Working in nature in the centre of Uppsala, a 7-storey wood-glass-construction

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1. Introduction

Magasin X is Sweden's, possibly even Europe's, largest office building with timber structure. By combining architecture built to last with cutting-edge innovation in energy and sustainability, the building sets a new standard for Swedish architecture. The building has an all-timber frame structure, and has not compromised on creating a long-lived, and as flexible building as possible. The energy solutions are at the forefront of innovation, with energy consumption at 20% of the already low Swedish building standard.
The developer, Vasakronan is one of the largest real estate owners in Sweden. They have for a long time been at the forefront of sustainability development. To develop this further, they looked for ways to test timber construction and the site where Magasin X was built was at a suitable stage in terms of planning and development. Work on the zoning plan was almost complete and an office building with a steel and concrete frame had been developed.
To investigate whether the building could be built with a timber frame White Arkitekter, along with a full consultancy team of engineers were brought in to carry out a feasibility study. Sweden has a long tradition of building in wood, but until 1994 legislation did not allow to build higher than three storeys with timber, and since then progress in the industry has been relatively slow. Many large and complicated timber buildings have been built but there are few examples of well-developed and functioning multi-tenant office buildings.
The feasibility study showed that it would be possible to build a flexible office building with an all-timber frame structure on the site. It was clear that trying to convert the previously designed concrete structure was not the most efficient way. The most well-functioning and efficient timber solution was in many ways different. When the project was to be realised, the team that carried out the feasibility study was chosen to continue.

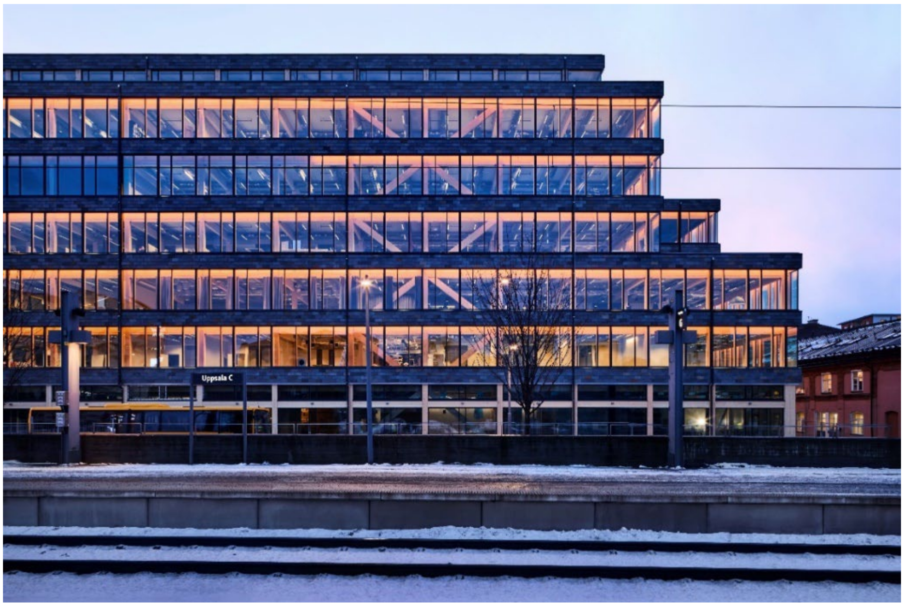


Figure 1: Façade towards the railway, the timber frame made visible interior lighting.
Photography: Måns Berg.

2. Background

During the feasibility study, the possibilities and risks of timber construction were examined. Based on the knowledge gathered during the feasibility study, ten different variants of structural systems were developed and compared against a wide range of criteria.

The issues addressed were as follows:

- Scope of timber construction: Impacts of the different options in terms of buildability, wood retention/environmental impacts and impacts on the other study points.
- Spans and structure: The core system and spans according to general conditions and Magasin X in particular. The core system affects the functionality at the garage level and the flexibility of furnishing at the office levels, as well as stability – requiring wooden or steel crane rods in the facade or stabilizing walls in the core.
- Floor structure and heights: a comparative study of different types of beams and their consequences for the design of the building, considering appropriate floor height regarding zoning regulations as well as possibilities and limitations of timber construction regarding perforations for installations.
- Installations: Different solutions for plumbing and electrical power on the office floor were evaluated, considering installation floors, while investigating the impact on energy performance, vibrations, and acoustics – given the conditions of timber construction. Thin included issues of sound insulation (walls and beams) as well as structure-borne noise from installations.
- Ceilings: The effect of the exposed timber frame on room design and flexibility.
- Furnishing and flexibility: The effect of the exposed timber frame.
- Façade: Comparative studies of different façade systems in terms of expression, maintenance, and buildability using references, considering the consequences for buildability, rentable area and daylight conditions of the chosen façade system.
- Risk: considering the risk situation and management of a timber frame in close proximity to the railway.
- Fire: The need for fire protection measures for timber structures and the extent of fire proofing timber cladding and painting.
- Moisture: the management and documentation of moisture risks during construction and facility management.
- Cost: Comparisons between the initial steel and concrete alternative, and the timber solution.
- Workplace organisation, construction time and working environment: The effect of timber construction on workplace organization, achieving health and safety benefits while considering construction time of timber frame versus precast concrete for equivalent building.
- Sustainability: the environmental benefits of timber construction were considered deeply.

