Low Carbon Construction

Green Transition in Construction webinar

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Strategic choices

- Vitality to working life through competence
- Education-based immigration and internationalisation
- Sustainable well-being in a sparsely populated area
- Intelligent production and services
- **Carbon neutral solutions**

Degree Programme for Construction Engineering – RDI activities

- Wood construction
- Low carbon construction
- Digitalisation in construction

https://rakentaminen.karelia.fi/en/

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Towards carbon neutrality

- The building sector representing 40% of the total energy consumption and 36% of CO_2 emissions in the EU

- Finland is aiming at to be carbon neutral by 2035 and after that carbon negative (emissions+sinks)

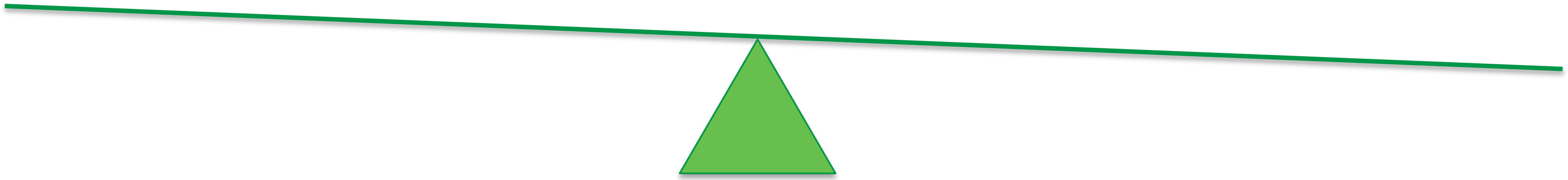
Carbon neutral building?

Carbon footprint

- Materials (A1-3)
- Construction (A4-5; B1-7)
- Energy consumption (C1-4)

Carbon handprint

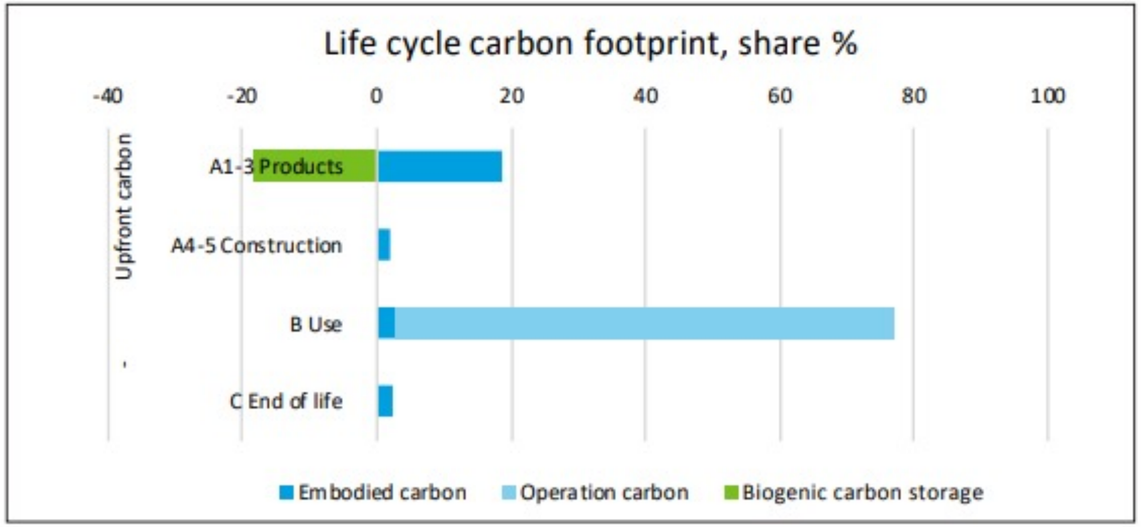
- Energy production, e.g. solar, geothermal (D)
- Renewable energy sales (D)
- Carbon storages (D)
- Benefits from reuse and recycling (D)
- Compensations (D)



Source: Granlund Oy / Ulla Nykter, 2021

Storing carbon into buildings

Carbon storage of the Lighthouse Joensuu is equal to annual CO2 emissions of 700 cars



Source: Sustainability Case Study - The Lighthouse Joensuu project, Stora Enso

Regulatory development in Europe

Netherlands

Life Cycle Analysis mandatory

France

Mandatory Environmental Product Declarations (EPD) for building materials

CO_2 limit values

Sweden

Climate certifications for buildings mandatory by 2022

CO_2 limit values by 2028

Norway

Life Cycle Analysis mandatory in public buildings

Finland

CO_2 limit values for different building types by 2025

Source: Finnish Ministry of the Environment, 2018/2021

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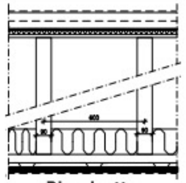
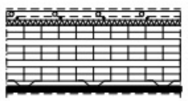
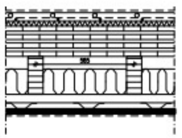
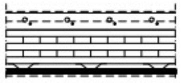
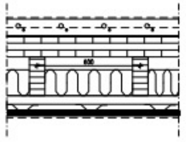
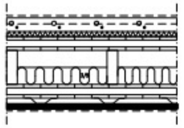
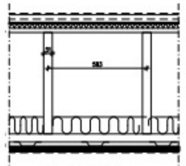
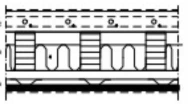
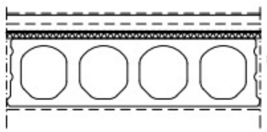
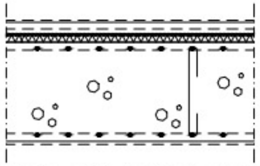
Design optimization-

