An assessment of greenhouse gas emissions from CLT and glulam in two residential nearly Zero Energy Buildings

Nicola Lolli

NZERO

Kouvola innovation

Aalto University

TAL TECH

VKAB Växjö Kommunföretag AB

Växjö kommun The Greenest City in Europe

SINTEF

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754177

NERO

- The NERO project looks for solutions to reduce the cost of future nearly Zero Energy Buildings through an efficient design and manufacturing process.

- The project focuses on improving the energy and cost-efficiency of wood-based prefabricated buildings, as well as demonstration projects in four participating countries.

- The NERO partners are:
  - Kouvola Innovation – Finland (project coordinator)
  - Aalto University – Finland
  - Tallinn University of Technology – Estonia
  - Stiftelsen SINTEF – Norway
  - Växjö kommune - Sweden

An assessment of greenhouse gas emissions from CLT and glulam in two residential nearly Zero Energy Buildings

- The scope of this study is to show the results from the LCA of two residential buildings.
- A student housing (Moholt Allmenning Tower B) and an apartment building (Vallen Norra Building A) in Växjö.
- Both buildings addressed the extensive use of wood elements (CLT and glulam) in the construction, and Passive House standard solutions. Both buildings have similar total floor area.
- Results from the comparison of GHG emissions of façade and floor structures are also presented

NERO SINTEF

Moholt Allmenning

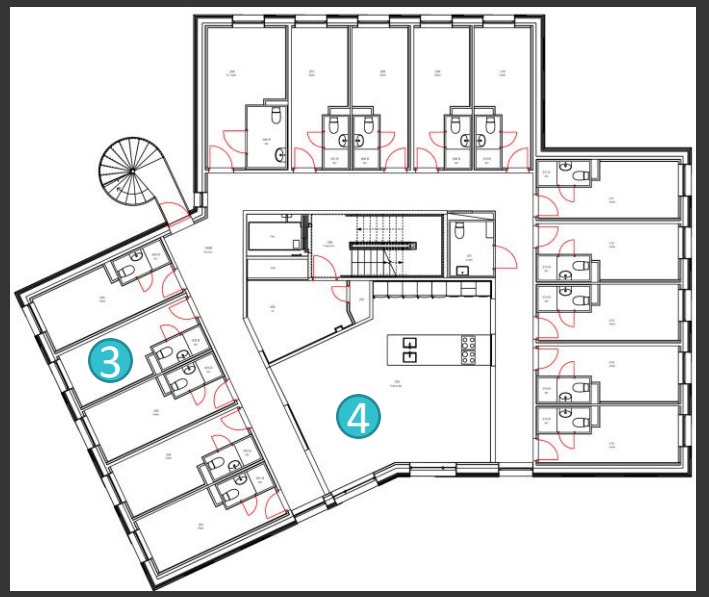
- Five towers of 9 floors each. Each floor has 15 residential unit for a total of 632 units
- The building complex hosts a kindergarten for 171 children and a public library
- The building efficiency solutions were designed to comply with the Norwegian Passive House standard NS 3700
- Building owner, Sit (Student welfare organization)
- Residential units built in 2015.
- Tower B analysed. Area 3801 m^2.

	Moholt Allmenning, Tower B.
Exterior walls	0.13 W/(m² K)
Roof	0.10 W/(m² K)
Ground floor	0.17 W/(m² K)
Windows	0.80 W/(m² K)
Window g-value	0.55
Doors	0.80 W/(m² K)

Moholt Allmenning

- The five towers, kindergarten, and library are connected to a ground-source heat pump with a total production capacity of 2.2 GWh/year.
- The residential towers have mechanical balanced ventilation in the students' rooms and in the living area with 85%-efficiency air heat recovery units.
- The ventilation supply is controlled by the CO2 sensors installed, and the flow of the air volume is controlled by the air extracts in the kitchens.
- The student rooms are with private bathrooms and organized in a Y-shape around the common area/kitchen/dining area

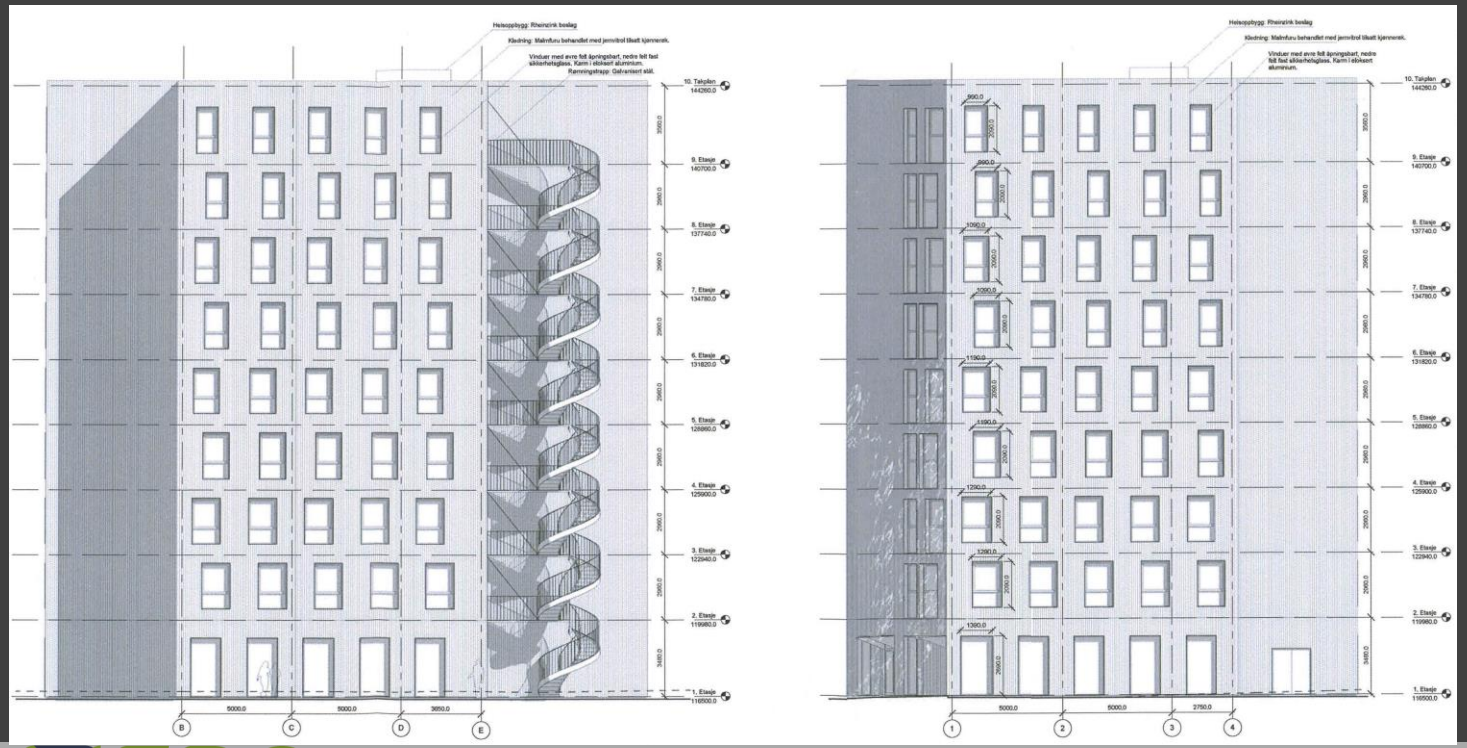
1. Ventilation supply
2. Ventilation extract
3. Students' rooms
4. Living room



NERO SINTEF

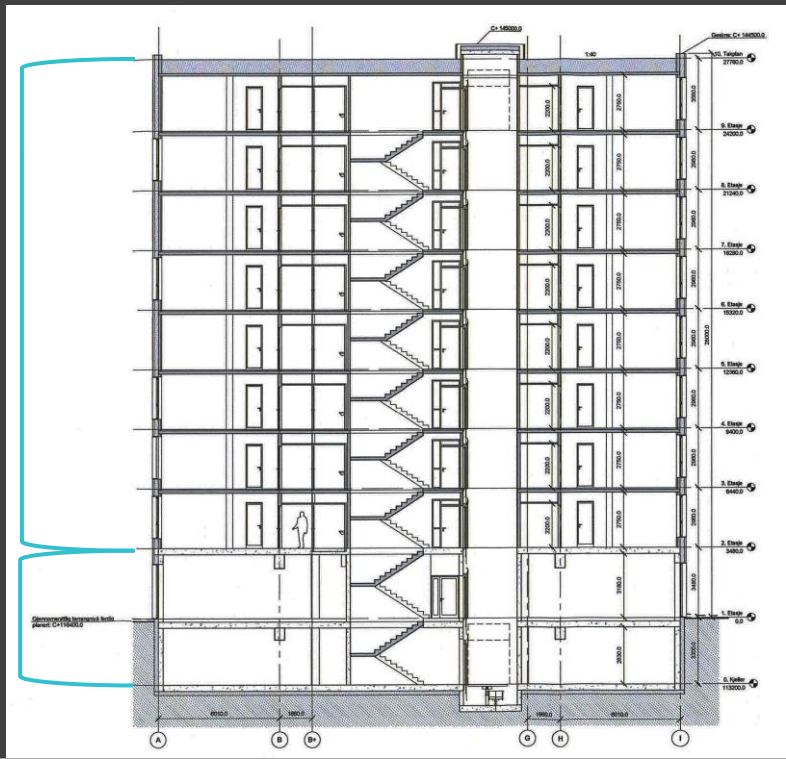
Moholt Allmenning

- The structural solutions of the floors from 2nd to 8th are mainly composed of CLT (floors, external walls, internal walls, stair well and the elevator shaft), glulam beams (across the living area), and LVL (stair ramps).
- The ground floor and the basement are mainly concrete (floors and walls).



