CIRCULAR
DESIGN
ATLAS

TILBURG UNIVERSITY LECTURE HALL

Architect(s):
Powerhouse Company

Year:
2023

Location:
Tilburg, Netherlands

More info:
www.powerhouse-company.com

Scales:
Buildings

Resources:
Nutrients
Biological
Technical

Design Approaches:
Design for Disassembly
Design for Adaptability

R-Strategies:
Rethink
Reduce
Reuse

Aspects:
Design
Management
Stakeholders

TU Delft
BK Bouwkunde

Design: Powerhouse Company | Image: © Powerhouse Company

Tilburg University's new lecture hall is a great achievement in sustainable architecture, setting the precedent for circular construction in the Netherlands. This energy-neutral structure of 33 x 33-meter footprint, exemplifies circularity through its careful material selection, disassembly-friendly construction, and adaptability to evolving needs.

Overcoming significant design challenges, such as implementing the predominantly cross-laminated timber structure and introducing 9-meter span wooden rib floors for educational demands, showcases the project's innovation. The dry construction system incorporates 4.6 kilometers of timber beams that can be disassembled, ensuring their potential for future reuse. Additionally, the limestone facade panels are suspended rather than permanently attached, making them easily recyclable. These approaches extend to the reduction of the carbon footprint, with conscientious choices resulting in negative CO_2 emissions.

Layers of Change and Lifecycle Duration

Site (Concrete pavers to asphalt and soil)
The site used to be a parking lot with concrete pavers which has been converted to asphalt for public use (Expected lifespan: 20-30 years) and soil and vegetation for its private use (Expected lifespan: Eternal).

The asphalt having a rather short lifespan will require periodic maintenance and replacement, impacting long-term stability while the soil can last indefinitely, offering stability. This works together with a sustainable water to water heat pump which can heat the building in the winter and cool during summer.

Skin (Muschel limestone)
The building's facade is mainly composed of 40 mm natural stone (Muschel limestone) with an expected lifespan of 50-100+ years). Its durability and resistance to weathering provides long-term structural integrity which can also be used in other projects since it has been designed for disassembly and future reuse.

Structure (CLT)
Cross-laminated timber (CLT) as structure has an expected lifespan of +/- 100 years when well-maintained. This durability provides structural strength and sustainability since it also used a dry construction system to be demountable. However, it may require periodic maintenance against moisture, potentially impacting long-term performance.

Services (HVAC)
The HVAC system has an expected lifespan of approximately 15-20 years. This relatively shorter lifespan may require frequent maintenance. The use of false ceilings for the lecture halls' acoustics may complicate access for maintenance, potentially affecting long-term adaptability and efficiency.

Space plan (Metal studs and plasterboard)
The space plan being for an educational purpose has a short expected lifespan of approximately 3-30 years. Its demountable nature therefore allows for flexibility in reconfiguration. However, frequent changes may lead to wear and tear, affecting longevity.

Stuff (Fixtures and furniture)
The stuff has a varying lifespan depending on furniture or fixture. However, being mainly made of wood, they may require maintenance over time to be continually functional, impacting durability.

Site
25-50 years became 20-30 years

Skin
50-100+ years

Structure
50-100+ years

Services
7-15 years

Space plan
3-30 years

Stuff
Various

Design: Powerhouse Company | Image: © Powerhouse Company

Carbon Footprint of Materials

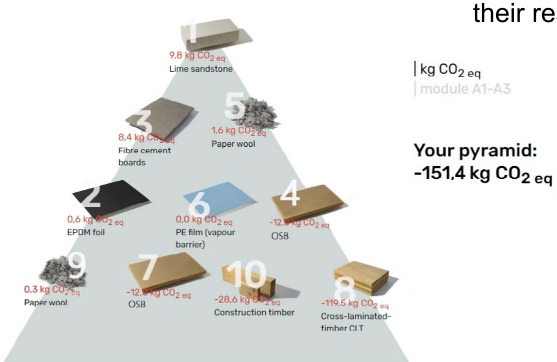
To calculate the CO_2 emissions for the facade elements, an estimation using the Construction Material Pyramid (Materialepyramiden) calculator was conducted, developed by the Danish Centre for Industrialized Architecture (CINARK) at the Royal Danish Academy.

For each type of facade, a 1-square meter area from a section of the exterior was analysed and an estimation has been made regarding carbon dioxide emissions.

This analysis was performed for both a closed facade without windows and a facade with windows. In this section, the focus lays on the closed facade, which is the most common type in the building and serves a structural purpose. The building's design strategy primarily emphasizes the use of sustainable materials and a dismountable construction approach. That is how the CO_2 emission score ended up being a negative number.

