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CLT and concrete in mid-rise buildings from environmental and cost perspectives

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SINTEF

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- 2004: Master in Architecture at Universitá degli Studi Roma Tre, Rome, Italy
- 2004-2008: Worked as assistant architect and archaeological sites surveyor, Rome, Italy
- 2009: Master in Sustainable Architecture at Cardiff University, Cardiff, UK
- 2014: PhD thesis "Life cycle analyses of CO2 emissions of alternative retrofitting measures" at The Research Centre on Zero Emission Buildings ZEB, Trondheim, Norway
- 2014-current: Senior researcher at SINTEF Community, group of architecture, Trondheim, Norway
- Current research activities in SINTEF:
  - Daylighting in buildings
  - Thermal and visual comfort in office and residential buildings
  - Greenhous gas emission in buildings' construction and operation
  - Cost analysis of energy efficiency measures

- This presentation is divided as such:

1. **Comparison of use of CLT and concrete in two residential buildings (greenhouse gas emissions)**
   - A student housing (Moholt Allmenning Tower B) in Trondheim, Norway, and an apartment building (Vallen Norra Building A) in Växjö, Sweden.
   - Both buildings addressed the extensive use of wood elements (CLT and glulam) in the construction. Vallen Norra has a larger use of concrete.
   - More info here:

     N. Lolli, S.M. Fufa, M. Kjendseth Wiik, An assessment of greenhouse gas emissions from CLT and glulam in two residential nearly zero energy buildings, Wood Material Science & Engineering, (2019) 1-13.

     https://www.researchgate.net/publication/335231816_An_assessment_of_greenhouse_gas_emissions_from_CLT_and_glulam_in_two_residential_nearly_zero_energy_buildings

2. **Comparison of use of CLT and concrete in two residential buildings (cost and construction time)**
   - Two apartment buildings in Trondheim, Maskinparken 2 (MP2) and Maskinparken TRE (MP3).
   - MP2 made with concrete and MP3 with CLT modules
   - More info here: https://neroproject.net/sites/default/files/research/d4.1_report_on_cost_reductions_technical_elements_0.pdf

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Part 1 – 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.

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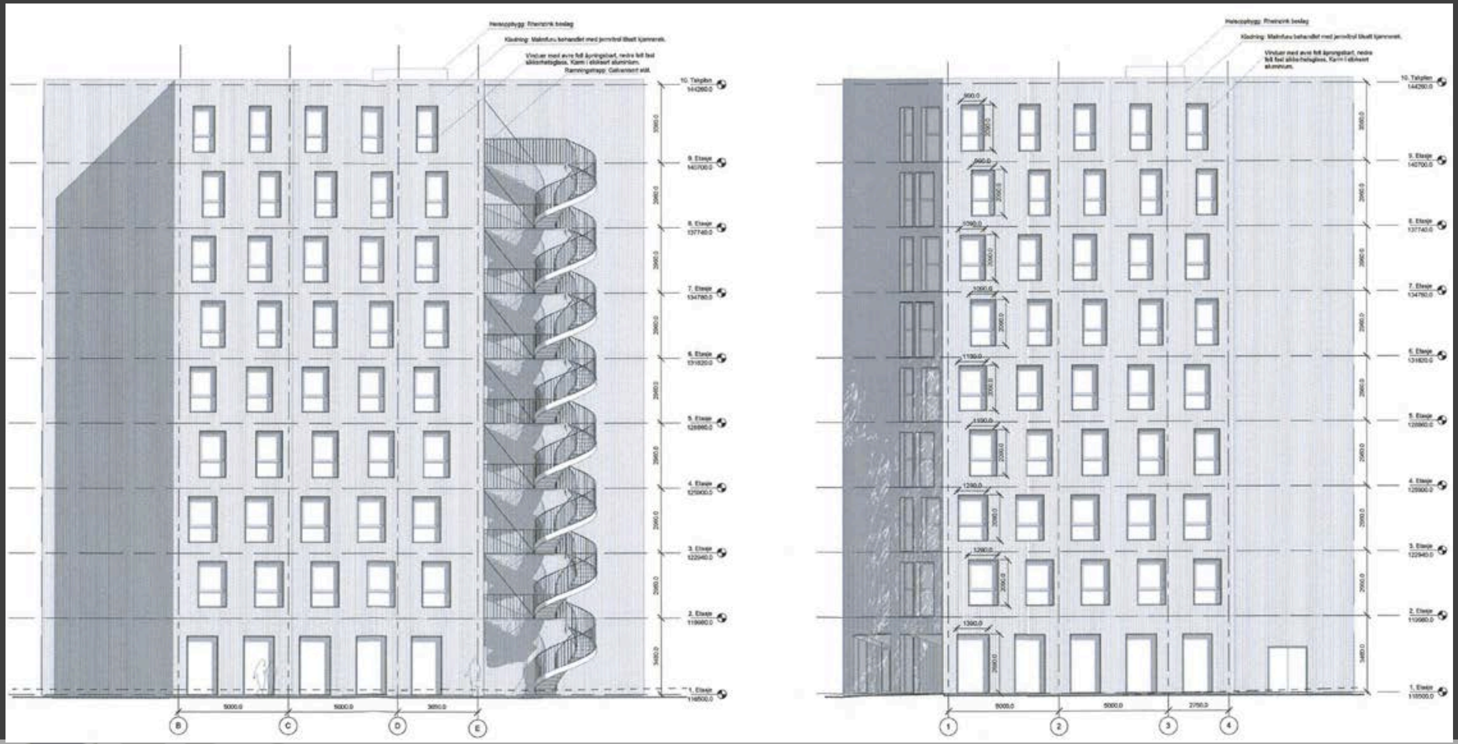
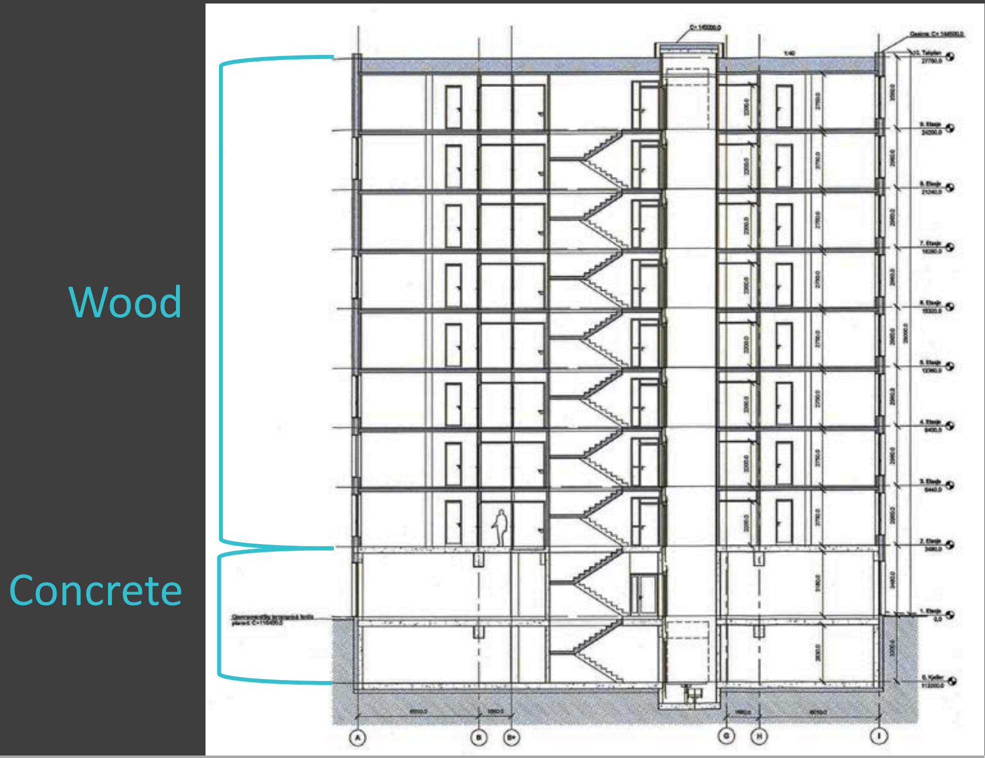
Part 1 – Moholt Allmenning