Choosing more advanced solution leads to lower CO2e

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

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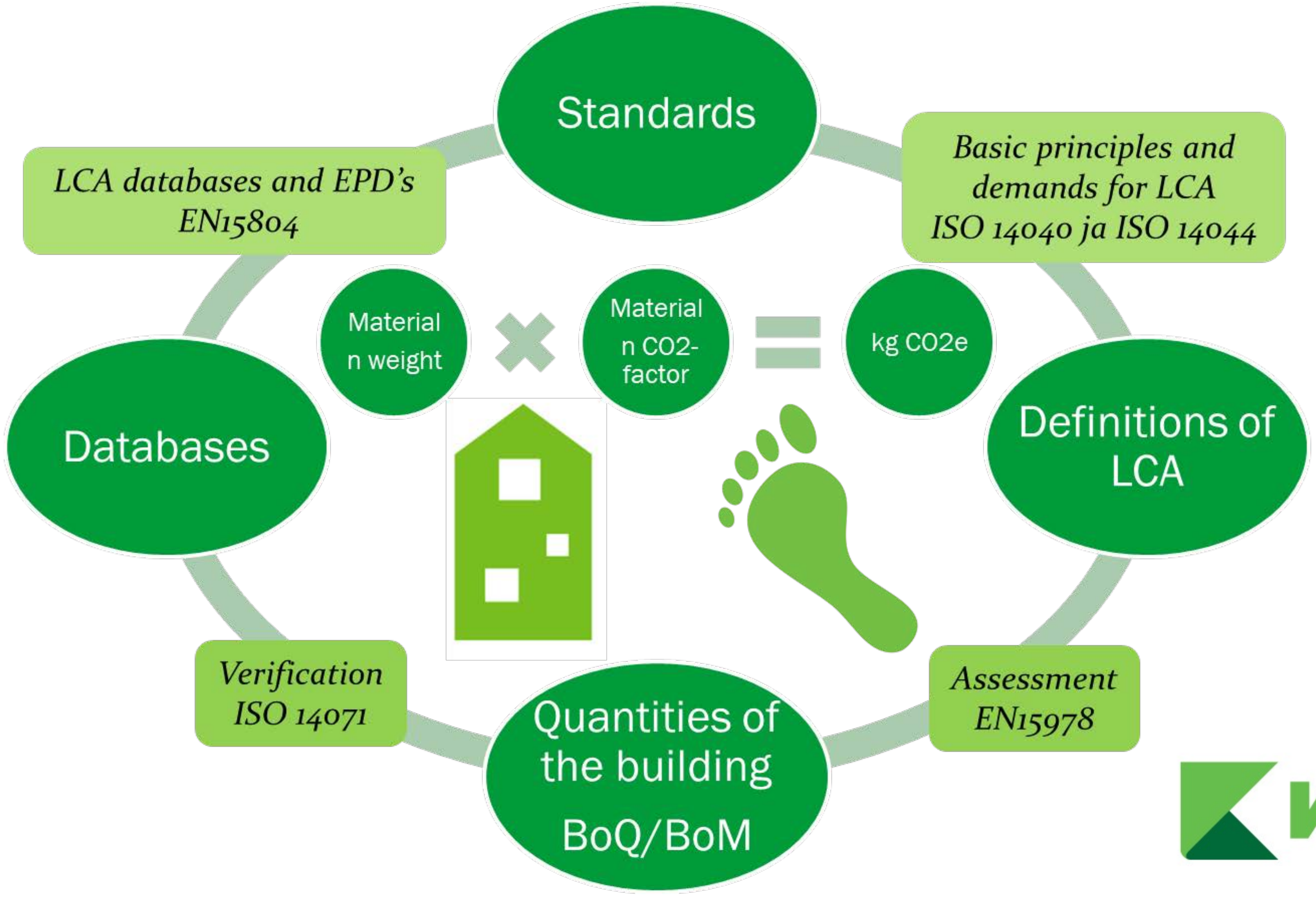
The basis of consistent data and results



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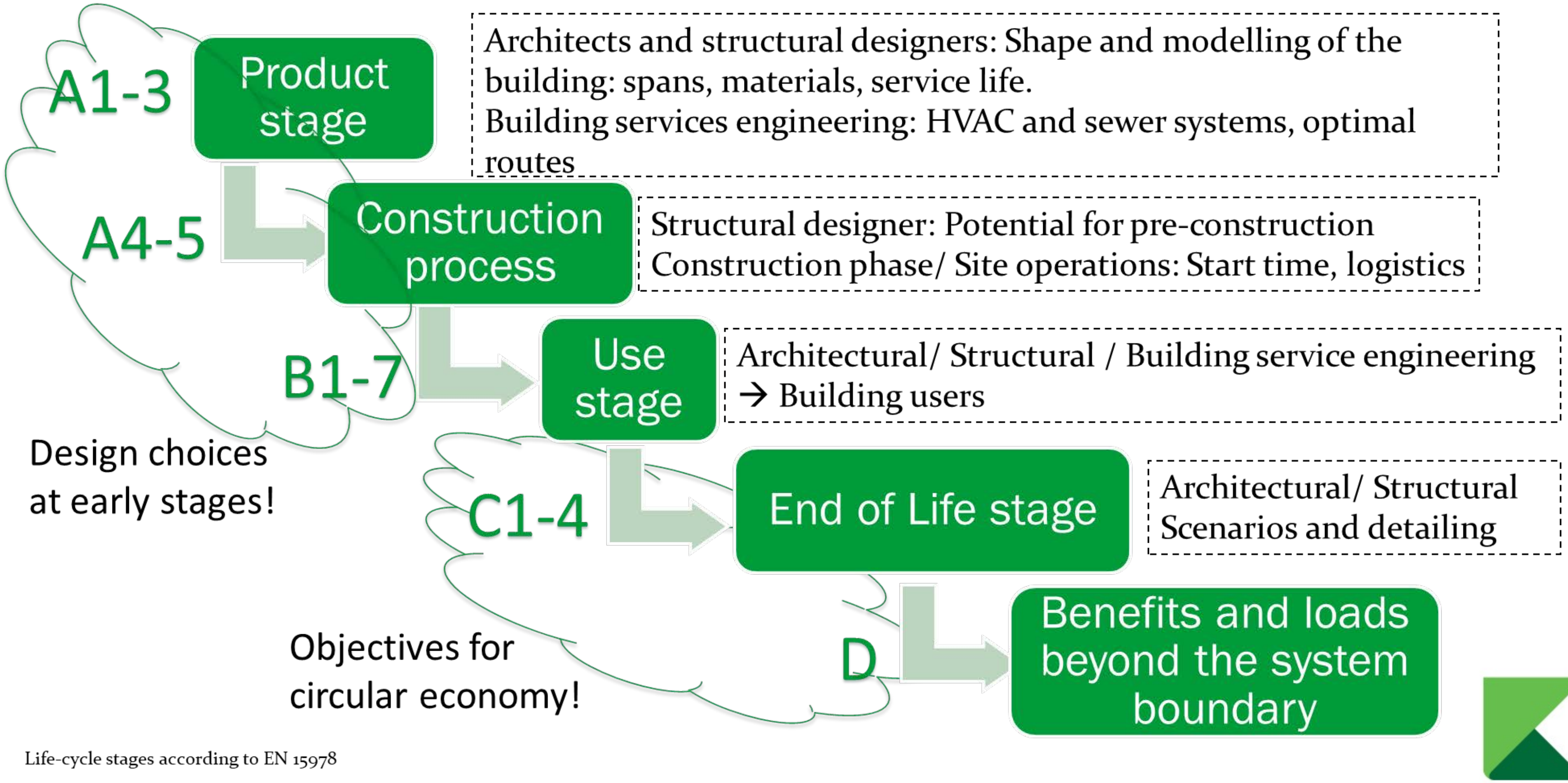
Who and what are the major influencers at construction sector?

