ETH zürich

Anrechenbarkeit und Umsetzbarkeit von Kohlenstoffspeicherung in Baukonstruktionen

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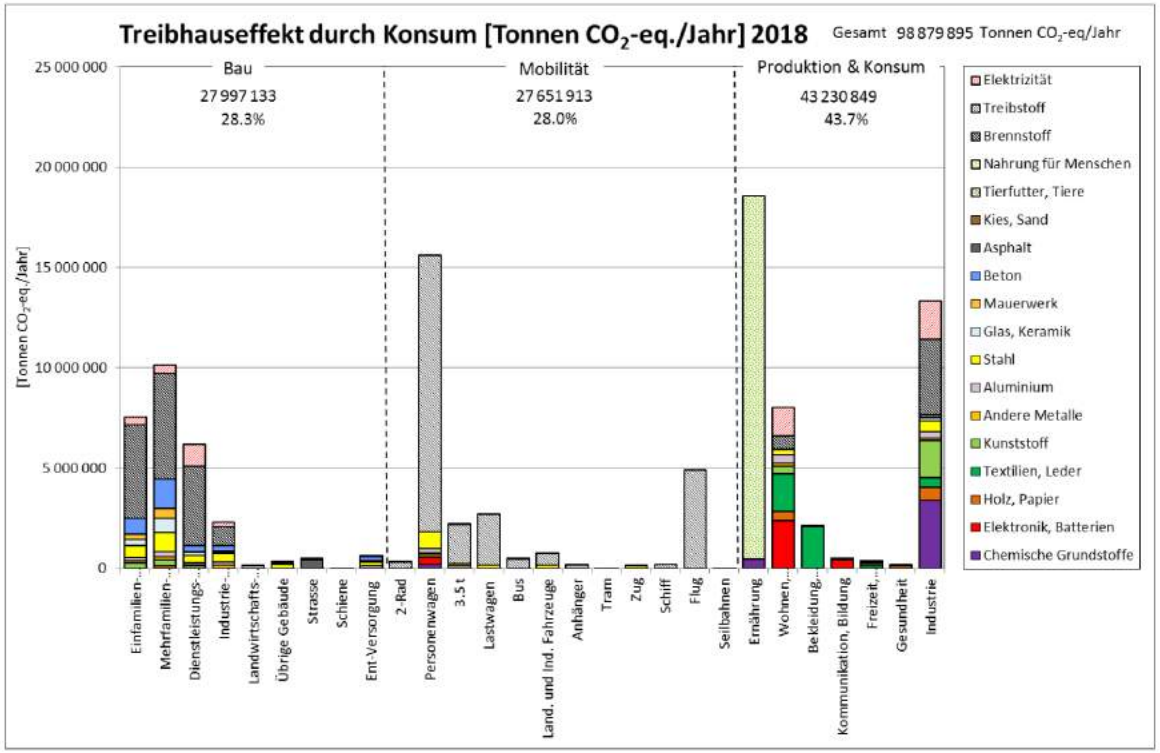
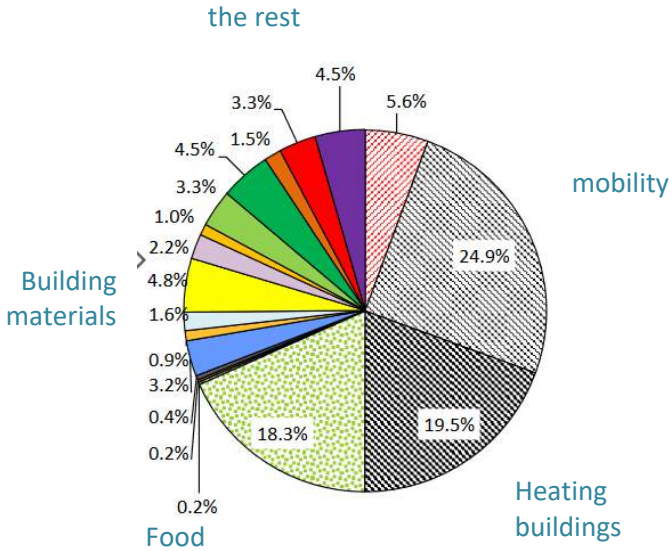
Atba architecture, Soubeyran