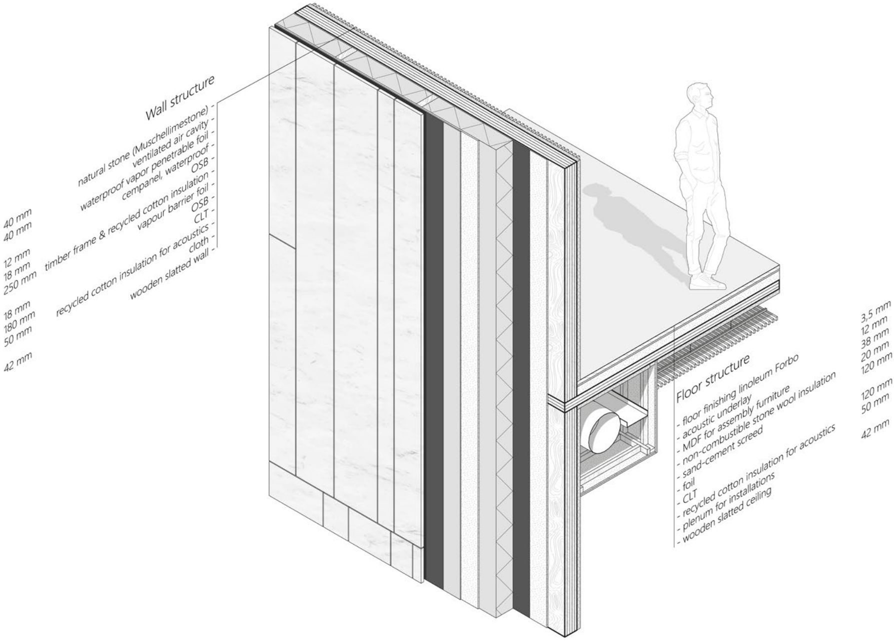
The composition of the facade, from interior to exterior, includes a wooden slatted wall finish on top of a layer of cloth and recycled cotton insulation for acoustic purposes. Next, you will find the CLT structural element, which bears the load of the closed facade. Subsequently, there is a complex assembly consisting of OSB board, a vapor barrier foil, cotton insulation, another layer of OSB board, a waterproof cempanel, and a waterproof foil. This part manages insulation, acoustics, and ensures the building's waterproofing. As the final finishing layer, a natural stone type is used, which can be easily disassembled.

These are the materials that make up the facade, and on this page, you can find information about each of these materials along with their respective CO_2 emissions.



Construction Material Pyramid, CINARK | R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

AXO closed facade



Design: Powerhouse Company | Image: R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

CO_2 footprint materials

	material	group	impact / m3	volume [m3]	area [m2]	thickness [mm]	result
1	Lime sandstone	mineralsk	244.8 kg CO2eq/m3	0,04 m3	1 m2	40 mm	9,8 kg $CO_{2\ eq}$
2	EPDM foil	kunststof	5733.3 kg CO2eq/m3	0,00 m3	1 m2	0,1 mm	0,6 kg $CO_{2\ eq}$
3	Fibre cement boards	mineralsk	699.0 kg CO2eq/m3	0,01 m3	1 m2	12 mm	8,4 kg $CO_{2\ eq}$
4	OSB	trae	-669.0 kg CO2eq/m3	0,02 m3	1 m2	18 mm	-3,3 kg $CO_{2\ eq}$
5	Paper wool	biobaseret	6.2 kg CO2eq/m3	0,25 m3	1 m2	250 mm	1,6 kg $CO_{2\ eq}$
6	PE film (vapour barrier)	kunststof	266.3 kg CO2eq/m3	0,00 m3	1 m2	0,1 mm	0,0 kg $CO_{2\ eq}$
7	OSB	trae	-669.0 kg CO2eq/m3	0,02 m3	1 m2	18 mm	-12,0 kg $CO_{2\ eq}$
8	Cross-laminated-timber CLT	trae	-664.0 kg CO2eq/m3	0,18 m3	1 m2	180 mm	-119,5 kg $CO_{2\ eq}$
9	Paper wool	biobaseret	6.2 kg CO2eq/m3	0,05 m3	1 m2	50 mm	0,3 kg $CO_{2\ eq}$
10	Construction timber	trae	-680.0 kg CO2eq/m3	0,04 m3	1 m2	42 mm	-28,6 kg $CO_{2\ eq}$

Construction Material Pyramid, CINARK | R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

Carbon Footprint of Materials

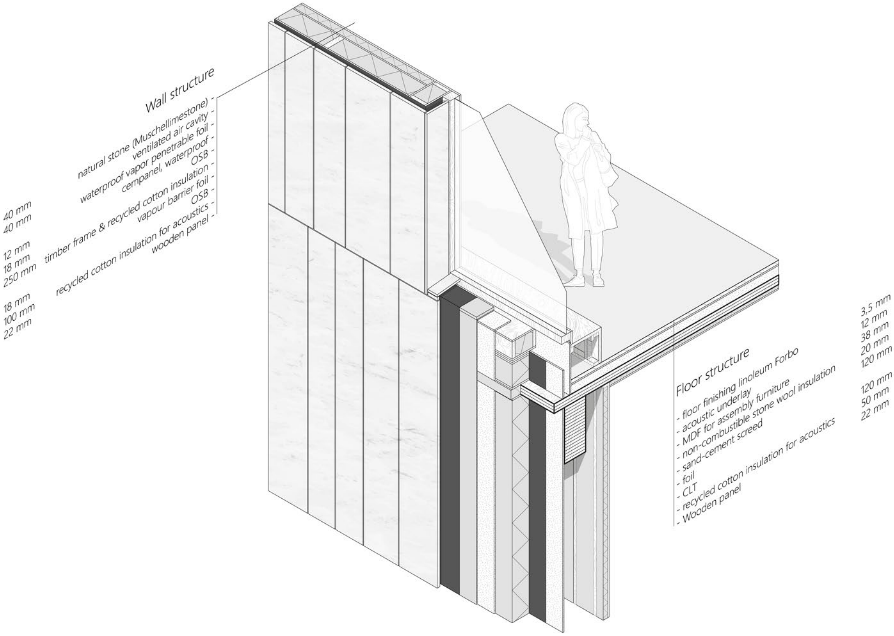
The same CO_2 emissions calculations have been conducted for a facade with windows. Facades with openings typically feature different layers as they do not serve a structural role. The structural elements for these facades consist of columns and beams, which are also constructed with sustainability and disassembly in mind.