Wood

Concrete



Moholt Allmenning

① CLT

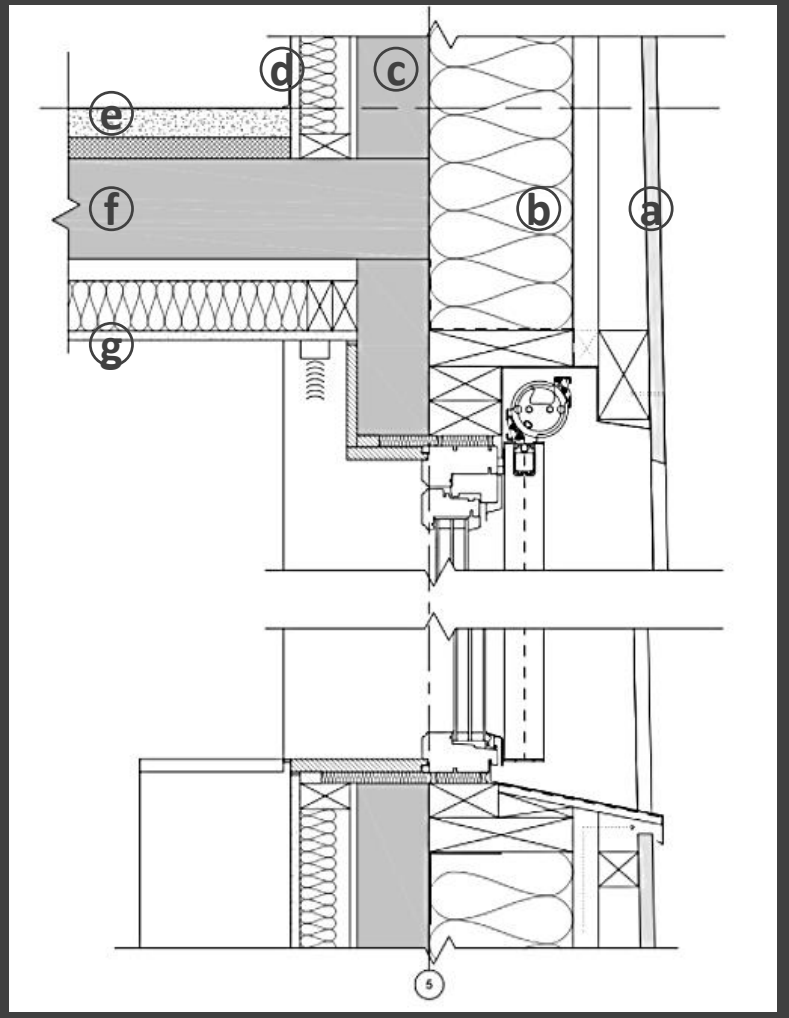
② Glulam

③ Gypsum board

- Internal CLT walls (40 - 160 mm thickness)
- External 100-mm CLT walls
- CLT floor decks (140 - 200 mm thickness)
- Glulam beams (200x560 mm – 240x480 mm)
- LVL stair ramp
- Concrete external walls

Moholt Allmenning

	Exterior walls (outside to inside) 395 mm
a	20 mm wood façade panel
	90 mm air gap and timber frame for façade panels
b	200 mm mineral wool
c	100 mm CLT
	30 mm air gap + timber frame for gypsum panels
	50 mm mineral wool
d	13 mm gypsum board
	Internal floors in students' rooms 2nd-8th (top to bottom) 323 mm
	Linoleum
e	40 mm floor screed
	30 mm sound insulation
f	140 mm CLT
	50 mm air gap
	50 mm mineral wool
g	13 mm gypsum board



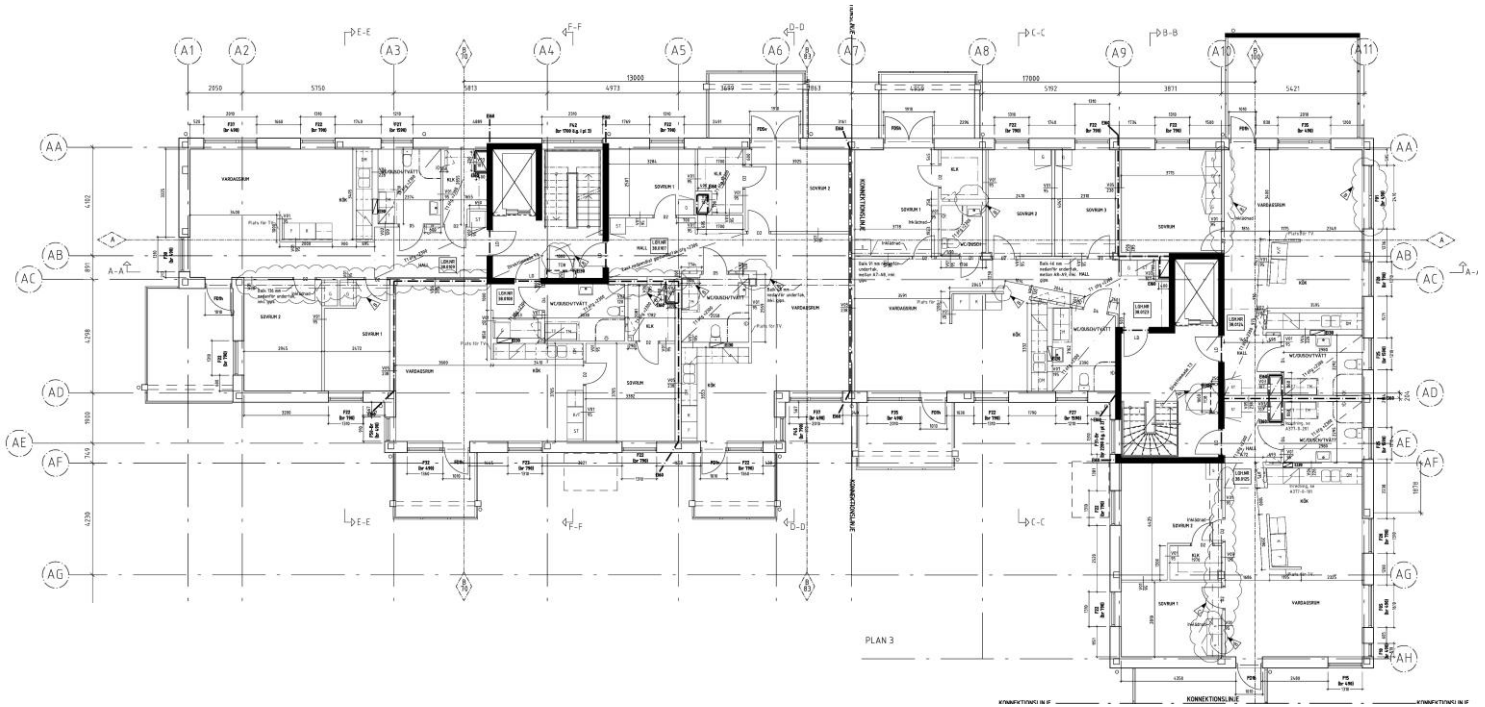
Vallen Norra

- Three apartment buildings (A, B, and C). Building A was built in 2015
- 3483 m^2, 45 rental apartments
- The building's energy performance based on actual energy use is Class B

	Vallen Norra Building A
Exterior walls	0.11 W/(m² K)
Roof	0.09 W/(m² K)
Ground floor	0.11 W/(m² K)
Windows	0.9 W/(m² K)
Window g-value	0.47
Doors	1.4 W/(m² K)

