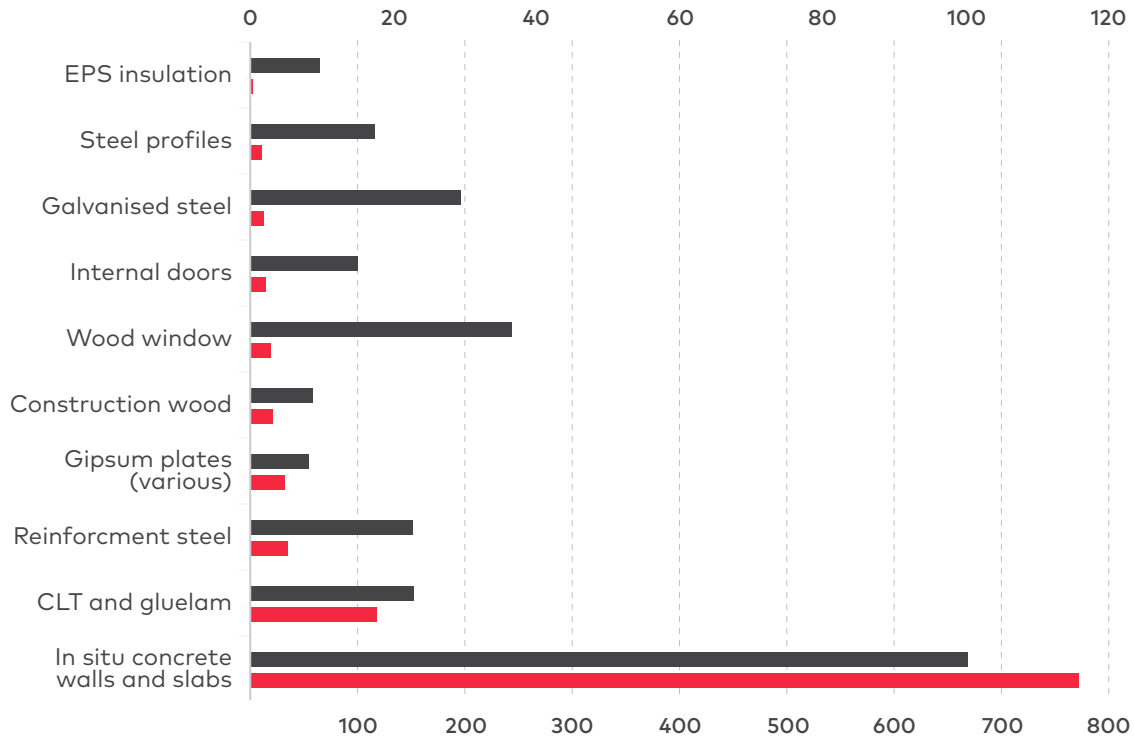
Material inventory: All materials

Life cycle modules: A1-A4, B4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

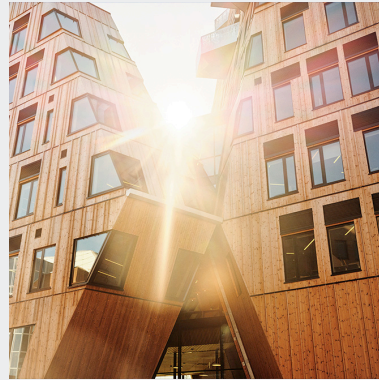
■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A4, B4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

Note that the reference area in this case is the usable floor area.



Photos by Avantor

23 Vertikal Nydalen

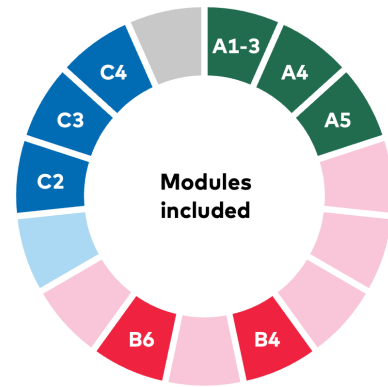
Norway

Building use	Apartment building, office and hotel	Stories above ground	18
Location	Gullhaug Torg 2a, Oslo	Basement area	1 floor
Client	Avantor	Structural system	Steel frame
LCA consultant	Skanska	Façade type	Kebony (wood) cladding
Year of completion	2023	Roof type	Flat roof
Reference area	11,188 m ² (Gross floor area)	Heat demand /source	Heat pump and district heating

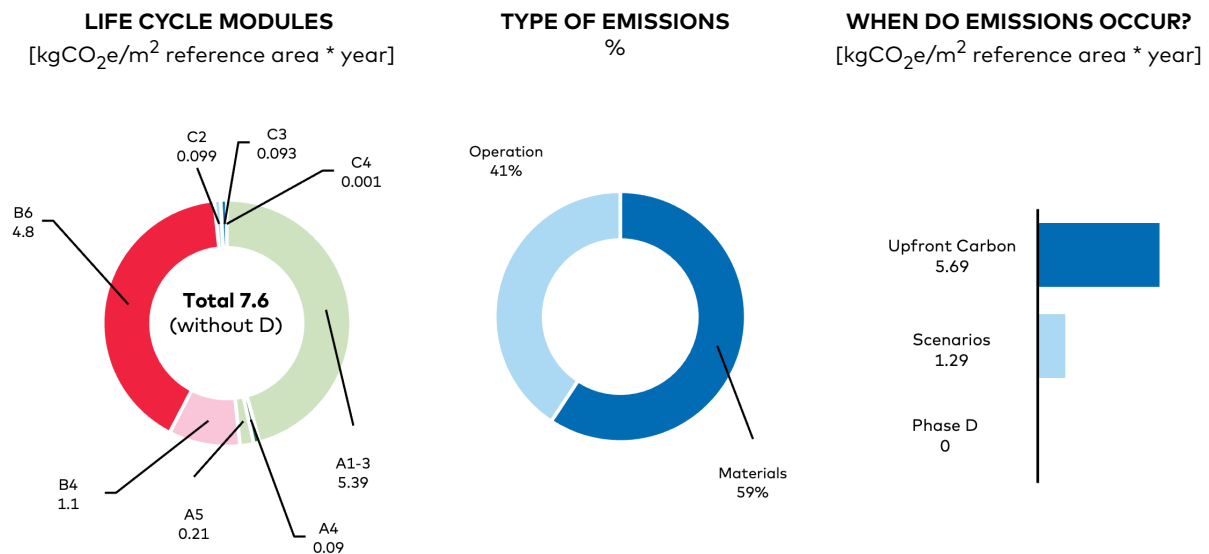
The building includes offices, restaurants and residential units and is Norway's first combination building with natural air conditioning. Its design prioritises simple operation and maintenance, resulting in a lower environmental impact compared to traditionally mechanically ventilated buildings, while enhancing user experience through better indoor climate control. A critical aspect of the building is its integration into the LowEx and Naturally research projects, both funded by the Research Council of Norway. The building is environmentally certified according to BREEAM NOR. Its architecture promotes natural ventilation, with a unique geometric design that effectively channels air and creates pressure differences throughout the structure. Each apartment features high ceilings, ample natural light and materials that promote a healthy indoor atmosphere. Instead of traditional air conditioning units and ducts, the building utilises strategically placed façade hatches that open and close in response to external temperature and wind conditions. This passive system is complemented by computer simulations allowing for precise placement of air vents to optimise airflow. Further carbon mitigation is accomplished by using heavy, low-emitting materials, waterborne underfloor heating, and solar panels. The heat pump system is supported by groundwater drawn from 300-metre-deep wells, significantly reducing energy consumption.

Assessment method

LCA scheme compliance	BREEAM NOR
LCA tool version	OneClickLCA
Life cycle stages included	A1-3, A4-A5, B4, B6, C2-C4
Material emission data	Generic Norwegian database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Emission factor for scenario 2 in NS 3720
Energy, dynamic scenario	EU28+Norway mix



LCA results: Life cycle modules



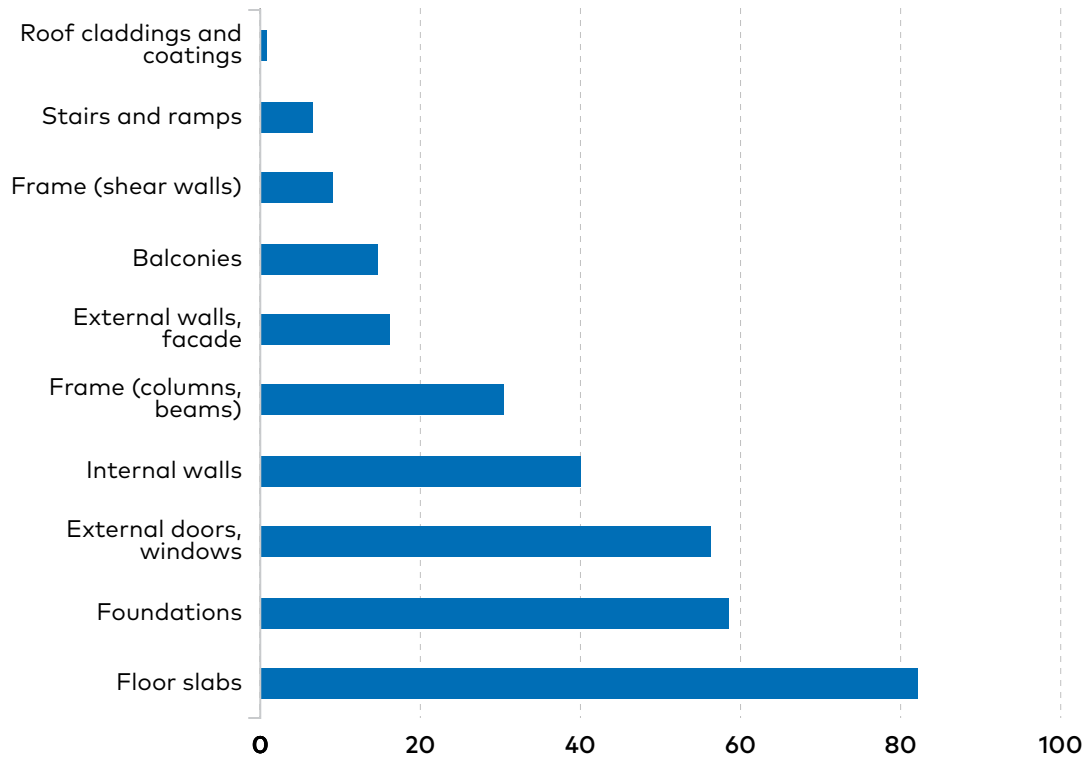
The system boundary includes the product, use and end-of-life stages.