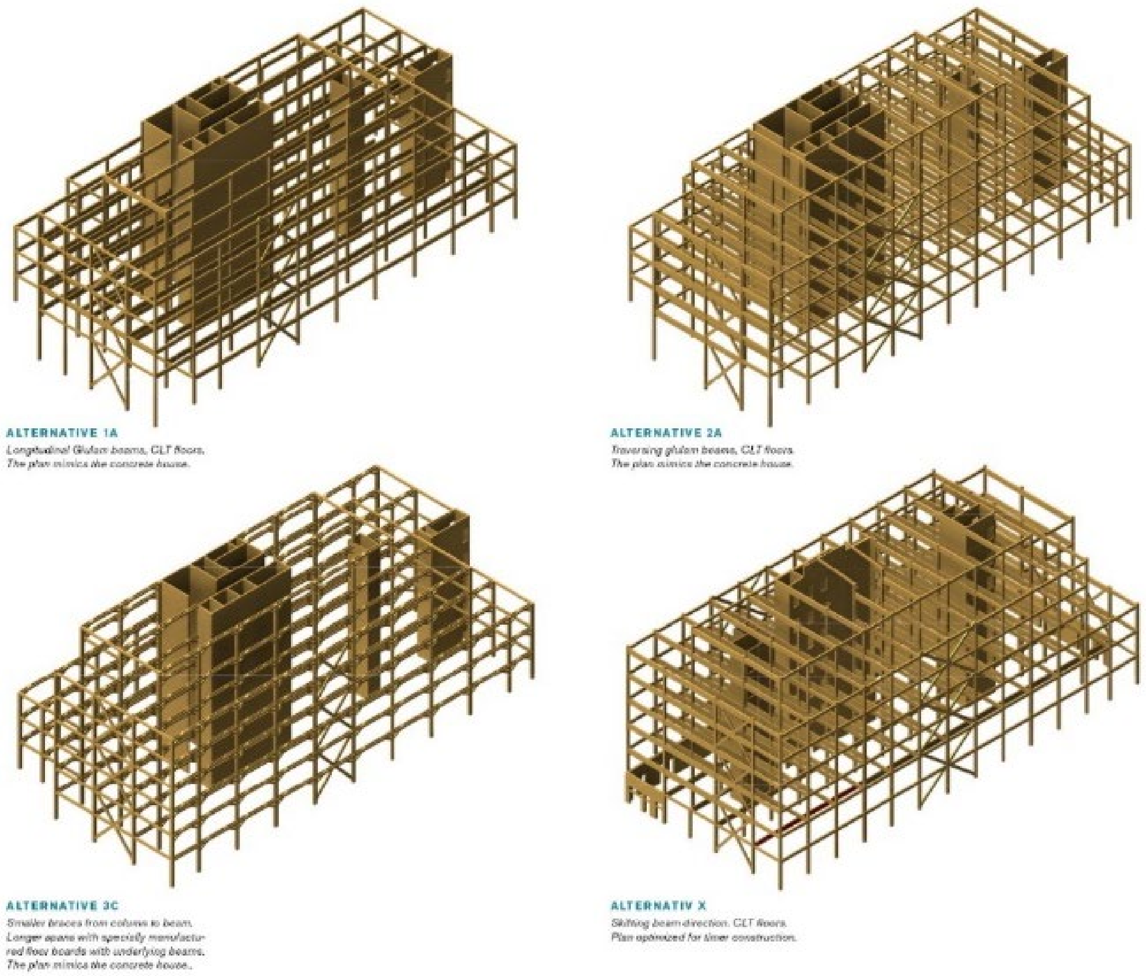


Figure 2: Four of the ten different structures evaluated in the feasibility study.

3. Design principles

3.1. Structure

The knowledge developed during the timber building feasibility study provided a very good starting point for further design. Above all, it was good to have a well-developed basis for how the frame would be developed.

Based on the ten tested frame systems, a relatively simple structure with glulam columns and beams and a slab layer of CLT panels was chosen, based on a 90 cm module. The beams have spans of alternating 5.4 and 7.2 metres, with varying beam heights. The shorter span allows for lower beams and higher clear height over the office landscapes along the main façade. The 200 mm thick CLT slab spans 5.4 metres. Since the CLT-slabs are on top of the beams, they can protrude a bit and allow the facade to be free from the frame.

On the ground floor the beams are turned 90 degrees to create better room for large ducts from the main ventilation room. This also made it possible to insert a 10.8-meter-long steel beam, taking one column out to create the possibility for a larger room. In the end this option was not utilized.

The core structure works well for the basement parking. No offsets in the structure are made between the garage and the house above ground. Wind stabilization is done with large attic crosses in the facade and with CLT walls around the emergency stairwells and elevators and a solid wall behind the toilet pack. No concrete has been used above the basement level. There are steel beams in the ventilation room on the ground floor due to potential intersection between larger dimensions of timber beams and the large ducts – otherwise steel is used only for joints.
The floor height of the office levels is 4.1 metres. This leaves 2.85 metres of clear height under the largest beams.
Installations pass through perforations in the beams and are carefully coordinated to provide flexibility and clear structure in the largely ceiling-less building. No installations go under beams.
The timber building has a tighter column structure than an equivalent steel and concrete building. To manage that without compromising flexibility, it will be important to arrange all fixed and stabilising elements according to the core grid system. This gives some constraints, but also the possibility to clearly show the frame. To make the wooden frame clear, care was taken to make it visible, especially in terms of structural timber.