Building project owner gives a bigger picture but…



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
  - 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

- 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.

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Best scenarios for low carbon construction?

Identify structural design alternatives

Grid Spacing	Span distance	Floor height	Load combinations	Load Cases

Don’t desing a concrete building first and then move using wood. Design has to be updated for this change.

Create theoretical limits for material alternatives

Best properties	Worst properties	Optimal properties

Decrease alternatives and variations

Alternatives	Goals	Variations

Choose the most important ones for each building location and size.

Classify goals and possibilities

Price	Strenght	Availability	Density	Carbon footprint/ handprint	Social impacts	Environmental impacts

Optimize e.g. cross-sections by structural demands

Allowed height (buckling)	Allowed weight	Fire resistance	Vibrations	Load-bearing capacity	Durability

Design should allow also conversion flexibility and uses from residential to office.

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Lähde: Low-carbon design of structural components by integrating material and structural optimization. C.Zhang, H.Huang, L.Zhang, H.Bao, ZF. Liu

Low carbon materials (virgin materials)

It is not only about kg CO2e/ kg for each material

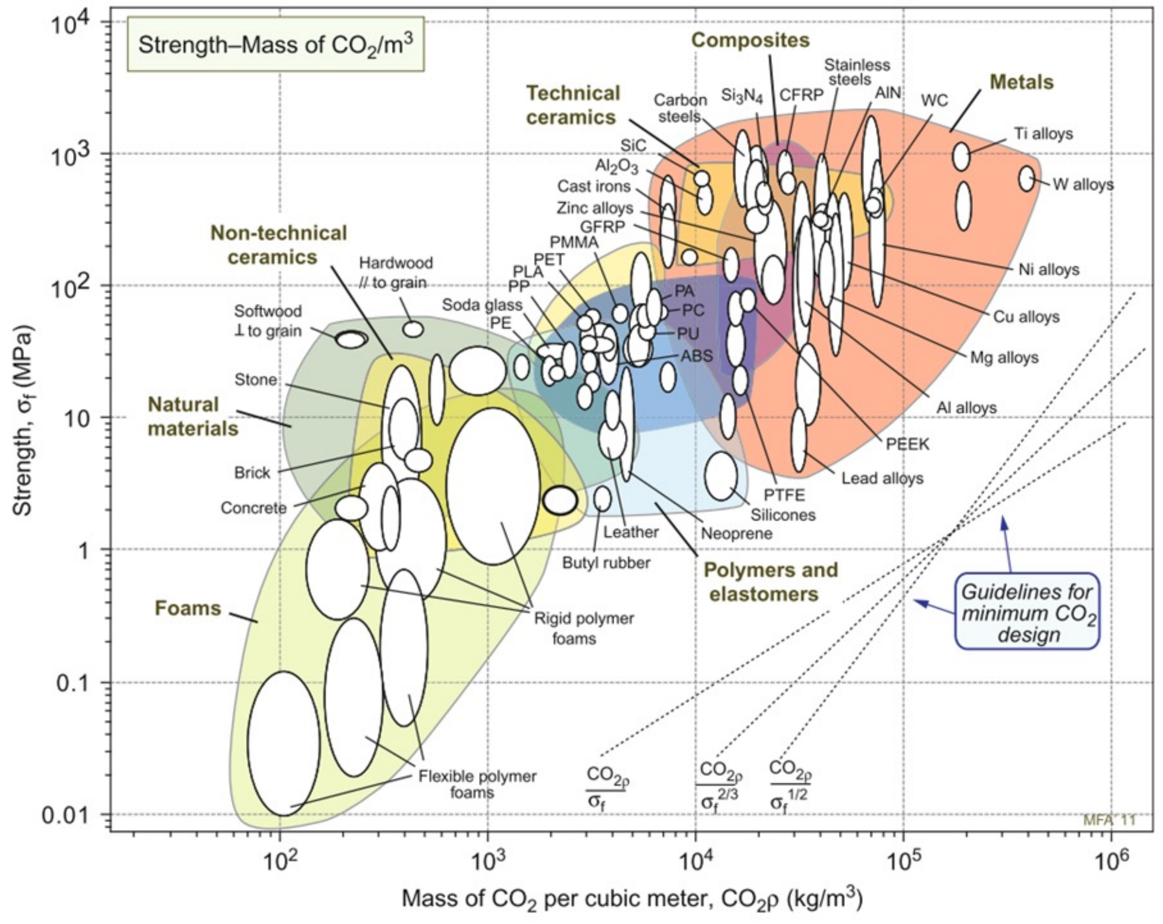

Figure 2.2: Ashby diagrams Embodied carbon (kgCO2e/m3) versus strength (MPa) (Ashby, 2012)