The material inventory includes a detailed account on building services (lifts, electricity system, HVAC system, solar cells). In the estimation for B6, the energy grid EU28+Norway has been used. If an energy grid for only Norway had been used, the impact of B6 would have been 0.62 kgCO₂e/m² reference area/year.

In the second figure, *Operation* includes B6, while materials include A1-A5, B4, C2-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B4, C2-C4, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



GWP / reference area [kgCO₂e/m² reference area]

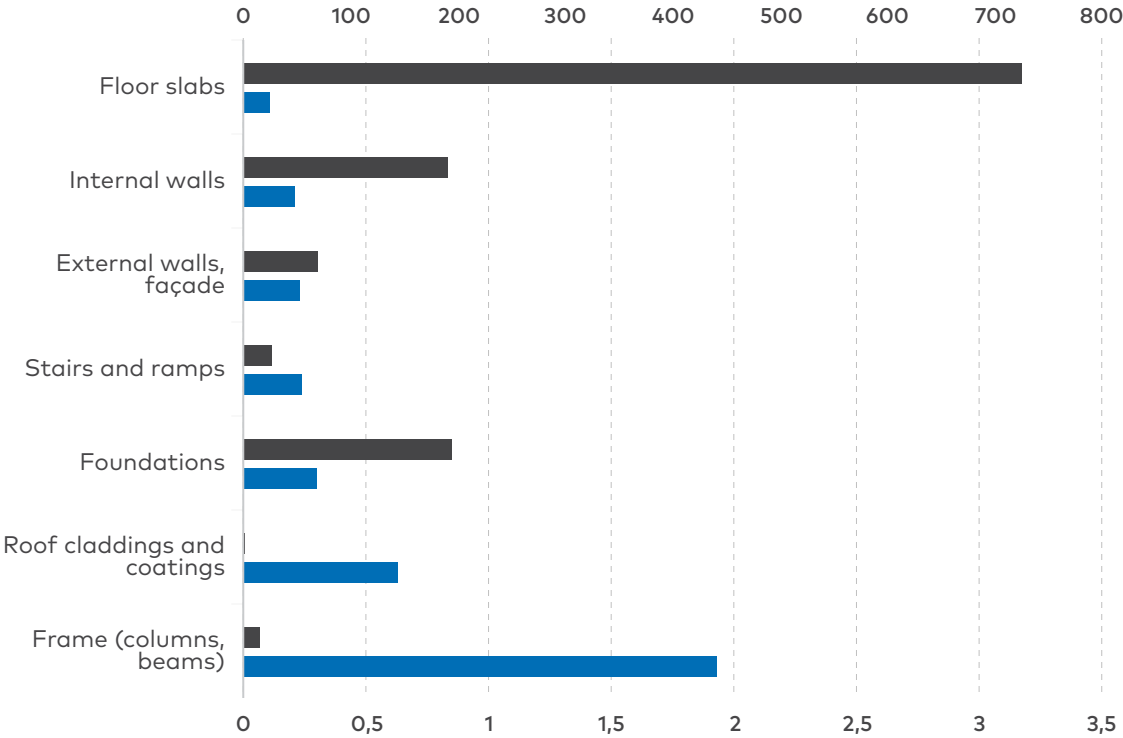
Material inventory: All materials

Life cycle modules: A1-A5, B4, C2-C4

Foundations include piling, interior walls included finishes and coverings, Floor slabs include flooring and ceilings, exterior wall includes façade cladding.

In this project, floor slabs are dominating due to the high-rise layout.

Building Element quantity / reference area [kg building element / m² reference area]



GWP of building element GWP / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

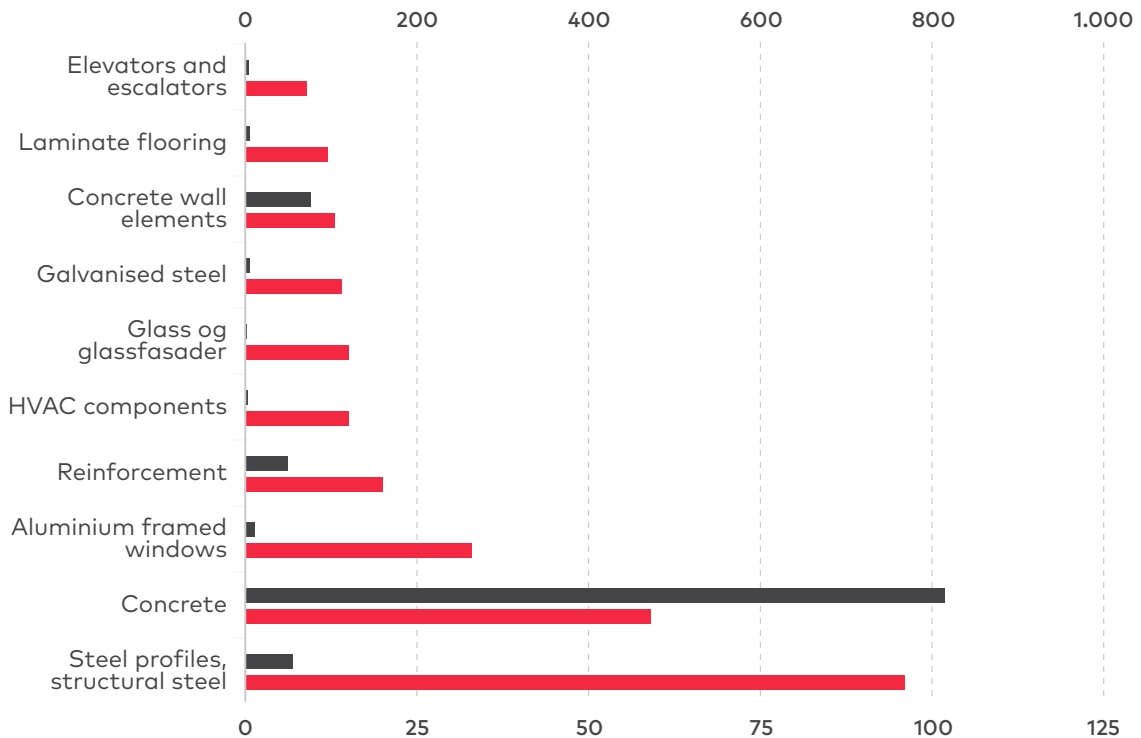


Material inventory: All materials
Life cycle modules: A1-A5, B4, C2-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B4, C2-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The graph shows that It is the structural system that has the highest GWP/area where the system is made of mainly steel with some concrete columns. Quantity/area of the two structural elements shows that the steel quantity is much lower than that of concrete – even as main structural material.



Photo by Oslobygg KF



24 Rusløkka skole

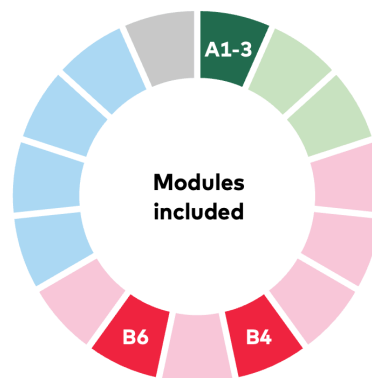
Norway

Building use	School	Stories above ground	6
Location	Løkkevejen 15, Oslo	Basement area	2496 m ²
Client	Oslobygg KF	Structural system	Steel columns and hollow core concrete slabs.
LCA consultant	Asplan Viak	Façade type	Bricks and façade solar cells
Year of completion	2021	Roof type	Hollow core concrete slab with green roof cover + terrace
Reference area	10,300 m ² (gross floor area)	Heat demand /source	District heating

Ruseløkka School is a primary and secondary school for 690 pupils in Vika in Oslo. The project has been carried out as a turnkey contract with Veidekke, and there has been user participation throughout all phases of the project. The architect from GASA has been continued from the preliminary project to detailed design and implementation. The environmental goals have been anchored in FutureBuilt's quality program and followed up during the project. The school building meets the energy requirements of a near-zero-energy building (nZEB). In practice, this means a building body that meets the requirements for passive houses, in addition to building-integrated solar cells in the façade (320 m²) and solar cells on roofs (370 m²) that supply renewable energy. The solar cells on the roof are combined with a green roof for retention of stormwater. It is estimated that the solar cells on the façade and roof will produce approximately 75,000 kWh/year. District heating with low carbon emissions is used for heating and a small cooling demand is covered by adiabatic cooling, which is a very energy-efficient way of cooling the building using water vapour. At Ruseløkka, we have tested low-carbon concrete extreme (CEM III/B) on all site-built concrete. Approx. 4500 bricks were picked out from the old school building, which were reused as interior walls at the knowledge staircase in the main entrance. Old granite steps have been used as benches outside. Mitigation measures were also implemented at the construction site. District heating was used for building heating and construction, and the project had several electric construction machines such as dump trucks, wheel loaders and lifts under construction.