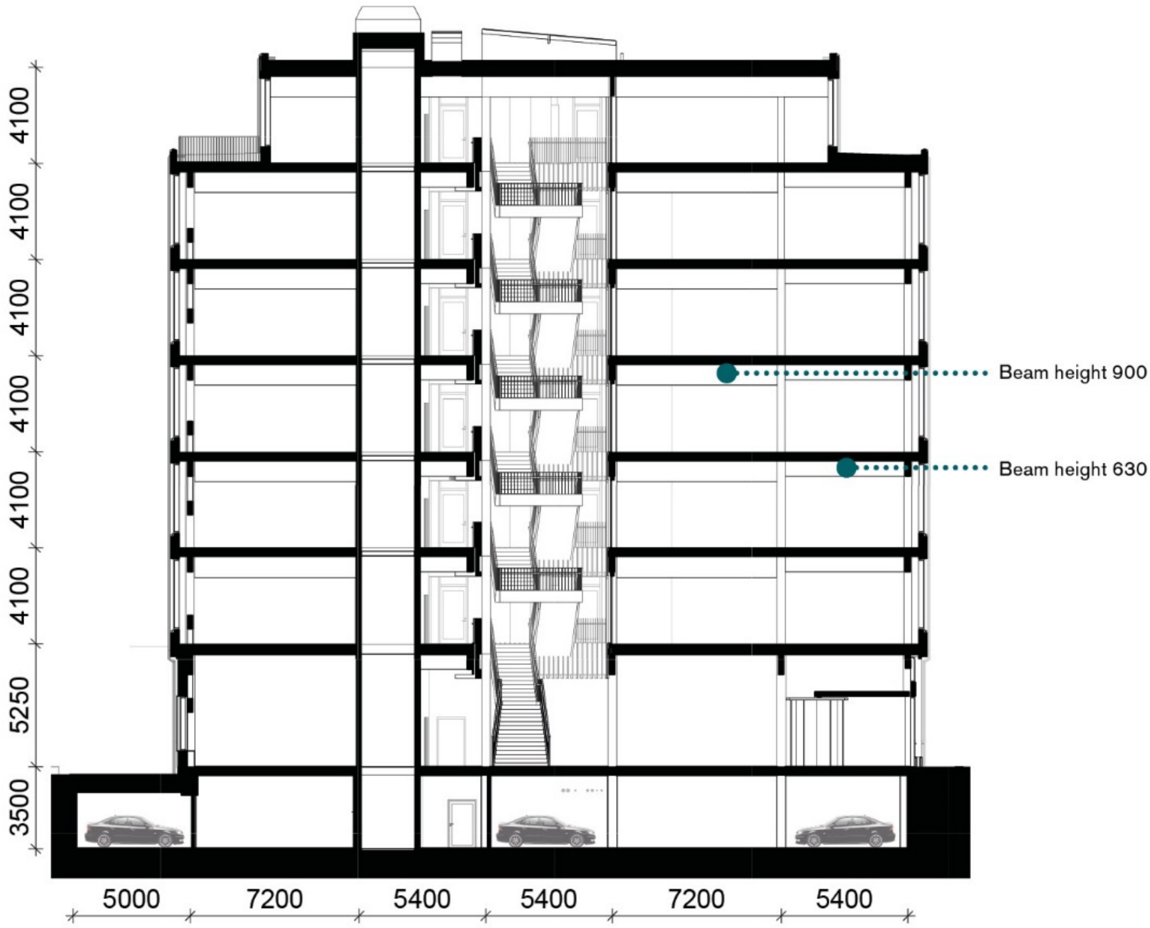


Figure 3: Typical section.

3.2. Multi-tenant offices

An office building is often refurbished, making a large part of the environmental impact of the building to take place during its lifetime. For Vasakronan, the average lease term for a tenant is 5-7 years, after which they often do a lot of alterations of the space. Parts that are fixed and long-lived are primarily the facade and public circulation areas. These can be designed with fixed solutions and exclusive materials, but office areas should be adaptable for good flexibility. Magasin X has a general interior design principle employing carpets and wall colours that do not vary between tenants. The acoustic conditions of spaces within a timber structure are in many respects challenging, requiring extra effort especially in the management of flexibility of tenant divisions. The most obvious example is how the core grid of partition walls were slightly offset from the frame, so that one layer of the partition walls can pass uninterrupted past the frame without unsightly and awkward recesses. This avoided visible coverings of beams and columns. See figure 16.

