Karelia

KARELIA-AMMATTIKORKEAKOULU | KARELIA UNIVERSITY OF APPLIED SCIENCES

Comparison of Different Design Solutions – Case: Low Carbon Apartment Building

22.10.2020

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Mika Keskisalo

KARELIA UNIVERSITY OF APPLIED SCIENCES

Research, development and innovation activities

Karelia

Volume
13
€ million

Development activities with
650
companies

70
projects

Personnel
50
person-years

Working life feedback
84%
(satisfied or very satisfied partners)

International partners
70

TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT

- *Implementation period:*
  1.9.2018 – 31.12.2020
- *Budget:*
  292 960 €
- *Funding:*
  Centre for Economic Development, Transport and the Environment/European Structural Fund
- *In cooperation with cities:*
  Joensuu, Kontiolahti, Kitee, Tohmajärvi, Lieksa, Nurmes

TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT

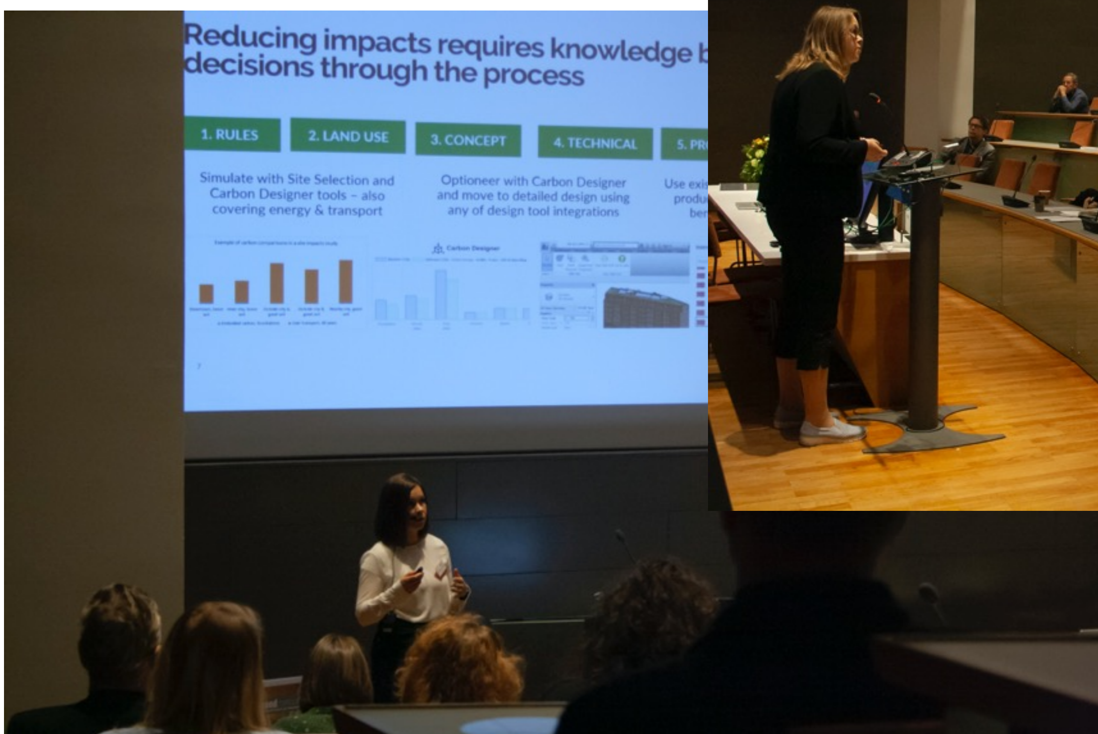
Project objectives:

The overall aim of the project is to strengthen understanding related to low carbon buildings within the different organisations in North Karelia region

The project activities include making of the Life Cycle Assessment for different types of buildings (pilot cases)

Concept design of the low carbon city block specially from the "product stage" perspective

TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT



TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT

TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT

Kontioniemi school, Kontiolahti

Kuhmonkatu school campus, Lieksa

Nepenmäki school, Joensuu

Pikku-Kaarle kindergarten, Nurmes

Sivistyskeskus Maiju school, Tohmajärvi

Koy Nurmeksen Vuokratalot, apartment building

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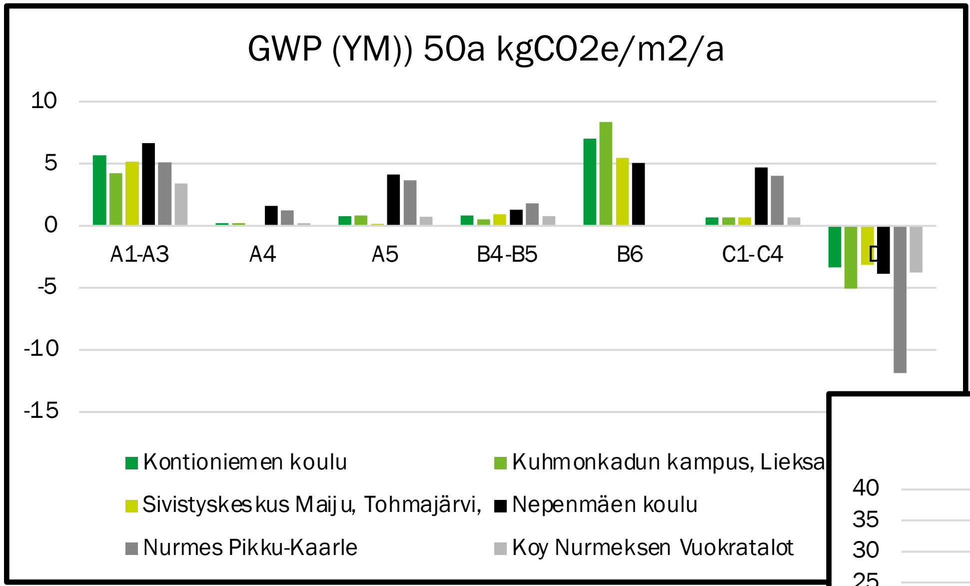
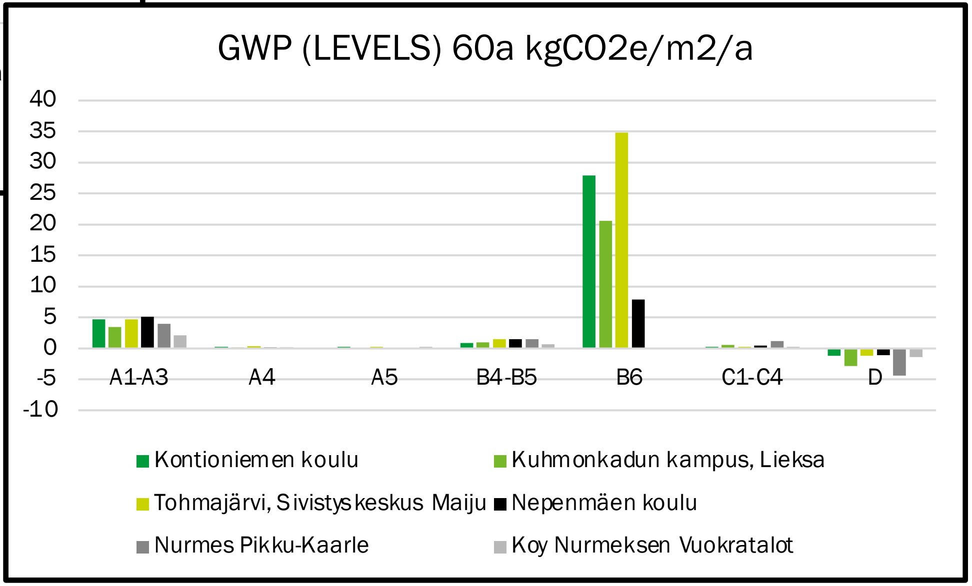