The composition of this windowed facade, from interior to exterior, includes a wooden panel finish with recycled cotton insulation beneath it, an OSB panel, a vapor barrier foil, cotton insulation for thermal purposes, another layer of OSB panel, a waterproof cempanel, and a waterproof foil. Once again, the facade is constructed using a natural stone type that can be readily disassembled.

The primary distinction between a closed facade and a facade with windows lies in the replacement of the structural wall by columns and beams in the windowed facade. For the CO_2 calculation, a 1 m^2 section of the facade is analysed, with closed elements being 0,75 m^2 and the window being 0,25 m^2. Detailed information about the materials comprising this facade can be found on this page, which includes data on each material and its corresponding CO_2 emissions, and which again states that it is a negative CO_2 emission.

Construction Material Pyramid, CINARK | R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

AXO facade with window



Design: Powerhouse Company | Image: R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

CO_2 footprint materials

	material	group	impact / m3	volume [m3]		area [m2]		thickness [mm]		result
1	Lime sandstone	mineralsk	244.8 kg CO2eq/m3	0,03	m3	0,75	m2	40	mm	7,3 kg $CO_{2\ eq}$
2	EPDM foil	kunststof	5733.3 kg CO2eq/m3	0,00	m3	0,75	m2	0,1	mm	0,4 kg $CO_{2\ eq}$
3	Fibre cement boards	mineralsk	699.0 kg CO2eq/m3	0,01	m3	0,75	m2	12	mm	6,3 kg $CO_{2\ eq}$
4	OSB	trae	-669.0 kg CO2eq/m3	0,01	m3	0,75	m2	18	mm	-9,0 kg $CO_{2\ eq}$
5	Paper wool	biobaseret	6.2 kg CO2eq/m3	0,19	m3	0,75	m2	250	mm	1,2 kg $CO_{2\ eq}$
6	PE film (vapour barrier)	kunststof	266.3 kg CO2eq/m3	0,00	m3	0,75	m2	0,1	mm	0,0 kg $CO_{2\ eq}$
7	OSB	trae	-669.0 kg CO2eq/m3	0,01	m3	0,75	m2	18	mm	-9,0 kg $CO_{2\ eq}$
8	Paper wool	biobaseret	6.2 kg CO2eq/m3	0,07	m3	0,75	m2	100	mm	0,5 kg $CO_{2\ eq}$
9	Construction timber	trae	-680.0 kg CO2eq/m3	0,02	m3	0,75	m2	22	mm	-11,2 kg $CO_{2\ eq}$
10	Glass pane, double-glazed	komponenter	266.1 kg CO2eq/m3	0,01	m3	0,25	m2	40	mm	2,7 kg $CO_{2\ eq}$

Construction Material Pyramid, CINARK | R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

Building Material Origin

The Carbon footprint of materials highlights which materials are used in the facade and their respective CO_2 footprints. The origins of these materials are depicted on the satellite map, illustrating the distances these building materials had to travel to reach the construction site.

The utilized building materials and components are categorized into one of three groups: they are either repurposed through recycling, derived from natural sources (biodegradable), or intentionally engineered for disassembly and future reuse.

Technical

T1 Natural stone (Muschel Limestone)
Origin: Austria/Germany
Use: Facade cladding