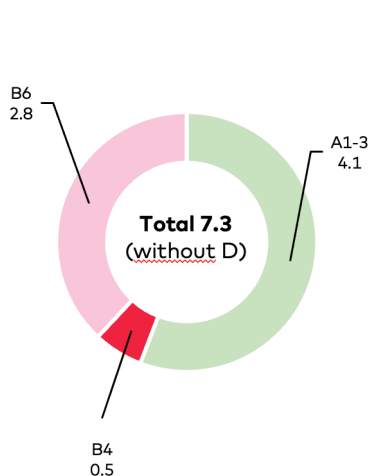
Assessment method

LCA scheme compliance	FutureBuilt, NS3720
LCA tool version	ByggLCAv1.1
Life cycle stages included	A1-A3, B4, B6
Material emission data	-
Material decarbonization scenario	-
Energy calculation method	NS3031:2014, NS3701:2012
Energy, dynamic scenario	-

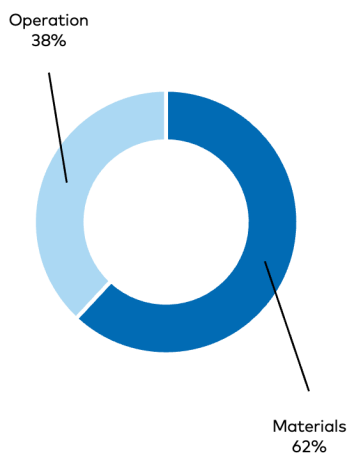


LCA results: Life cycle modues

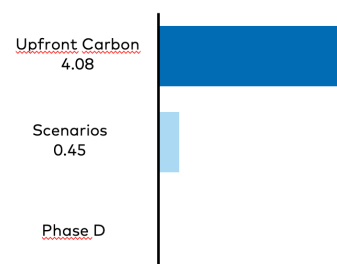
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%



WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



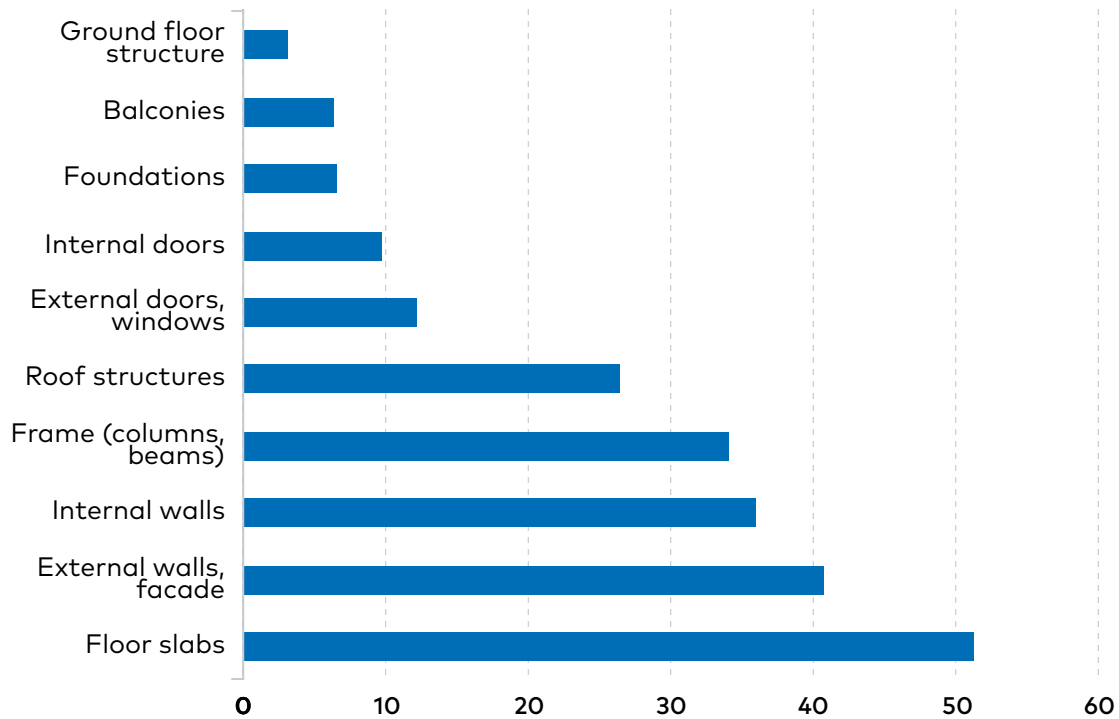
The system boundary includes the product, use and end-of-life stages.

The material inventory includes a detailed account on building services (lifts, electricity system, HVAC system, solar cells). In the estimation for B6, the energy grid EU28+Norway has been used. If an energy grid for only Norway had been used, the impact of B6 would have been 0.62 kgCO₂e/m² reference area/year.

In the second figure, *Operation* includes B6, while materials include A1-A5, B4, C2-C4.

In the third figure, *Upfront* includes A1-A5, scenarios include B4, C2-C4, and D is shown separately, had it been included in the assessment.

LCA results: Building elements



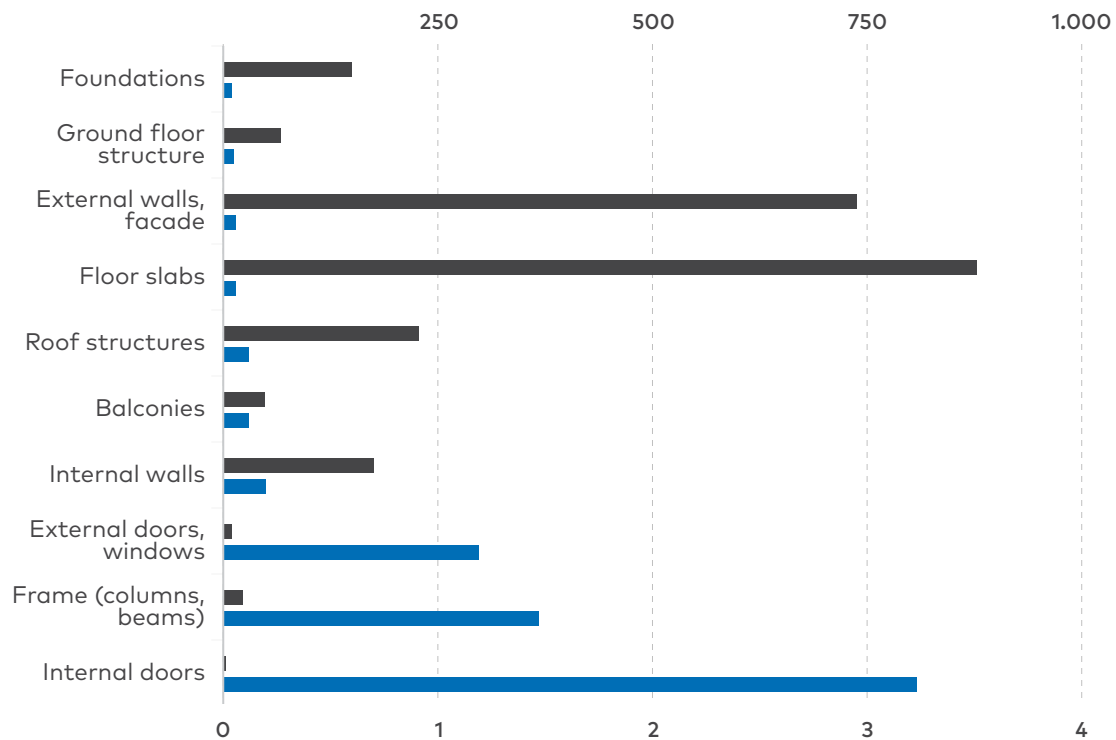
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A3, B4

Interior walls included finishes, Floor slabs include flooring, external walls include façade cladding, and roof includes exterior cladding. The floor slabs and external walls are dominating due to the building layout.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