The situation is changing from this Ashby chart!
Markets have introduced more low carbon and re-use alternatives for "green" concrete (Lujabetoni) and steel (Ruukki/SSAB HYBRIT Fossil Free steel)

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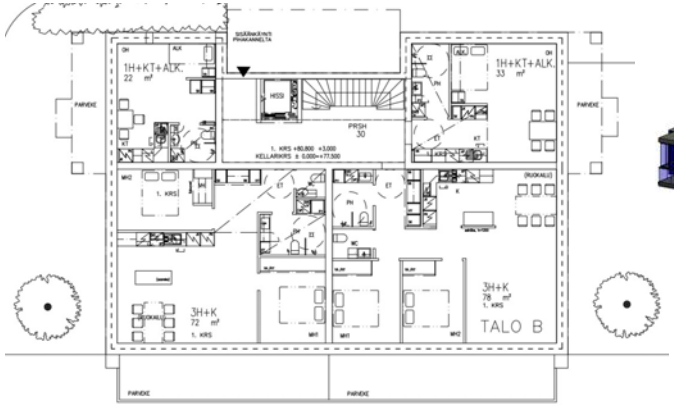
Lähde: Low Carbon Pathways for Structural Design:Embodied Life Cycle Impacts of Building Structures Catherine De Wolf

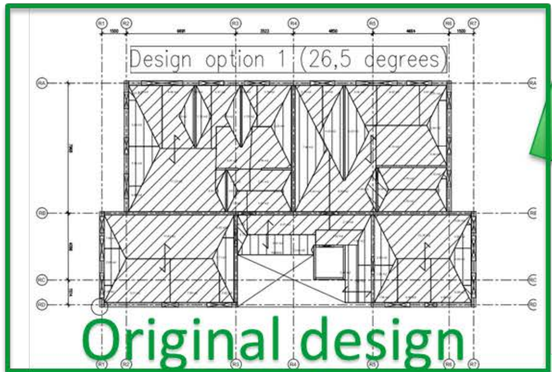
Structural optimization from carbon footprint viewpoint



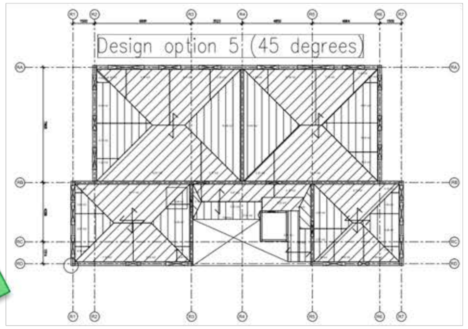
- Concept design for the block houses
- Alternatives for
  1. timber frame (W/W)
  2. CLT/LVL (W/W2)
  3. Conrete/hollow core slabs (C/C)
  4. Hybrid Conrete/CLT (C/W)
  5. CLT/concrete (W/C)

- Optimization should be started first from one floor and then applied to others
  - Making life easier for LCA expert can be one good goal as well

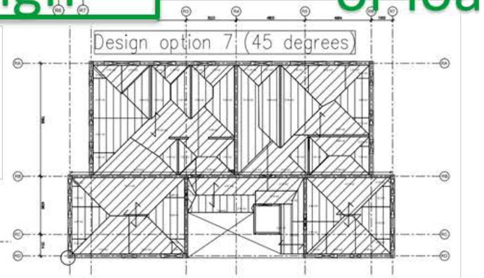
First step: Define goals
Find the best grid spacing and span distances.

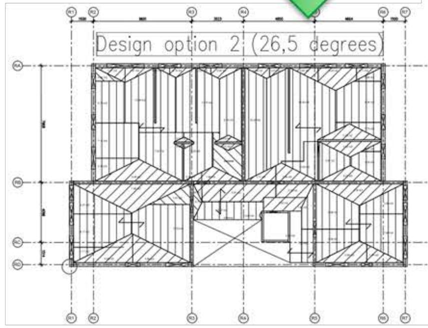


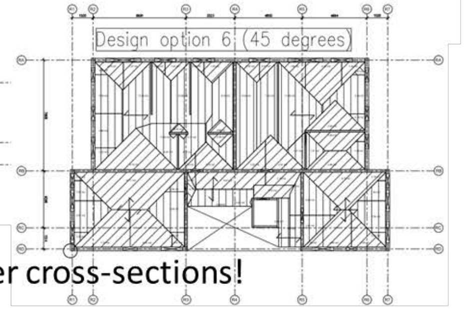
Which one has smaller initial carbon footprint or loads?



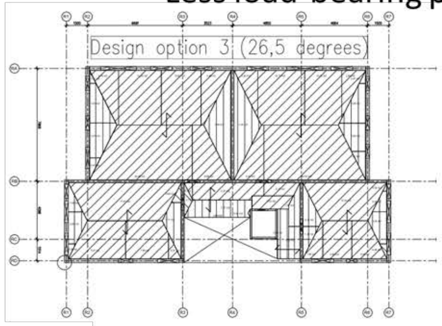
Goal: Improved building adaptability in the future!
Less load-bearing partition walls..