Vallen Norra

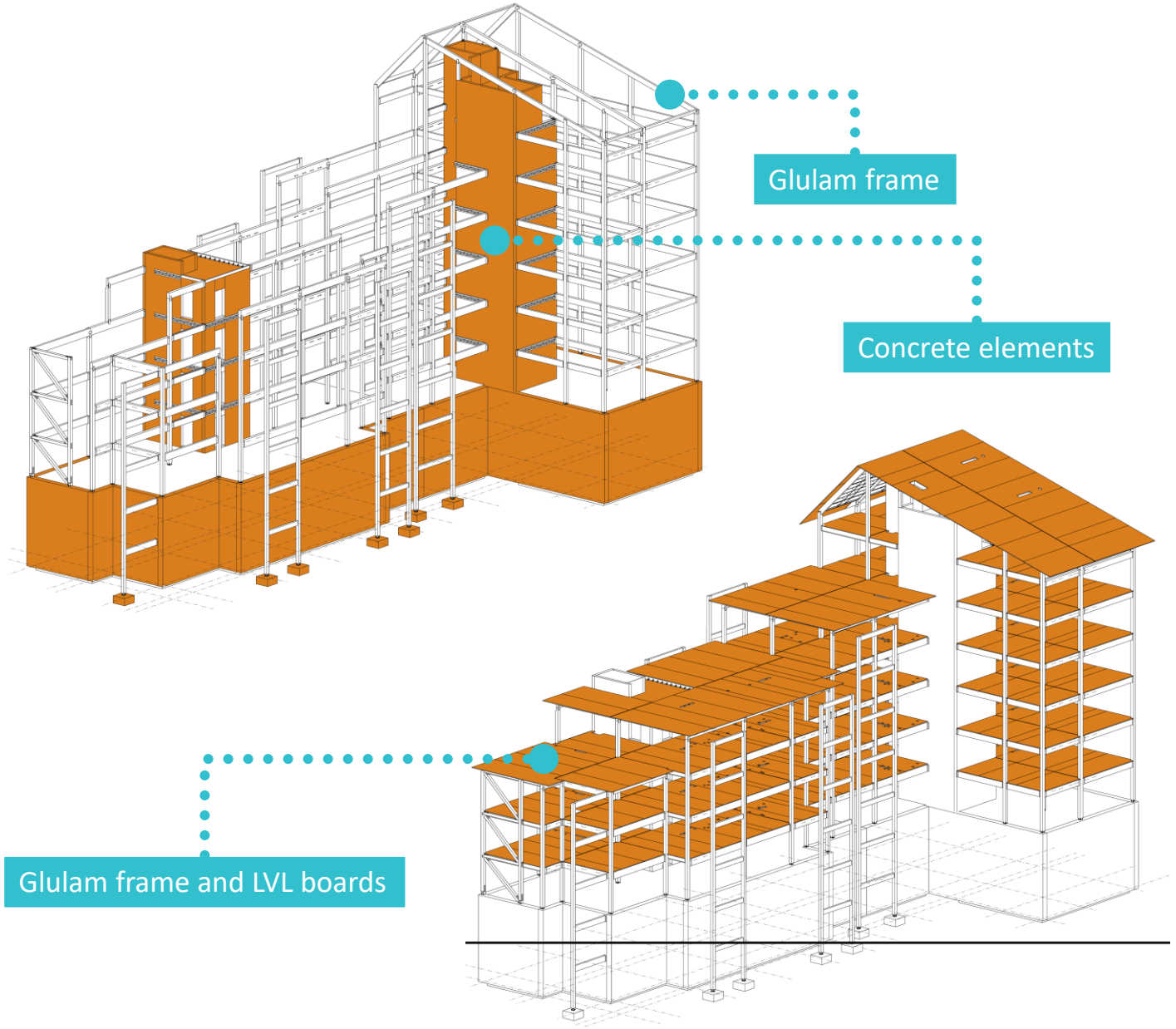
- Connected to the Växjö Energi AB´s district heating distribution system (Växjö Energi) for the apartments' heating and domestic hot water demands.
- Heat to the apartment is distributed via balanced mechanical ventilation system water loops connected to water-based radiators.
- Electricity is used for lighting, appliances plug loads and fans.



Vallen Norra

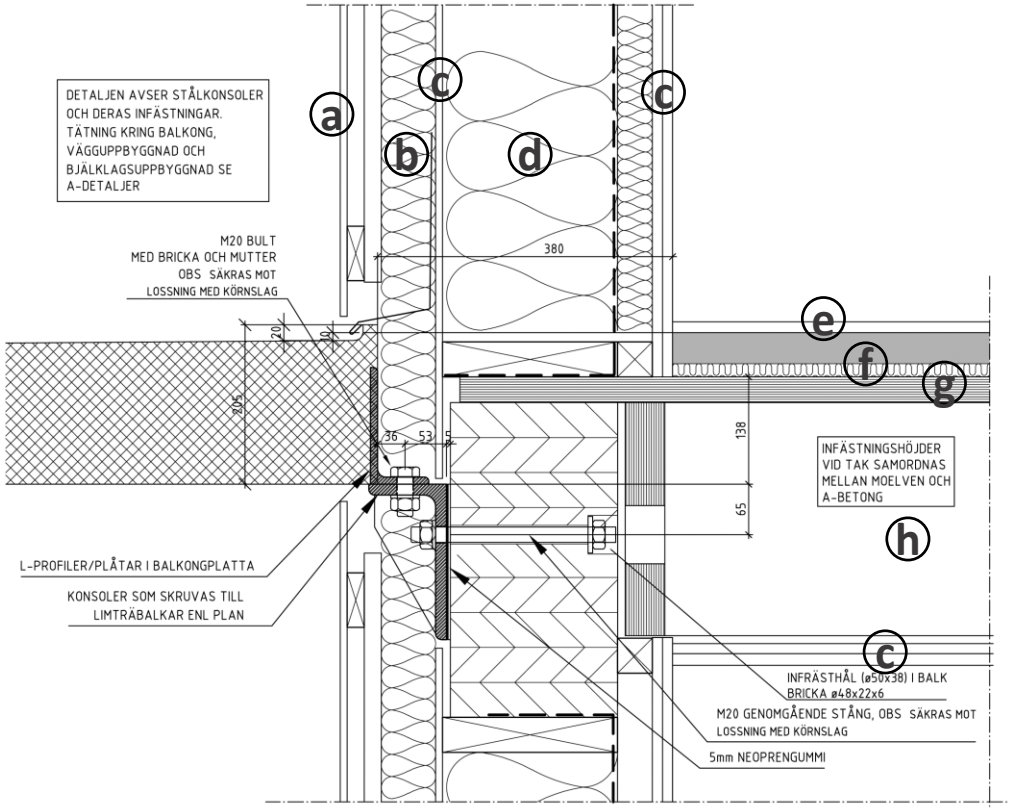
Structural solution:

- Concrete sandwich walls and concrete floor decks in the first two floors, concrete stairwells and elevator shafts
- Glulam frame (beams and columns)
- Glulam frame with LVL boards in the floor decks



Vallen Norra

	Exterior walls (outside to inside) 380 mm
a	12 mm wood façade panel
	44 mm air gap and timber frame for façade panels
b	70 mm glass wool
c	13 mm gypsum board
d	270 mm glass wool
c	13 mm gypsum board
	13 mm gypsum board
	Internal floors 2th-9th (top to bottom) 410 mm
e	Wood flooring
	40 mm floor screed
f	20 mm acoustic insulation
g	33 mm LVL board
h	300 mm air gap and glulam floor structure
	14 mm wood board
c	13 mm gypsum board