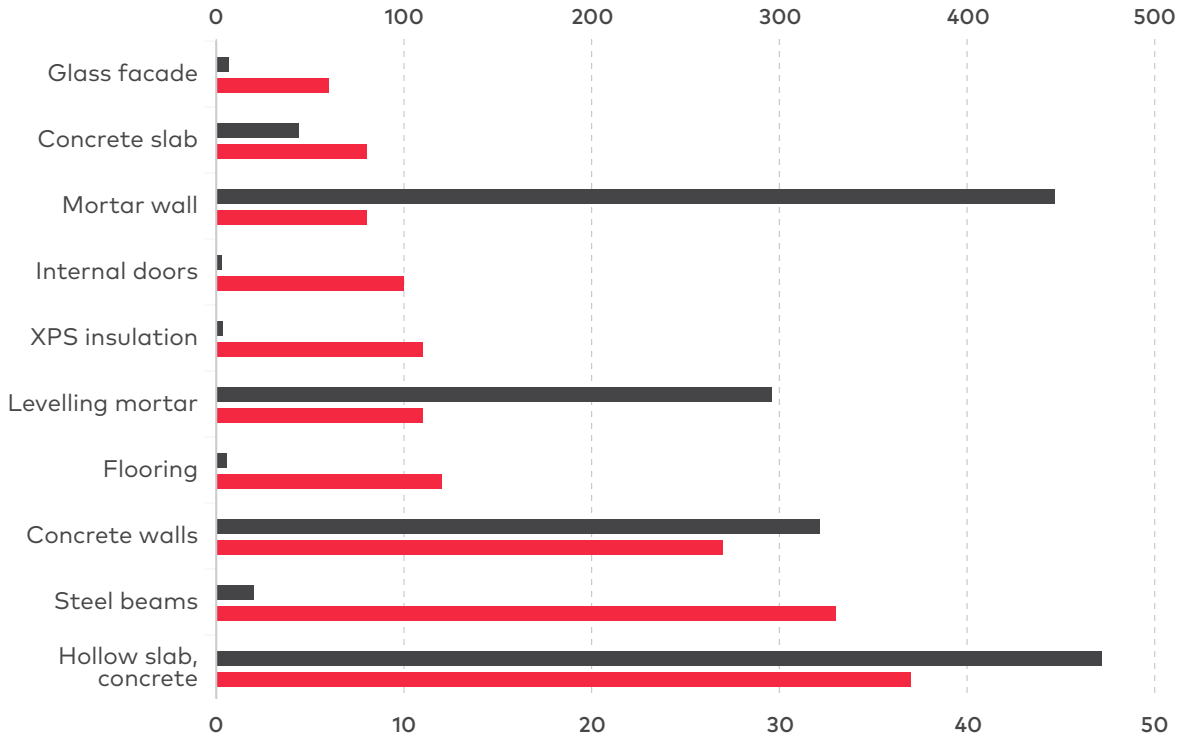
Material inventory: All materials

Life cycle modules: A1-A3, B4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for carbon intensity of the elements relative to their weight.

LCA results: Products

Product quantity / reference area [kgCO₂e/m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

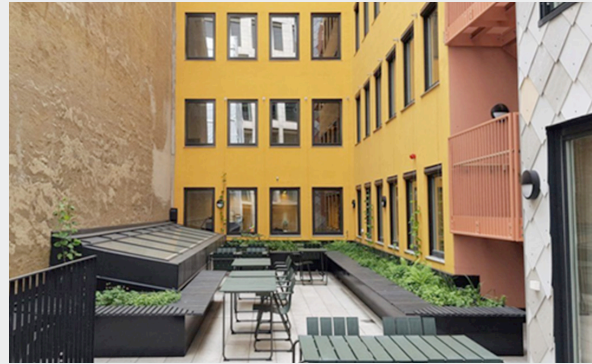
■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B4, C2-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

The graph shows that It is the structural system that has the highest GWP/area where the system is made of mainly steel and concrete. Quantity/area of the two structural elements shows that the steel quantity is much lower than that of concrete – even as main structural material.



Photos by Entra

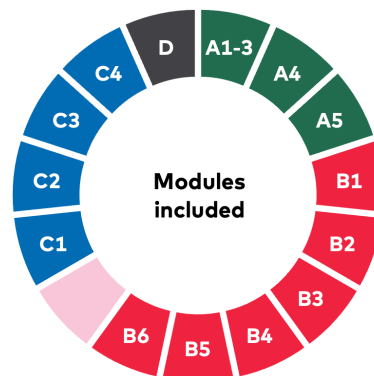
25 Kristian August gate 13 Norway

Building use	Office	Stories above ground	8
Location	Kristian August gate 13, Oslo	Basement area	372 m ²
Client	Entra	Structural system	Steel columns (existing)
LCA consultant	Asplan Viak	Façade type	Concrete plates and brick
Year of completion	2021	Roof type	Flat roof – adding sedum
Reference area	4,050 m ² (Gross floor area)	Heat demand /source	District heating

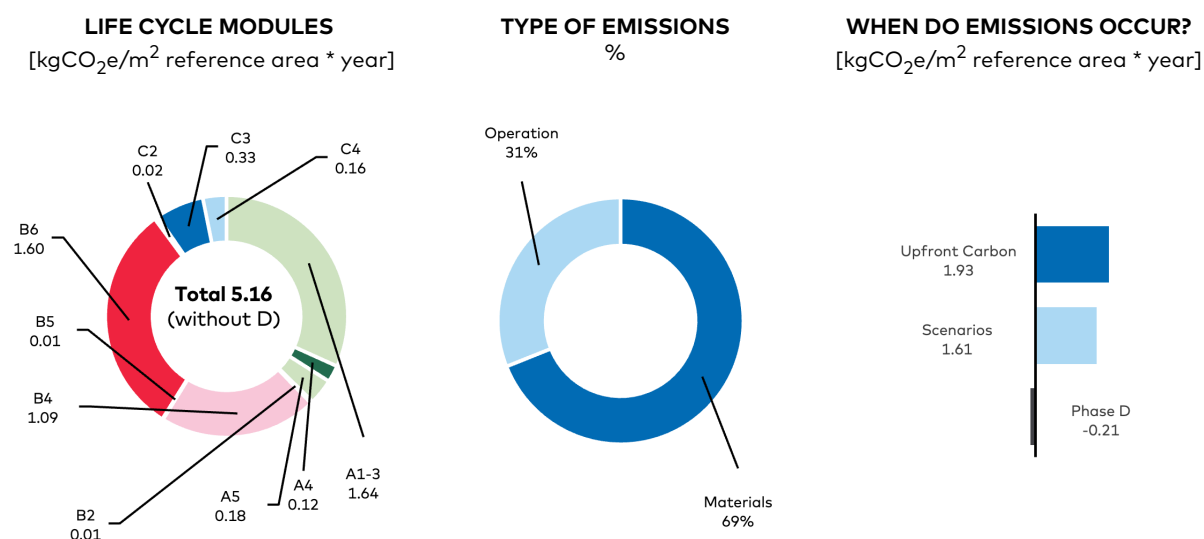
The project is Norway's first building to utilise large-scale reuse of materials and circular solutions, achieving up to 80% material reuse. Key aspects of the project included repurposing components from the existing structure, such as support systems and interior surfaces, alongside materials sourced from various "donor buildings". The existing support system and outer walls have been retained, with the exception of necessary holes and reinforcements. In the extension, hollow-core slabs from the government quarter (R4) have been used on three floors. Approximately 75% of the steel is reused. There is also a lot of reuse in other parts of the project, such as façade cladding and interior equipment such as radiators, sanitary equipment, ducts and pipes, office fronts and doors. Workshops facilitated knowledge sharing within the industry, focusing on regulations regarding documentation for reused building products. Entra, the project's developer, engaged legal experts and government officials to navigate these regulations, addressing the limited availability of established players and materials in the reuse market. Collaborative efforts from contractors, particularly those involved in demolition, significantly contributed to identifying reusable building components. With a design rooted in the 1950s, the existing structure showcases original features like mosaic tiles and terrazzo stairs. The project includes an extension of approximately 60 m² across eight floors, adhering to current building regulations. The design emphasises openness and accessibility, with a glass façade and a large roof terrace promoting green spaces and urban integration.

Assessment method

LCA scheme compliance	FutureBuilt
LCA tool version	ByggLCA v.1.1
Life cycle stages included	A1-3, A4-A5, B1-B5, B6, C1-C4
Material emission data	Generic Norwegian database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Emission factor for scenario 1 in NS 3720
Energy, dynamic scenario	Norway Mix



LCA results: Life cycle modules

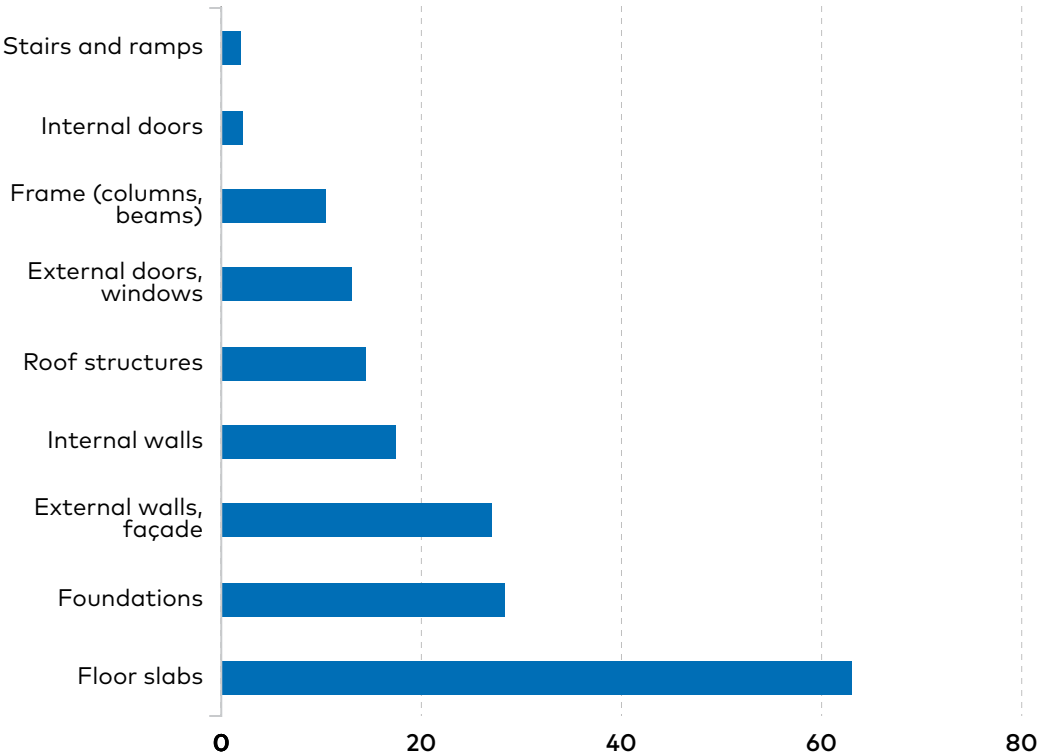


The system boundary includes all modules except B7. The impact for B6 is estimated with the Norwegian electricity mix, if instead the Norwegian+ EU28 electricity mix had been used the impact of B6 would have been 9,4 kgCO₂e/m² reference area / year. The reason behind the relative high emissions related to the B-modules is that the upfront emissions are greatly reduced by various reuse measures.