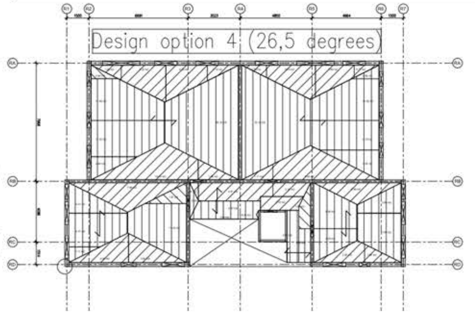






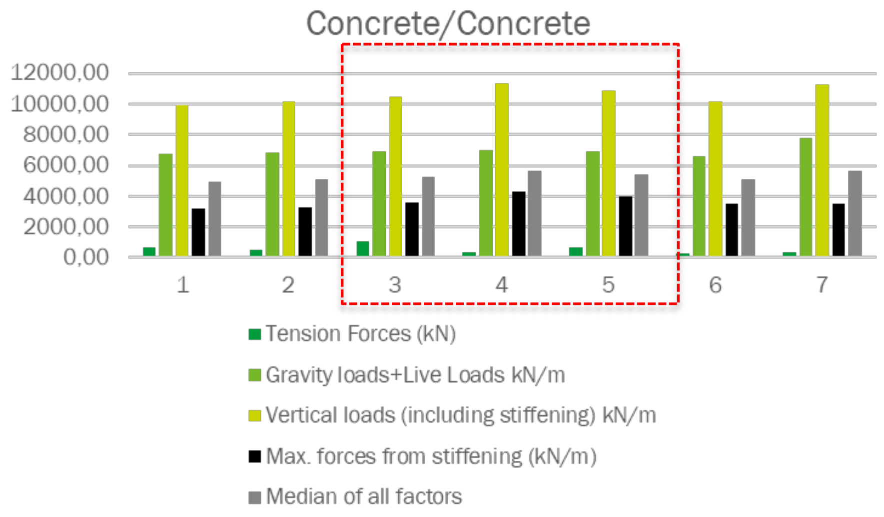
Goal: Less loads and smaller cross-sections!

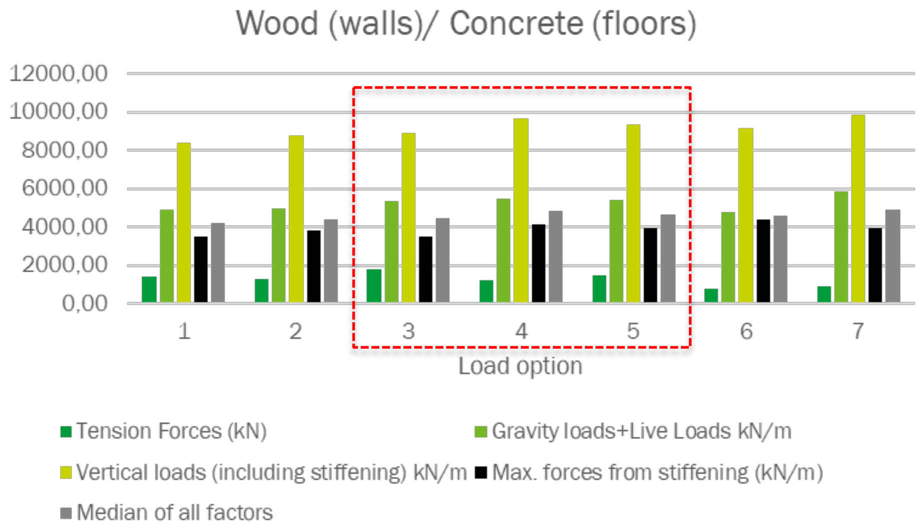


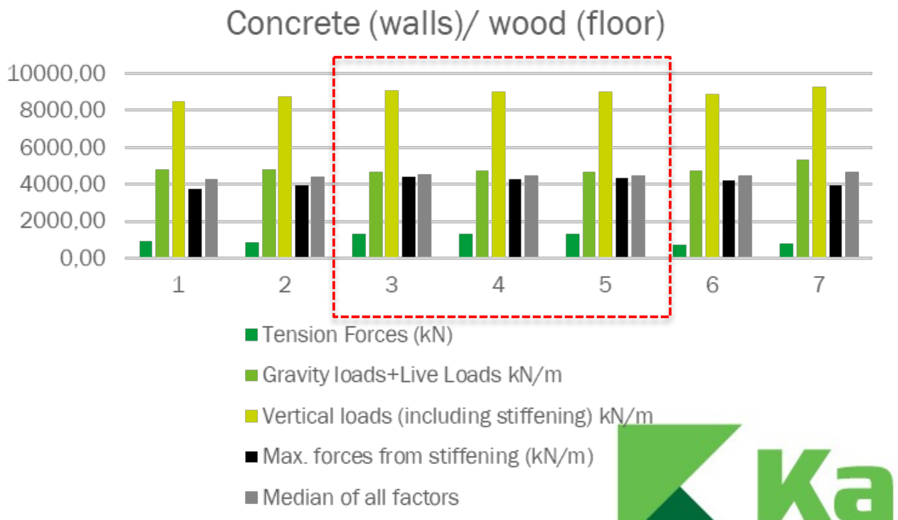


Less walls leads to more simple load path for lightweight walls needing stabilizing gravity loads. This design choise however increases shear loads for fewer walls.