- 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).





Part 1 – Moholt Allmenning

① CLT

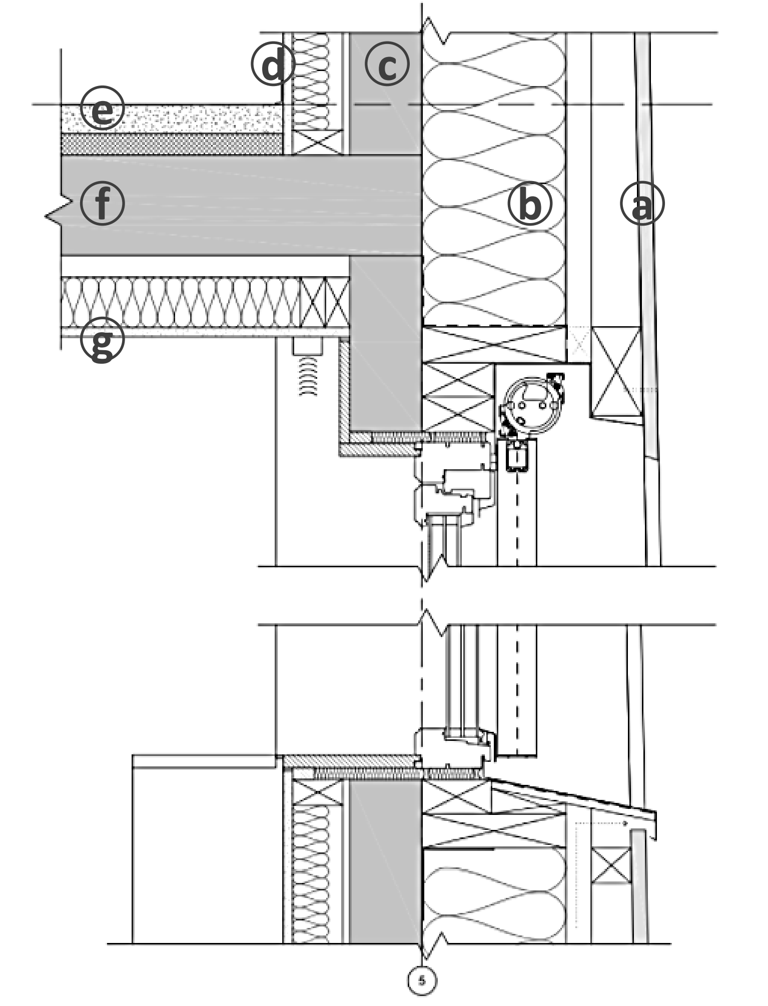
② Glulam

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

Part 1 – 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 2^{nd}-8^{th} (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