Method

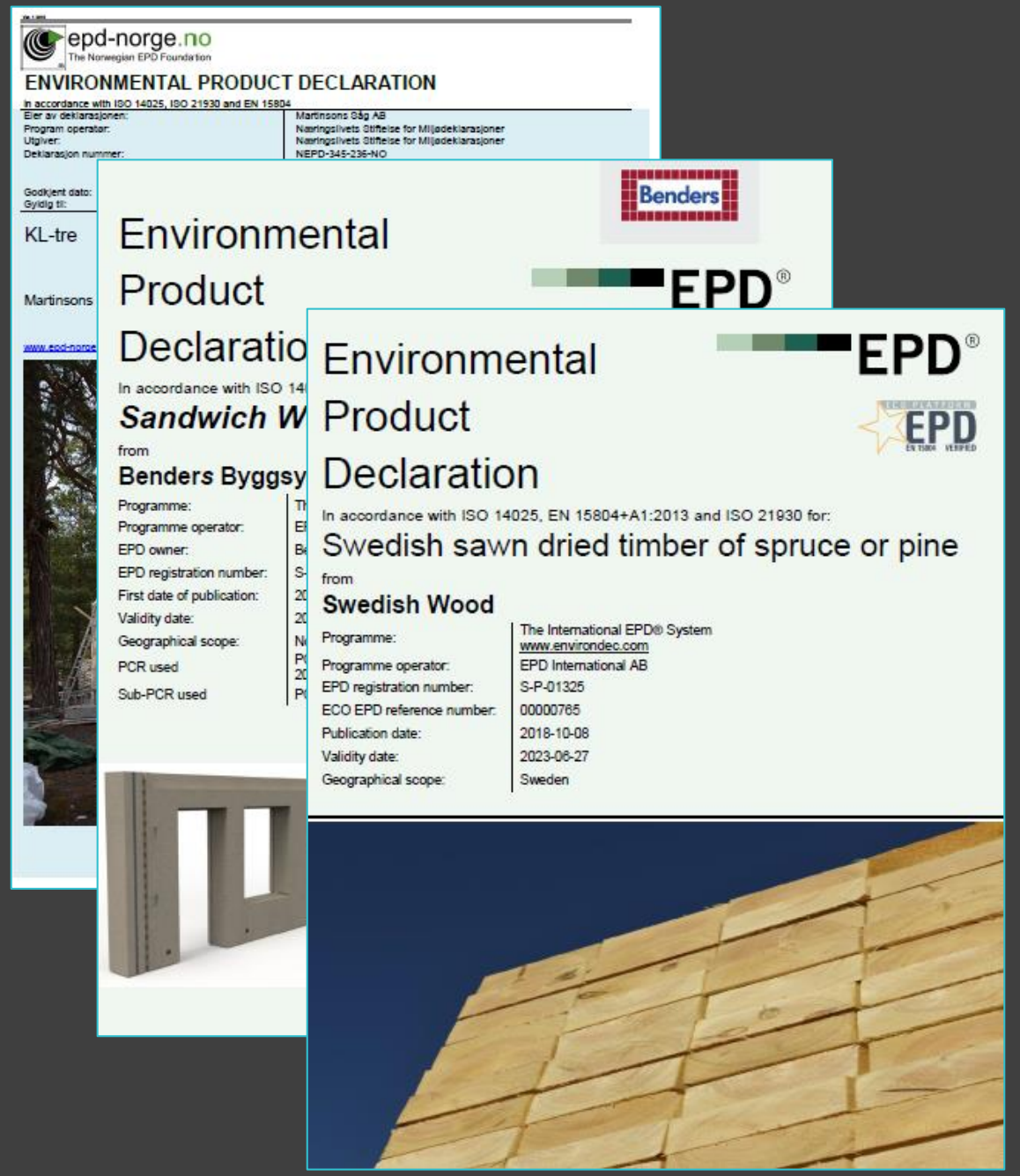
- Life cycle assessment (LCA) according to ISO 14040/44
- Global Warming Potential 100 years-time horizon (kgCO2eq)
- Modules A1-A3 (GHG emissions of material/components manufacturing at factory gate)
- Biogenic carbon from wood products not included (because A1-A3 modules only)

A1-3 Product Stage			A4-5 Construction Process Stage		B1-7 Use Stage							C1-4 End of Life				D Benefits and loads
A1: Raw Material Supply	A2: Transport to Manufacturer	A3: Manufacturing	A4: Transport to building site	A5: Installation into building	B1: Use	B2: Maintenance (incl. transport)	B3: Repair (incl. transport)	B4: Replacement (incl. transport)	B5: Refurbishment (incl. transport)	B6: Operational energy use	B7: Operational water use	C1: Deconstruction / demolition	C2: Transport to end of life	C3: Waste Processing	C4: Disposal	D: Reuse, recovery, recycling
x	x	x														

- Buildings' LCA:
  - Building life: 50 years
  - Functional Unit of buildings: 1 m^2 Heated Floor Area (HFA)/year
  - Results: kgCO2eq/m^2 year
- Buildings' elements LCA:
  - Building element lifetime: 50 years
  - Functional Unit of building elements (floor deck and façade): 1 m2/year
  - Results: kgCO2eq/m2 year

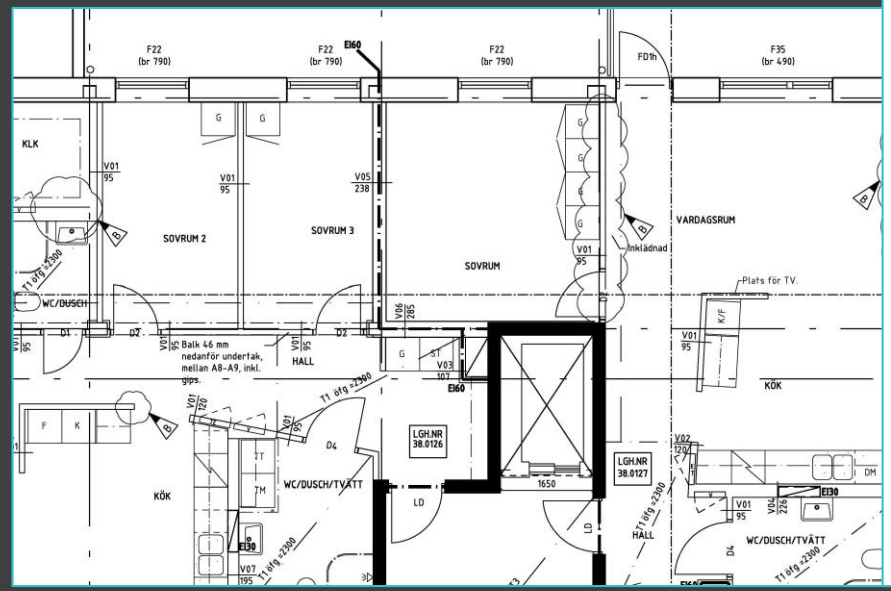
Method

- Buildings' Life Cycle Inventory:
  - Averaged impact factor for same materials from different manufacturers
  - Used Environmental Product Declarations (EPDs)
  - EPDs retrieved from epd-norge.no and Environdec.com
  - Same impact factors for materials in both buildings to make comparison



Method

- Buildings' Life Cycle Inventory:
  - Material quantities extracted from CAD drawings and BIM inventories



HÄNVISNINGAR

Fast inredning se Inredningsritningar.

FÖRKLARINGAR

= BRANDGRÄNS ENLIGT PLANER
= KONNEKTIONSLINJE

LITTERERING

Se uppställningsritningar

F27 etc = UTVÄNDIGT FÖNSTER
ALP-11 etc = ALUMINIUMPARTI
SD-10 etc = STÅLDÖRR
D10 etc = INNERDÖRR AV TRÄ

= Sandwichvägg
= Lättvägg
= Skalvägg

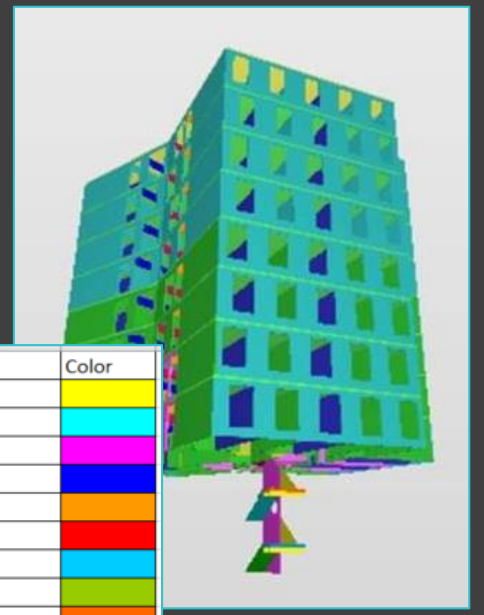
VÄGGTYPER

Lättväggar; väggtyper enl. Gyprocs handbok.

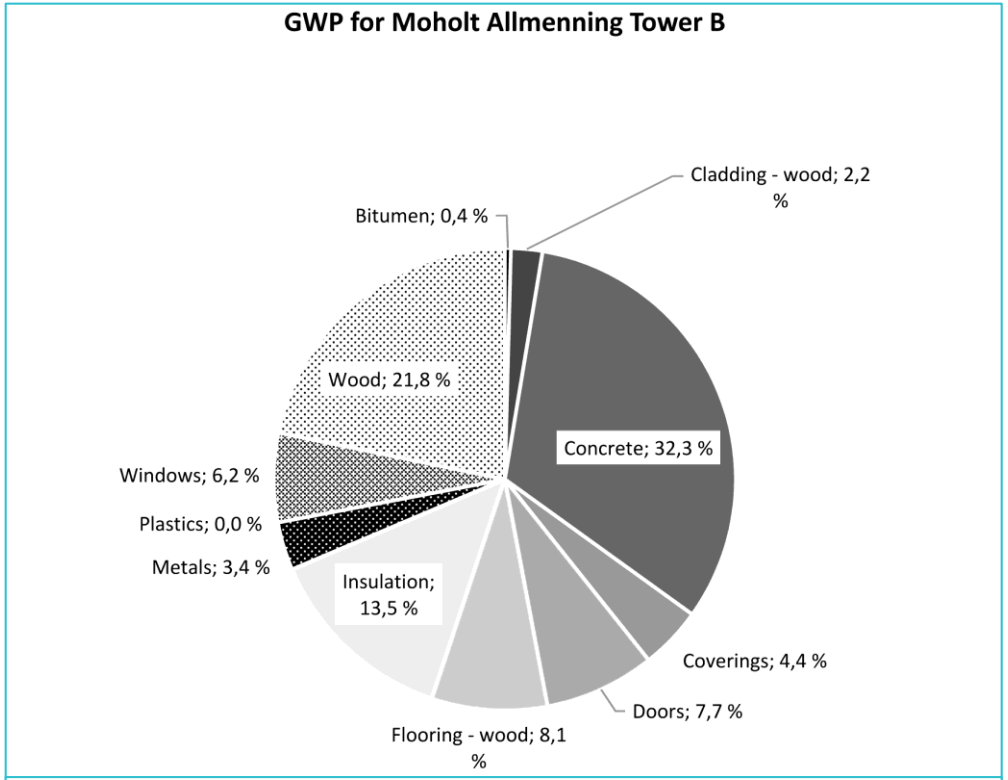
V01 = XR 70/70 (450) 1-1 MO, tjocklek= 95mm
V02 = XR 95/95 (450) 1-1 MO, tjocklek= 120mm
V03 = XR 70/70 (450) 3-0 MO, tjocklek=107mm
V04 = 2x13 gips, XR 70/70x2 (145mm reglat)(cc450), 1 protect 28x120 läkt, 1 gips, tjocklek 226mm
V05 = 3x13 gips, 70 regel/min.ull, 20mm luftspalt, 70 regel/min.ull, 3x13 gips, tjocklek 238mm.
V06 = 3x13 gips, 70 regel/min.ull, 102mm luftspalt, 70 regel/min.ull, 3x13 gips, tjocklek 285mm
V07 = 2x13 gips, XR 70/70x2 (145mm reglat)(cc450),2x13 gips, tjocklek 195mm
V08 = 1 skiva gips(Robust), 1 skiva plywood XR 70/70 (450), 1 skiva plywood, 1 skiva gips(Robust), tjocklek 120mm
V09 = 13 gips, 70 regel, inklädnad pelare 2x13 gips, 13 gips, tjocklek 129mm