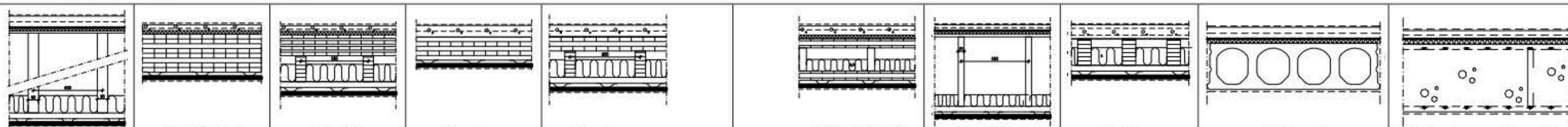
TOWARDS LOW CARBON CONSTRUCTION – JOENSUU WOOD CITY -PROJECT

Puurakenteiden hiilijalanjäljen optimointi rakenne-suunnittelijan näkökulmasta

Optimising the carbon footprint of wood structures from a structural engineer perspective

Taulukko 1. Välipohjien GWP100 hiilijalanjäljen, hiilivaraston sekä välipohjan korkeuden tuloksia

Table 1. Results for GWP100 carbon footprint, carbon storage, and intermediate floor height



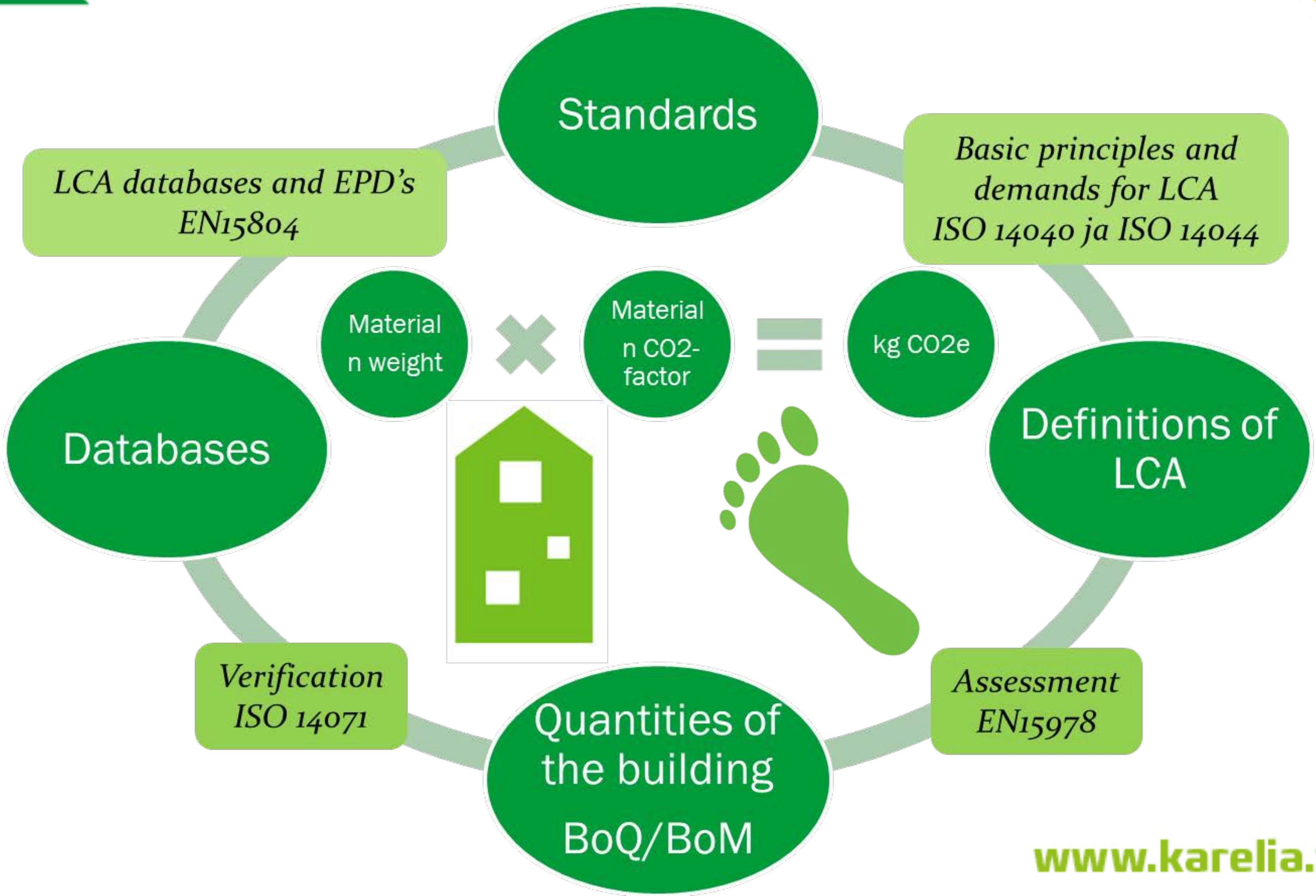
Rakennekuvaus *Structure description*	**Ripa-laatta** *Ripa slab* GL30c 90x810 k600	**CLT 320 L8s-2**	**RIPA-CLT:** GL30h 90x225 + CLT 180 L5s	**Liittolaatta** Composite slab 100 mm + CLT200 L5s	**Liittolaatta** *Composite slab* 100 mm + RIPA-CLT: CLT120 L3s+GL30h 90x225 k600	**Kotelolaatta CLT** *Box slab CLT* 80 L3s + LVL-S 63x200 k590 + CLT 80 L3s	**Kerto-Ripa:** Kerto-Q levy 25 mm + Kerto-S 51x600 k583	**Liittolaatta** *Composite slab 120 mm + Ripa GL30h 115x225 k380*	**O32, betoni C30/37+kelluva laatta** *O32, concrete C30/37 + floating panel*	**Paikalla valettu teräsbetonilaatta** *Reinforced concrete cast-in-situ slab* C25/30 hl=400 mm, A500HW (75 kg/m³)
GWP100 (kg CO_2e/m²)	60,8	77,7	66,9	63,9	66,7	59,2	42,3	52,1	77,0	95,4
Hiilivarasto *Carbon storage* (GWPbio/GWPdyn) (-kg CO_2e/m²)	123,3	249,0	168,1	155,6	121,4	144,4	73,5	53,7	Ei laskettu, vaikuttaa karbonoitumisnopeudet hiilinieluna toimiessa (käyttö, elinkaaren loppu) *Not Calculated, Affects Carbonation Speed When Acting as a Carbon Sink (Use, End of Life Cycle)*	Ei laskettu, vaikuttaa karbonoitumisnopeudet hiilinieluna toimiessa (käyttö, elinkaaren loppu) *Not Calculated, Affects Carbonation Speed When Acting as a Carbon Sink (Use, End of Life Cycle)*
Htot (mm)	945	460	600	360	560	535	810	460	430	480

L, jänneväli=8,5 metriä
Kuormituksina; hyötykuorma q,k1=2,5 kN/m² ja Qk,1=3,0 kN (luokka C1), pysyvät kuormat g,k1=1,8 kN/m²
Taipumarajat SLS: Winst=L/400, Wnet,fin=L/300 ja Wfin=L/200.
Välipohjan värähtelylle taajuuskriteeri min. 4,5 Hz ja esiintymistiheys kriteeri 9,0 Hz. Kiihtyvyyskriteeri 0,050 m/s².