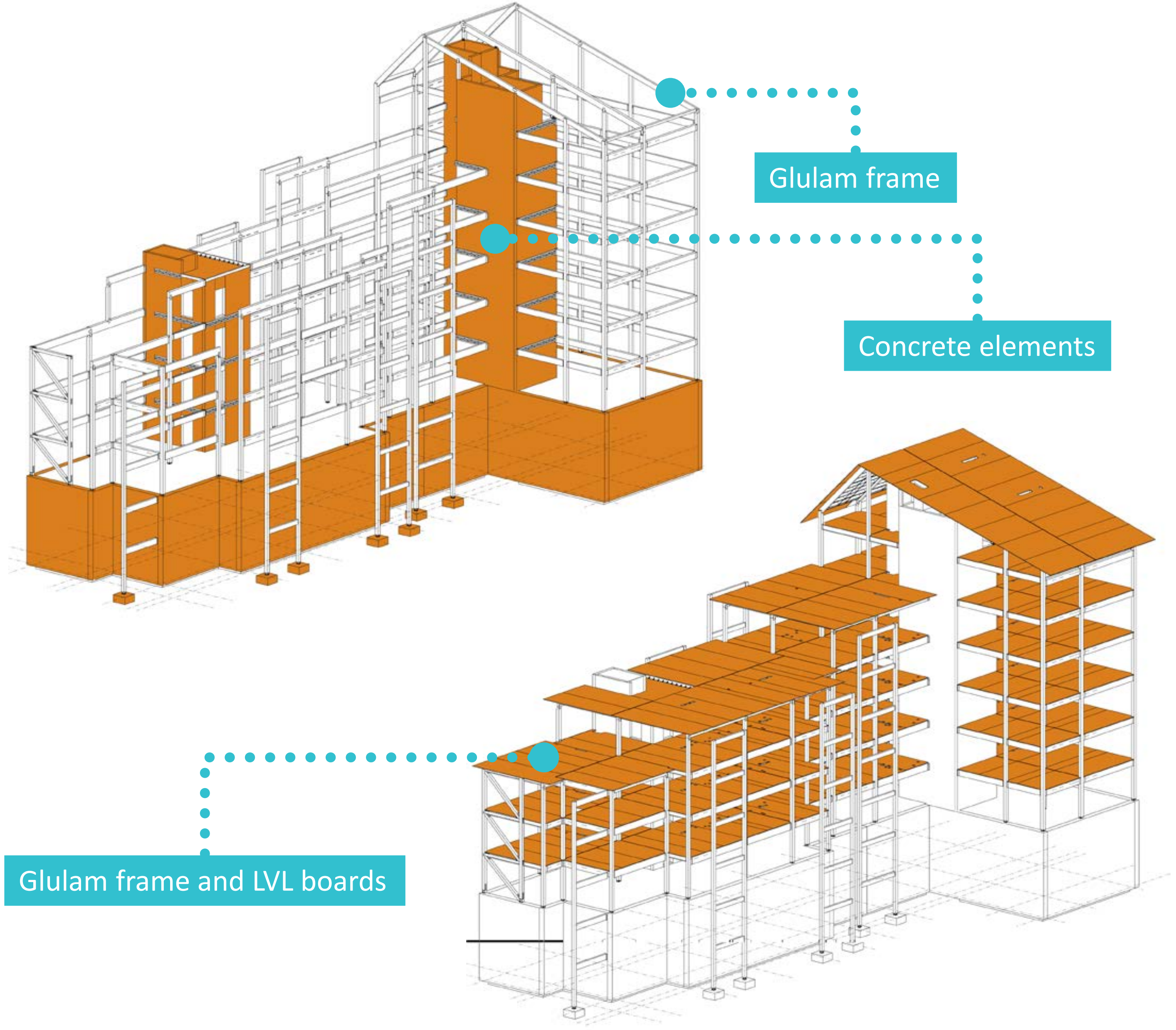
Part 1 - Vallen Norra

- 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

Part 1 - 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



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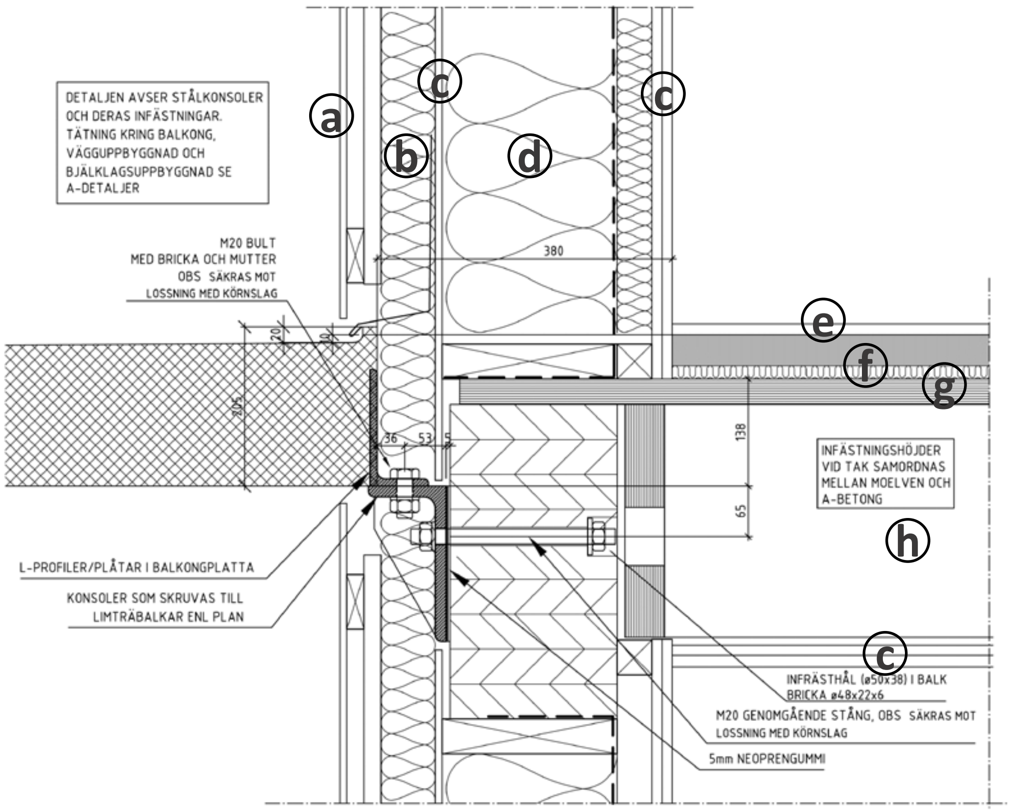
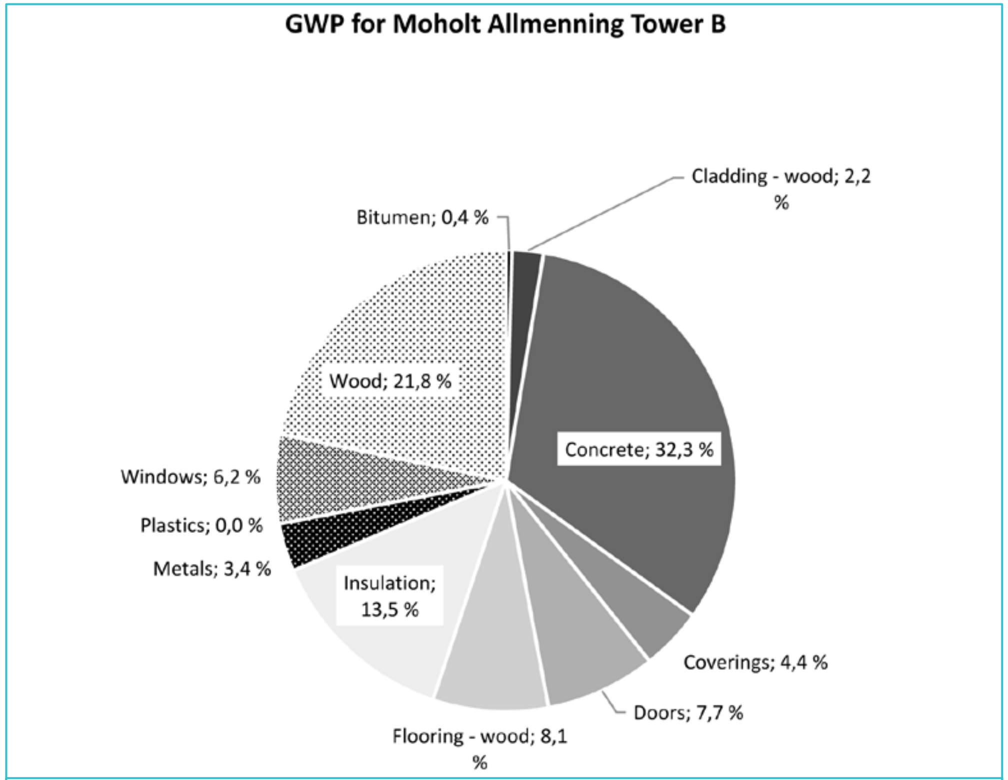
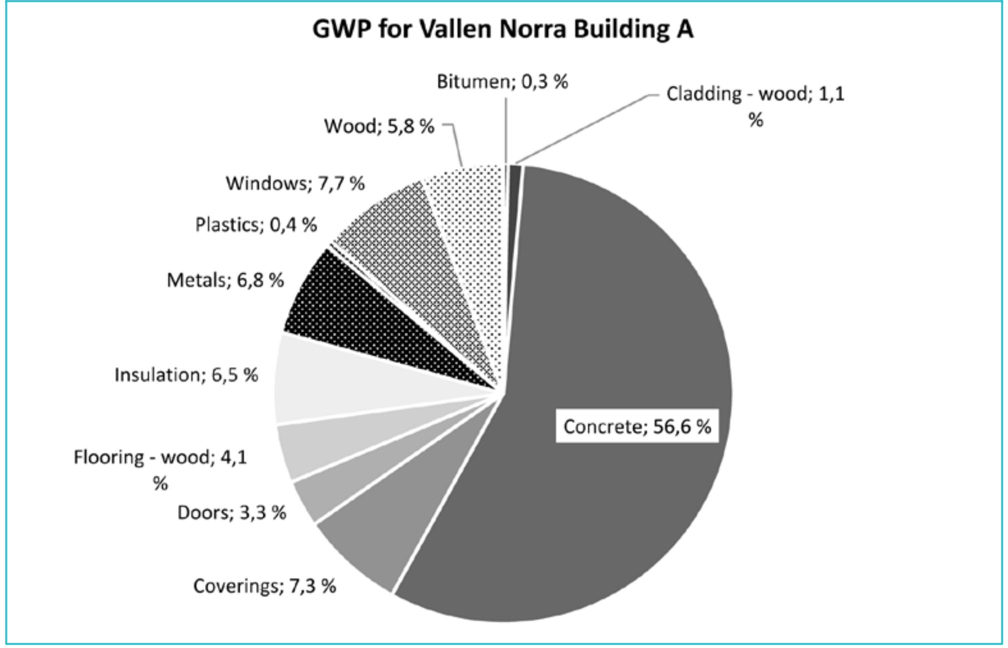
Part 1 - Vallen Norra