Forum Energie Zürich – 6.02.2024

Context





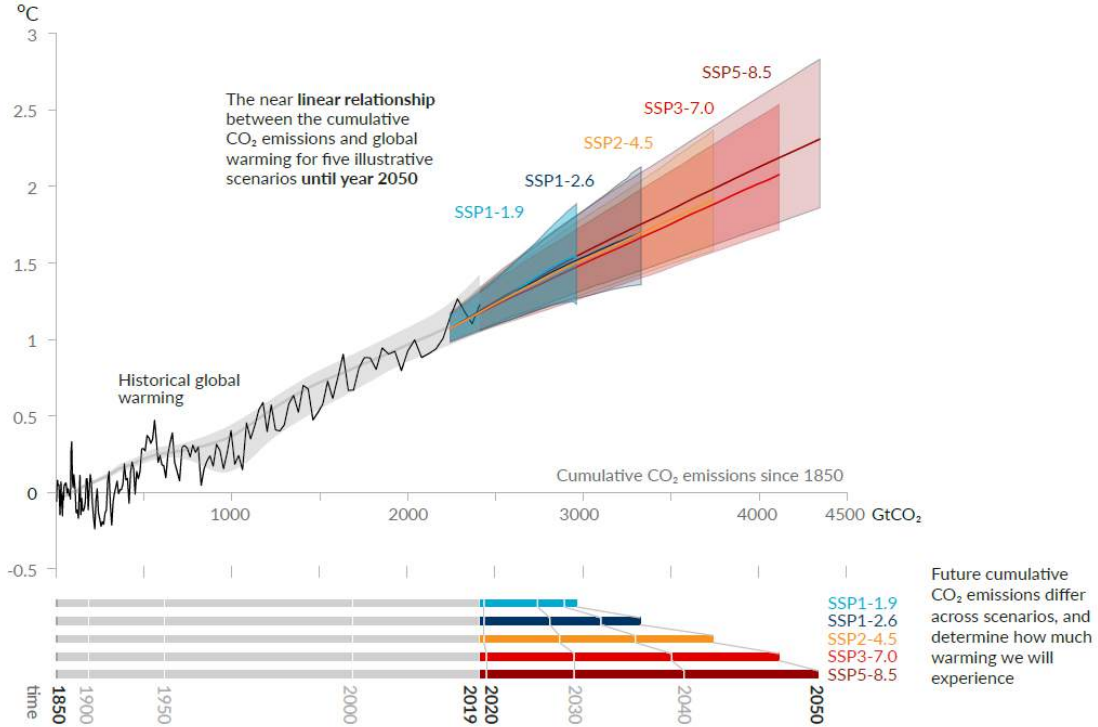
In Switzerland, around 20% emissions linked with building use and around 10% to building materials

Sce: EMPA. 2019. MatCH. Material- und Energieflüsse der schweizerischen Volkswirtschaft. *BAFU*

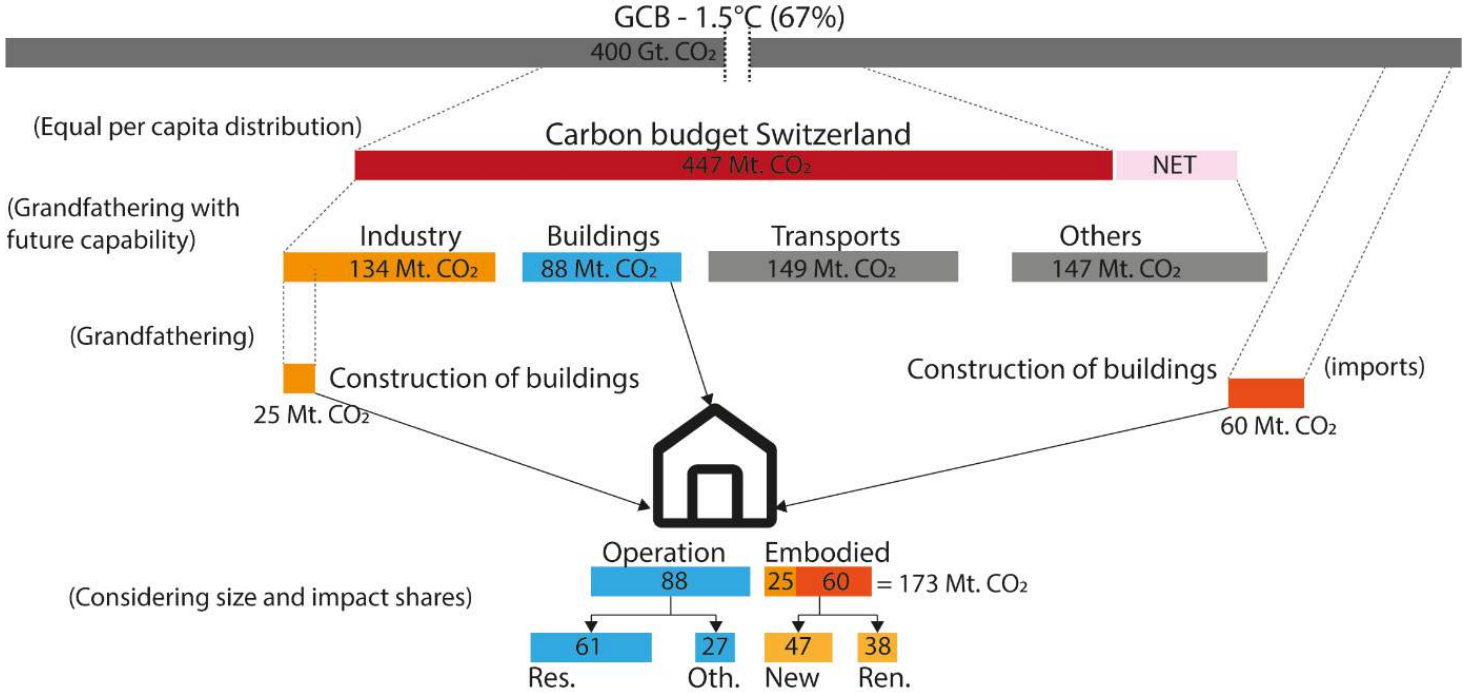
Climate change is very simple

CO_2 stays 10'000 years in the atmosphere and the global warming is linearly correlated with the CO_2 concentration in the atmosphere