In the second figure, Operation includes B6, while materials include A1-A5, B1-B5, C1-C4.

In the third figure, Upfront includes A1-A5, scenarios include B1-B5, C1-C4, and D is shown separately.

LCA results: Building elements



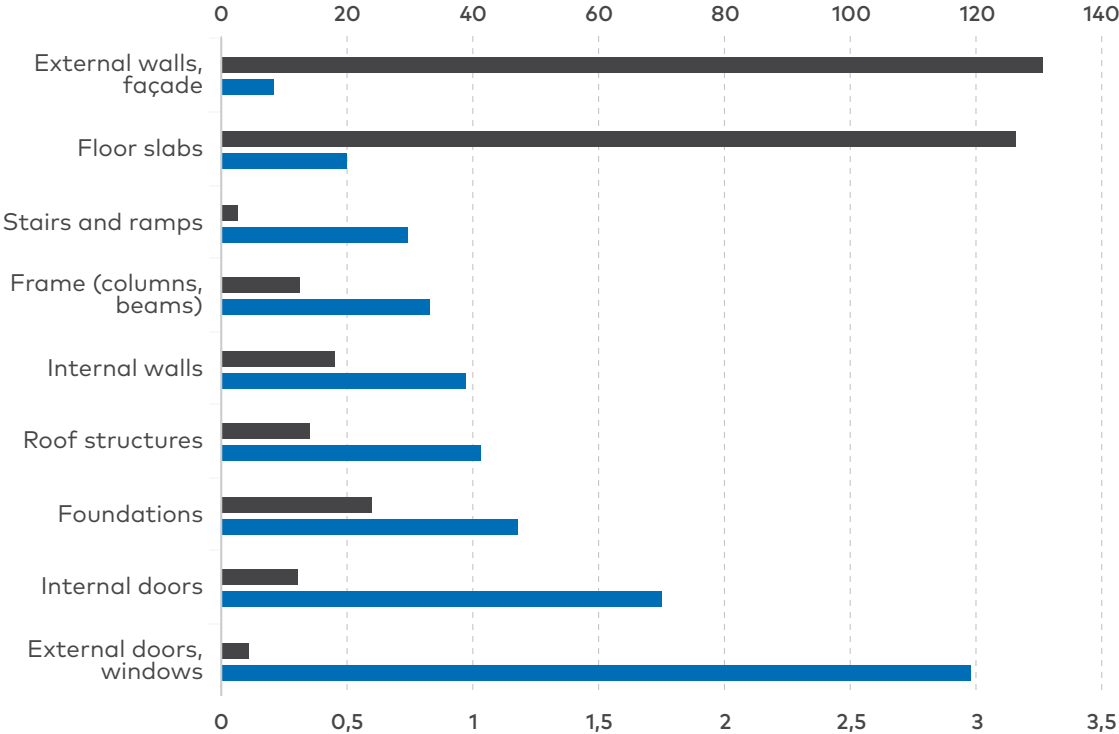
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B1-B5, C1-C4

Foundations include piling, interior walls include finishes and coverings, floor slabs include flooring and ceilings, exterior walls include façade cladding, roof structure includes exterior cladding.

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

■ Quantity/Area ■ GWP/Quantity

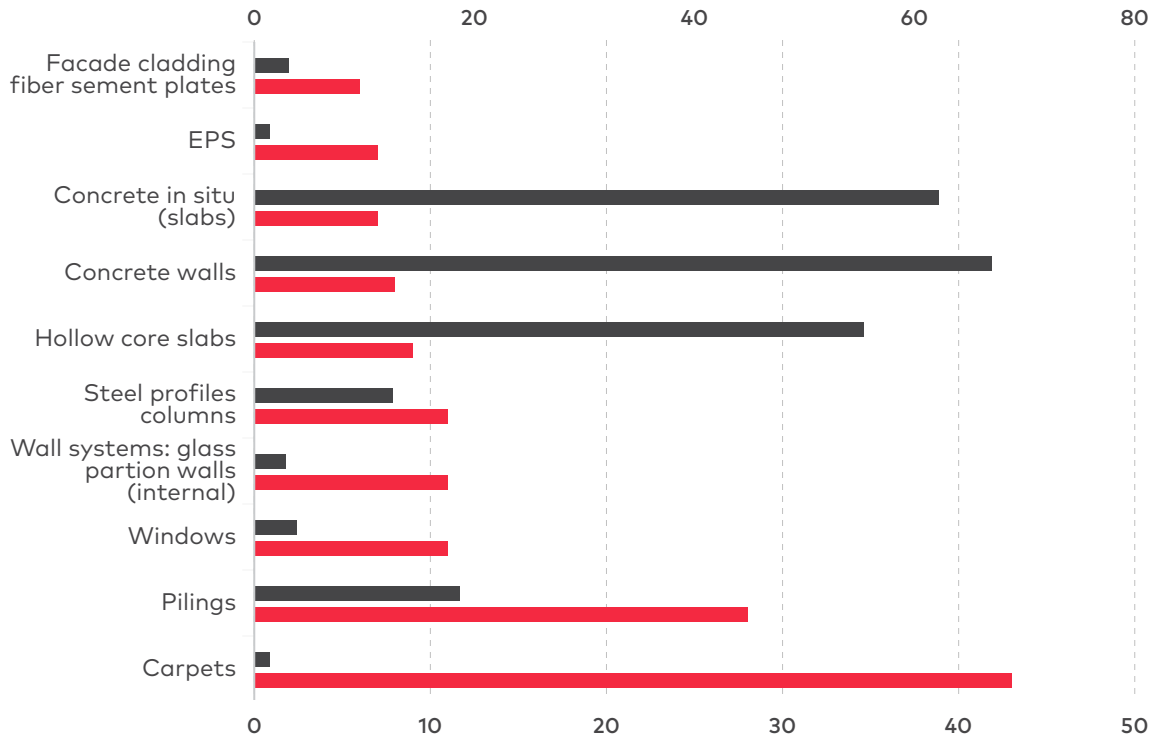


Material inventory: All materials
Life cycle modules: A1-A5, B1-B5, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A4, B4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.



Photos from future Built website

26 Tåsenhjemmet

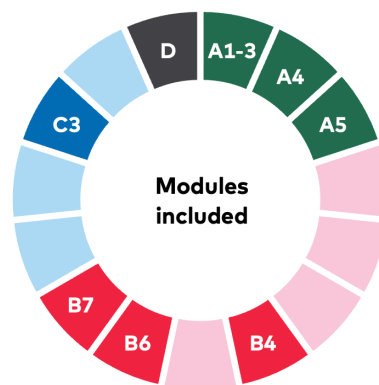
Norway

Building use	Nursing home	Stories above ground	4
Location	Pastor Fangens vei 26 - 28, Oslo	Basement area	1185 m ²
Client	Oslo Bygg KF	Structural system	Glulam, CLT, steel, and concrete
LCA consultant	LINK Arkitektur	Façade type	Painted wood
Year of completion	2024	Roof type	Flat roof, CLT slab, Roof terrace
Reference area	11 392 m ² (heated floor area)	Heat demand /source	Heat pump

The environmental ambitions have been high and in line with the City of Oslo's strategy to reduce greenhouse gas emissions, both in the construction phase and in the operational phase. In addition, the project will be certified as a BREEAM Excellent building. Tåsenhjemmet will be a recognizable and safe place for the building's users. At the same time, it has been a goal to create a building that works well in its surroundings, with a scale and use of materials that fits into the surrounding buildings. Most of the bearing load elements are composed of Glulam wood and about half the slabs and the roof are composed of CLT wood. To reduce emissions from the CLT slabs it has been opted for gravel instead of the otherwise normally used concrete used for levelling mortar and acoustical barrier. CLT wood has also been extensively used in bearing walls and in balconies and stairs. The total emission reduction from materials according to the FutureBuilt scope (A1-A3 + B4) amounts to 26% compared with a standard geometry reference building, when excluding the PV-panels and the foundation measures. It should here be noted that the emissions from the ground floor slab is higher than the reference due to foundation needs (this extra thickness may also be allocated to the foundation but this is not done here). Carbon storage in the wood is not included in these calculations but would improve the results significantly if it was. Also emissions in the construction phase has been reduced as a result of a large proportion of emission-free machines on the construction site.