Second step: Define loads







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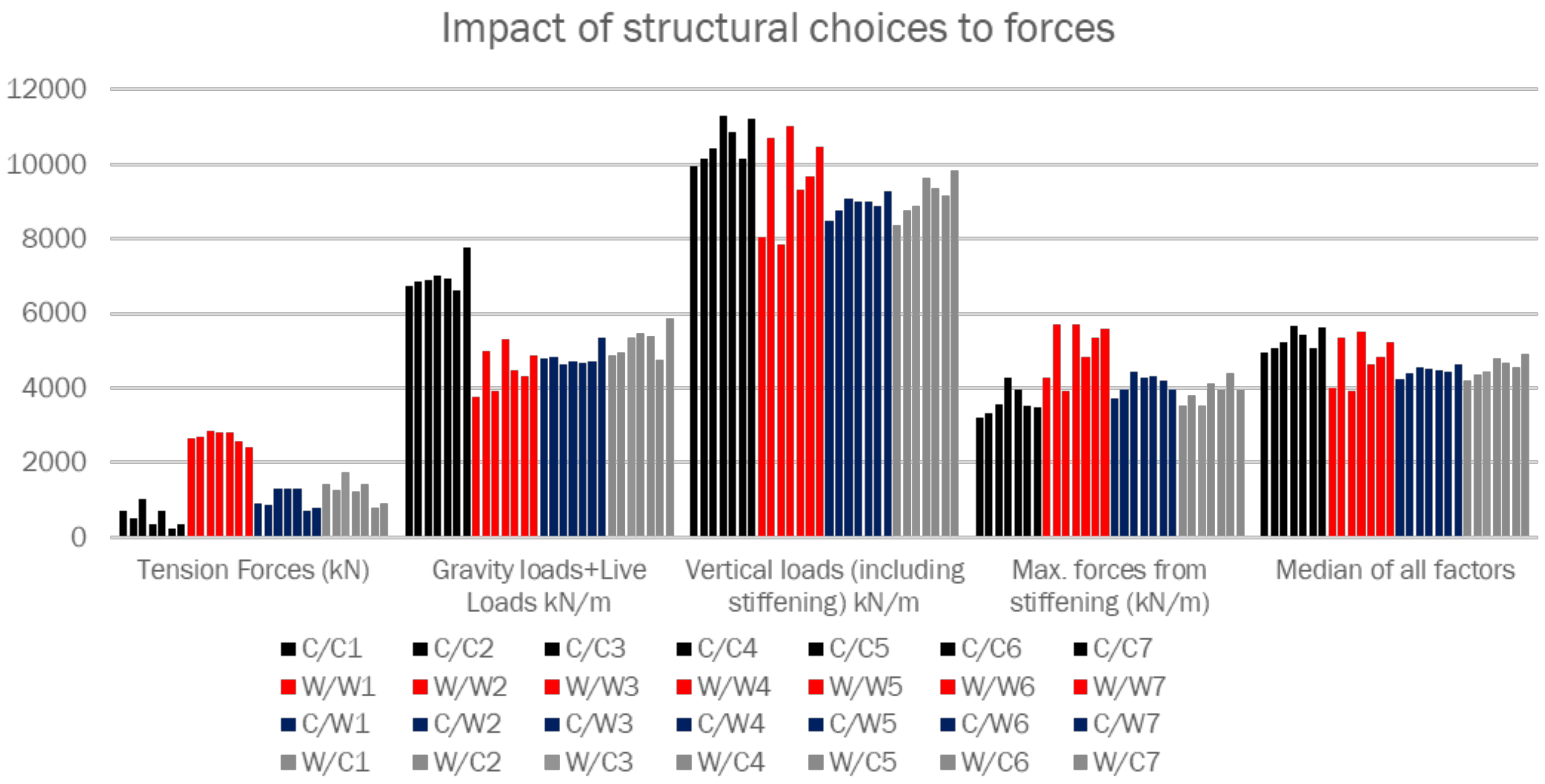
Second step: Define loads
Overall impact?



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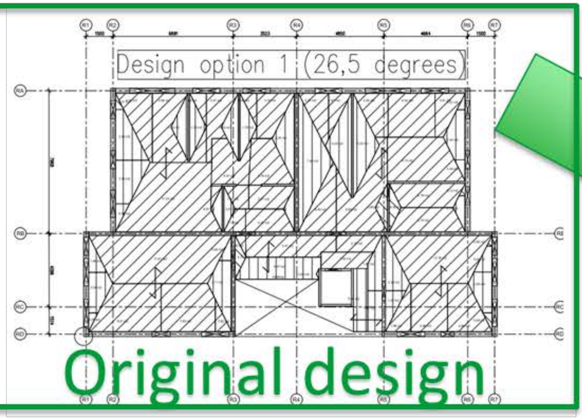
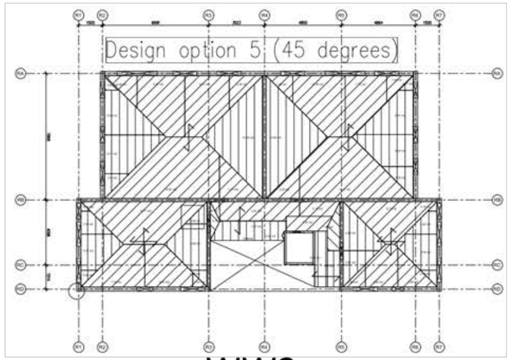
Third step: Define best option
Is the main goal fulfilled?



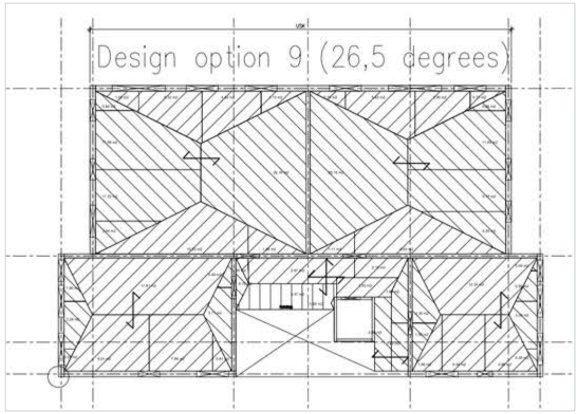
Goal: Improved building adaptability in the future!
Less load-bearing partition walls..