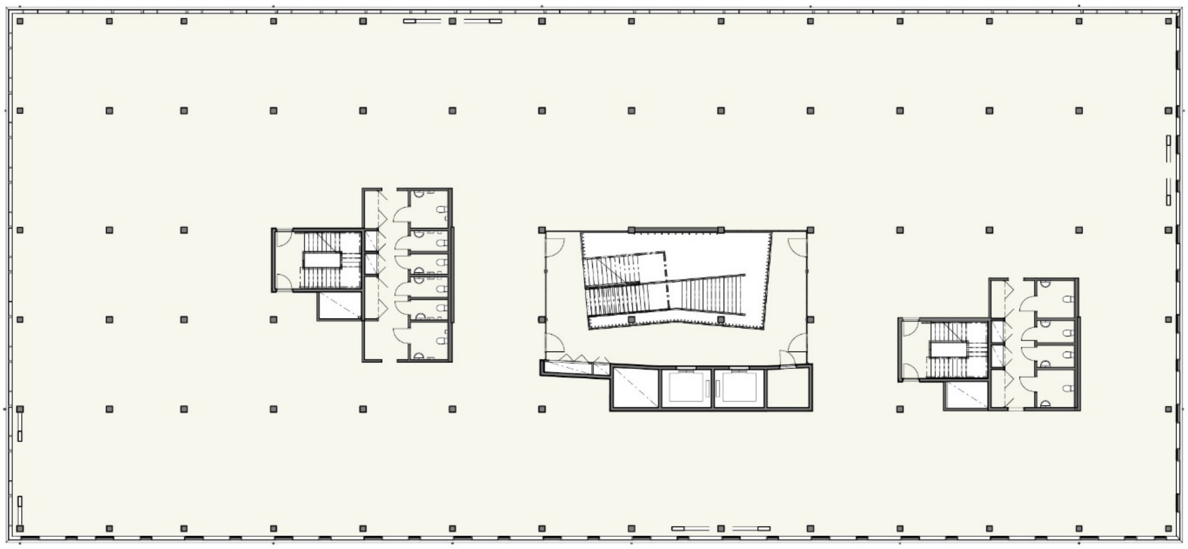


Figure 4: Office floor without fittings, showing the well-organized structure.