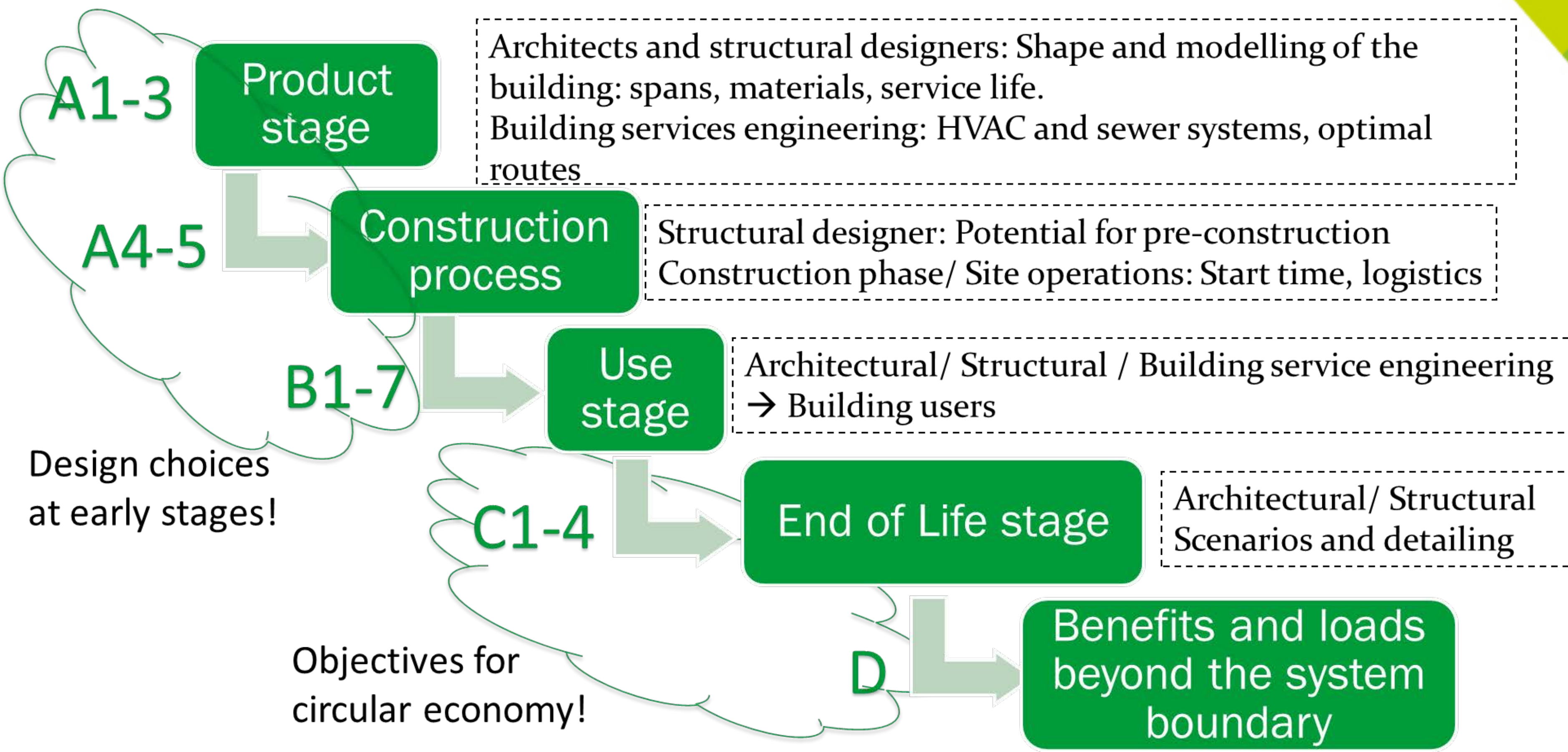
L, span = 8.5 meters
load; useful load q, k1 = 2.5 kN/m² and Qk, 1 = 3.0 kN (class C1), permanent loads g, k1 = 1.8 kN/m²
Deflection limits SLS: Winst = L/400, Wnet, fin = L/300 and Wfin = L/200.
Frequency criterion for intermediate floor vibration min. 4.5 Hz and appearance frequency criterion 9.0 Hz. Acceleration criterion 0.050 m/s².

https://puuinfo.fi/wp-content/uploads/2020/06/Puu_2_19_kokonaan_low_res_0.pdf

Is the assessment of carbon footprint difficult?



Building life cycle stages. Who and what are the major influencers at construction sector?



Life-cycle stages according to EN 15978

Building life cycle stages A1-5
Early stages of planning contribute the most..

- Most contributing building elements should be
  - identified and optimized
  - cut-out rules should be applied to early design for fast results
  - Goals for design should be made

- By experience the most affecting are by far horizontal and vertical structural elements (A1-3). Focus should be on them…
  - 122 Ground floor
  - 123 Structural frame, especially intermediate floors
  - 124 Facades
  - 126 Roofs

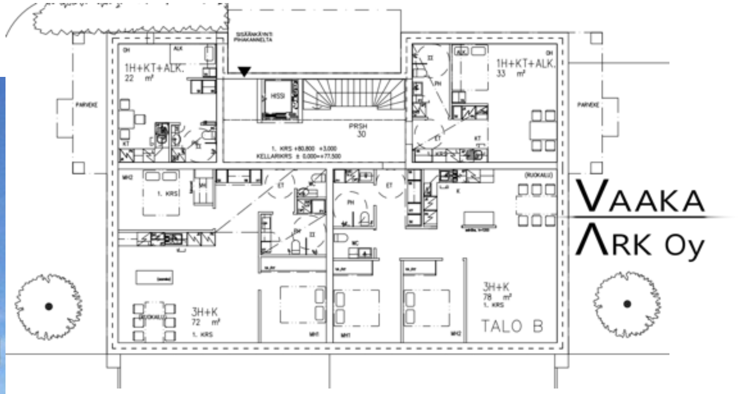
Building life cycle stages A1-5
Early stages of planning contribute the most..

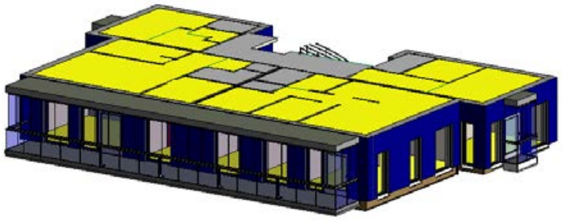
- Foundations (121) are also a major player but not suitable for larger optimization, due to
  - Minimun foundations sizes (building regulations)
  - The location itself is determined in the city/municipal planning
  - Optimization can mostly be made with concrete classes and reinforcement. Site works dont contribute that much.