T2 Plaster (Knauf)
Origin: Germany
Use: Interior finishing

T3 EPDM Foil
Origin: Germany
Use: Waterproofing

T4 PE-Film
Origin: Italy
Use: Vapor barrier

T5 Fiber Cement Board
Origin: Netherlands
Use: Waterproofing

Recycled

R1 Cotton (Métisse)
Origin: Belgium
Use: Insulation

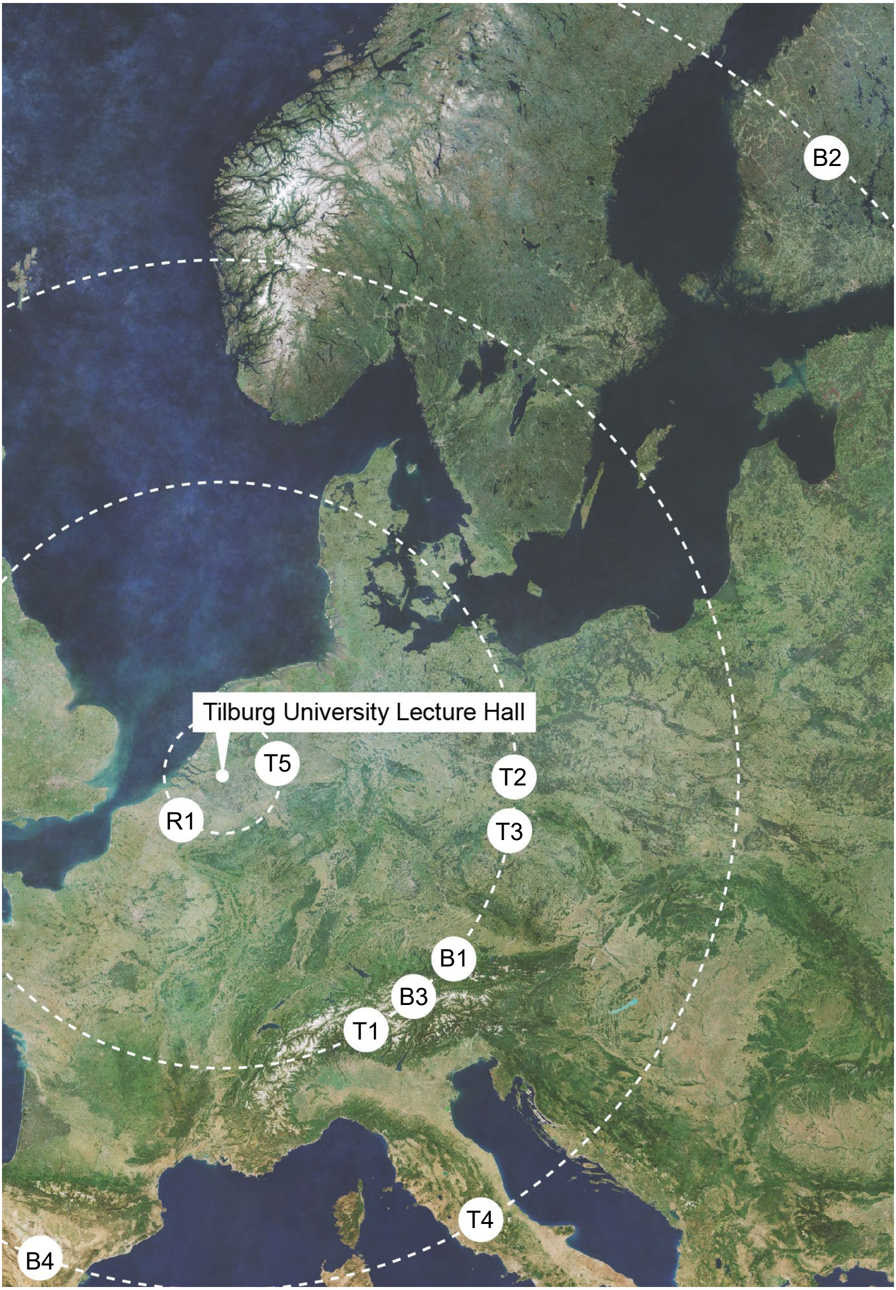
Biological

B1 OSB (Binderholz)
Origin: Austria/Germany
Use: Facade structure

B2 CLT (Stora enso)
Origin: Finland
Use: Structure

B3 Construction Timber (Binderholz)
Origin: Austria/Germany
Use: Facade structure

B4 Wooden window frames (accoya)
Origin: Spain
Use: Window frames



Map based on satellite image of ESA | R.E. Çiftçi, K.D. Aubeeluck & J. L. Niewiadomski

R-Strategies

SMARTER USE & MANUFACTURING:

<u>Refuse</u>
1. The functionality of the fragment relies on various materials, each serving specific purposes making the overall selection of materials align with the building's intended use and performance requirements. However, the wooden slatted ceilings could have been discarded for an open ceiling since this was mostly an aesthetic choice.

Rethink
1. The architecture of the fragment elements has been designed with adaptability in mind. For example, the cross-laminated timber (CLT) structure and natural stone cladding are demountable, enhancing flexibility for future uses.
2. While leasing or sharing fragment parts and components is not explicitly mentioned, the demountable nature of the CLT structure and natural stone (Muschel limestone) cladding allows for the potential disassembly and reuse.

Reduce
1. The selection of recycled cotton insulation for acoustics and CLT as structural material exemplifies a strong commitment to reducing environmental impact. These choices are not only sustainable but also demonstrate a conscious effort to minimize the project's carbon footprint, as both materials have a low environmental impact throughout their lifecycle.
2. The dry construction system used for the CLT structure and the potential for future disassembly and reuse can help reduce emissions related to production and transport by minimizing waste and material losses.

EXTENDING LIFESPAN OF PRODUCT AND ITS PARTS:

Reuse
1. Many fragment components, such as the CLT structure, recycled cotton insulation, and wooden slatted walls, can potentially be reused elsewhere without fundamental changes. They could find future use in construction projects or renovations, benefiting from the building's adaptability.
2. To encourage reuse, information on component dimensions, material specifications, condition, and previous use should be provided to potential users. This transparency is important for facilitating informed decisions regarding reuse.
3. The possibility of reuse may influence the dimensions by promoting standardized sizes for components. Surface qualities and appeal can be maintained or improved through proper maintenance and refurbishment, enhancing the attractiveness of reused components.

Repair

1. Maintenance can generally be conducted without compromising other parts of the construction.

Refurbish
1. The components have been designed to meet existing and potential future regulations concerning comfort, energy performance, and safety, reflecting a commitment to long-term compliance in this energy-neutral building
2. Potential future upgrades, such as energy efficiency improvements or changes in room function, can be accommodated by the current fragment construction, given its adaptability and modularity.

Remanufacture
1. Components like the CLT structure, being designed for disassembly, can potentially be remanufactured and reused with the same function without damage.

Repurpose
1. Parts of the fragment, such as the CLT structure and wooden slatted walls, may find a second life in different functions or projects, especially since they are designed for adaptability and ease of extraction (Dry construction system).

END OF LIFE SCENARIO:

Recycle
1. The materials used in the fragment, such as the CLT and wooden slats, have the potential to be recycled to the same or higher quality of the original resource, contributing to sustainable resource management.

Design: Powerhouse Company | Image: © Powerhouse Company

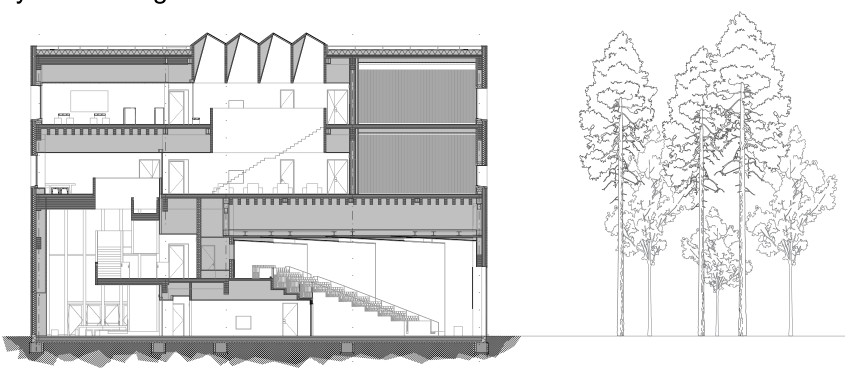
The NEW Nexus

Nutrients
The site's conversion from a concrete-paved parking lot to soil and vegetation positively influences nutrient management. The soil can support natural landscaping and host a heat pump system, promoting sustainable water management. This vegetation not only contributes to aesthetic appeal but also enhances on-site nutrient recycling and biodiversity.