WW2
CW

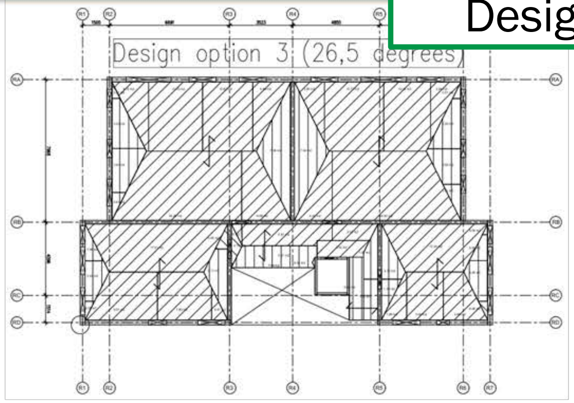
Design option 5

Mix of load options 3 and 4



CC
WC

Design option 9



WW

Design option 3

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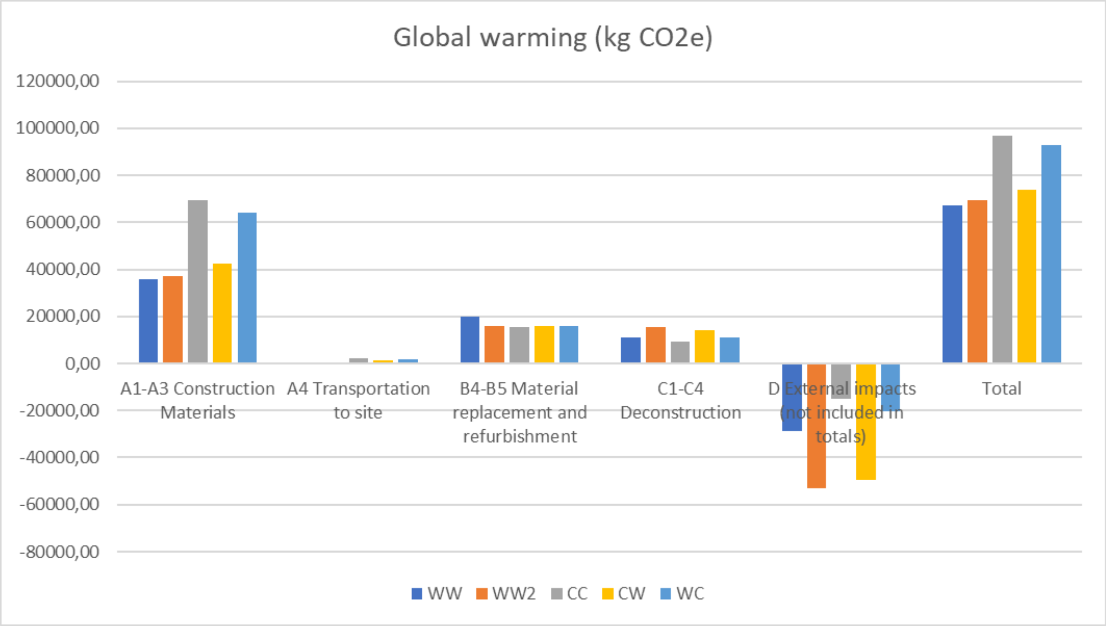
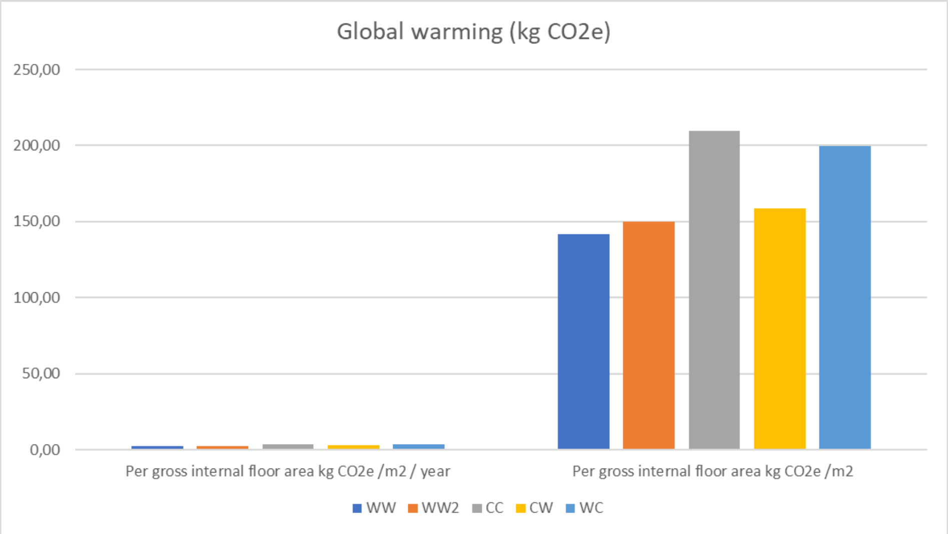
Final step: Did the choices make any difference?





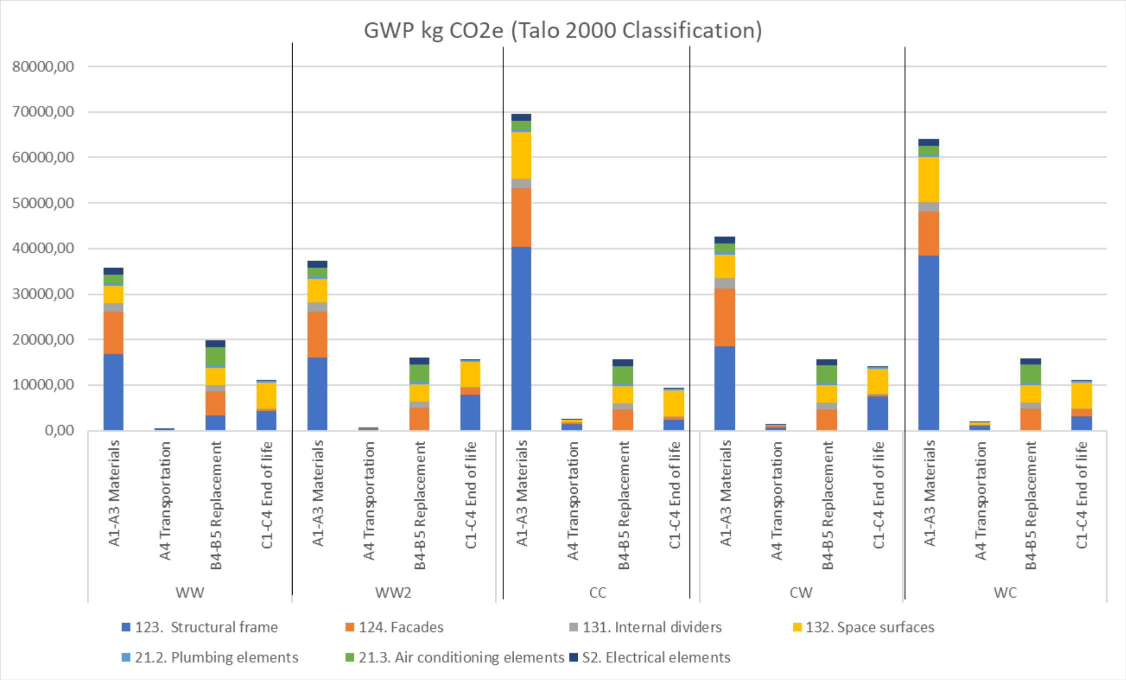
- In the end results are quite expected…
- The structural choise with light material and large amount of wood products leads to smaller carbon footprint
- But by defining goals for adaptability doesn't increase the carbon footprint that much!
- Also the choise of using mix of conrete walls and CLT floors can lead to efficient design
- There is also smaller CO2 alternative for concrete Luja-Vähähiilibetoni and PARMA Green hollow core slab which would have changed results in favour of concrete CC and hybrid CW and WC solutions.
- https://parma.fi/vastuullisuus/parma-green/