- In general construction process (A4-5) has quite small effect on carbon footprint→ Benefits however are noice reduction, logistics and city air quality

Structural optimization from carbon footprint viewpoint

- Concept design for the block houses
- Optimization should be started first from one floor and then applied to others
- Doing it for the whole building at once can be time consuming (is time consuming by experience)

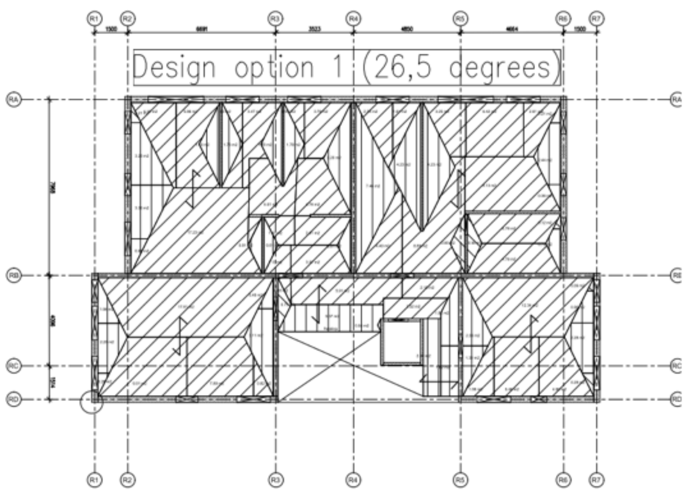


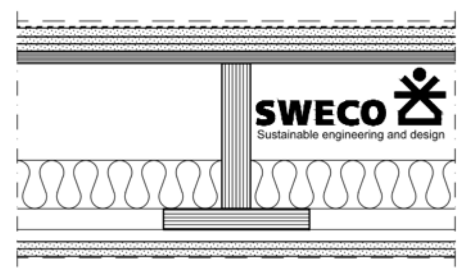


Original might be good to begin with..

- *Original design option 1 (Structural designer: Hannes Tähtinen, Sweco):*
- Goal to minimize cross- section by providing additional load-bearing/ shear walls
- Designed service life 50 years
- Only minimal adaption possibilities after completion
  - Category of use A: Areas for domestic and residential activities
  - Fire requirements: R60
  - No possibility to re-arrange partition walls
  - Additional extra floors not accounted for (roof-structures, load-bearing capacities)

Intermediate floor main load bearing direction

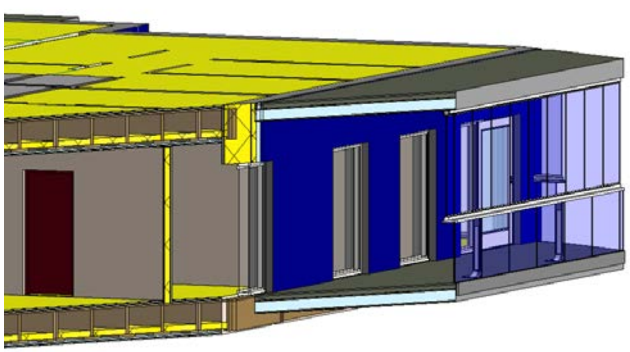


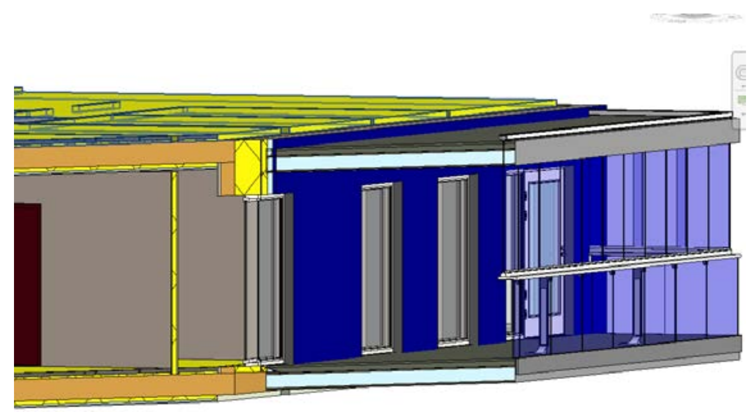


Original might be good to begin with..

- ***Original design option 1 (WW)*** (Structural design: Sweco):
- Most of the internal and external walls are load-bearing/shear walls made of glulam
- Intermediate floors Kerto-Ripa open box slabs

- **Design option 2 (WW2)** (Structural design: Karelia UAS)
- Walls made of LVL (laminated veneer lumber) or CLT (cross-laminated timber)
- Intermediate floors made of CLT



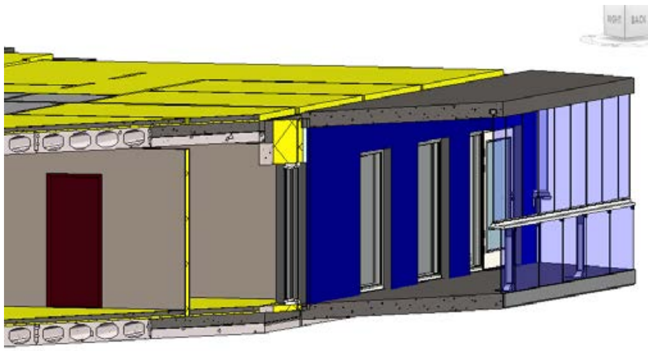


Mix- and match options for wood/conrete

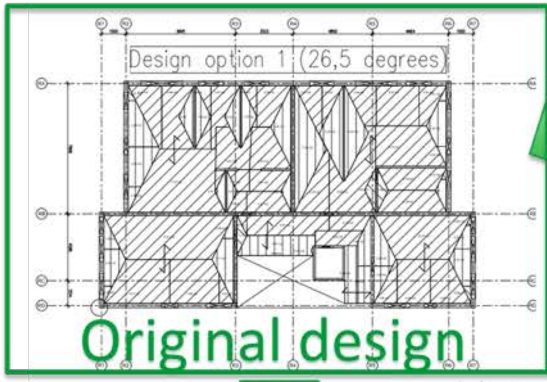
- **Design option 3 (CC)** (Structural design: Karelia UAS)
- Concrete walls (minimal reinforcement) and hollow core slabs (O32)

- **Design option 4 (CW)** (Structural design: Karelia UAS)
- Concrete walls (minimal reinforcement) and Intermediate floors made of CLT

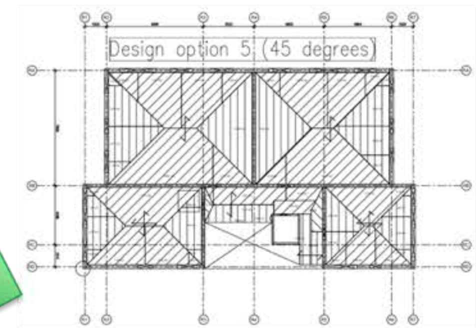
- **Design option 5 (WC)** (Structural design: Karelia UAS)
- Walls made of LVL (laminated veneer lumber) or CLT (cross-laminated timber)
- Intermediate floors made of hollow core slabs



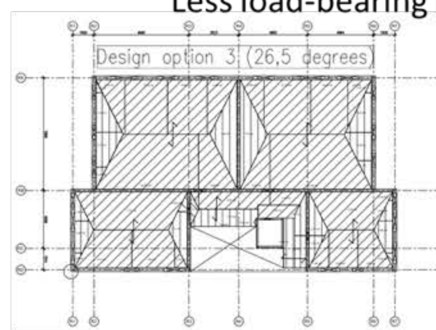
First step: Define goals

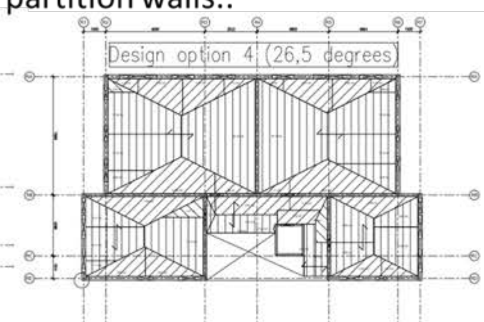


Which one has smaller initial carbon footprint or loads?