Energy
The conversion of the site's parking lot to asphalt for public use impacts the building's energy dynamics. Asphalt's short lifespan necessitates frequent maintenance and replacement, which can be energy-intensive. In contrast, the soil's perpetual stability and its potential role in heating the building through a heat pump system during winter contribute positively to energy efficiency.

Water
The transition from concrete pavers to soil benefits water management. Soil and vegetation have an indefinite lifespan and naturally assist with water infiltration and purification. They promote rainwater harvesting and reduce stormwater runoff. This enhances the building's sustainability and minimizes reliance on external water sources.

The site conditions, notably the conversion to soil and vegetation, favor the circular performance of the building by supporting nutrient recycling, reducing energy consumption, and enhancing water management. However, the conversion to asphalt may have negative energy implications. The design carefully considers these aspects, aligning materials and systems with the site's specific conditions to maximize sustainability and minimize environmental impact.



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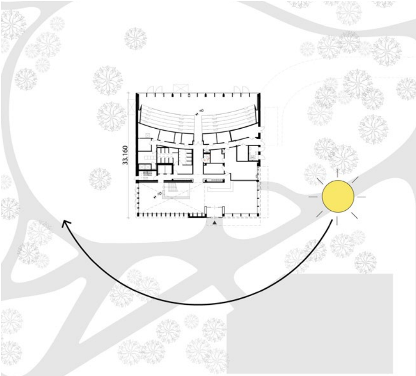

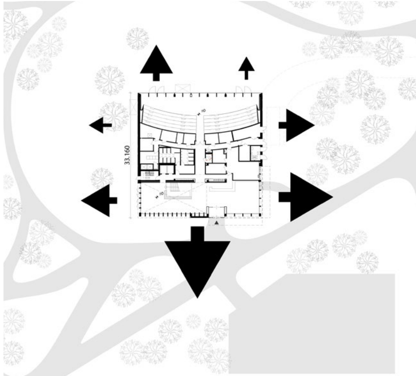

Design & Image: Powerhouse Company | Edits: R.E. Çiftçi, K.D. Aubeeluck & J.L. Niewiadomski

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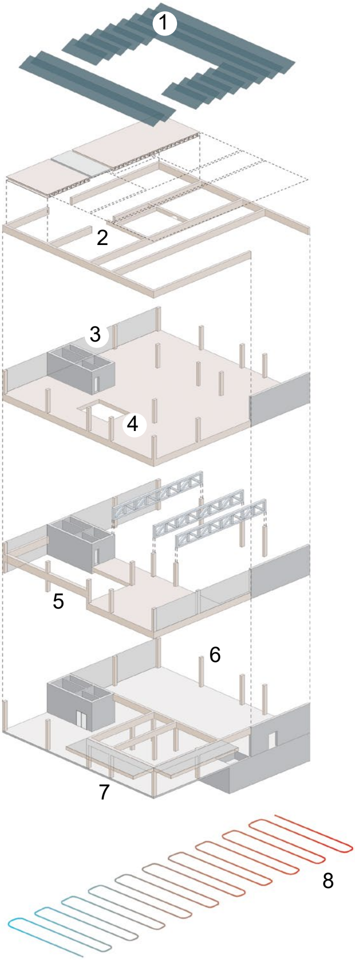
The NEW Nexus



Nutrients
The building's park landscape sustains a healthy environment through native vegetation and green spaces, improving air quality and well-being. This aligns with a circular approach, creating a mutually beneficial connection to the site.

Energy
The building's orientation optimizes solar aspects, strategically placing windows to maximize natural light, reducing artificial lighting needs. This bolsters energy efficiency and alignment with the context.

Water
Strategically placed within a park landscape, the building's design allows for rainwater harvesting, lessening reliance on external irrigation, demonstrating efficient water resource management.

In the selected case-study, a symbiotic relationship between the building and its surroundings therefore enhances circular performance.

Legend
1: Solar panels
2: Skylight
3: Strategic openings
4: Skylight
5: Natural ventilation
6: Reusable wood
7: Shading
8: Heatpump

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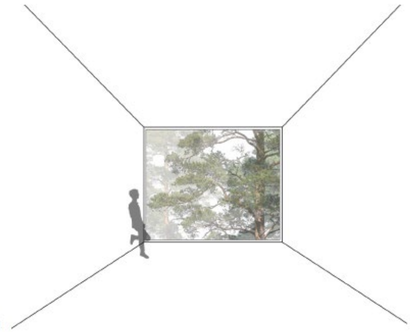
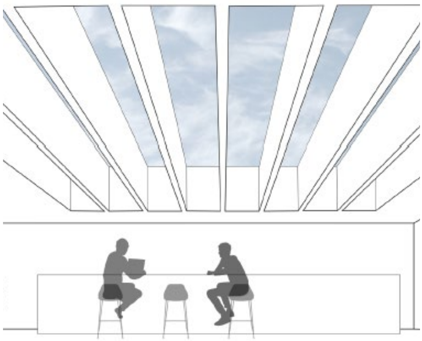
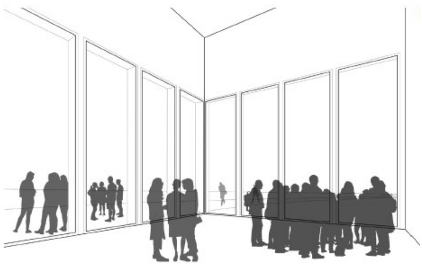