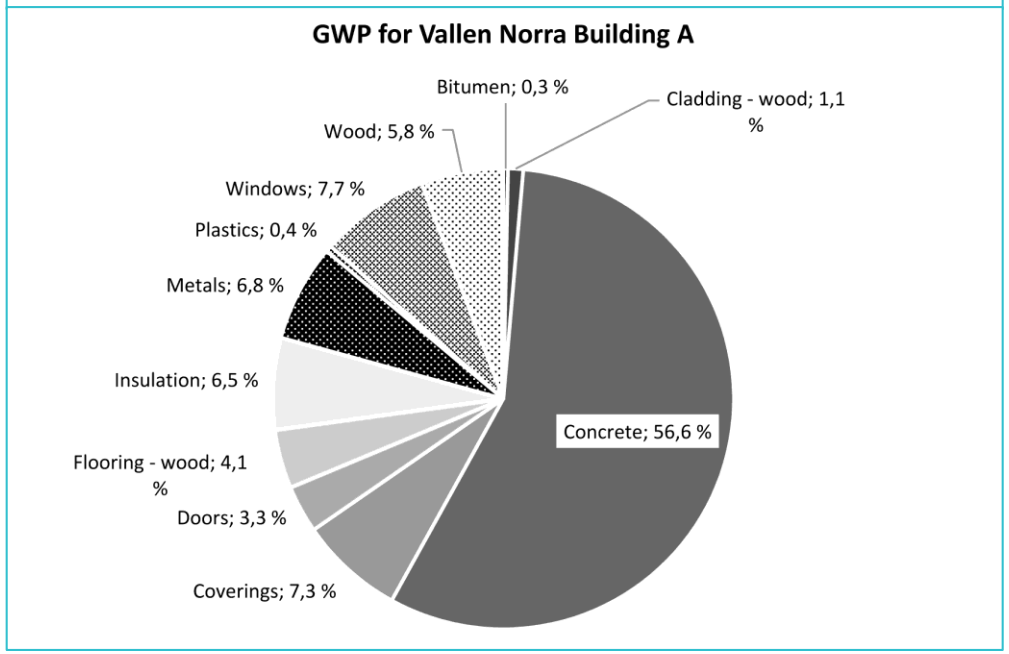
UNDERTAK

T1 FAST GIPSTAK PÅ REGLAR OCH 13 GIPS
T2 HELTÄCKANDE DEMONTERBART UNDERTAK, TYP ECOPHON FOCUS KANT A, EL LIKV.
T3 DIREKTLIMMADE UNDERTAKSPLATTOR, KANT B. MONTERAS I FÄLT ANPASSADE EFTER ARMATURER.
T4 DIKTMONTERAT FAST GIPSTAK 13 GIPS.
T5 FAST GIPSTAK PÅ REGLAR OCH 13 GIPS, INKL. VENTKANALER KLÄS IN MED 2X13 GIPS.



Type	Volume		Color
Dragere trapp	4,39	m3	
Hovedrepos	3,37	m3	
Hovedrepos7-9etg	1,7	m3	
Limtrebjelke 200x560	7,21	m3	
Limtrebjelke 200x560 - akse B+	6,93	m3	
Limtrebjelke 240x480	5,78	m3	
Mellomrepos kjeller	0,565	m3	
Mellomrepos1	5,61	m3	
Mellomrepos1etg	0,565	m3	
Repos 9etg	0,828	m3	
Trappeløp	4,93	m3	
Trappeløp 1	1,4	m3	
Trappeløp kjeller	0,787	m3	
Trappeløp1etg	0,83	m3	
Trappeløp2	4,35	m3	
Massivtre dekke - 200mm	1,05	m3	
Massivtre tak - 110mm	43,75	m3	
Massivtredekke 140	376,34	m3	
Limtresøyle 140x240	0,627	m3	
MV - 40 mm	0,063	m3	
MV 01 - 140 mm	27,8	m3	
MV 01 - 160 mm	3,54	m3	
MV 02 - 120 mm	170,44	m3	
MV 03 - 100 mm	215,52	m3	
MV 04 - 80 mm	63,86	m3	
Massivtreskive 100mm	6,57	m3	
Sum massivtre	958,805	m3	

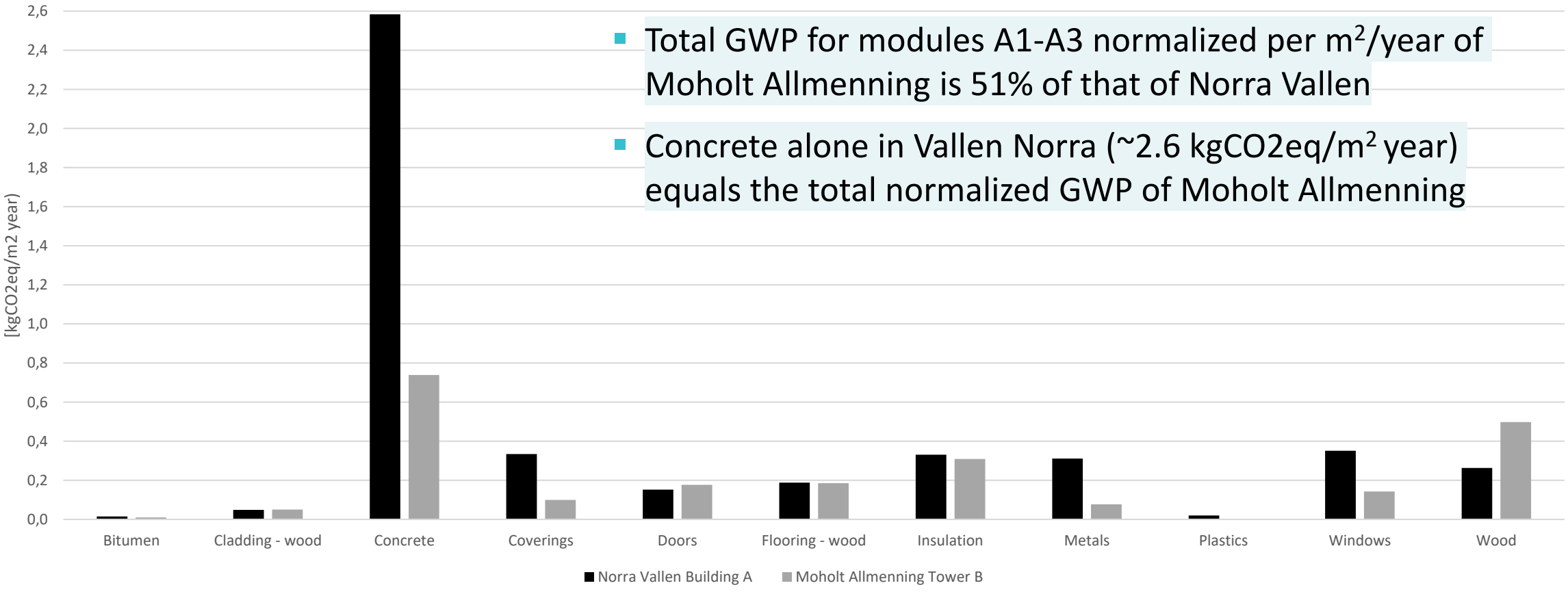




Results - buildings

- Total GWP for modules A1-A3
- **Moholt Allmenning (2.23 kgCO2eq/m² year)**
  1. Concrete (32.3%), basement and ground floor
  2. Wood (21.8%), structural vertical and horizontal elements (CLT) from 1st to 8th floor
  3. Insulation (13.5%), foundation (EPS), facades, floors, and roof (glass wool)
- **Vallen Norra (4.56 kgCO2eq/m² year)**
  1. Concrete (56.6%), cast-on-site for floor decks, prefab walls up to 2nd floor
  2. Windows (7.7%)
  3. Coverings (7.3%), gypsum boards in external and internal walls
  4. Metals (6.8%), in concrete decks and glulam frame stiffening