	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



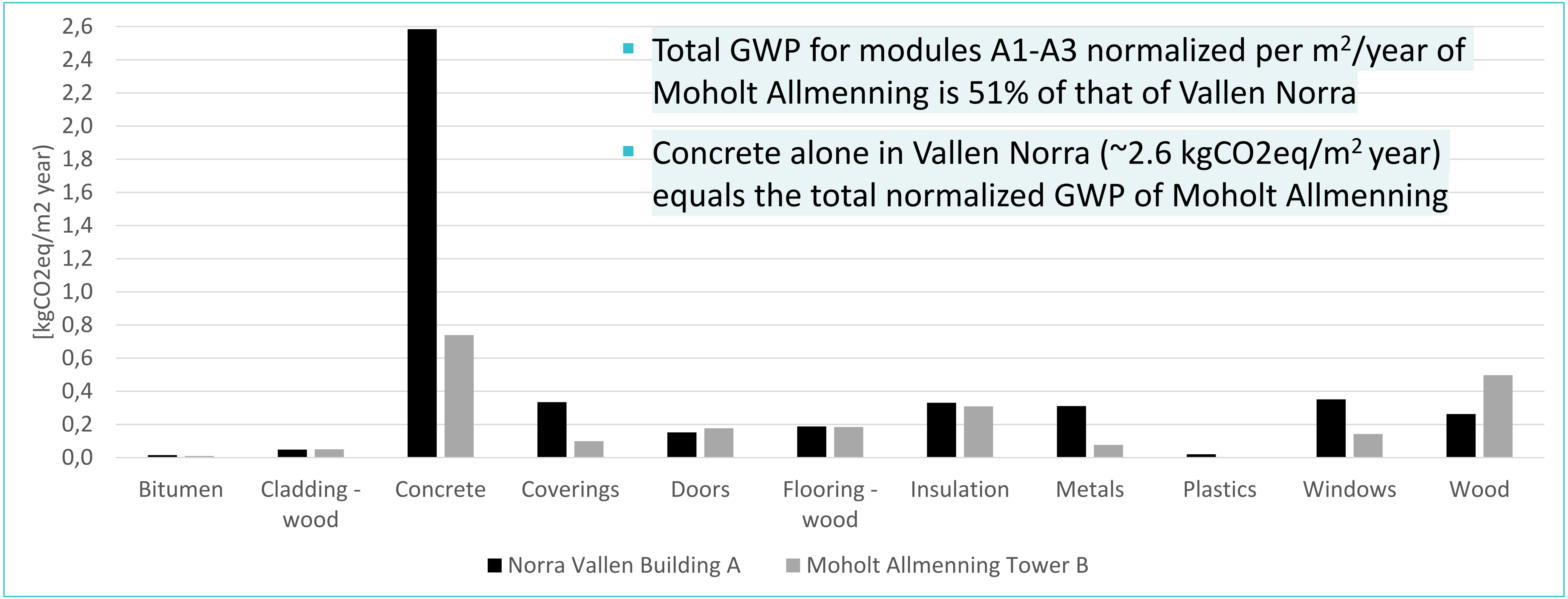




Part 1 - Results

- Total GWP for modules A1-A3
- **Moholt Allmenning (2.23 kgCO2eq/m^2 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/m^2 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 stiffeners