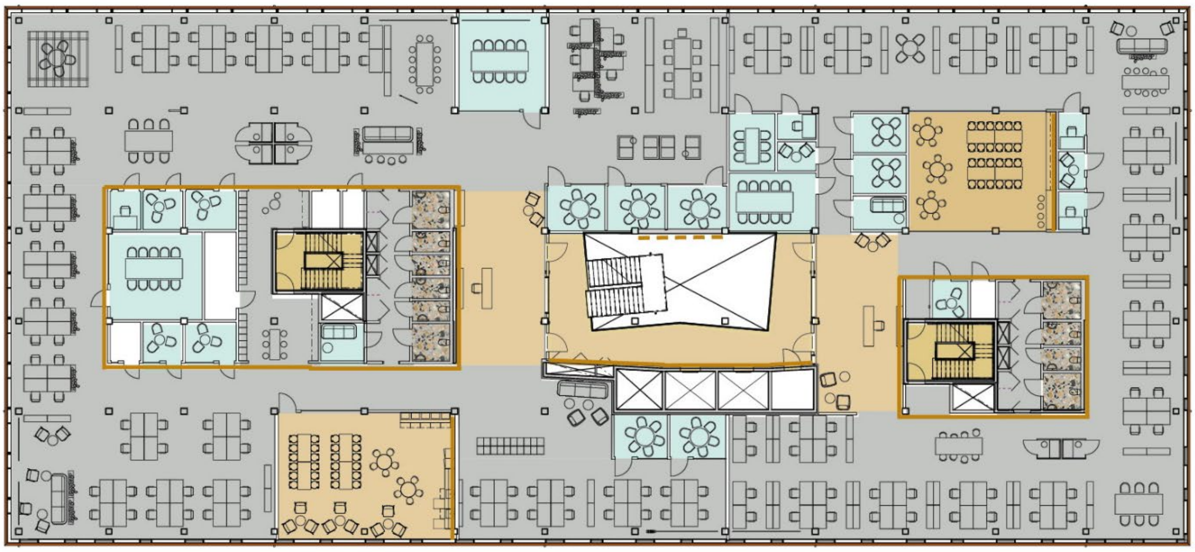


Figure 5: Office floor outfitted for a general tenant

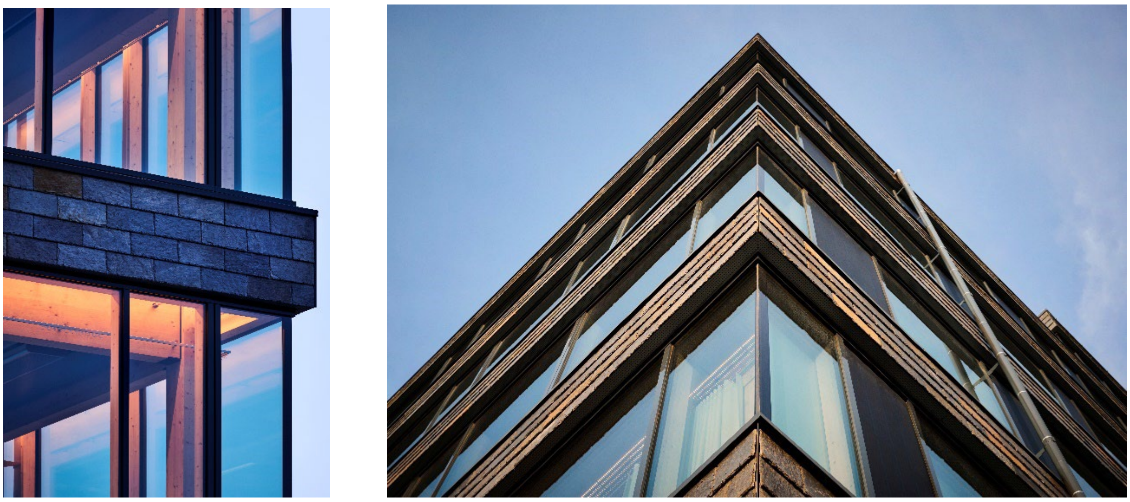
3.3. Main stair

To attract the building's users to daily exercise, a lot of energy was put into the beautiful, free-hanging staircase. It is in frequent use and the decision to remove one of the earlier designed lifts is justified. The staircase is constructed from load bearing CLT railings with steel suspension braces stabilising it.
The elevator walls made of CLT are clad with a 19 mm three-layer spruce board to create a higher quality surface.
The relatively small atrium widens at the base of the building to let in more light and expose the frame. Here, the staircase extends into a podium used by tenants for larger seminars and gatherings.

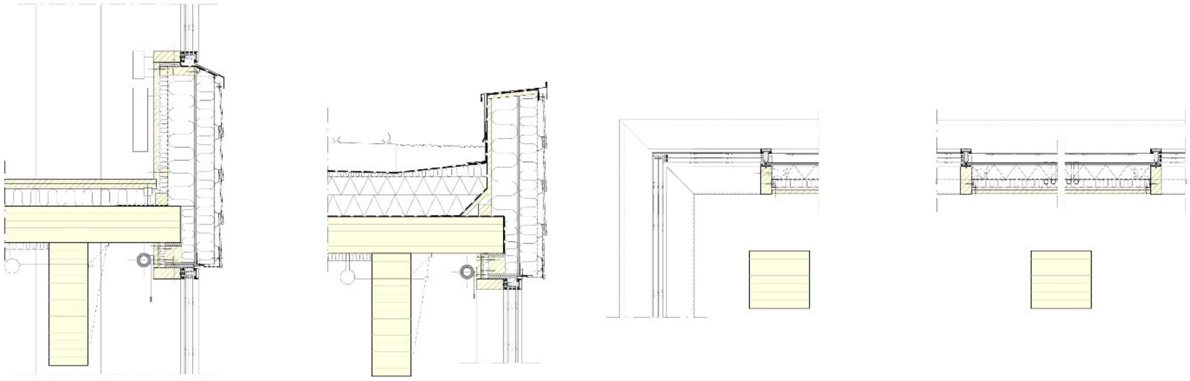
Figures 6-8: Hanging stair and podium.
Photography: Måns Berg.

3.4. Façade

There was a decisions to have exterior timber in the exterior only where it is easy to access for maintenance. All exterior timber is employing bevel-sawn plank of spruce. On the glazed parts of the ground floor and on the recessed floor of the top level it is used to replicate the interior frame, and on the closed parts it is used as large-scale panels. Otherwise, the timber frame of the building is highlighted by the extra clear glass with simple interior LED strips that illuminate the frame.
The energy efficient shape of the building and the geo-storage for heating and cooling allowed relatively large glass surfaces. The glass type and proportion were carefully developed through intensive collaboration between the architect, glass consultant, HVAC consultant and energy specialists to achieve good daylight, insulation, solar heat gain and design requirements. On the south-facing sides, a 40% reduction in glazing area was required to avoid excessive solar heat gain. Here, part of the glass was replaced with solar panels that are part of the same profile system. The profile system is made of glulam with a simple aluminium add-on profile that holds the glass. This saved 5.5 km of aluminium profiles, and the same profile holds the solar panels. See figures 11-14.
The skirtings are covered with Norwegian rust-coloured slate. Quarried directly from the rock, requiring no finishing and indefinite reusable it is probably the facade material with the lowest climate impact. With its slight lustre and natural-looking surface, it provides a façade that changes beautifully in different light and weather.



Figures 9-10: The facade from different angles, showing glazed corners änd PV-panels in the window system. Photography: Måns Berg.



Figures 11-14: Vertical and horizontal detail examples.

4. Technical notes

4.1. Fire

As any modern office building Magasin X has sprinklers installed, well-adjusted to the timber structure. The sprinkler system is not necessary to enable timber construction but has allowed a more visible and untreated timber solution, the open stairwell as an escape route and longer distances to escape stairwells.
The timber frame is essentially its own fire protection and it is dimensioned so that the char build-up during a fire will insulate the frame. The underside of the CLT in the floor slab is fire protected with a 40 mm thick rock wool board which also has the function of acoustic absorbent.
In escape routes, timber parts are painted with a flame-retardant varnish. Swelling fire-protection paint is used only on smaller, non-visible parts.
The fire consultant has assisted with clear calculations to determine the extents of exposed timber in the office levels without triggering fire protection requirements.
During the design and construction phase, the fire issue was carefully studied. Gaps larger than 5 mm were sealed with swelling fire grouting.