Reflection

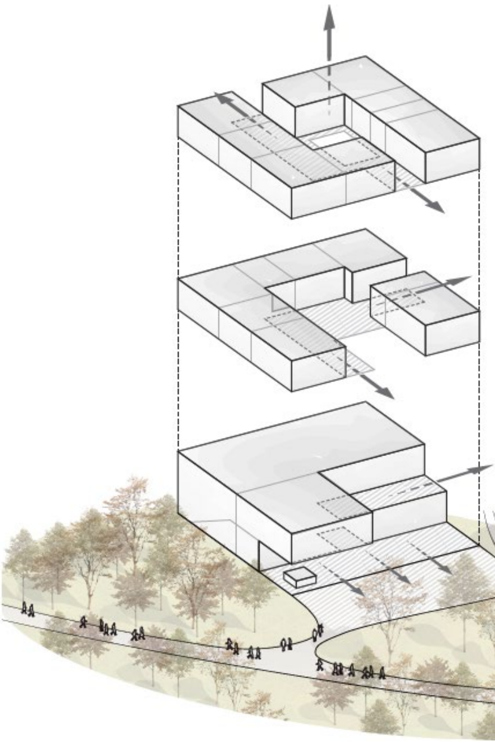
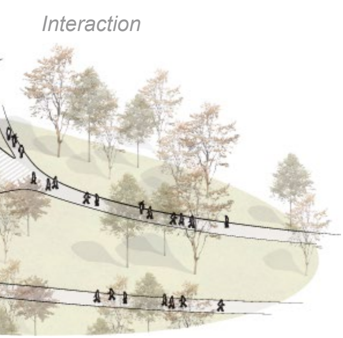


Concentration

Dialogue



Interaction

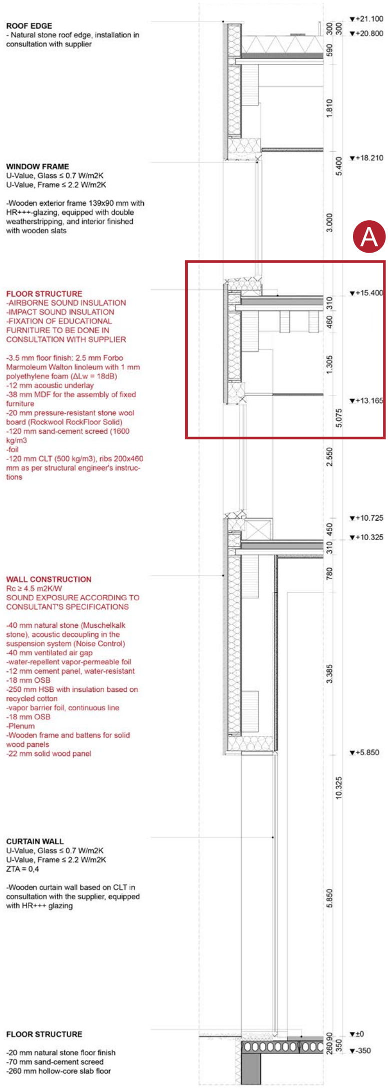
Design & Image: © Powerhouse Company

Design for Disassembly

A.

The project has been designed with disassembly and circular strategies in mind. The building's various layers are engineered for easy and rapid disassembly, primarily achieved through a dry construction system. For example, the natural stone cladding is securely attached to fibre Cement panels, while the primary timber framework is fastened with steel angle brackets and screws. Additionally, the ceiling utilizes a metal suspension system, all of which facilitate disassembly.

Notably, many components within the building, such as the CLT structure, recycled cotton insulation, and wooden slatted walls, have been chosen to promote reusability without requiring substantial alterations. These components hold the potential to be repurposed in future construction projects or renovations, making the building adaptable and contributing to a circular economy by reducing waste and promoting sustainability.



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ROOF EDGE
- Natural stone roof edge

FACADE
-Natural Stone

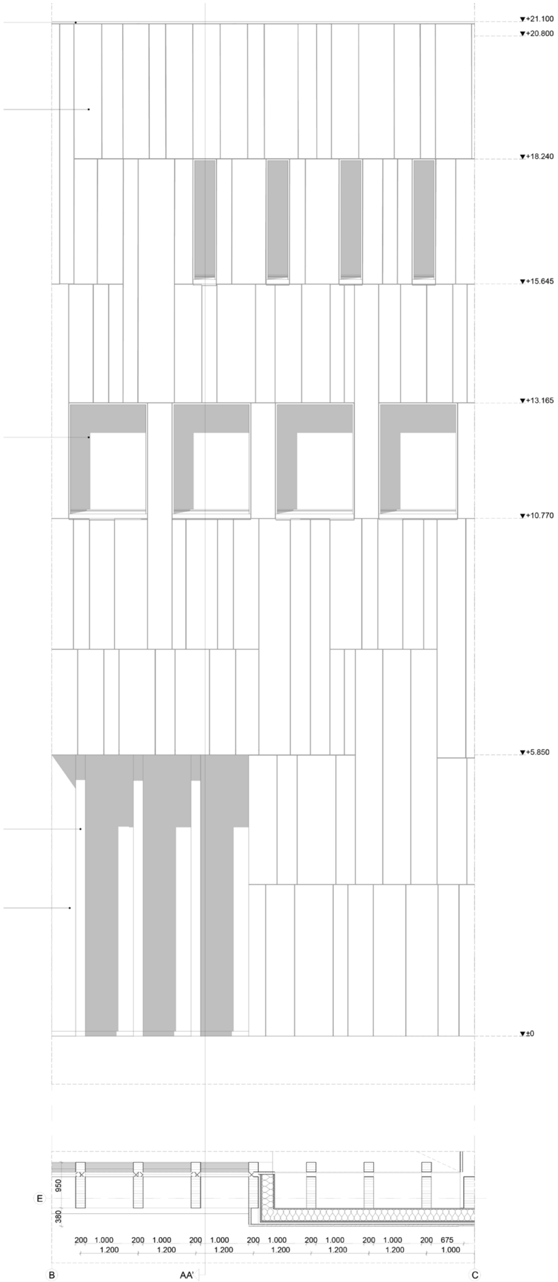
WINDOW FRAME
-U-Value, Glass ≤ 0.7 W/m2K
-U, FRAME ≤ 2,2 W/m2K