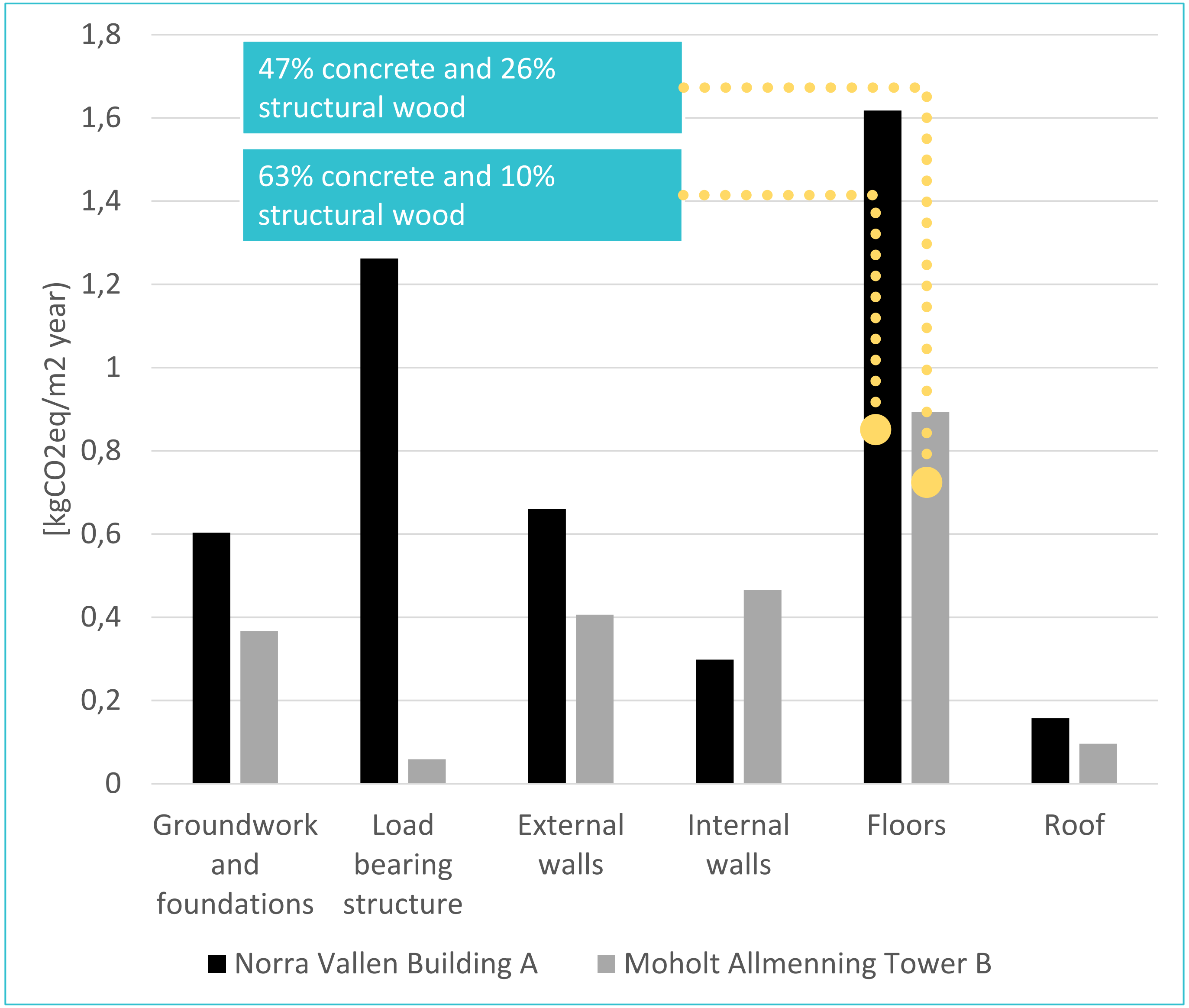
Part 1 - Results



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

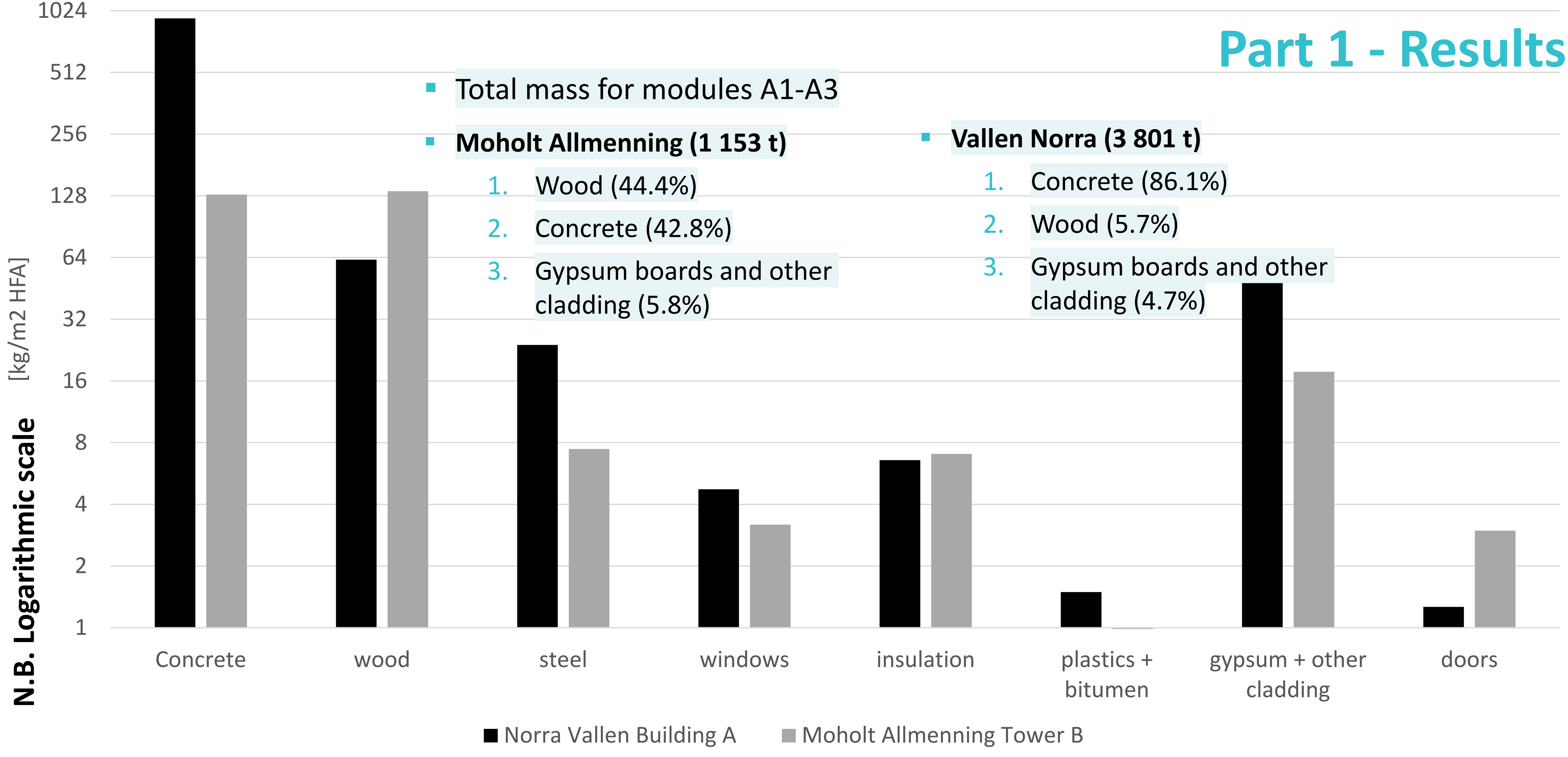
Part 1 - Results

- **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%)



Part 1 - Results

- 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%)