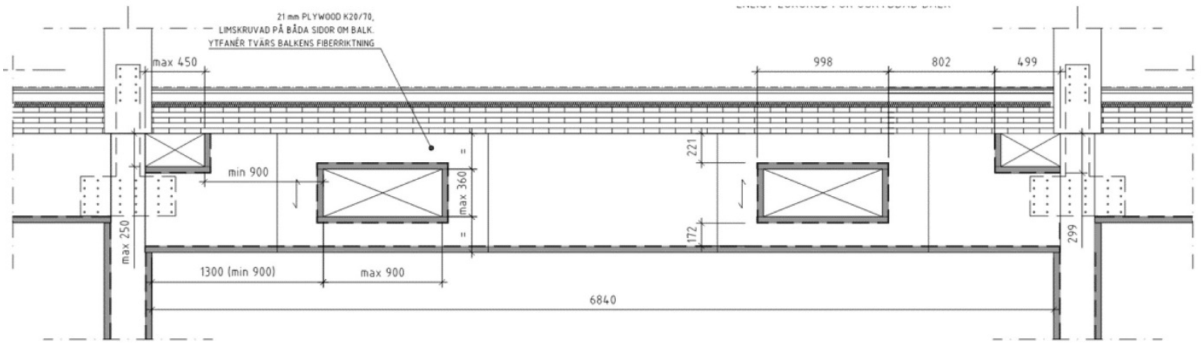


Figure 15: Beam with what is burned after 60 minutes of fire marked in grey.
Drawing: Bjerking

4.2. Acoustics

As described in chapter 3.2, one of the challenges of a multi-tenant house is that tenant boundaries that have the highest acoustic requirements can be moved during the lifetime of the house. To have flexibility in the face of this, staggered positions for partition walls were used, meaning that no cladding to columns or beams with acoustically dampening plasterboard was needed.
Between floors, the acoustics were solved with a top floor on rubber feet. Only tenant-separating walls are supported on the CLT floor itself.
Since experience with the acoustic properties of wood is somewhat limited, some oversizing was done. Continuous sound measurements have ensured that the sound classification is maintained.

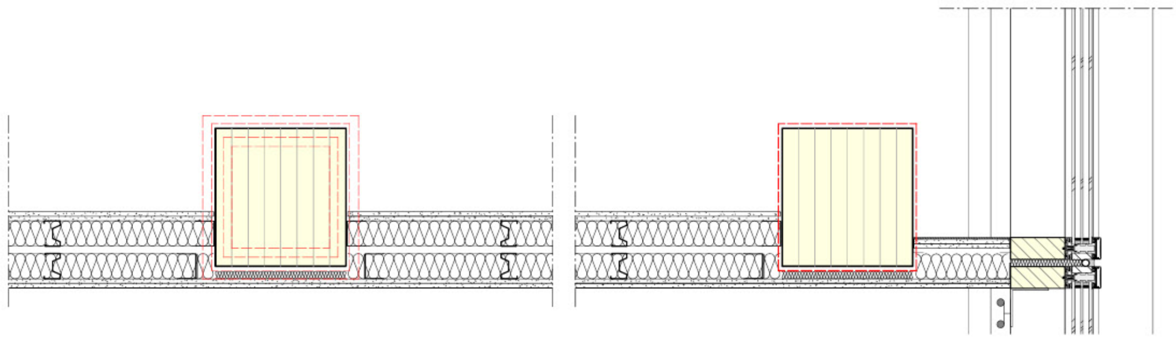


Figure 16: Detail drawing of how walls can connect to the façade without complication.

4.3. Installations

Swedish office buildings are installation-intensive, with a high focus on good indoor climate and a high degree of heat recovery. This results in relatively large installations which had to be carefully fitted into the perforations that could be taken in the glulam beams in the factory. Clear paths for each type of installation were created according to a system that could be maintained throughout the project. Real-time linked Revit models ensured an ongoing dialogue on how to solve the installations without compromises.