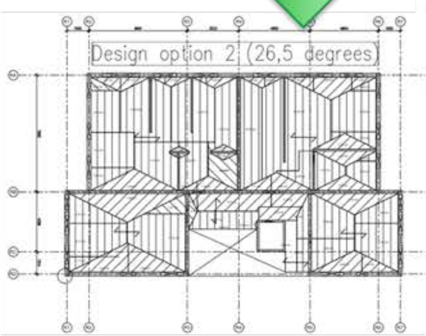


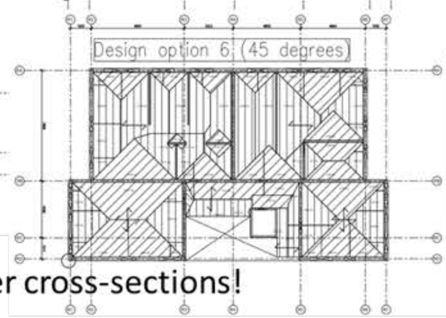
Goal: Improved building adaptability in the future!
Less load-bearing partition walls..





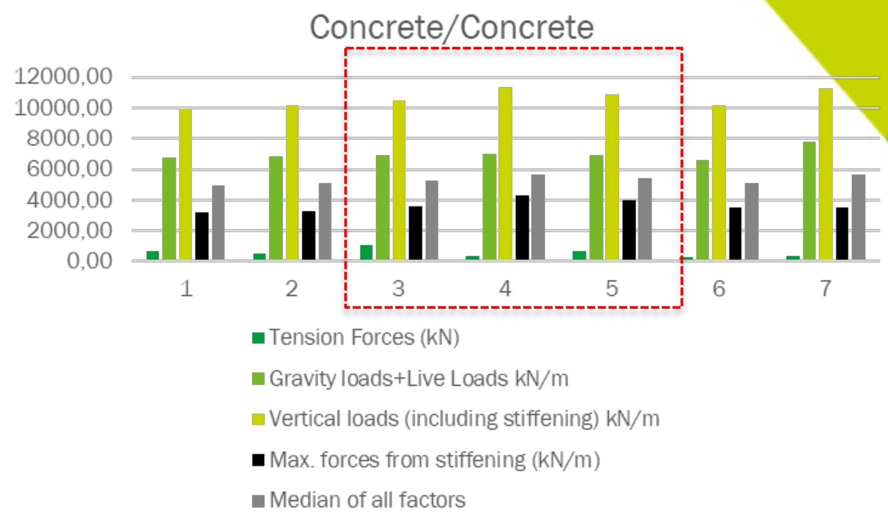
Less walls leads to more simple load path for lightweight walls needing stabilizing gravity loads. This design choise however increases shear loads for fewer walls.

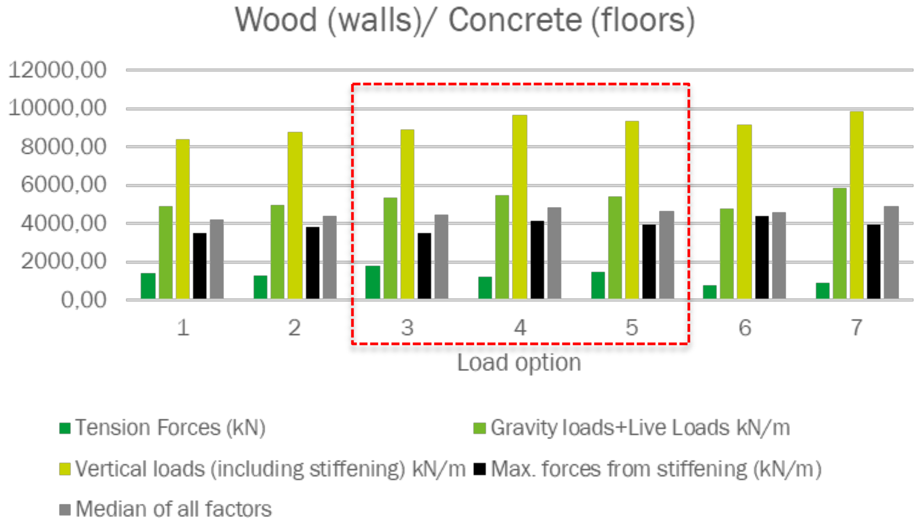


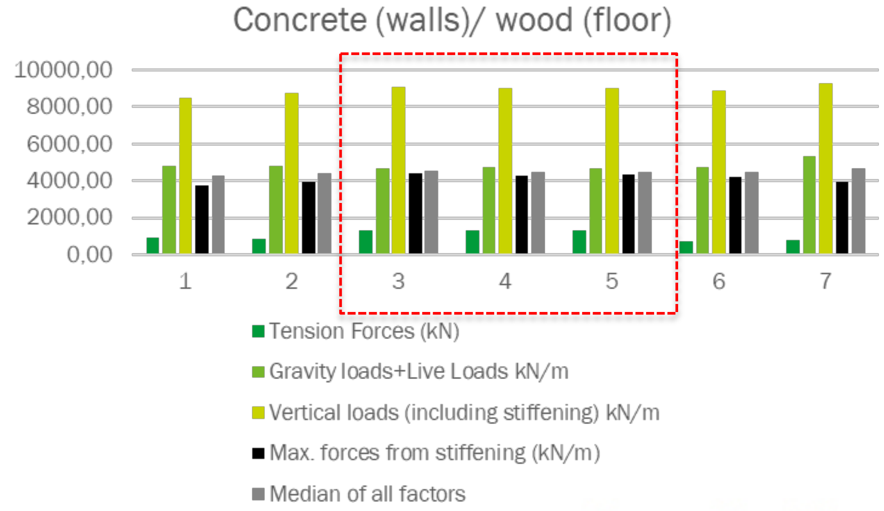


Goal: Less loads and smaller cross-sections!