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



Climate change is very simple
So we have a carbon budget



75% carbon budget for existing buildings *(operation emissions + embodied emissions for renovation)*

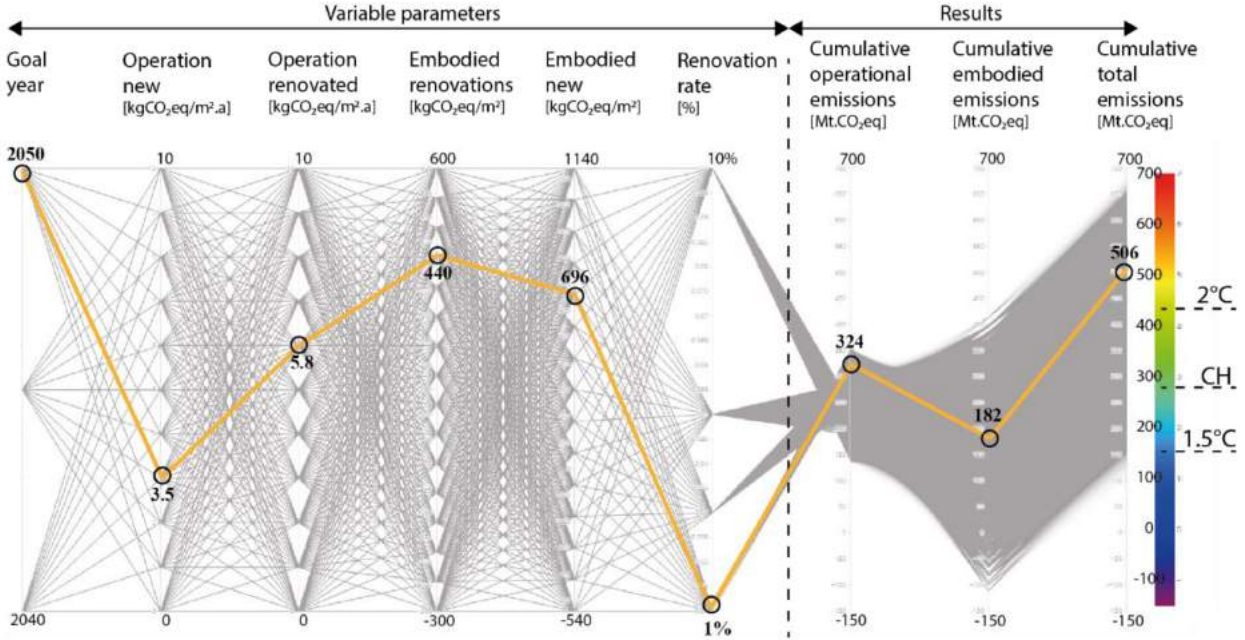
25% carbon budget for new construction *(embodied emission for construction + no emission during operation)*

Sce: Priore et al. 2023. Exploring the gap between carbon-budget-compatible buildings and existing solutions – A Swiss case study. *Energy and Buildings*

What should we do?

Current situation brings us way above 2°C

Kumulierte Emissionen von heute bis 2050 nach dem Szenario «Business as usual»