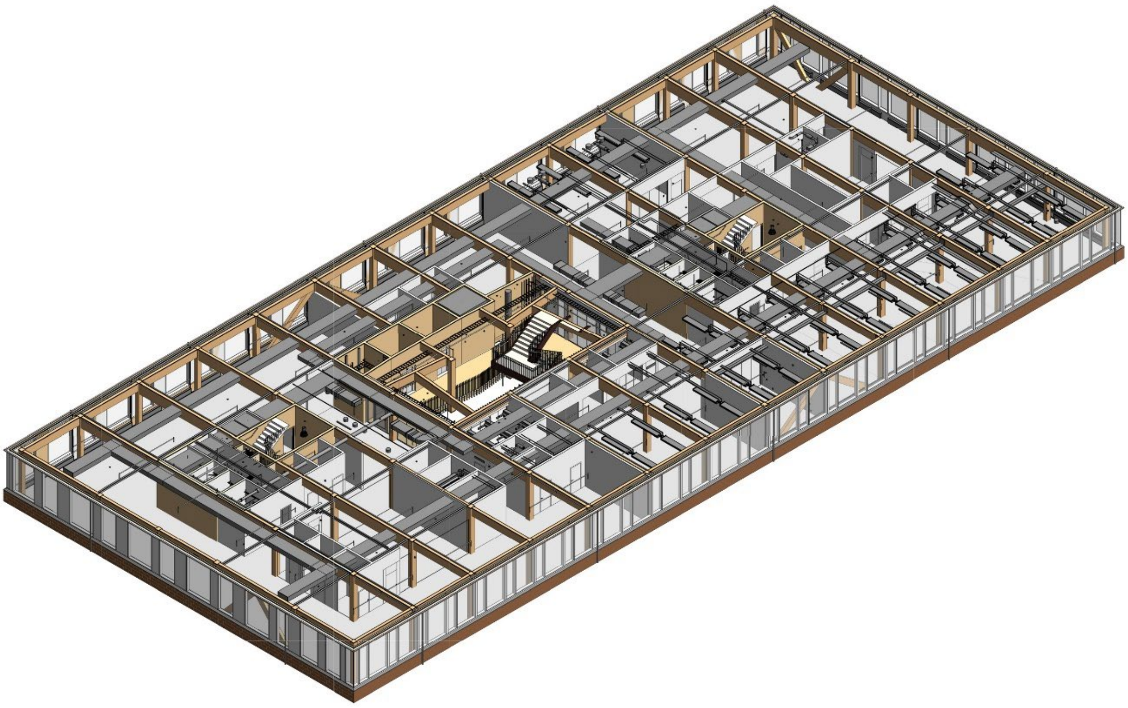


Figure 17: 3D-plan showing installation organization

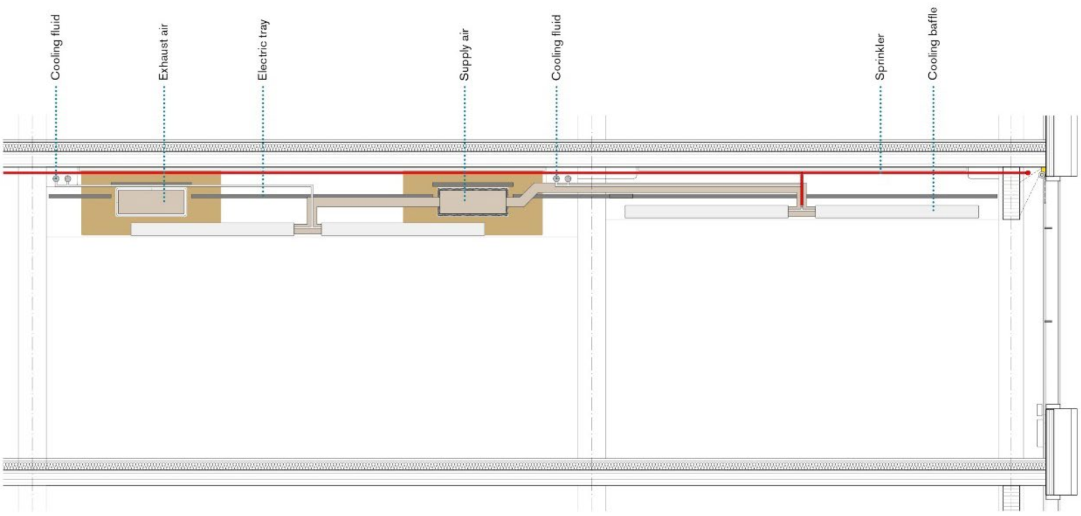


Figure 18: Simplified section showing hole pattern and installations

4.4. Buildability

The promised time savings of the timber frame construction were not really fulfilled. Precision was slightly lower than promised. This does not negatively affect the finished result, but it did add to the cost and time of fire grouting. It was not possible to build a tent over the whole site. In order to moisture-proof the frame as much as possible, it was erected in three stages to reach the roof as quickly as possible. While the frame was being erected, scaffolding with roofs was built over the joist channels. The multi-storey wind brazing crosses were test-assembled in the factory, dismantled and assembled on site in a horizontal position, three storeys at a time. These required more complicated connection fittings and compared to steel crosses, were probably relatively more expensive.
The construction industry is still not fully mature and attuned. The contractor had not worked with timber before, which required some learning. As architects, however, we are delighted that they are made of wood. There is hope that this will develop in the future, with more contractors acquiring capabilities for timber construction.
The column sections that stood outside without floors over darkened considerably compared to columns that had the floors over installed quickly. To achieve an even colour inside the offices, a large portion of the columns were sanded.
The working environment was greatly improved in a quieter workplace compared to a concrete or steel building.

Figure 19: Construction site.
Photography: Gustav Kaiser

4.5. Sustainability

The building is LEED Platinum certified with one of the highest point accumulations ever. In addition to the timber frame structure, the house includes several prominent sustainability features:

- A battery storage system creates redundancy for sprinkler pumps without the need for diesel generators. The battery storage system is also used as a backup in the event of a power outage and to store solar power for overnight property operation. In addition, Vasakronan sells electricity during power peaks.
- In total, about 1100 m² of solar cells is mounted on the roof and facade.
- Borehole thermal energy storage is used for cooling and heating. No district heating and no cooling machines are needed, and the pumps are largely powered by self-generated solar energy. Overall, the building is estimated to have an energy consumption of less than 20 kWh/m²/year, which is less than a quarter of the Swedish requirement for new buildings.
- Wireless sensors for heating and ventilation, wireless light switches save many kilometres of cable.

The long-term perspective on sustainable architecture, with materials that age well and with structures that are simple to adapt for future needs contributes to the incalculable sustainability factors.
The LCA for Magasin X shows a 40% reduction in carbon footprint compared to the Swedish Housing Agency's baseline building. This is still far from zero, but a considerable reduction.