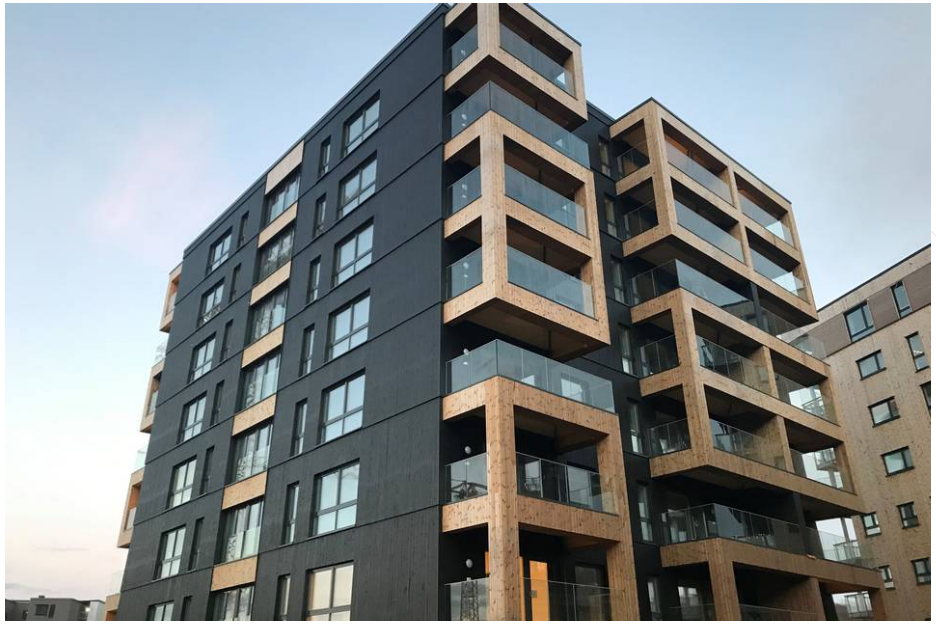


Part 2 – Maskinparken 2 (MP2)

- Located in Lilleby, Trondheim. Built between 2017-2018.
- Five floors and 31 apartments (between 30-85 m^2). Area 2 374 m^2
- Load bearing structure made with reinforced cast-on-site concrete.
- The building efficiency solutions were designed to comply with the TEK-17
- Turnkey contract

Part 2 – Maskinparken TRE (MP3)

- Located in Lilleby, Trondheim. Built between 2017-2018.
- Eight floors and 47 apartments (between 30-115 m^2). Area 3 790 m^2
- Load bearing structure made with CLT elements
- The building efficiency solutions were designed to comply with the Norwegian Passive House standard (NS3701)
- Turnkey contract

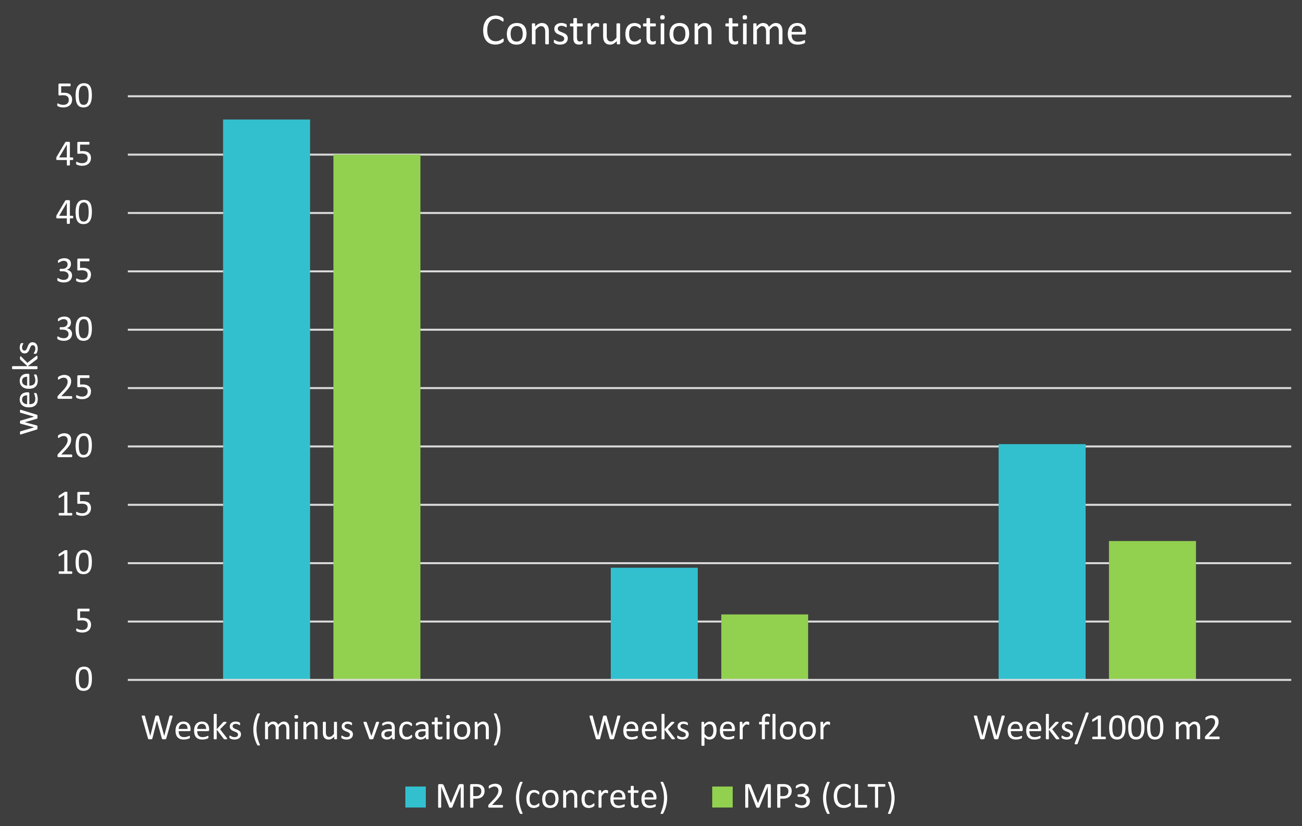


Part 2 – Method

- Analysis based on the following studies:
  - Østnor, Torstein, 2018: Massivtre og Plasstøpt Betong: en casestudie - forskjeller, erfaringer og forbedringspotensial. Masteroppgave, NTNU 2018.
  - Østnor, T., Faanes, S., and Lædre, O. (2018). "Laminated timber versus on-site cast concrete: a comparative study." In: Proc. 26 th Annual Conference of the International. Group for Lean Construction (IGLC), González, V.A. (ed.), Chennai, India, pp. 1302–1312. DOI: doi.org/10.24928/2018/0313. Available at: www.iglc.net
  - Halseth, Petter Torås, 2019: Boligbygging i massivtre: Sammenligning av boligblokk i massivtre og betong. Masteroppgave, NTNU 2019.
- The following aspects of the two buildings were compared:
  - Working hours for the construction activities
  - Cost of the design and construction stages