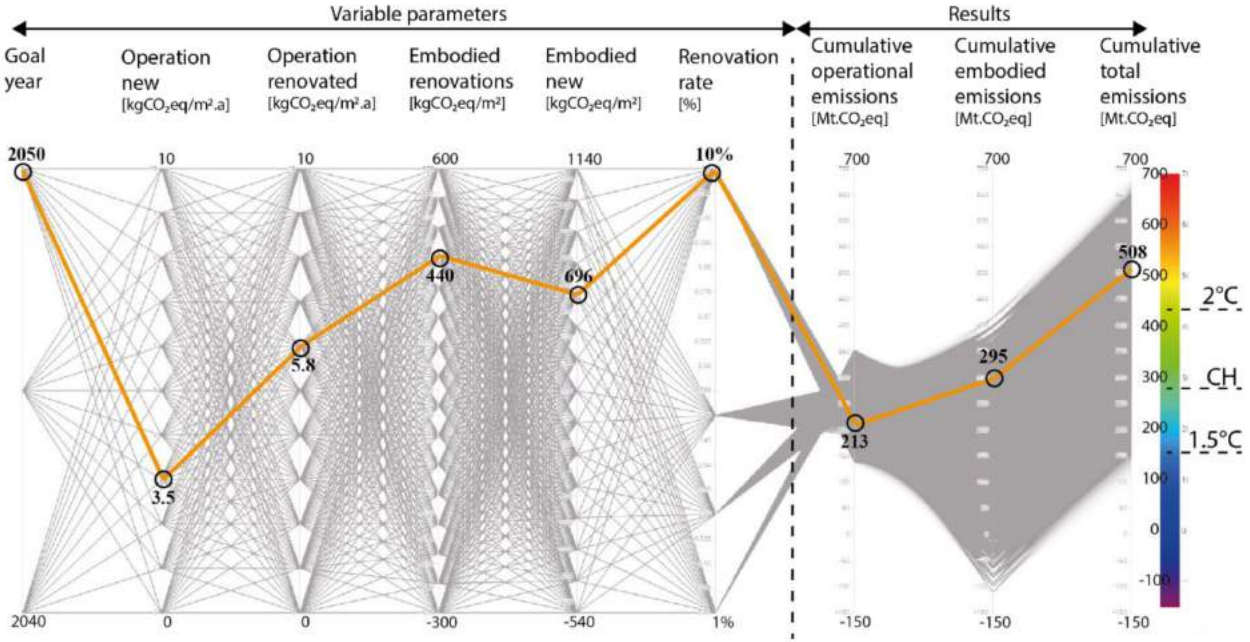


Sce: Priore et al. 2020. Exploring long-term building stock strategies in Switzerland in line with IPCC carbon budgets.
IOP Conf. Ser.: Earth Environ. Sci. 1078 012023

What should we do?

Increase renovation rate changes nothing!

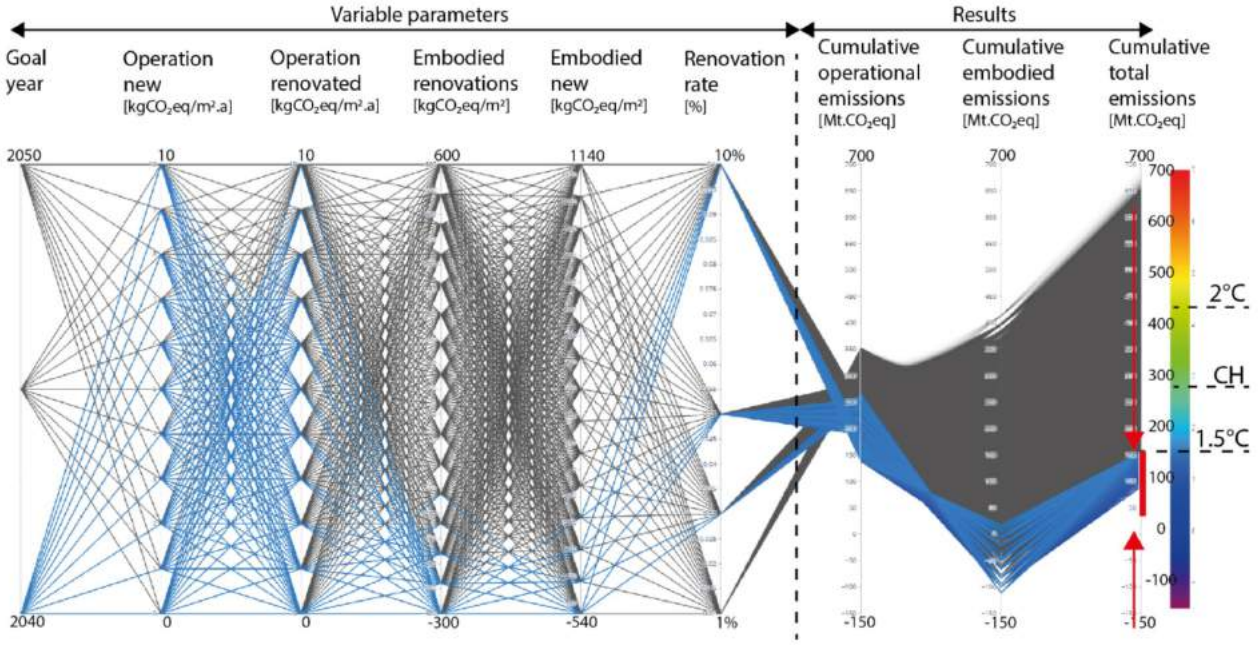
Kumulierte Emissionen von heute bis 2050 nach dem Szenario «Business as usual»



Sce: Priore et al. 2020. Exploring long-term building stock strategies in Switzerland in line with IPCC carbon budgets.
IOP Conf. Ser.: Earth Environ. Sci. 1078 012023

What should we do?

To stay below 1.5°C we have to control embodied emissions and build carbon negative buildings



	Goal year	Operation new	Operation ren	Embodied ren	Embodied new	Renovation rate
Max	2040	10	10	-120	-180	10%
Min	2040	0	0	-300	-540	3%

Sce: Priore et al. 2020. Exploring long-term building stock strategies in Switzerland in line with IPCC carbon budgets. IOP Conf. Ser.: Earth Environ. Sci. 1078 012023

What should we do?