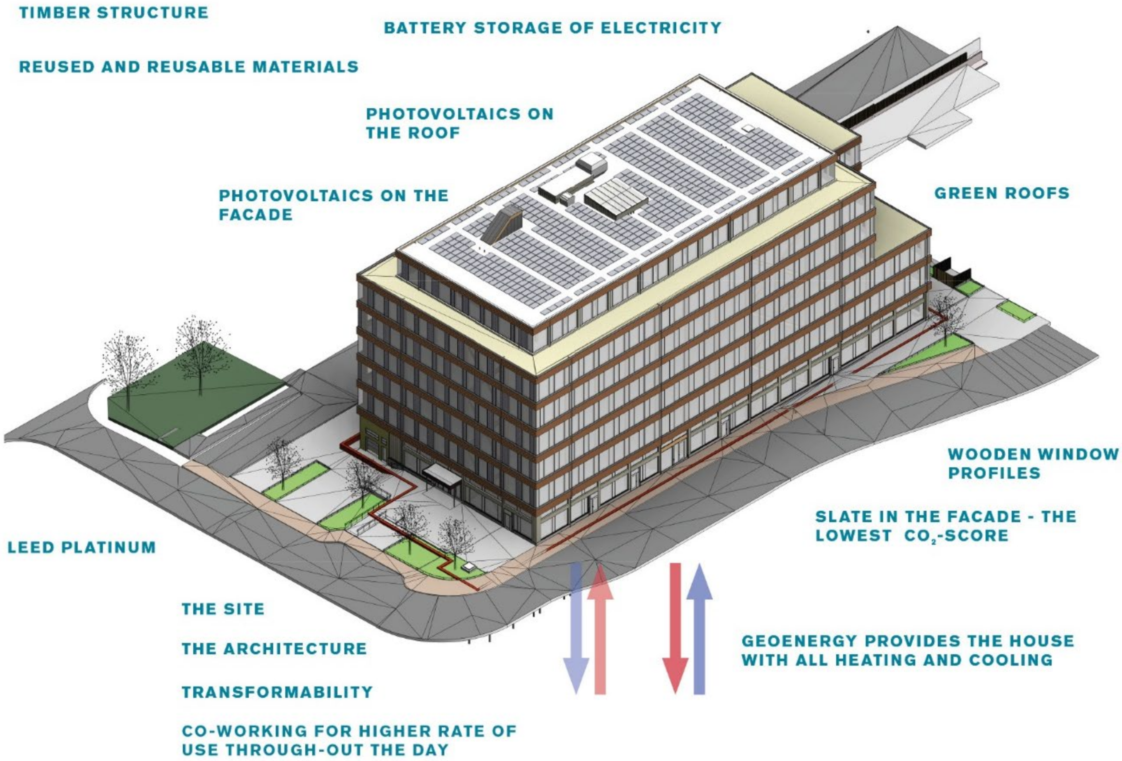


Figure 20: overview of sustainability factors.

4.6. Economy

The building was completed on time and on budget. The frame structure cost slightly more than a prefabricated concrete structure estimate, but this was more than offset by the fact that the premises were easy to rent at some of the highest rents in Uppsala. As the sector matures, the economic benefits of wood should be further developed.

5. Conclusions

5.1. Buildability

It is possible to build well-functioning office buildings with timber frames, achieving good spatial qualities and well-functioning workplaces. With good architectural design and collaboration with engineers, the denser column grid does not have to be a constraint, but it does require more coordination. The building industry is quickly adapting. Parallel to the Magasin X project White Arkitekter has been working on several other office buildings, schools, and housing projects with timber structure, and it is obvious that knowledge and skills in all parts of the sector is growing fast.

5.2. Architectural qualities

Building with timber gives the architect renewed possibilities to express the structure in a tectonically interesting way. The higher beams, while demanding a slightly higher building height can be used to get higher spaces in the offices. Using CLT slabs on top of the beams gives possibilities to easily create energy efficient and flexible façade solutions. Combined with other natural materials the timber frame can create a calm feeling that is very appreciated by the users.

5.3. Sustainability

To further reduce the climate impact, the LCA analysis indicates a number of key points for further development – and the following calls for action:

- Decrease of concrete and a greater proportion of climate-friendly concrete.
- Adapt the foundation. Magasin X has parking spaces in parts that protrude out-front of the building itself. These were calculated to be economically viable, despite their large amount of concrete, but they significantly increased the climate impact.
- Develop the steel brackets in the timber frame - steel accounts for almost half of the carbon footprint of the timber frame itself, even though there were limited to fittings and the two steel beams in the fan room.
- Adapt the proportion and type of glass in the facade.
- Increase the proportion of recycled material.
- Increase the attention to the carbon footprint of all building components.

6. Acknowledgements

This project would not have been possible without the deep and committed cooperation from a lot of different parts. Some of them are here, but unfortunately there is a page limit. Thank you all.

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Landscape architect:	White, Stefan Rummel
Interior architect:	White, Magnus Lindgren
	Kanozi, Hanna Bolin
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Final documenting, wood structure:	Tyréns, Niclas Kjell
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Electrical engineer:	Bjerking, Marcus Karlsson
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Accessibility:	ProjekTIL, Jenny Afvander
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	WSP, Sarah Norling

Figure 21: Interior of the White office.
Photography: Måns Berg.