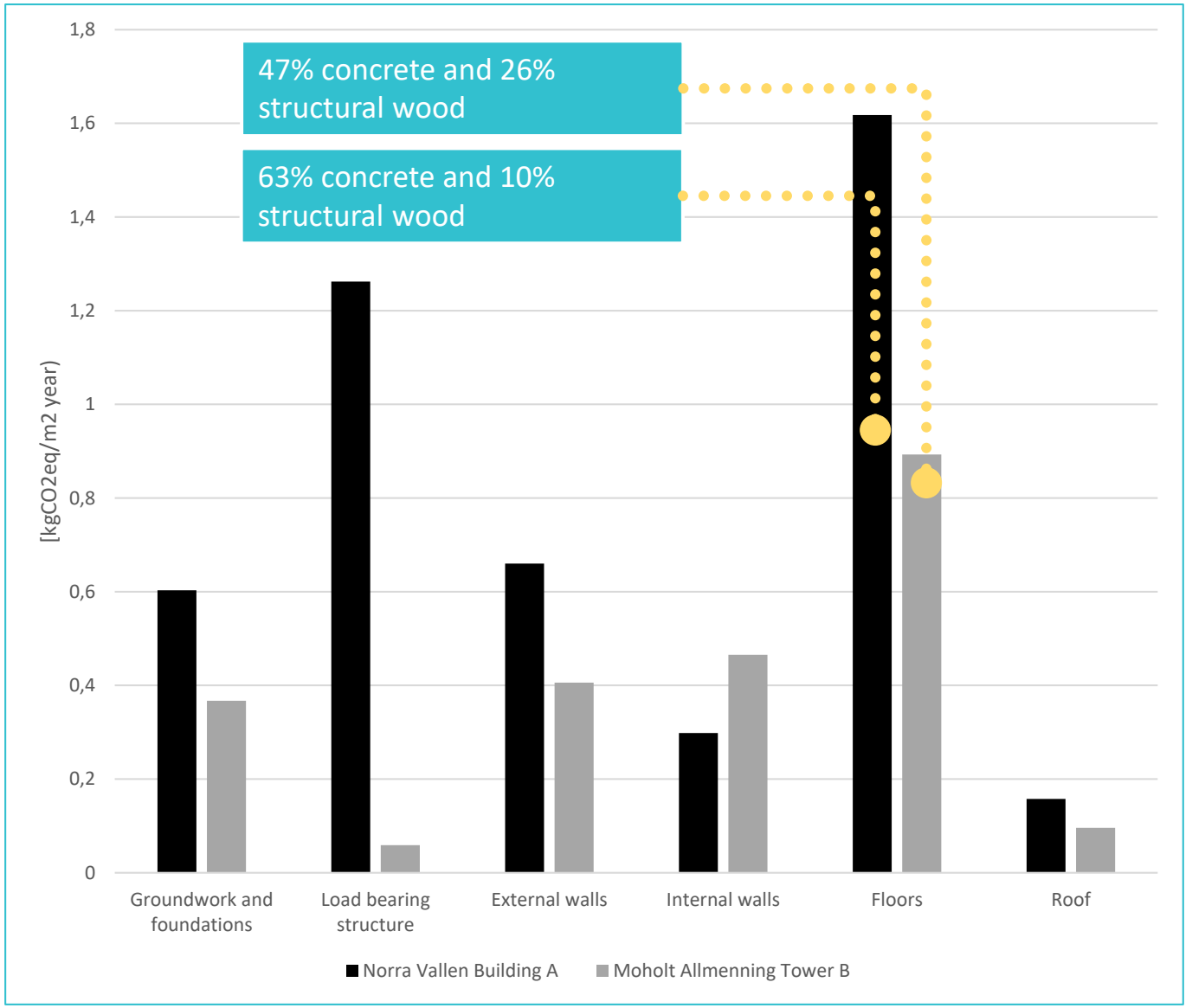
Results - buildings



- Total GWP for modules A1-A3 normalized per m^2/year of Moholt Allmenning is 51% of that of Norra Vallen
- Concrete alone in Vallen Norra (~2.6 $kgCO2eq/m^2$ year) equals the total normalized GWP of Moholt Allmenning

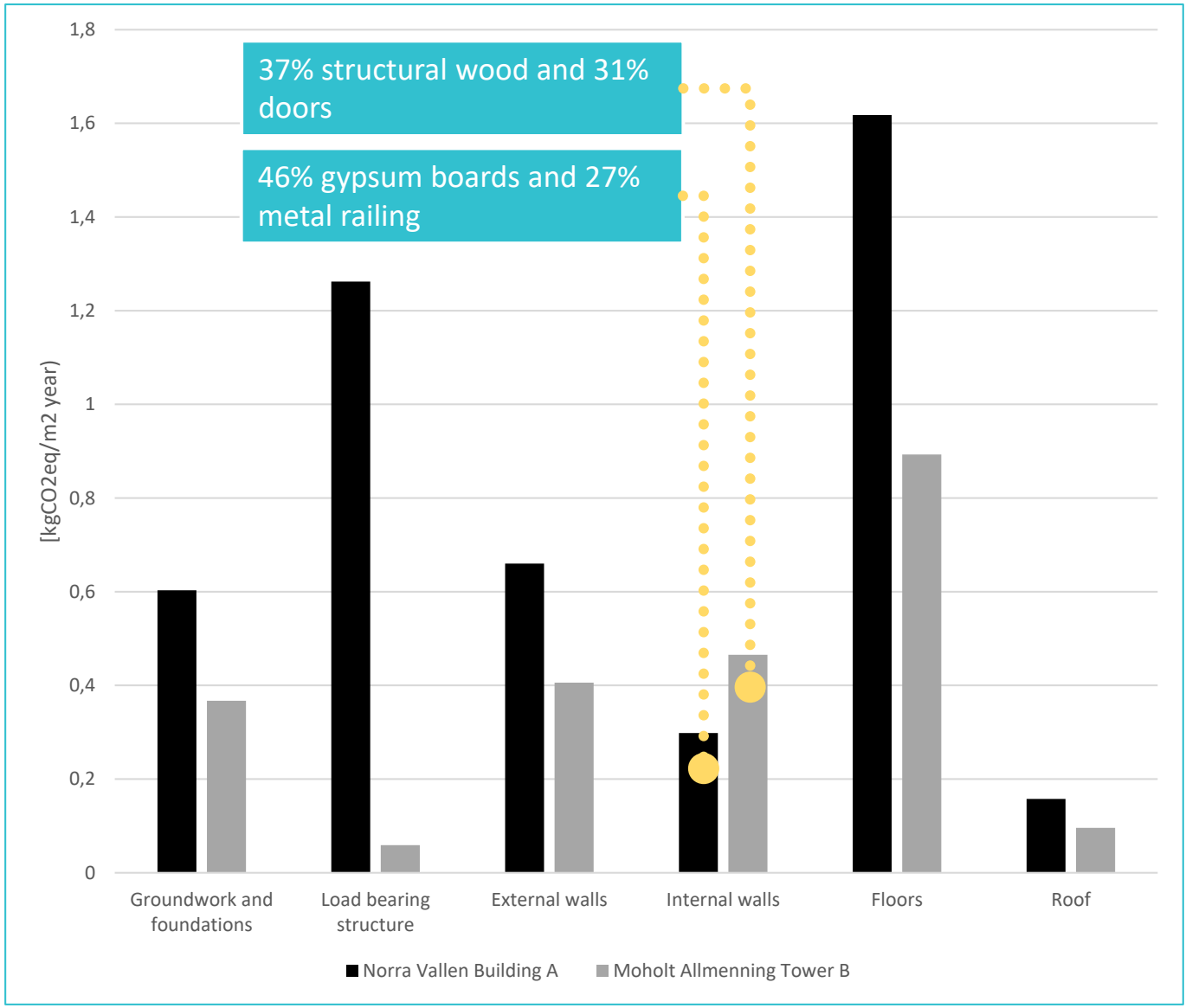
Results - buildings

- **Moholt Allmenning (2.23 kgCO2eq/m² year)**
  1. Floors (19.4%)
  2. Internal walls (10.1%)
  3. External walls (8.8%)
- **Vallen Norra (4.56 kgCO2eq/m² year)**
  1. Floors (35.2%)
  2. Load bearing structure (27.4%)
  3. External walls (14.4%)