To achieve Swiss strategy we have to control embodied emissions and always be below SIA 2040 targets

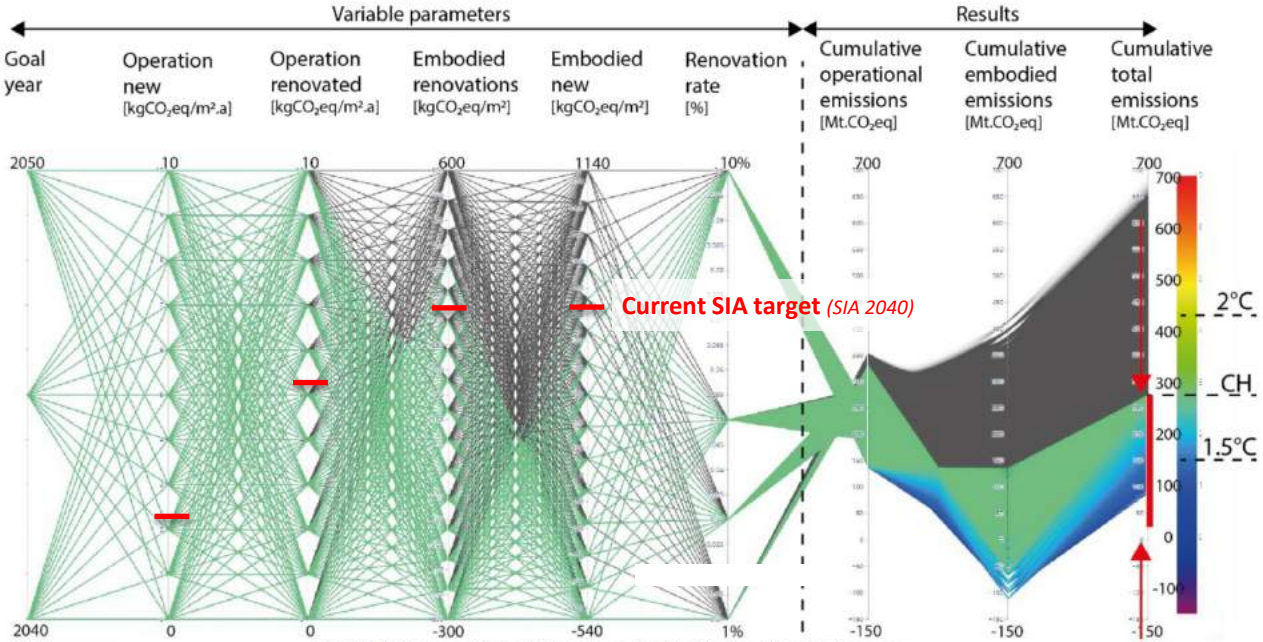


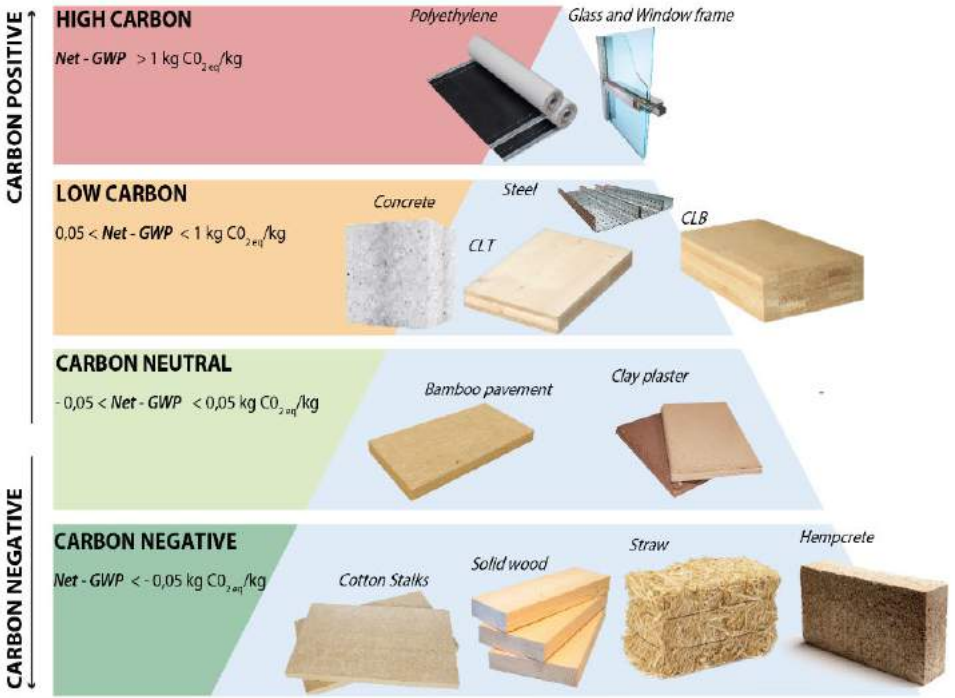
Table 5. Range of possible values for the Swiss climate strategy.

	Goal year	Operation new	Operation ren	Embodied ren	Embodied new	Renovation rate
Max	2050	10	10	420	780	10%
Min	2040	0	0	-300	-540	1%

Sce: Priore et al. 2020. Exploring long-term building stock strategies in Switzerland in line with IPCC carbon budgets. IOP Conf. Ser.: Earth Environ. Sci. 1078 012023

What should we do?