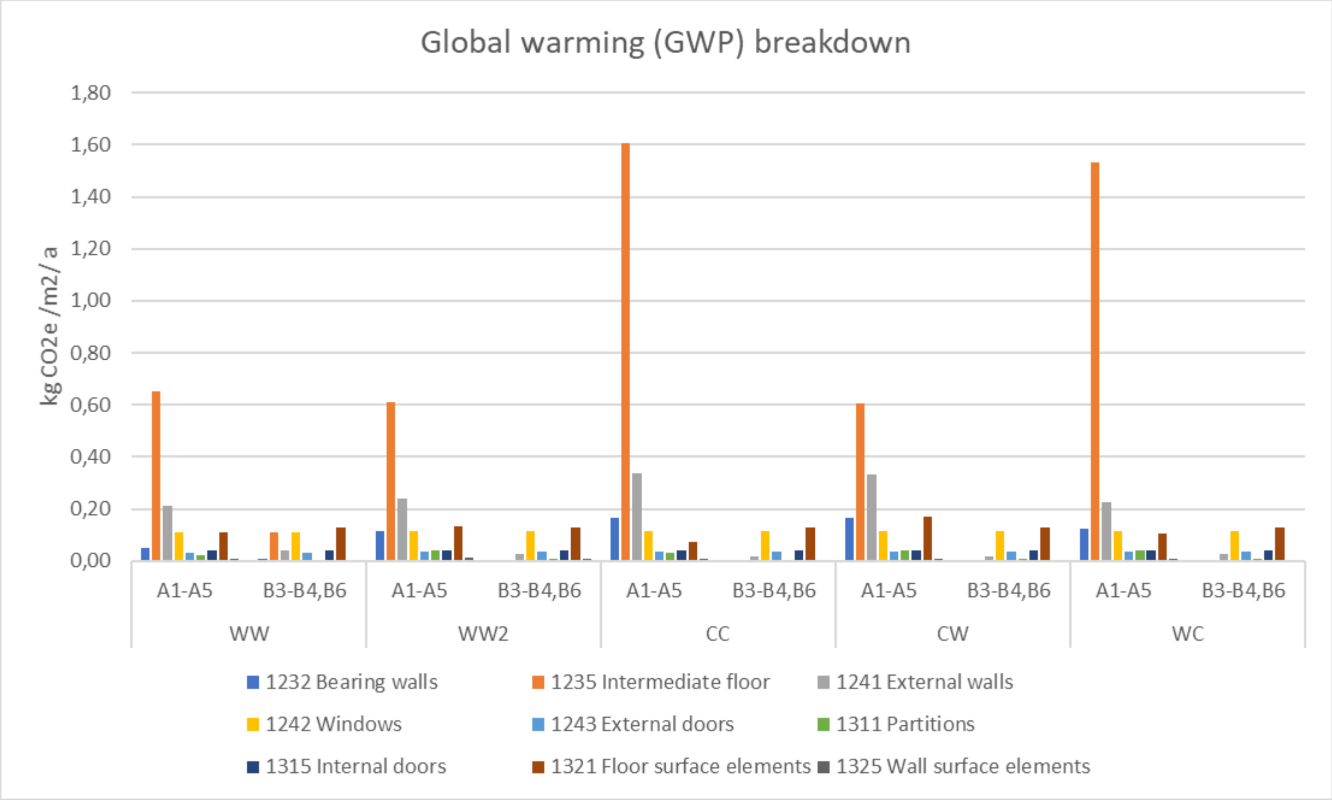
https://www.lujabetoni.fi/vahahiilibetoni/

- Also a alternative for low carbon footprint steel Ruukki/SSAB HYBRIT

There boundary between low carbon wood building and concrete/ steel building is fading.

Final step: Did the choices make any difference?





How about the use stage energy?

	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 %)

– Source for data: Karhapää, Konsta. TP3 – Hiilineutraalisen kaupunkikorttelin konseptisuunnittelu Kohti vähähiilistä rakentamista – Joensuu Wood City Kehittämishanke.

- 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 a bit material usage
- BUT the largest effect can be made by decreasion emission of district heat and electricity in general

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The future of low carbon construction

- Best drivers for low carbon materials and solutions are
  - Incentives
  - Regulations
  - Open markets
  - Consumer demands
  - Commercial drivers

  - Demand for low construction is high which means there is a larger market potential for all construction operations
  - **In the end money talks to reduce carbon footprint**

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WoodJoensuu.fi

https://www.thinglink.com/card/1404083925793374210

Let's craft a better tomorrow. Together.

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