-Wooden exterior window frame 139x90 mm with HR+++-glazing, equipped with double weatherstripping, and interior finished with wooden slats"

COLUMN
-Laminated wooden column, CLT, as per structural engineer's specifications, 650x200 mm

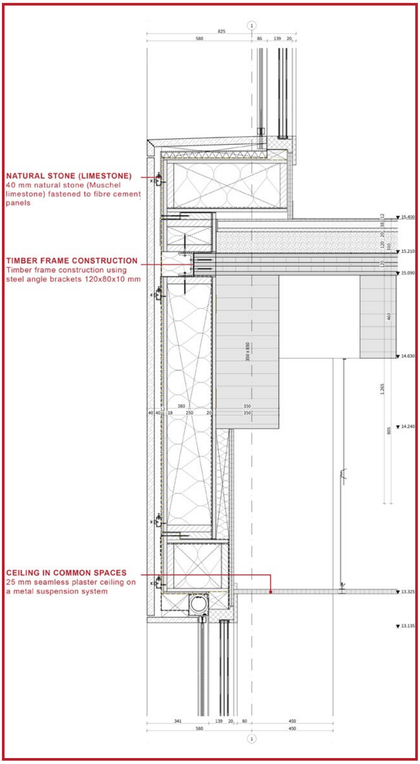
CURTAIN WALL
U-Value, Glass ≤ 0.7 W/m2K
U-Value, Frame ≤ 2.2 W/m2K
ZTA = 0,4

-Wooden curtain wall based on CLT in consultation with the supplier, equipped with HR+++-glazing



Design for Disassembly

A



Design for Adaptability

B.

The project's adaptability can be seen in the generous clear ceiling heights, exceeding 4.4 meters in many areas, which offers flexibility for various uses.

Furthermore, the layout of the building has been designed to accommodate adaptable and multifunctional spaces as evidenced by the floor plan, which allows for flexible rooms and furniture arrangements. The strategic placement of vertical circulation and bathrooms also facilitates the potential for creating small lecture halls or expanding into larger rooms in the future.

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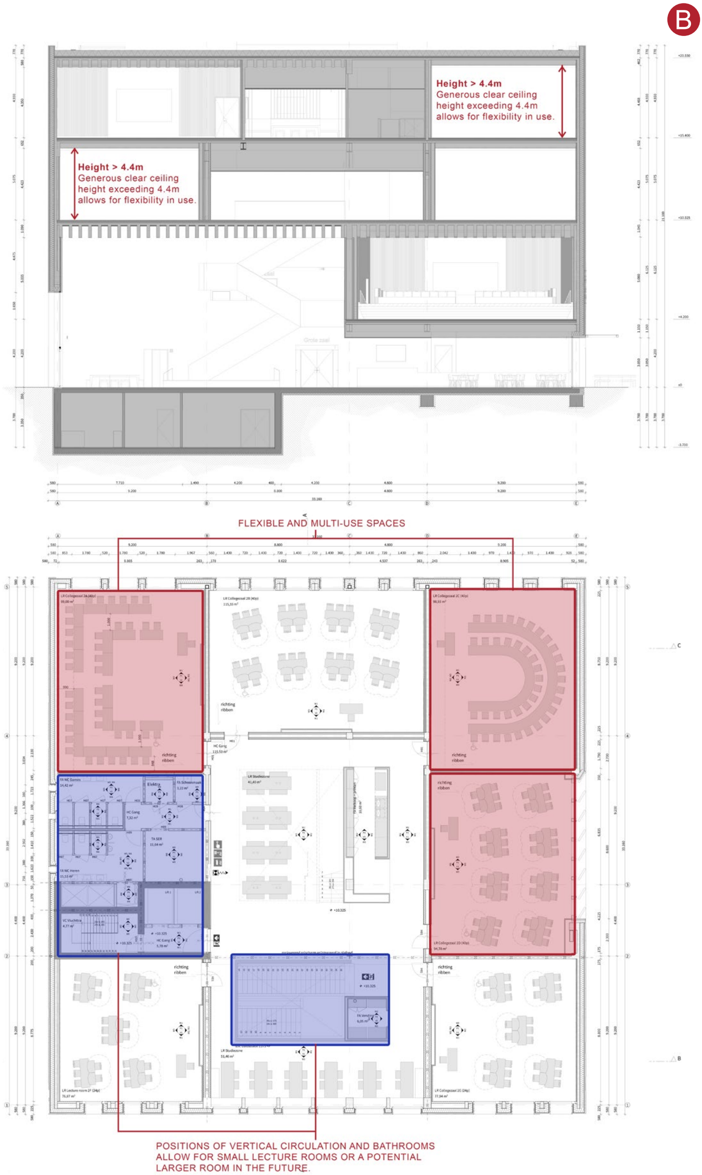

Design & Image: Powerhouse Company | Edits: R.E. Çiftçi, K.D. Aubeeluck & J.L. Niewiadomski

Stakeholders & Value Chain

Due to the growth in the number of students and the changes in the way of education, Tilburg University was motivated to construct a new educational building.