We need a new material diet



Opening & waterproofing

Structure

Interior & finishing

Insulation

Remark:
Earth structure allows carbon neutral structure…

Sce: Carcassi et al. 2022. Material diets for Climate-Neutral construction. *Environmental Science and Technologies*

Steel structure
Hempcrete as insulation

Social housing
37, rue Myrha, Paris
North by Northwest architectes

Timber structure
Strawbale as insulation

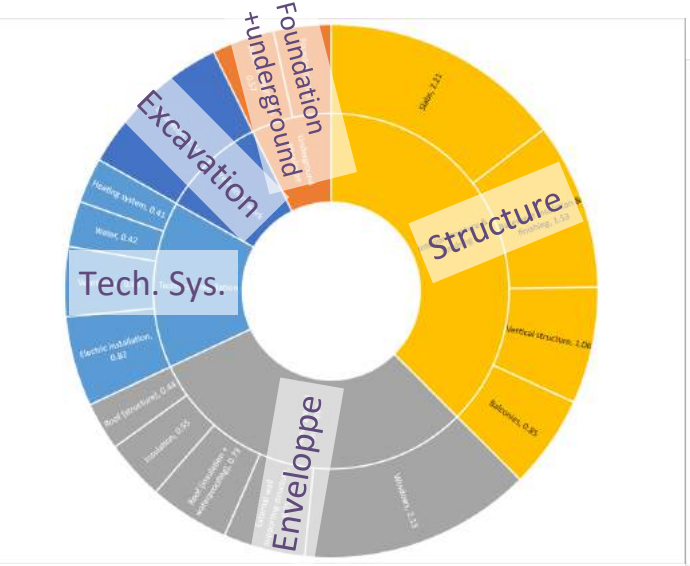
7 storey residential building
Saint-Dié-des-Vosges, France
Arch. ASP, Antoine Pagnoux

Concrete structure
Strawbale as insulation

5 storey residential building
Soubeyran, Geneva
Atba Architectes

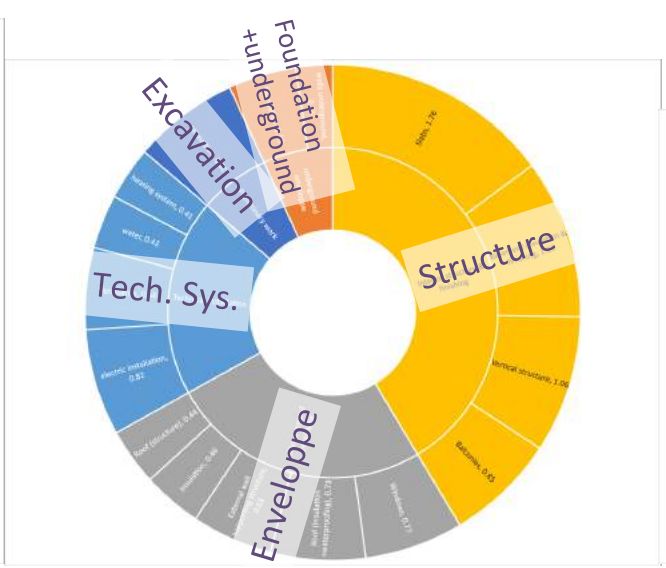
Pathway to net Zero new construction

Concrete building
4 storey, low compacity
Window wall ratio = 50%
2 underground floor