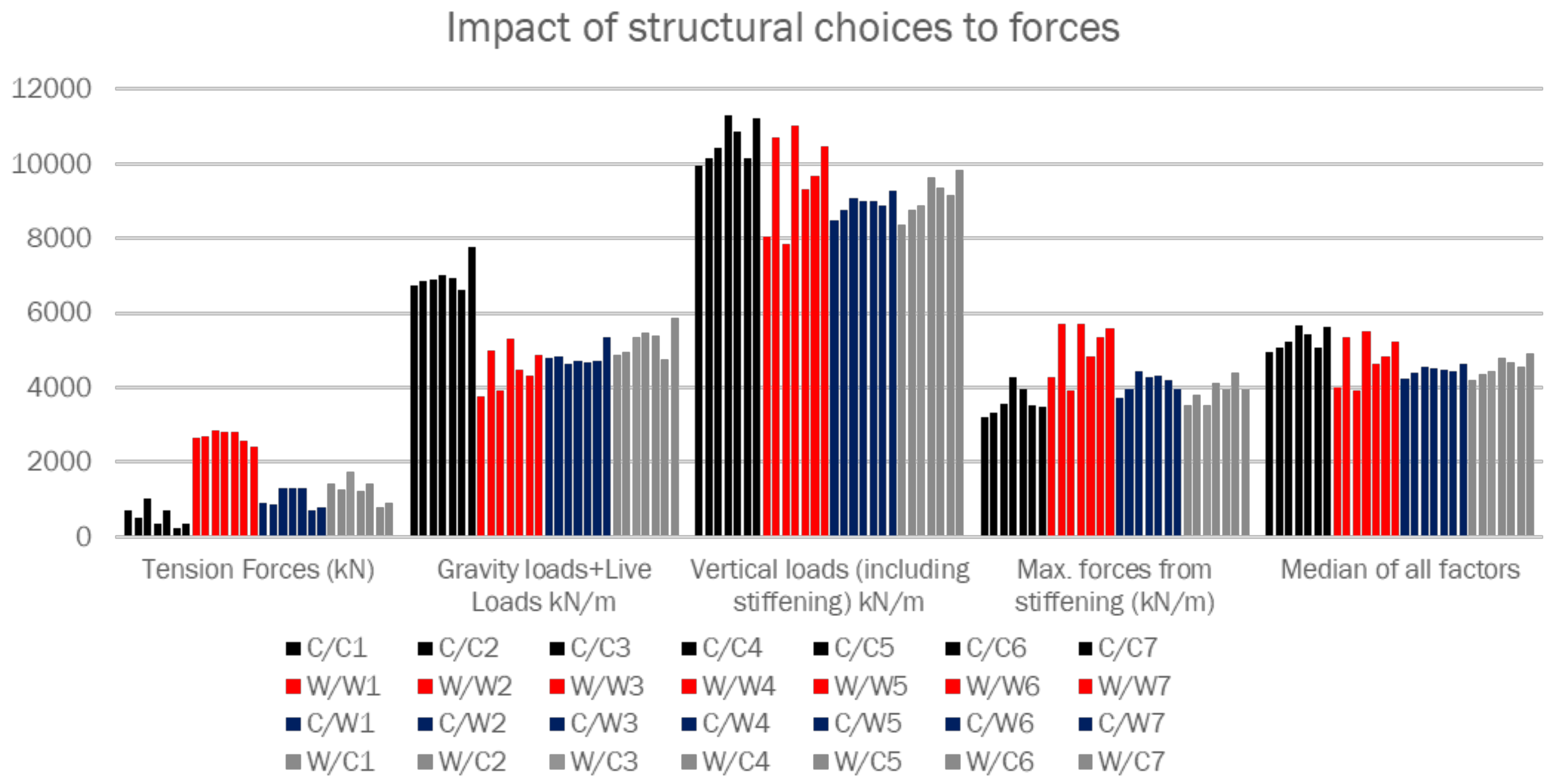
Second step: Define loads



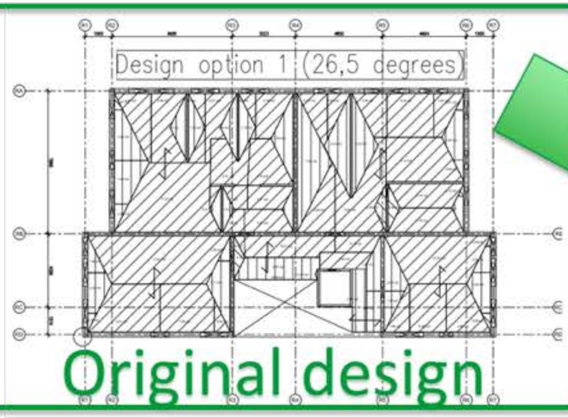




Second step: Define loads

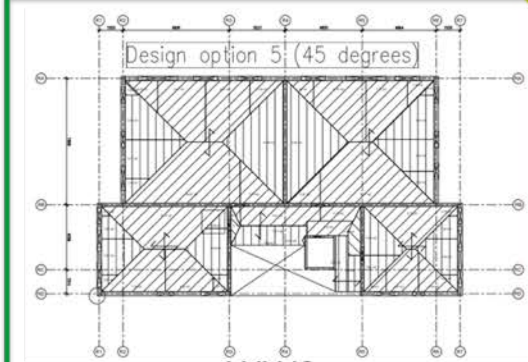


Third step: Define best option



Goal: Improved building adaptability in the future!
Less load-bearing partition walls..