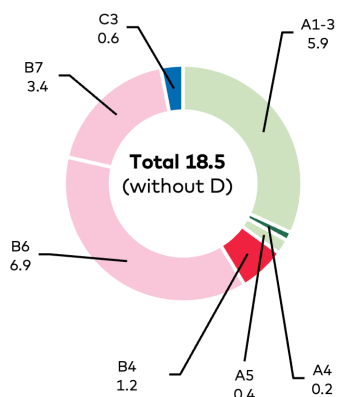
Assessment method

LCA scheme compliance	FutureBuilt
LCA tool version	ByggLCA v.1.1
Life cycle stages included	A1-3, A4-A5, B1-B5, B6, C1-C4
Material emission data	Generic Norwegian database, EPDs
Material decarbonisation scenario	—
Energy calculation method	Emission factor for scenario 1 in NS 3720
Energy, dynamic scenario	—

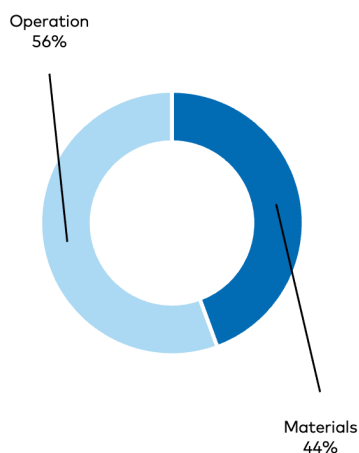


LCA results: Life cycle modules

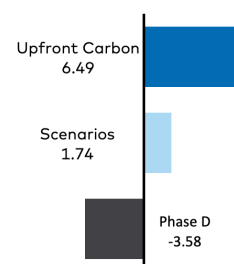
LIFE CYCLE MODULES
[kgCO₂e/m² reference area * year]



TYPE OF EMISSIONS
%

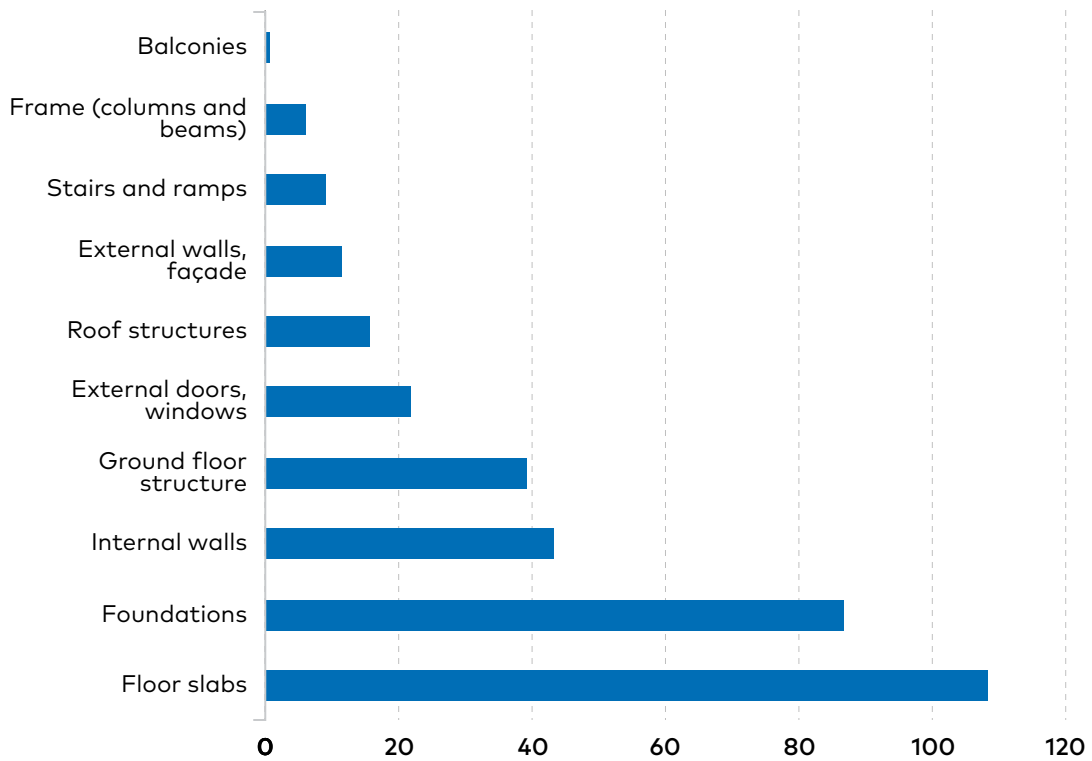


WHEN DO EMISSIONS OCCUR?
[kgCO₂e/m² reference area * year]



The system boundary includes the product, use and end-of-life stages. The material inventory also includes solar cells. In the middle figure operation includes B6 and B7, while materials include A1-A5, B4, C3. Operation B6 contain electricity, district heating and solar power. For electricity it is used an emission factor at 130 gCO₂e/kWh. The building uses 66,1 kWh/m² electricity specific and 14,6 kWh/m² electricity for heat pumps. It produces 12,5 kWh/m² with solar panels. In the third figure upfront includes A1-A5, scenarios include B4, C3, and D is shown separately.

LCA results: Building elements



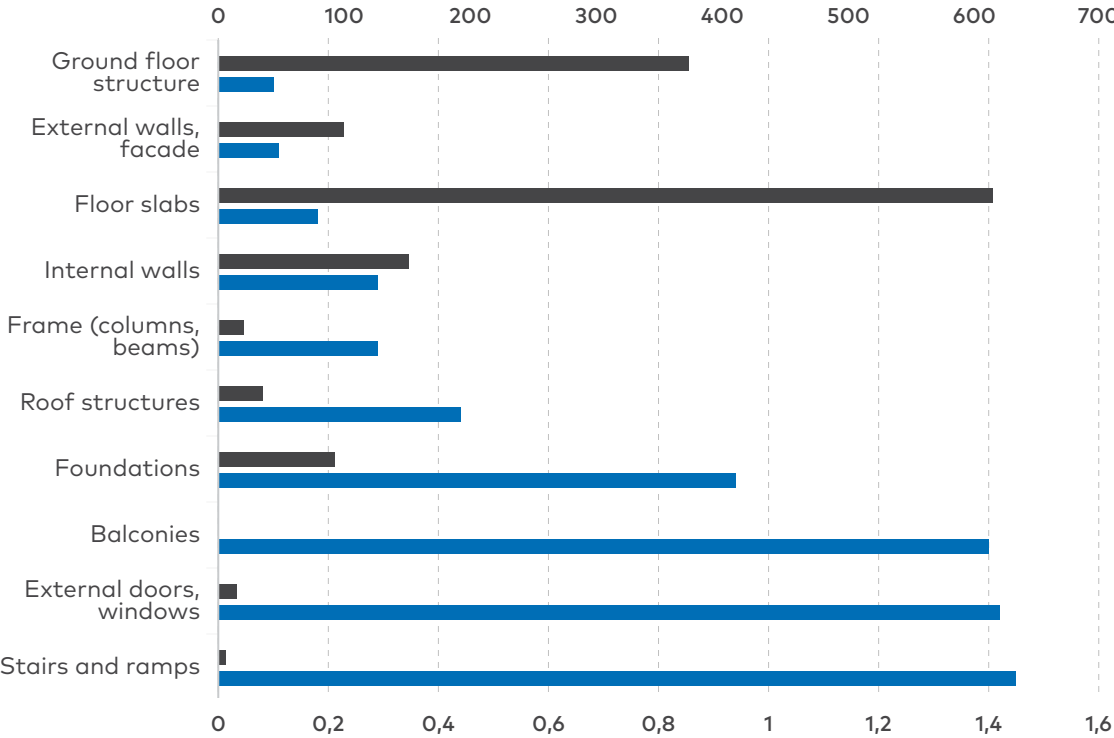
GWP / reference area [kgCO₂e/m² reference area]

Material inventory: All materials

Life cycle modules: A1-A5, B4, C3

Interior walls are included finishes, Floor slabs include everything from flooring to ceilings, External walls, include the facade cladding, roof structure include external cladding. Solar cells were also calculated (A1-A5, C3), but they are not shown in figure, there impact is 34 kgCO₂eq./m²

Building element quantity / reference area [kg building element / m² reference area]



GWP of building element / building element quantity [kgCO₂e / kg building element]