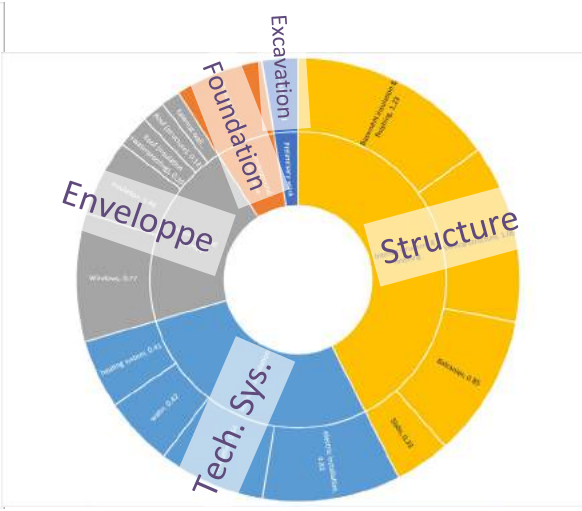
910 kg CO_2/m^2

Concrete building
4 storey, compact
Window wall ratio= 30%
1 underground floor



710 kg CO_2/m^2

Wood building
4 storey, compact
Window wall ratio= 30%
0 underground floor



495 kg CO_2/m^2

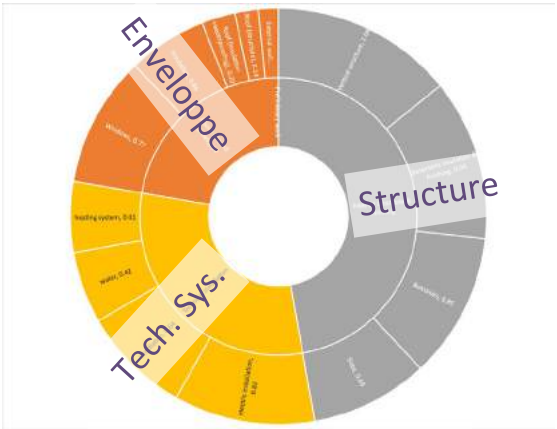
- 208 kg CO_2/m^2

Pathway to net Zero new construction

Wood building
4 storey, compact
Window wall ratio= 30%
0 underground floor

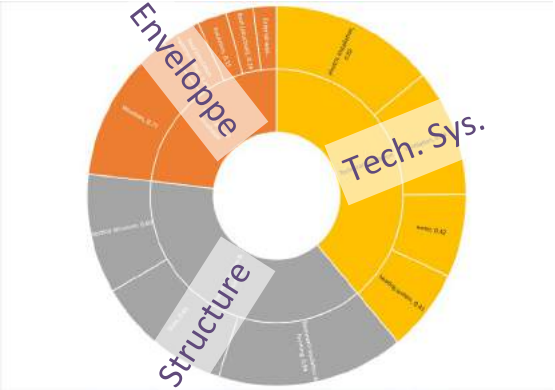
495 kg CO_2/m²
- 208 kg CO_2/m²

Wood building
4 storey, compact
Window wall ratio= 30%
0 underground floor
Light foundation



450 kg CO_2/m²
- 208 kg CO_2/m²

Wood building
4 storey, compact
Window wall ratio= 30%
0 underground floor / No concrete balconies
Light foundation
Straw insulation / indoor earth walls

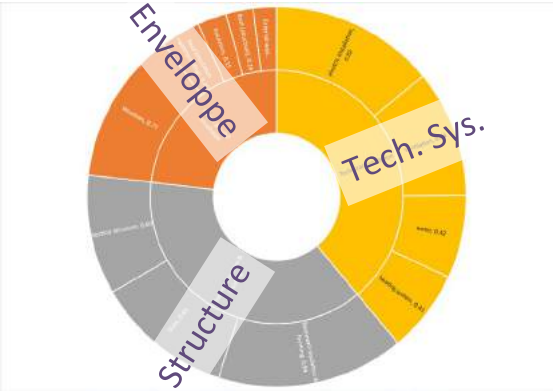


350 kg CO_2/m²
- 400 kg CO_2/m²

Pathway to net Zero new construction

Wood building
4 storey, compact
Window wall ratio= 30%
0 underground floor / No concrete balconies
Light foundation
Straw insulation / indoor earth walls

→ **Climate neutral building is possible right now!**



Ventilation: 40 kg CO_2/m^2
Reduced by considering moisture buffer capacity

Heating: 25 kg CO_2/m^2
Reduced with mass and high insulation (2226 concept)

Windows: 46 kg CO_2/m^2
Reused windows

FREO

2226 energy concept
Circular
& Biobased construction

350 kg CO_2/m^2
- 400 kg CO_2/m^2

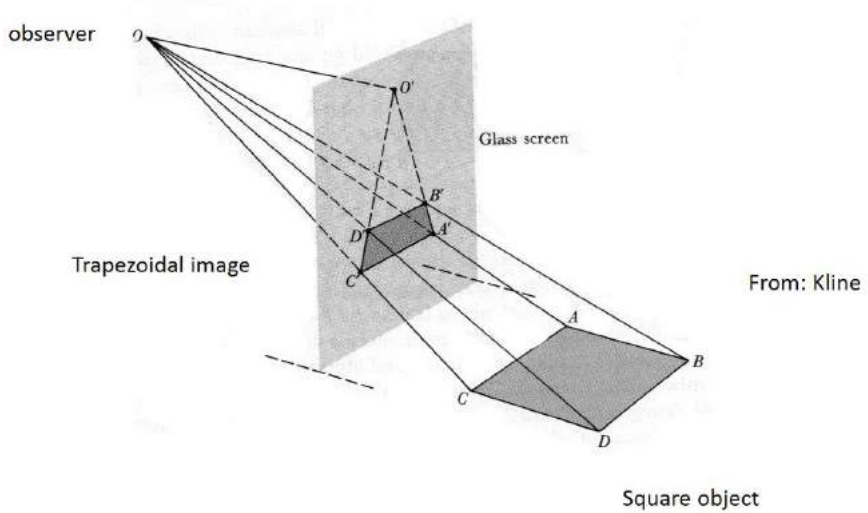
= - 160 kg CO_2/m^2

→ **1.5°C Climate compatible building is possible right now!**
but very ambitious

ETH zürich | Chair of Sustainable Construction
Prof. Dr. Guillaume Habert

Carbon storage calculation – a question of perspective

Depending on the perspective
Calculation choices are different..
All are right, they just don't represent the same view point



Carbon storage calculation – a question of perspective

Current understanding of the system

View point is one building life time

	Material	Building	Building stock
1 yr			
1 generation (50 yr)		✗	
1 era (200 yr)			
1 civilization (2'000 yr)			
1 CO_2 molecule in atmosphere (10'000 yr)	✗		