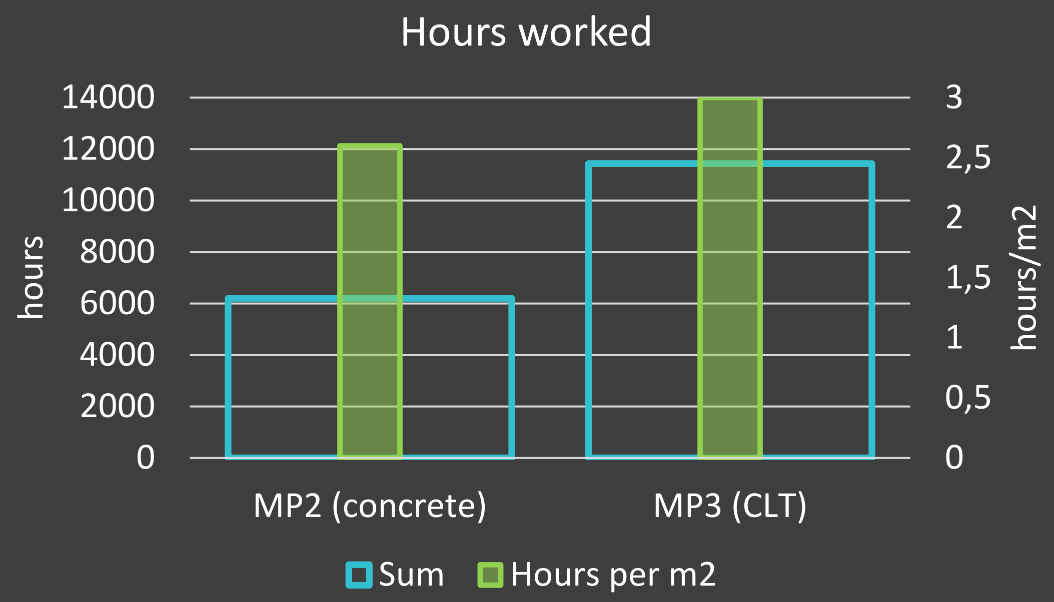
Part 2 – Results

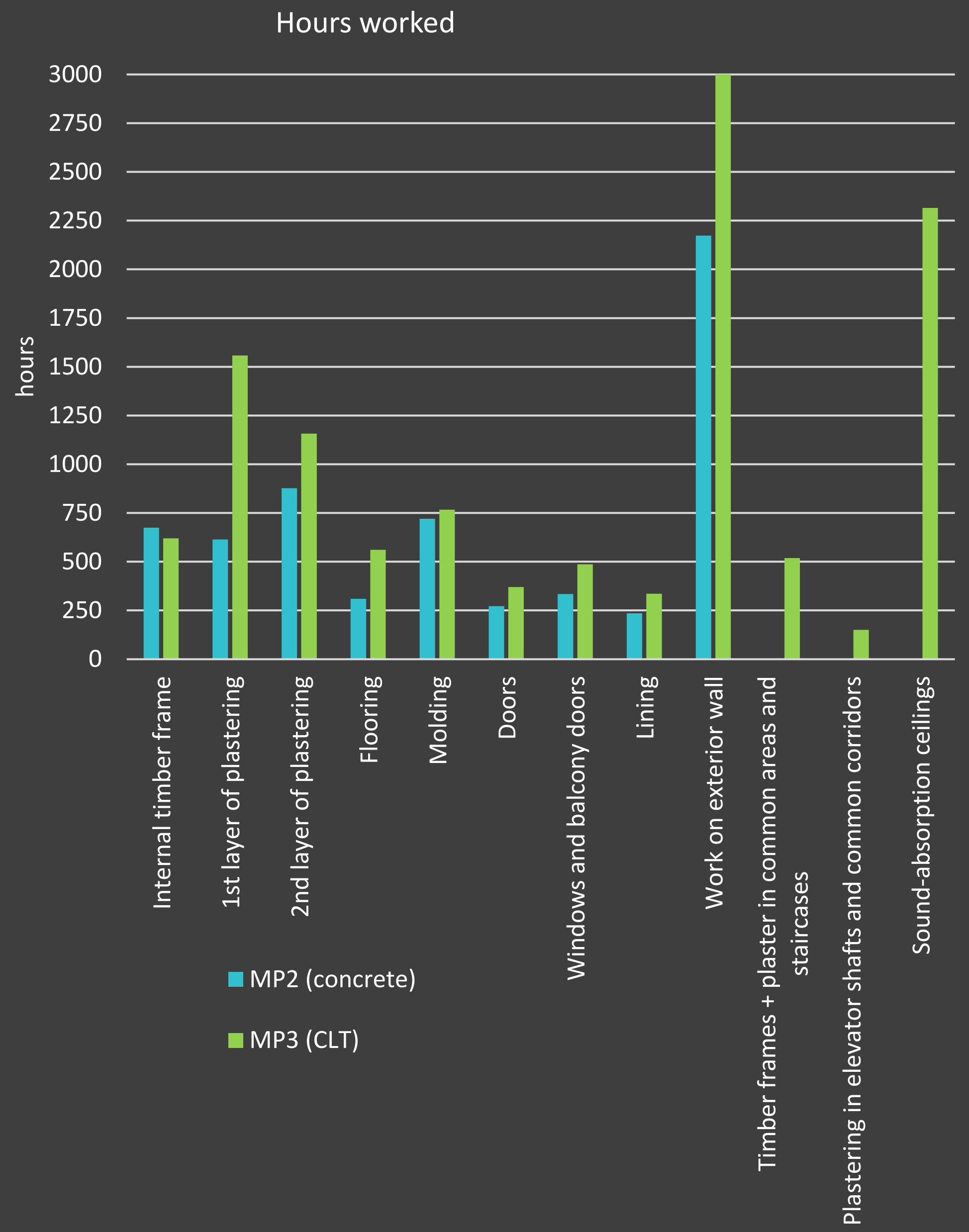
- Maskinparken TRE required 45 weeks for being built, against 47 weeks of Maskinparken 2.
- These meant 12 weeks/1000 m^2 GIA (Gross Internal Area) for Maskinparken TRE vs 20 weeks/1000 m^2 GIA for Maskinparken 2 (~40% difference)