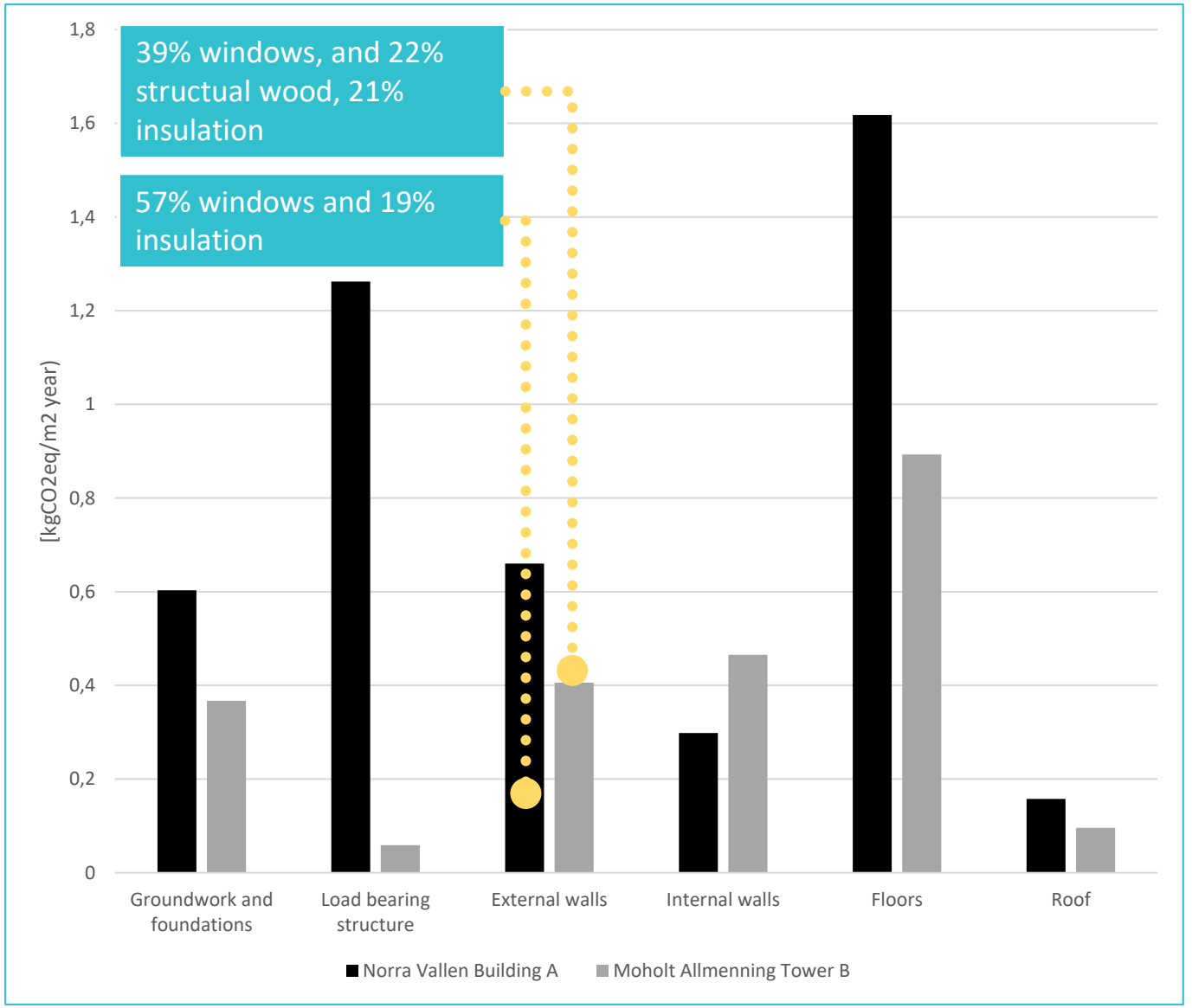
Results - buildings

- **Moholt Allmenning (2.23 kgCO2eq/m² year)**
  1. Floors (19.4%)
  2. Internal walls (10.1%)
  3. External walls (8.8%)
- **Vallen Norra (4.56 kgCO2eq/m² year)**
  1. Floors (35.2%)
  2. Load bearing structure (27.4%)
  3. External walls (14.4%)



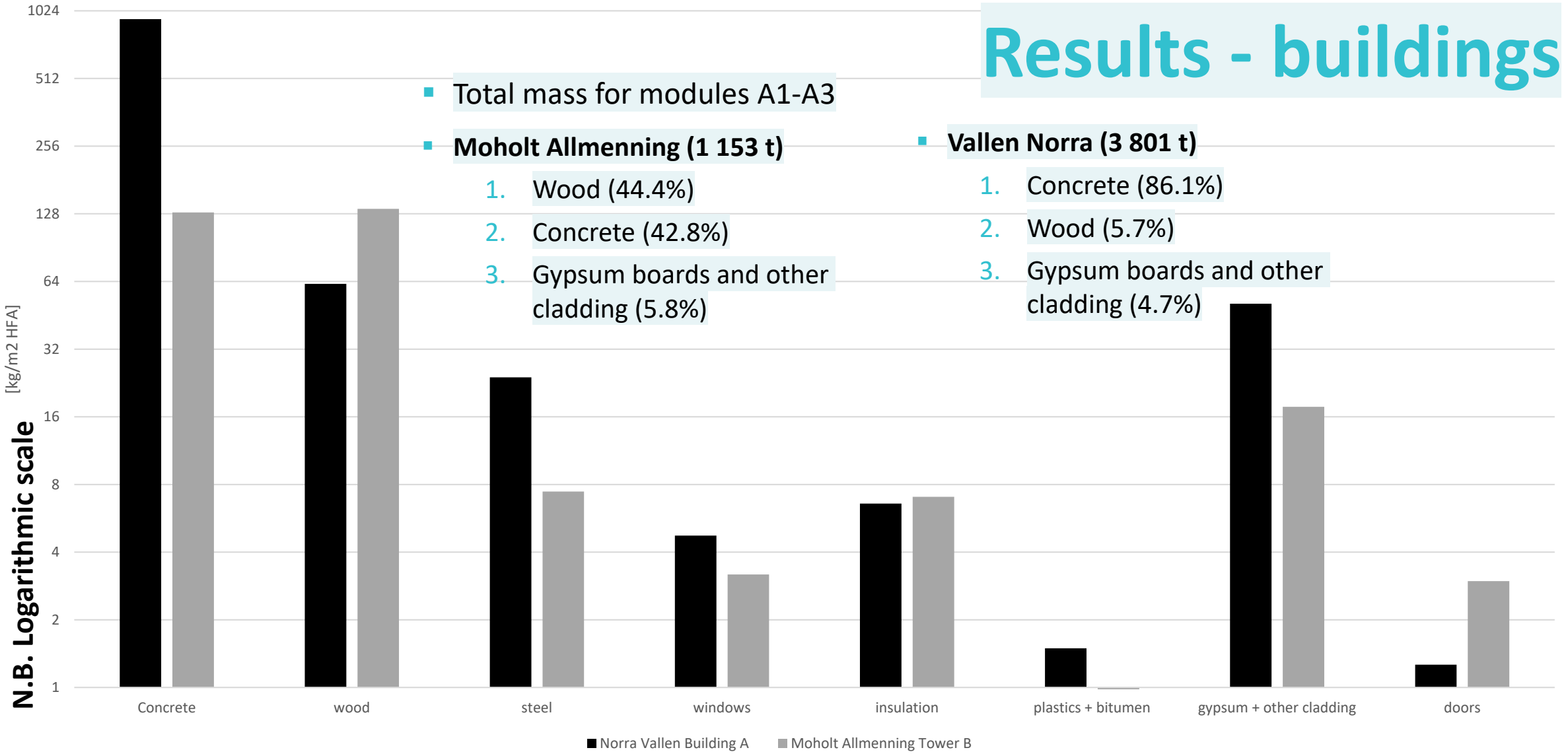
Results - buildings

- **Moholt Allmenning (2.23 kgCO2eq/m² year)**
  1. Floors (19.4%)
  2. Internal walls (10.1%)
  3. External walls (8.8%)
- **Vallen Norra (4.56 kgCO2eq/m² year)**
  1. Floors (35.2%)
  2. Load bearing structure (27.4%)
  3. External walls (14.4%)