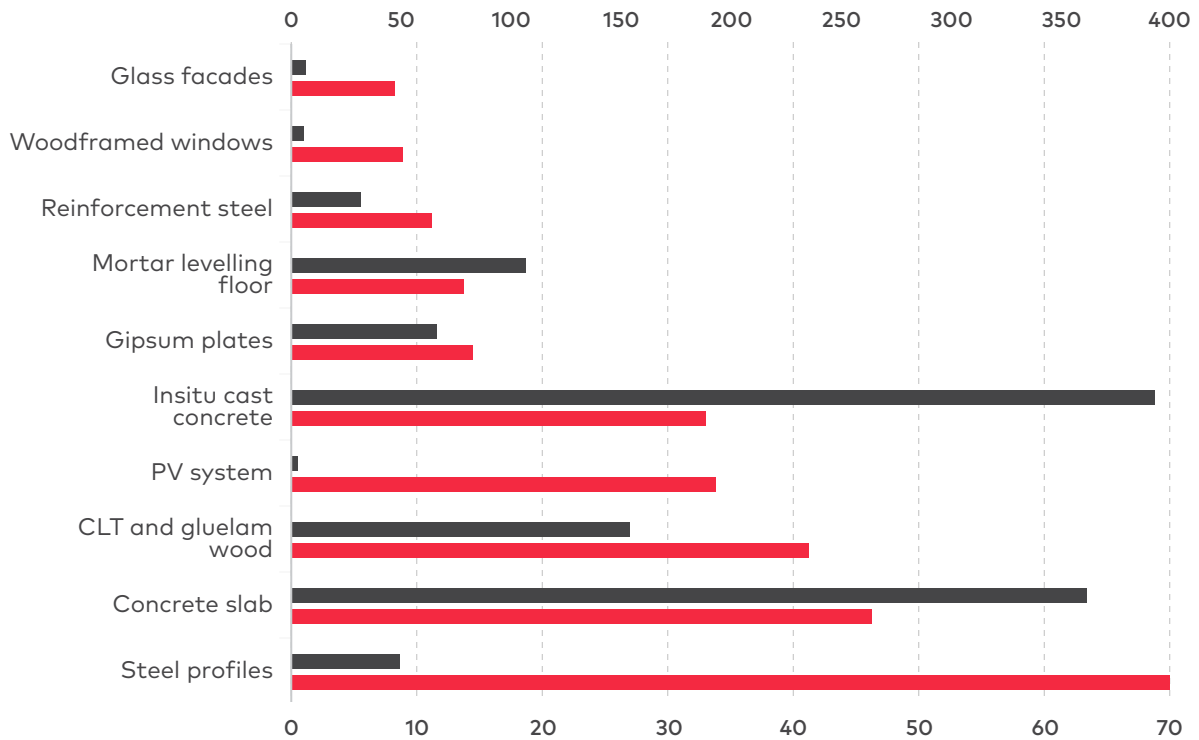
■ Quantity/Area ■ GWP/Quantity

Material inventory: All materials
Life cycle modules: A1-A5, B1-B5, C1-C4

Building element quantity per building reference area is a measure for the material intensity, while element impacts per element quantity is a measure for the elements' carbon intensity relative to their weight.

LCA results: Products

Product quantity / reference area [kg product / m² reference area]



GWP of product / reference area [kgCO₂e/m² reference area]

■ Quantity/Area ■ GWP/Area

Material inventory: Top 10 products with the highest impacts

Life cycle modules: A1-A5, B4, C2-C4

Construction product quantity per building reference area is a measure for the material intensity, while product impacts per building reference area is a measure for carbon intensity.

CROSS-CASE ANALYSIS

The selected cases across the Nordic region – Denmark, Norway, Sweden, Finland, Estonia and Iceland – cover a variety of building types and sizes, providing a comprehensive view of the diverse approaches being implemented to achieve reduced whole-life climate impacts. The report includes at least two case studies from each Nordic country, representing a mix of building types – such as residential, commercial, and mixed-use buildings – as well as various sizes, from small buildings to larger-scale developments. This diversity highlights that carbon reduction strategies are applicable across different scales of development, not just in single-family homes, which are often easier to address in terms of carbon footprint.

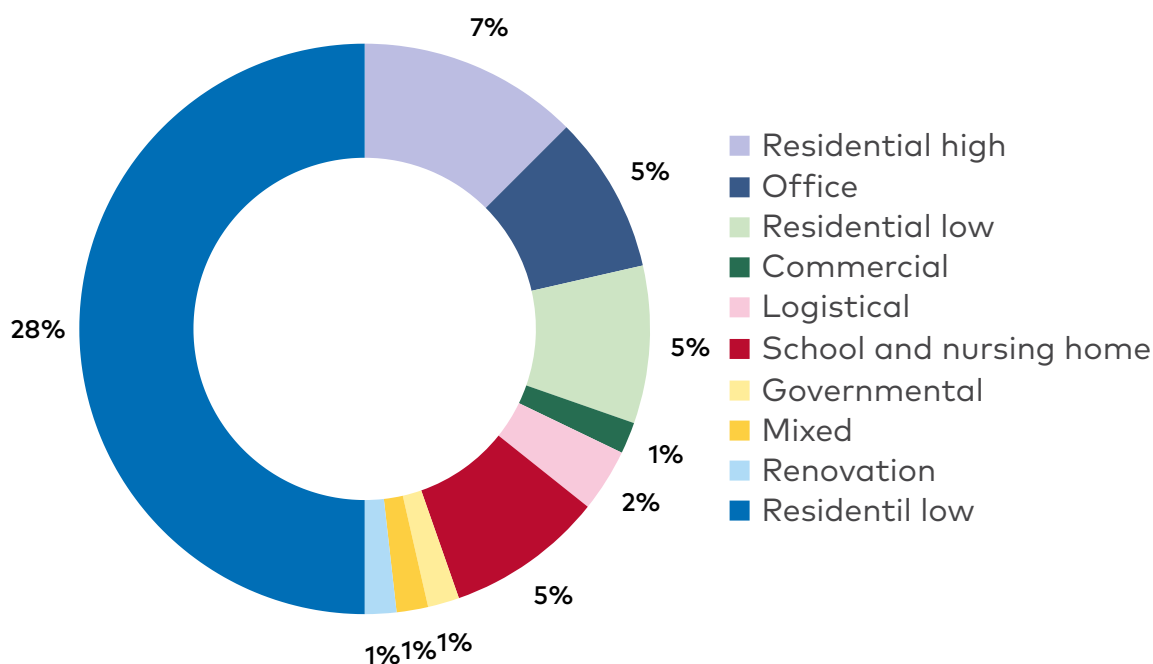


Table 2 (below) provides a snapshot of the most important carbon mitigation measures implemented in the analysed cases. Main strategies include:

Bio-based and optimised materials: A common strategy across the cases is the use of bio-based materials or optimised conventional materials. These materials, such as wood and other natural resources, were selected not only for their lower embodied carbon, but also for their potential to reduce the need for energy-intensive materials like concrete and steel.

Material efficient design: In several cases, slimmer, optimised structures were used to reduce material consumption, demonstrating the potential of more efficient design to reduce carbon emissions. Many of the best-practice cases focused on reducing the use of steel for reinforcement and eliminating joints in concrete structures. By minimising the amount of steel, which has a high embodied carbon footprint, these buildings achieved

significant reductions in emissions. This approach aligns with broader trends in the construction sector to reduce reliance on high-carbon materials in favour of lighter, more sustainable alternatives.

Photovoltaic systems: Another prevalent strategy was the installation of photovoltaic (PV) systems on building roofs to offset operational carbon emissions. In some cases, surplus exported energy was produced and modelled to compensate embodied impacts.

Stakeholder collaboration and early LCA integration: Across the majority of the cases, stakeholder collaboration played a crucial role in the success of carbon reduction strategies. Early engagement between architects, contractors, and LCA (Life Cycle Assessment) consultants allowed for more informed decision-making and better identification of potential carbon reduction opportunities. Several cases also stressed the importance of introducing LCA targets early in the design phase to ensure that carbon reduction was integrated into the project from the outset.

Environmental Product Declarations (EPDs): The use of EPDs to identify and select products with the lowest environmental impact was another common strategy. This allowed project teams to make informed decisions about materials and products, ensuring that only those with the least carbon impact were used in construction. The identification of specific low-impact products was integral to achieving the stringent targets set for these projects.

Optimised use of technical systems: In some cases, buildings were designed with fewer technical systems reducing energy consumption and associated emissions. By focusing on passive design strategies, such as natural ventilation and thermal mass, these buildings minimised their reliance on active systems, leading to both carbon and cost savings over time.

Table 2: Carbon mitigation measures in the case projects.



Bio-based materials



Collaboration



Carbon optimised conventional products



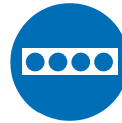
Renewable energy systems











Reuse, recycling, recovery






























Transport supply chain


























Material efficient design

Case	Country	Building type	Types of whole-life carbon reduction measures	
01	Denmark	School		Extensive use of wood (columns, beams, façade cladding, interior).
02	Denmark	Renovation farm		Use of traditional, local materials (i.e. oakwood and a straw roof) that reduce transportation emissions
				The farmhouse is built using over-dimensioned oakwood and a straw roof
				Restoration as a pilot project by The Agency for Culture and Palaces indicates an emphasis on sustainable practices in the conservation of heritage buildings
03	Denmark	Residential low		Optimised building design, with focus on available knowledge and materials, can reduce the climate footprint and improve the indoor environment compared to the current practice.
				Use of CLT in the walls and roof, and with a ground screw foundation
				Optimal use of natural ventilation through placing windows and openings in the interior structure
04	Denmark	Residential high		Extensive use of wood
05	Estonia	Commercial		Solar park installed on the roof of the building, producing more electricity than consumed Connected to Gren's district heating and cooling network
				AI-based energy management Energy efficiency rating A, significantly outperforming the required minimum energy standards
				Electric vehicle charging infrastructure supporting the transition to cleaner transportation Sustainable mobility design Biodiverse landscaping, also designed to adapt to climate challenges such as heat islands and flooding