Part 2 – Results

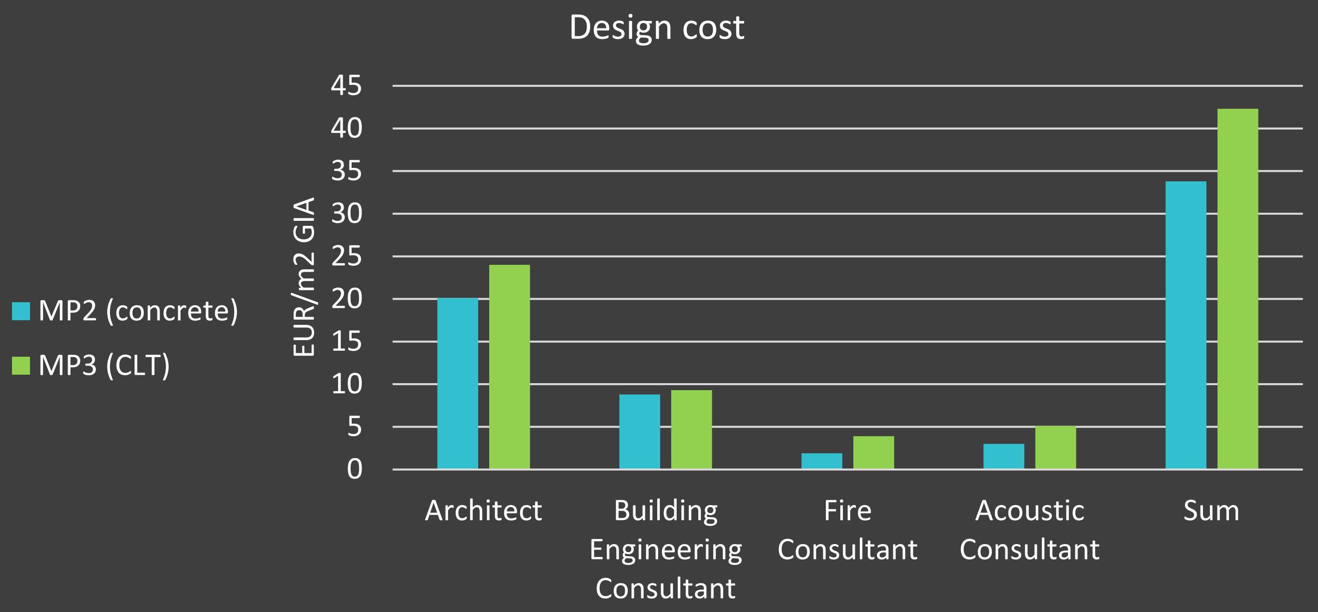
- Installation of CLT elements in MP3 was done by shifting workers groups.
- As a result, MP3 required almost twice the amount of hours for construction.
- However, given the different GIA of the buildings, this resulted in just 15% difference between the hours worked/m^2 (MP2 = 2 374 m^2, MP3 = 3 790 m^2)
- Most of the activity in MP3 was due to installation of CLT elements and soundproofing

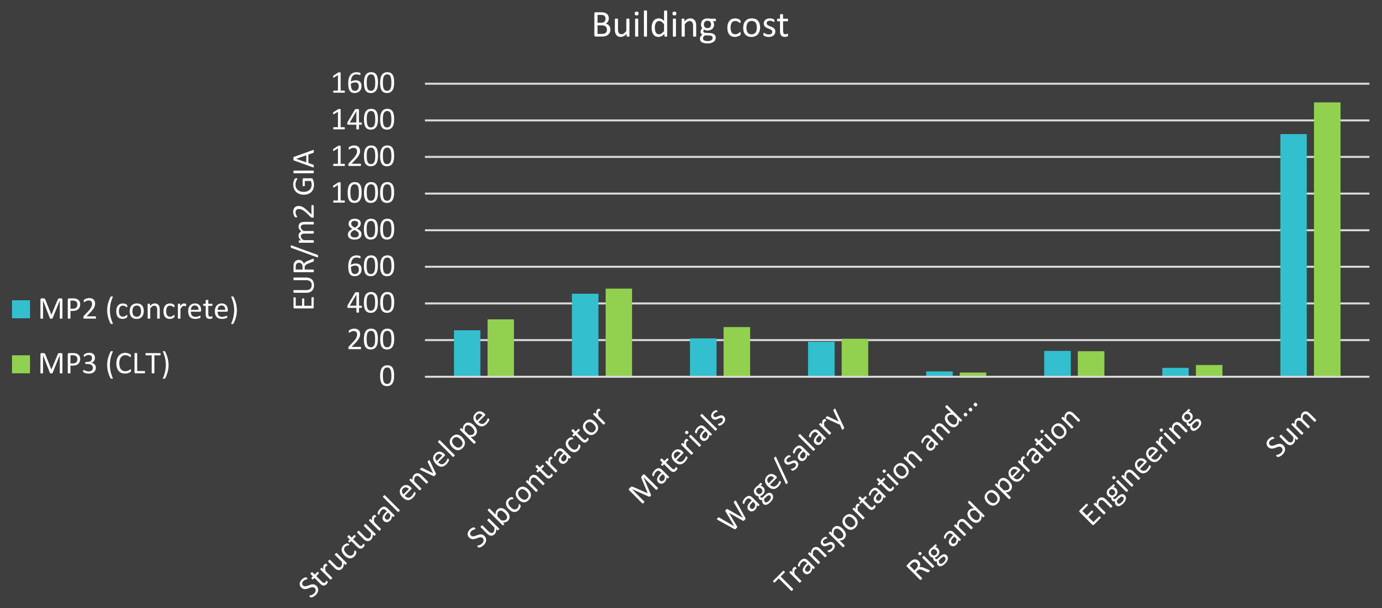




Part 2 – Results

- Design cost of MP3 was 42 EUR/m² GIA vs 34 EUR EUR/m² GIA of MP2 (~25% higher).
- Most of higher design cost due to architectural solutions, fire safety, and sound engineering.
- Cost for the construction of MP3 was 339 EUR/m² GIA vs 138 EUR/m² GIA of MP2 (~2.5 times higher)
- The higher cost was due to the CLT elements and their installation. This was because the construction company had to buy the CLT elements from abroad and did not have knowledge for their installation.
- Workers from the CLT producer were on-site to install the elements.
- The total building cost of MP3 was 1498 EUR/m² GIA vs 1325 EUR/m² GIA of MP2 (~13% higher).





Conclusions

- From the analysis, the difference of total GHG emissions between Moholt Allmenning and Vallen Norra is 51%.
- However, by considering the followings:
  - additional GHG emissions in Moholt Allmenning due to steel plates and connections
  - Lower GHG emissions in Vallen Norra by using low-carbon concrete
  - Assuming the same building footprint (currently higher for Vallen Norra)
- The difference of total GHG emissions between Moholt Allmenning and Vallen Norra decreases to 34%.
- For same building types and shapes, the difference of total GHG emissions between CLT/glulam and similar timber+concrete structures has been found in literature to be approximately 26%.
- Total cost of MP3 was 13% higher than that of MP2
- The construction time of MP3 was 40% shorter than that of MP2 (for weeks/1000 m^2). This was possible because of shifting working hours during the installation of the CLT elements.
- Long time during construction of MP3 was due to soundproofing.

Thank you.

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