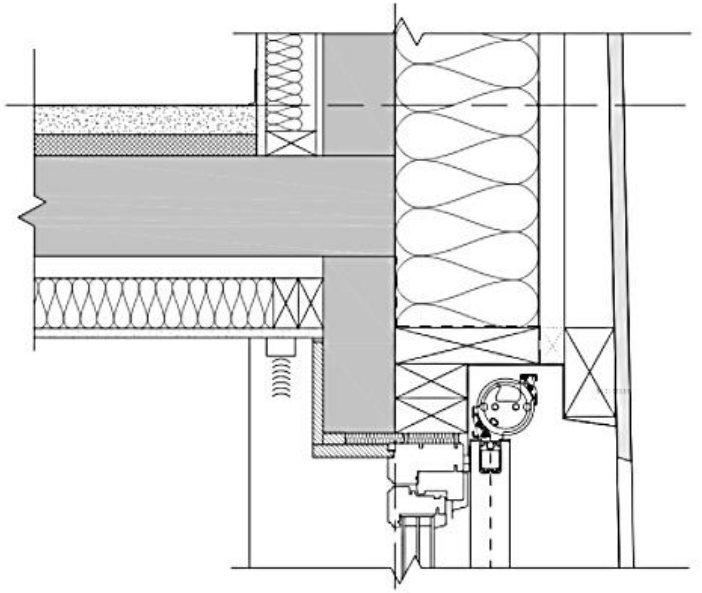
Results - buildings

- Total mass for modules A1-A3
- **Moholt Allmenning (1 153 t)**
  1. Wood (44.4%)
  2. Concrete (42.8%)
  3. Gypsum boards and other cladding (5.8%)
- **Vallen Norra (3 801 t)**
  1. Concrete (86.1%)
  2. Wood (5.7%)
  3. Gypsum boards and other cladding (4.7%)

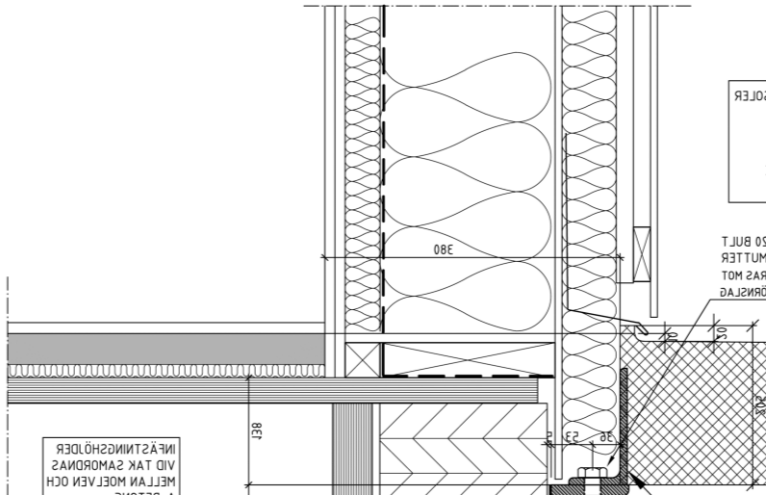


Results facades

Moholt Allmenning Tower B – external wall	kgCO2eq/m²yr
Total	**0.570**
20 mm wood façade panel	0.110
90 mm air gap and timber frame for façade panels	0.010
200 mm glass wool	0.170
100 mm CLT	0.180
30 mm air gap + timber frame for gypsum board	0.002
50 mm glass wool	0.040
13 mm gypsum board	0.050
-	-



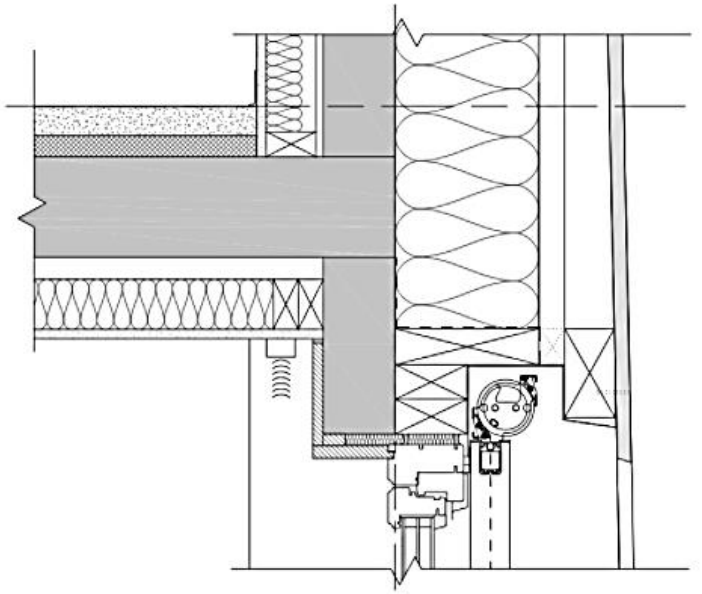
Vallen Norra Building A – external wall	kgCO2eq/m²yr
Total	**0.560**
12 mm façade panel	0.060
44 mm air gap and wood frame for façade panels	0.010
70 mm glass wool insulation	0.060
13 mm gypsum board	0.050
270 mm glass wool insulation	0.230
13 mm gypsum board	0.050
13 mm gypsum board	0.050
Glulam columns and beams	0.040



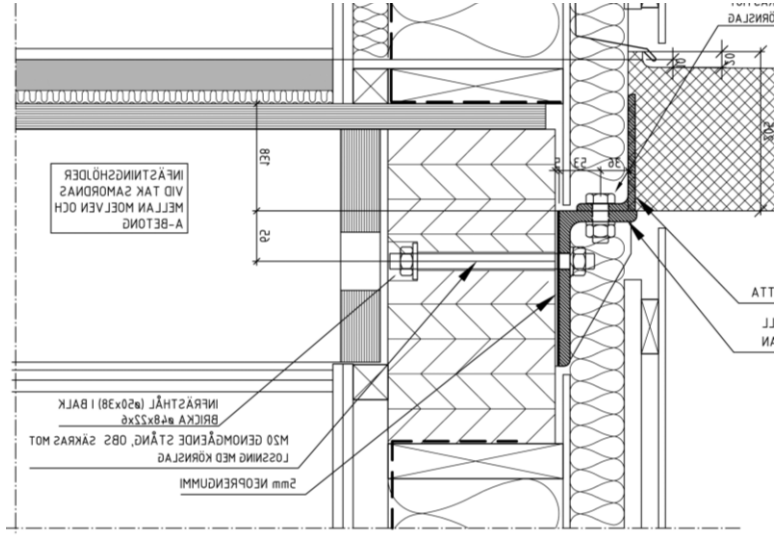
- Total GWP for modules A1-A3 normalized per $m^{2\ façade}$/year
- No significant difference between the two constructions

Results internal floors

Moholt Allmenning Tower B – internal floor	kgCO2eq/m²yr
Total	**0.680**
14 mm flooring	0.180
40 mm floor screed	0.120
30 mm acoustic layer insulation	0.030
140 mm CLT	0.250
50 mm air gap + timber frame	0.010
50 mm glass wool	0.040
13 mm gypsum board	0.050
-	-



Vallen Norra Building A – internal floor	kgCO2eq/m²yr
Total	**0.630**
14 mm flooring	0.180
40 mm floor screed	0.120
17 mm acoustic insulation	0.030
33 mm LVL board	0.130
300 mm air gap of floor structure (glulam)	0.040
14 mm LVL board (along the rafters only)	0.030
13 mm gypsum board	0.050
Glulam beams	0.050



- Total GWP for modules A1-A3 normalized per $m^{2\ floor}$/year
- GWP of floor in Moholt is 8% higher than Vallen

Conclusions

- From the analysis, the total GHG emissions of Moholt Allmenning was 51% of those of Vallen Norra.

however…

- GHG emissions of CLT in Moholt Allmenning did not include the impact from steel stiffeners. This is expected to increase the total CLT emissions of CLT structures by 54% and adds 15% to the total building GHG emissions.
- GHG emissions of concrete used in both buildings is obtained by averaging impact factors from various EPDs. The use of low-carbon concrete in Vallen Norra decreases the total concrete GHG emissions by up to 23% and the total building's GHG emissions by 12%.
- By considering the above, the difference between the total GHG emissions of Moholt Allmenning and Vallen Norra decreases from 49% to 34%.

Conclusions

- The large share of emissions due to concrete in the Vallen Norra is also due to the larger building ground floor area (579 m^2 vs 413 m^2), which determines the larger amount of concrete in the floor decks.
- By assuming Vallen Norra to have the same ground floor area of Moholt Allmenning (413 m^2) and keeping its same total floor area, 6% total GHG emissions could be reduced by a smaller area of the concrete floor decks (additional GHG emissions from wood floors is included).
- In such a way, the total GHG emissions of Moholt become ~70% of those of Vallen Norra (30% difference).
- For same building types and shapes, the difference of total GHG emissions between CLT/glulam and concrete structures has been found in literature to be approximately 26%.
- The use of CLT in substitution of structural concrete elements in the stairwells and elevator shafts (from 2nd to 9th floor) of Vallen Norra Building A may alone produce a 6% of potential reduction of building's total embodied GHG emissions.

Thank you.

Nicola Lolli
Nicola.Lolli@sintef.no

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 754177