06	Estonia	Residential high		Solar panels installed on the roof generate electricity for common areas and for electric vehicles
				Energy-efficient design Green roofs to mitigate the urban heat island effect and reduce the need for cooling Class A Elevators Water-efficient faucets to conserve resources and reduce energy required to heat and pump water
				Electric Vehicle (EV) charging infrastructure Biodiversity initiative including approximately 1,000 m ² of permanent flower sowing, insect hotels and planted trees and shrubs
07	Finland	Residential high		Use of traditional Nordic log construction to promote sustainable forest use and carbon storage Maximisation of carbon storage allowing a carbon handprint greater than carbon footprint
				Prioritisation of low-tech solutions Multifunctional spaces to allow for adaptable use, and reduce the need for additional buildings or modifications in the future
				Bearing log frames, floors, ceilings, insulations, clay renderings, windows, doors, fixtures etc. designed and built for deconstruction and reuse The log frames can be converted to different uses or relocated in whole or in parts
				Integration of photovoltaic solar panels Use of heat pumps to efficiently heat and cool the homes
				Use of local materials and ancient local tradition and handcrafts applied in innovative ways
				Conduction of LCA in three phases: concept, design, after construction to support discussions with the building officials about the project's ambition and achievement Engagement with end users/residents to monitor how the homes are functioning
08	Finland	Residential high		Use of CLT (cross-laminated timber) technology Wood as a visibility tool to promote the wood construction industry in Finland
				Green energy sources for heating and electricity
				Collaboration for efficient project management: partnership with JVR-Rakenne to ensure affordability while also implementing low-carbon building practices
			Class A energy efficiency standard	
09	Finland	Office		Effective cooperation with the customer to achieve accurate carbon footprint data, evaluation of carbon footprint using the Finnish Ministry of the Environment's low-carbon evaluation method
				Use of wooden load-bearing structures, CLT intermediate floors, use of wooden façades
				Choice of lowest impact products within the chosen categories, supported by EPDs Emphasis on reducing emissions despite using steel in the structure, with consideration of alternatives
				Focus on low energy consumption during operation
10	Finland	Residential high		Extensive use of wood and CLT, the latter for structural elements, including walls and elevator shafts

				<p>Pre-fabricated volumetric elements from CLT sheets and pre-assembled roof sections to reduce construction site impacts</p> <p>Weather protection measures, particularly during the assembly of roof sections, to protect materials from the elements, ensuring their longevity and reducing waste from damage</p> <p>Reduced sound displacement through rubber insulation, improving the comfort while potentially reducing the need for additional energy-intensive soundproofing measures</p>
11	Sweden	Residential low		<p>Wood-based structure and façade</p> <p>Cellulose insulation for external walls and the ceiling</p> <p>Wood fibre insulation is used for internal walls</p>
				Energy-efficient systems to reduce operational energy use
				Long-term climate impact evaluation to support ongoing improvements in sustainability
12	Sweden	Office		<p>LFM30 initiative participation</p> <p>Collaboration and active engagement with stakeholders and suppliers</p>
				<p>Flexible layout design to allows tenants to modify the space according to their needs</p> <p>Modular dimensions for installations to ensure efficient use of materials and easier future adaptations</p> <p>Slimmed-down structure</p>
				<p>Use of alternative binders in concrete</p> <p>Use of brick produced with renewable energy</p>
				<p>Selection of recycled materials, such as the drainage board on the exterior basement walls</p>
				Atrium roof modification to reduce the proportion of external walls to decrease the building's energy demand and overall climate impact
13	Sweden	Office		<p>Use of steel with high recycled content</p>
				<p>Use of climate-enhanced concrete</p>
				<p>Glulam and steel frame combination</p> <p>Modular dimensions to allow easy reconfiguration for future adaptability</p> <p>Use of prefabricated solutions for HDF joists</p> <p>In-situ construction of the façade with cantilever wall instead of using a material-intensive prefabricated façade system</p> <p>Durability and protection of materials double façade to protect the wooden façade structure to ensure longevity and reduce replacements and repairs frequency</p>
				<p>Renewable electricity purchase from hydropower and district heating systems</p>
				<p>Awareness raising among project stakeholders</p>
				Building airtightness before dehydration process to reduce energy consumption associated with drying and maintaining internal climate control
14	Sweden	Residential low		<p>PV systems</p>
				<p>Extensive use of wood (CLT in the foundation, pressure treated wooden roof cladding)</p> <p>Insulation made from wood fibres for external walls and roof</p>
				Building performance monitoring with sensors

15	Sweden	Logistical building		PV systems
				Sheet metal sandwich wall elements with a stone wool core Concrete slab without joints and reinforcement. Exemption from sprinkler system, smart fire zone division
16	Sweden	Logistical building		Key stakeholders (contractors, LCA consultants, subcontractors) worked together early in the process
				PV systems (embodied carbon compensation)
				Choice of lowest impact products within the chosen categories, supported by EPDs
Early LCA calculation to identify carbon impact-material hotspots, follow-up on carbon intensity and energy use three years after completion				
17	Sweden	Residential low		Use of CLT instead of concrete for the structural frame
				Nordic Swan Ecolabel certification ensures that all materials and components used meet strict environmental criteria, including low-carbon emissions.
				Optimised key building components
Maximised energy efficiency through careful selection of materials, layout and energy-saving solutions (e.g. local ventilation system for each apartment, air nozzles in every room)				
18	Iceland	School		BREEAM Community certification
19	Iceland	Nursing home		Use of ash from the Eyjafjallajökull eruption in concrete
				Use of sustainably sourced timber for exterior walls cladding
Energy-efficient design and environmental management				
20	Iceland	Parliament offices		Use of stone responsibly sourced from the foundations of previous construction projects
21	Norway	Residential low		Selection of building materials with lower GHG emissions, verified through EPDs, including improved choices in EPS, XPS, cross-laminated timber, mortar, and moisture barriers
22	Norway	Residential		Future built program with have the goal to reduce CO2 emissions from energy use and materials
				Structural system constructed with low carbon concrete and CLT
23	Norway	Retail, Office and Residential high		Use of low-emitting, heavy materials
				Solar panels

				<p>Natural air conditioning system Passive ventilation design promoted through the building's unique geometric design Computer simulations for airflow optimisation Heat pump system supported by groundwater Waterborne underfloor heating</p>
24	Norway	School		<p>Future built program with have the goal to reduce CO2 emissions from energy use and materials</p>
				<p>near-zero-energy building (nZEB)</p>
25	Norway	Office		<p>Large-scale material reuse, achieved up to 80% Repurposing of structural components Use of reclaimed hollow-core slabs Reuse of façade cladding and interior equipment 75% of the steel used in the project was recycled</p>
				<p>Collaborative efforts in demolition to identify reusable building components, fostering circular economy practices and reducing waste Knowledge sharing through workshops and regulation navigation around reused materials</p>
				<p>Design integration with urban green spaces</p>
26	Norway	Nursing home		<p>CLT slabs it has been opted for gravel</p>
				<p>BREEAM Excellent building</p>

CONCLUSION

The integration of low-carbon solutions in construction projects is a powerful strategy for reducing the built environment's climate impact. An overview on key measures for cutting carbon emissions along the building life cycle is provided in **Table 2**. The cases explored in this report demonstrate the effectiveness of early commitment to sustainability goals and the adoption of innovative, low-carbon materials and techniques. From the use of alternative concrete binders and high-recycled content steel to the extensive use of timber, particularly in innovative applications like CLT slab and walls elements, these projects show how material choices can significantly lower carbon footprints.

Collaborative approaches between stakeholders – designers, contractors, consultants and suppliers – have proven essential in achieving ambitious climate targets. Early involvement of all parties in defining and pursuing low-carbon goals ensures that climate-neutral certification schemes, such as NollCO₂ and Miljöbyggnad, can be successfully met. Moreover, employing solutions such as prefabrication, renewable energy sourcing, and minimising resource waste during construction not only cuts emissions, but also improves project efficiency and cost-effectiveness.

Ultimately, these examples highlight that a focus on low-carbon solutions in both design and construction phases leads to significant environmental impact reductions while enhancing building performance and resilience. With continued innovation and collaboration, the construction industry can move towards more sustainable and climate-neutral buildings, setting a strong precedent for future projects.

Beyond showcasing carbon cutting strategies, this report also underlines the current challenges in comparing climate impact assessments of building projects across Nordic countries and Estonia. Variations in methodologies, data sources and system boundaries create complexities in drawing direct comparisons, even within a single country. Factors such as the choice of area definitions, the inclusion or exclusion of specific life cycle stages and building components and the use of different Global Warming Potential (GWP) indicators all contribute to these discrepancies. Additionally, differences in how decarbonisation scenarios and exported energy are accounted for further complicate cross-country comparisons.

To enhance the transparency and usefulness of climate impact assessments, this report stresses the importance of clearly defining methodological choices and providing detailed explanations of the underlying assumptions. The method comparison table (**Table 1**) can aid interpretation and offers a transparent overview of the influential methodological aspects that affect the reported results. It is essential that future efforts focus on standardising key aspects of climate impact assessments, such as area definitions and GWP indicators, to improve comparability and provide more consistent, reliable data across the region.

Ultimately, while this report offers valuable insights into best practices, it is important for stakeholders to approach cross-country comparisons with caution, considering the varying contexts and methods used. A concerted effort towards greater harmonisation of assessment methods and data sources will be essential in advancing the goal of reducing the built environment's climate impact and achieving the region's decarbonisation objectives.

ABOUT THIS PUBLICATION

Best Practice Catalogue – Building LCA cases from the Nordic countries and Estonia

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Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland and Åland.

Nordic co-operation has firm traditions in politics, economics and culture and plays an important role in European and international forums. The Nordic community strives for a strong Nordic Region in a strong Europe.

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