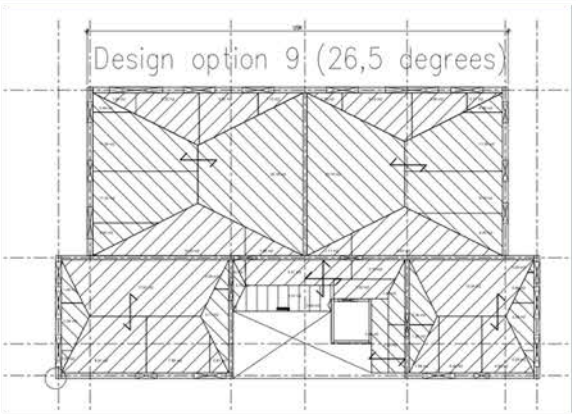
Design option 5



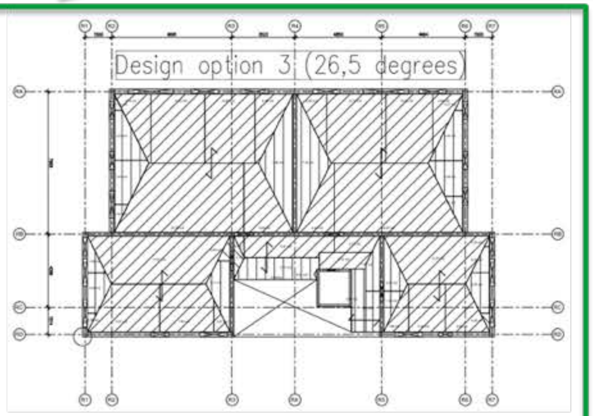
WW2
CW

Design option 9

Mix of load options 3 and 4



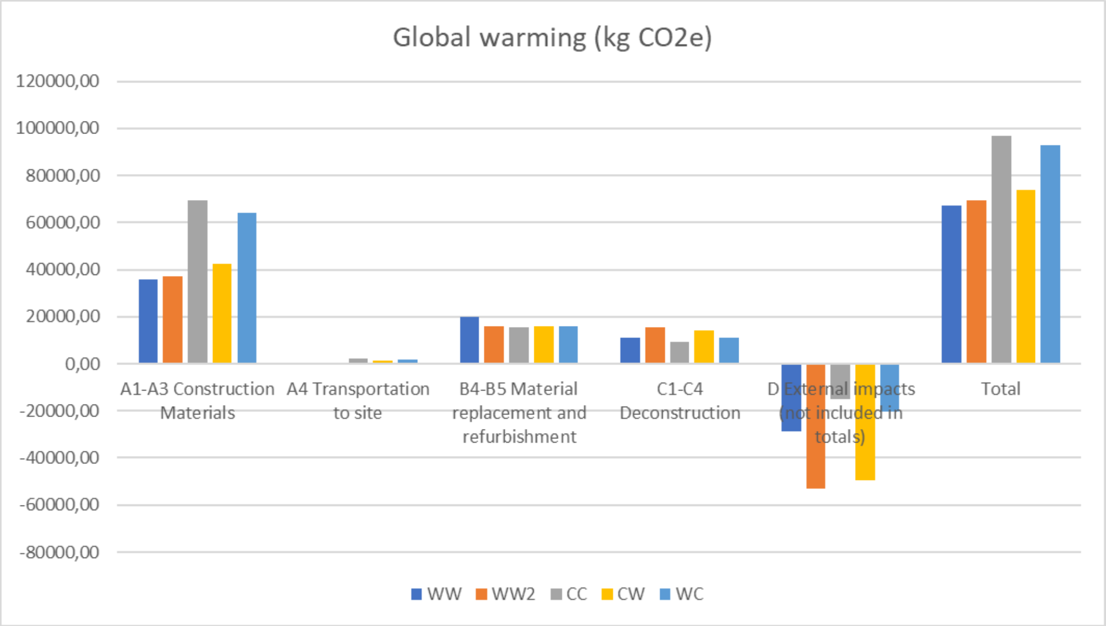
CC
WC

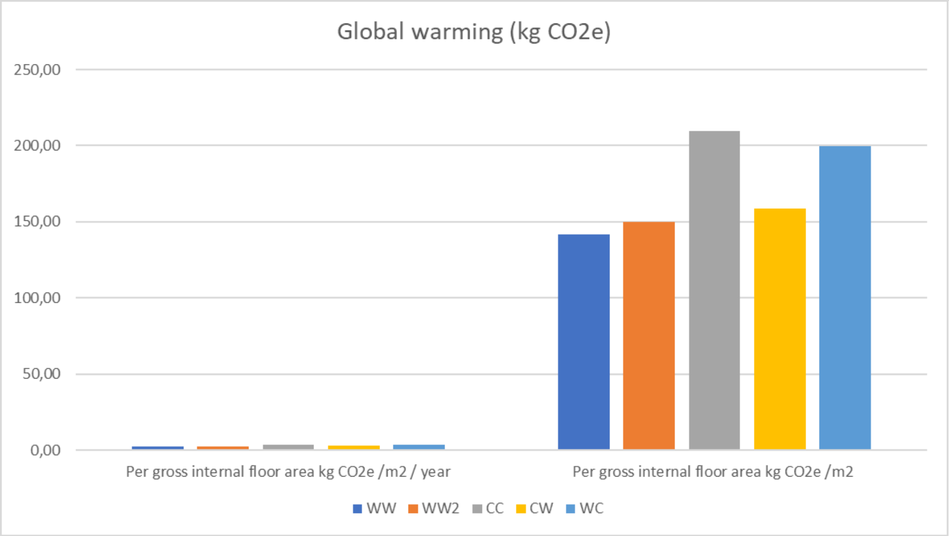


WW

Design option 3

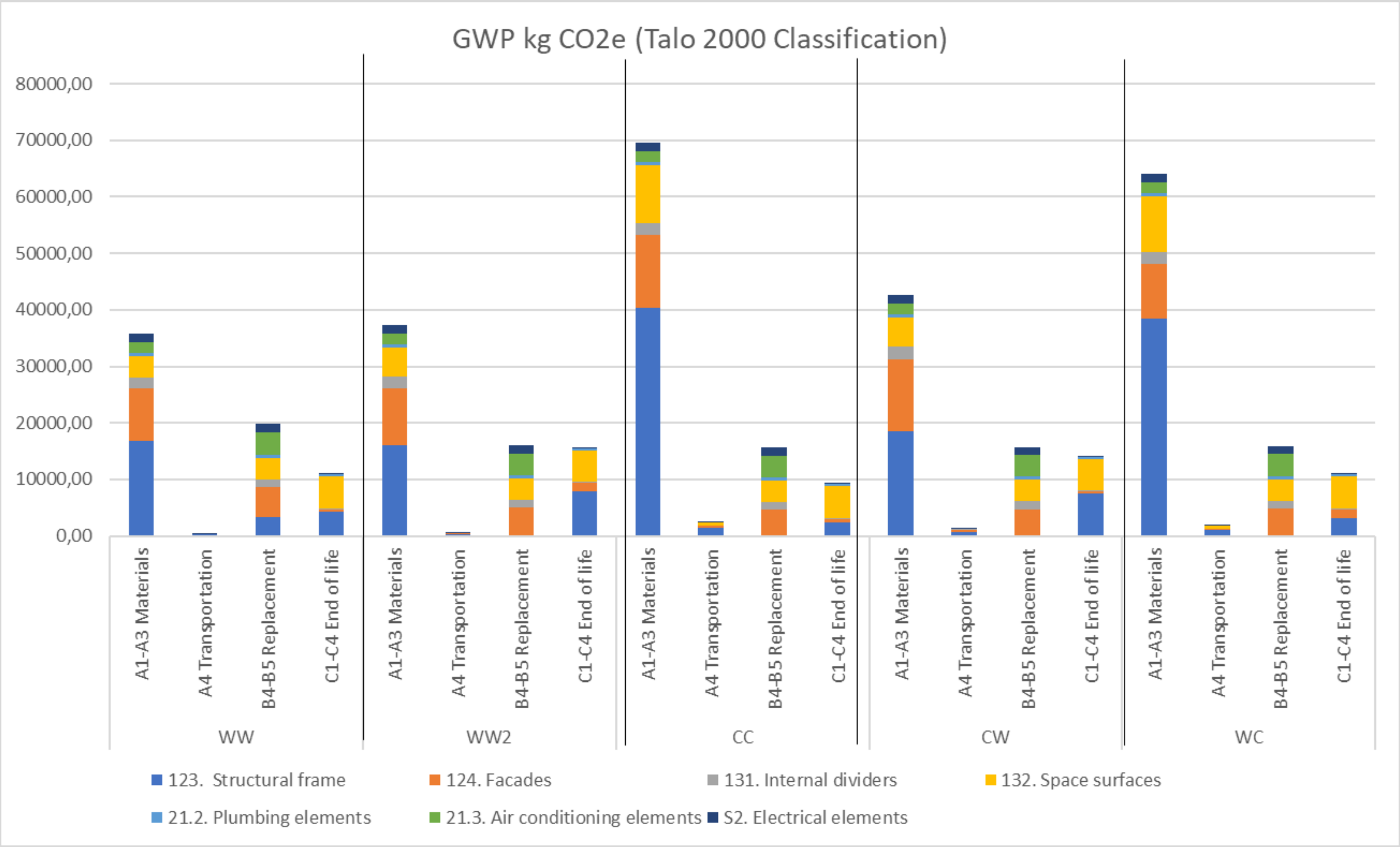
Final step: Did the choices make any difference?