In the design of the new building, consideration was given to creating an inspiring learning and working environment where both students and staff can reach their full potential. The building can accommodate approximately 1,000 students when all lecture halls and study areas are in use.

The placement of the building is aimed at improving the connection between Tilburg University Station, the surrounding neighborhood, and the campus.

In the early stages of the design process, the architects from Powerhouse Company were informed of the high sustainability ambitions. The building was designed with sustainable products and materials, and a fully reusable wooden structural plan was created for circularity. Additionally, the natural stone cladding on the facade is not glued but suspended, making it reusable as well.

By informing the architects about these sustainability aspects early in the design process, the building was able to be tailored to meet these requirements during production and engineering. The building can be used like any other structure, and when it reaches the end of its lifecycle, it can be disassembled and reused for a new production, thanks to its circular design.

The integration of ambitions, design, and engineering ensured that the building could be executed in a sustainable and circular manner.

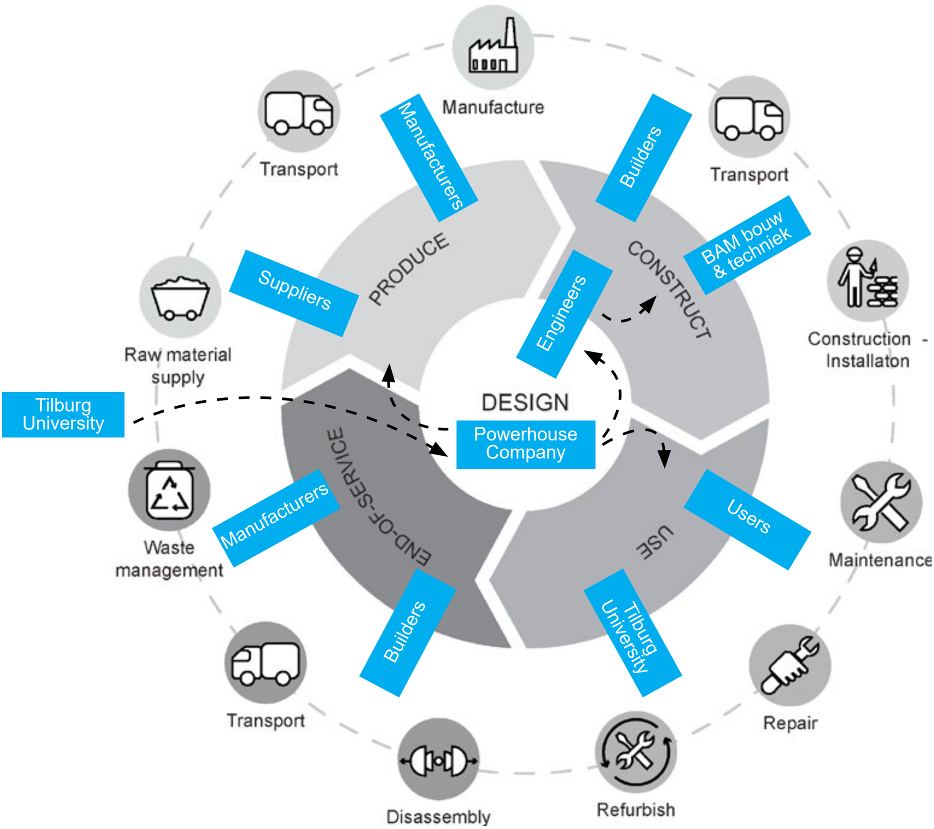

Image: R.E. Çiftçi, K.D. Aubeeluck & J.L. Niewiadomski

Lessons Learned

The new educational facility, the Tilburg University Leture Hall (Marga Klompé Building), is aa sustainable and circular construction, featuring a solid wooden framework. It is the first academic building in the Netherlands constructed using Cross Laminated Timber (CLT). The application of the CLT structure, which also is entirely reusable with detachable beams and columns, is an extraordinary achievement, particularly for a university building. This construction stands as a great example of a robust, low-carbon alternative to concrete and steel.

Tilburg University's early commitment to sustainability played an important role in ensuring that both the architect and the contractor integrated these goals into their designs, engineering, and execution. This once again underscores the significance of effective communication and clarity in projects of this nature.

Nonetheless, questions remain about how the structure and building can be repurposed and what its future users will be.

The use of CLT not only backs ecological responsibility but also elevates the overall quality of the built environment that enhances the well-being and experience of its occupants. This holistic approach, where sustainability meets design, showcases the true potential of CLT in reshaping our architectural landscape for a more eco-conscious and visually pleasing future.

In summary, this building has provided valuable insights into how a conventional structure can be executed in a sustainable and circular manner, without compromising functionality and design. It is inspiring that we live in an era where such trends are emerging, and we have the opportunity to actively engage in these developments. In times of economic recession and climate challenges, this building offers hope for a brighter future, not only for us but also for generations to come. It is an inspiration for the upcoming designers and engineers.

Colophon

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Studio:
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Tutor(s):
Florian Eckardt

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https://www.esa.int/ESA_Multimedia/Images/2018/04/Cloud-free_Europe

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