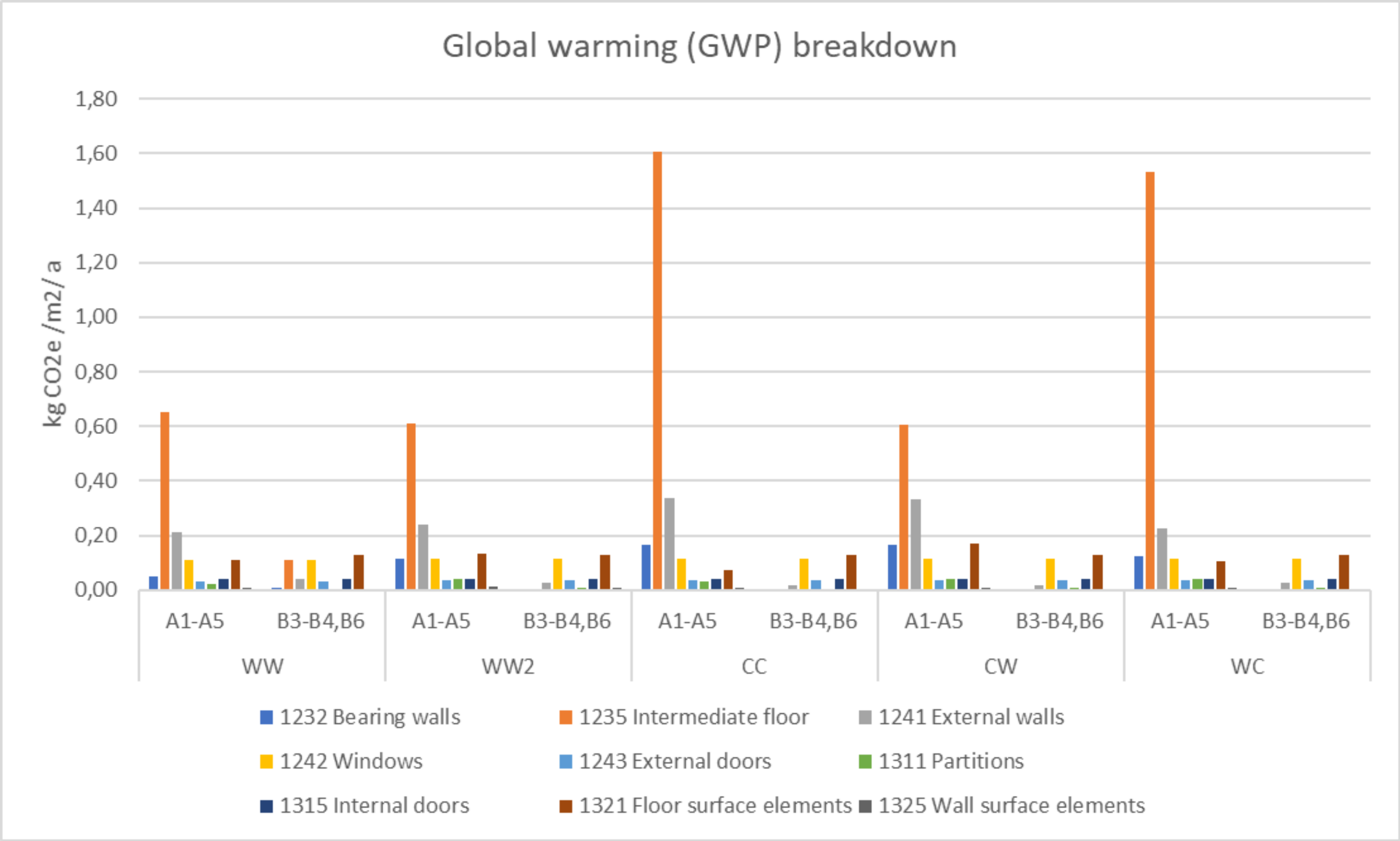


- In the end results are quite expected...
- The structural choise with light material and large amount of wood products leads to smaller carbon footprint
- But by defining goals for adaptability doesn't increase the carbon footprint that much!
- Also the choise of using mix of conrete walls and CLT floors can lead to efficient design

Final step: Did the choices make any difference?

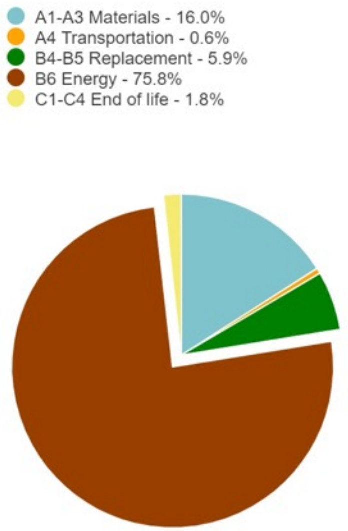


Final step: Did the choices make any difference?

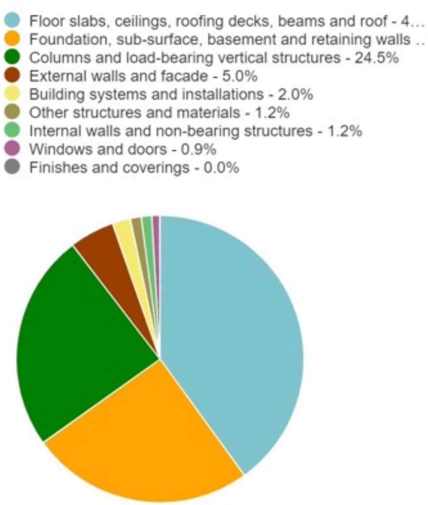


Overall results for original design (option 1)

Global warming kg CO2e - Life-cycle stages



Mass kg - Classifications



Building life-cycle carbon footprint for Level(s) in compliancy with EN 15978

Incomplete lifecycle according to Level(s) definitions (Draft Beta v1.0)

	Result category	Global warming kg CO_2e ⓘ	Biogenic carbon storage kg CO_2e bio ⓘ
A1-A3 ⓘ	Construction Materials	237 010,79	135 183,67
A4 ⓘ	Transportation to site	8 174,32	
A5 ⓘ	Construction/installation process		
B1 ⓘ	Use Phase		
B4-B5 ⓘ	Material replacement and refurbishment	88 200,67	
B6 ⓘ	Energy use	1 124 912,33	
B7 ⓘ	Water use		
C1-C4 ⓘ	End of life	26 329,18	
D ⓘ	External impacts (not included in totals)	−98 142,11	
	Total	**1 484 627,3**	**135 183,67**
	Results per denominator		
	Per gross internal floor area m2 / year	17,3	1,58
	Per gross internal floor area m2	1 038,2	94,53

How about the use stage energy?

- Some ways of reducing energy usage are
  - Orientation and shape of the building
  - Shading of surrounding structures or trees
    - In Finland at south side of the building should be planted with deciduous trees to provide shading at summer and at winter they drop their leafs
    - External shading or green facades
  - Increasing the HVAC system efficiency and heat recovery
  - Increasing the air tightness has also some effect but increases material usage

Results for one building

	Original desing	Low energy solution	Passive house
Electricity use (actual)	139 MWh/a	116 MWh/a -23 MWh/a (-16,5 %)	92 MWh/a -47 MWh/a (-33,8 %)
Net need of electricity	60,5 MWh/a	44,3 MWh/a -16,2 MWh/a (-26,8 %)	36,6 MWh/a -23,9 MWh/a (39,5 %)
Specific heat losses (in total)	711,97 W/K	543,22 W/K -168,75 W/K (-23,7 %)	432,29 W/K -279,68 W/K (-39,3 %)

- Electricity Finland (2020-2070, for 50 year service life).
- 0,048 kg CO2e /kWh
- District heating: Fortum Power and Heat Oy, Joensuu. 0.15 kg CO2e /kWh
- Source for data: Karhapää, Konsta. TP3 – Hiilineutraalisen kaupunkikorttelin konseptisuunnittelu Kohti vähähiilistä rakentamista – Joensuu Wood City Kehittämishanke.

www.karelia.fi/puurakentaminen

www.woodjoensuu.fi

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