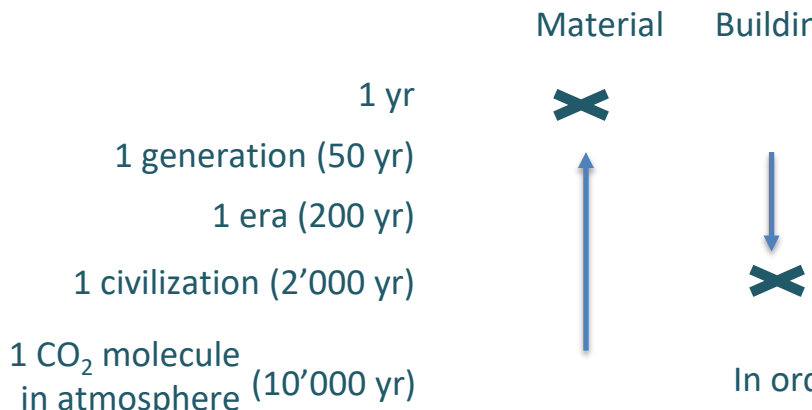
In order to store carbon out of atmosphere,
The material has to keep storing carbon after the end of life of building, otherwise carbon is released

→ No biogenic in calculation

Carbon storage calculation – a question of perspective

Carbon storage calculation – a question of perspective

Understanding of the system with civilization perspective *(long term future generation)*
View point is one civilization taking care of its «Baukultur»



In order to store carbon out of atmosphere,
The material is replaced, the building is maintained
And the amount of carbon stored in the building is kept out of atmosphere as long as building is maintained, although there is regular flow of material going out and going in the building…

→ Biogenic accounting in calculation

Carbon storage calculation – a question of perspective

Thinking building stock as forests…

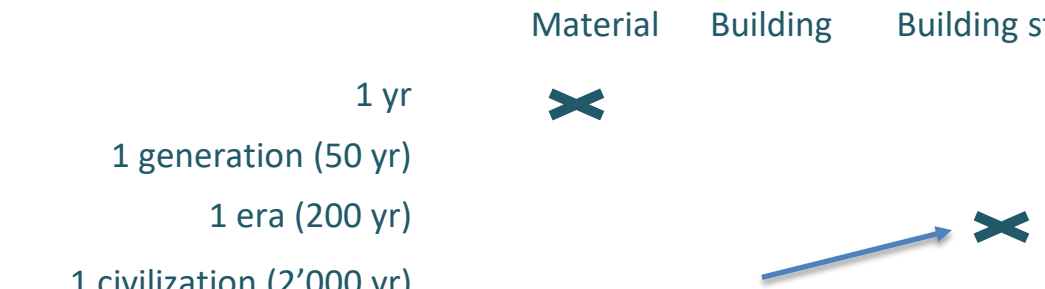
Do we ever look at life cycle of one tree to calculate carbon storage of a forest?

A building is like a tree and what's important is how many biobased buildings we have in the building stock

Carbon storage calculation – a question of perspective

Understanding of the system with current society perspective

View point is city/national level, political bodies managing building stock

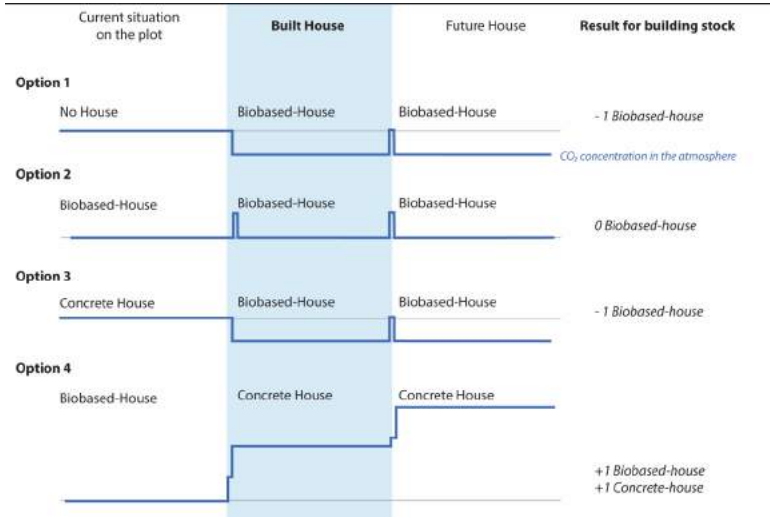


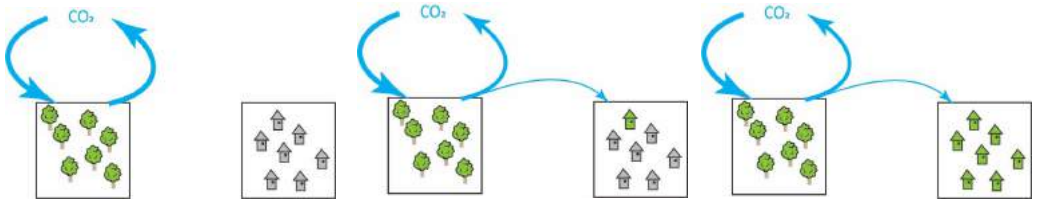
In order to store carbon out of atmosphere,
The material is replaced, the building is replaced, what is fundamental is that the total amount of carbon in the built environment keep increasing

It can be by maintaining a building or replacing one mineral building with a biobased one, or by adding more biobased insulation to an existing building.. Many possibilities as long as total amount of biogenic carbon is maintained and even better increased at city/national level

Carbon storage calculation – a question of perspective

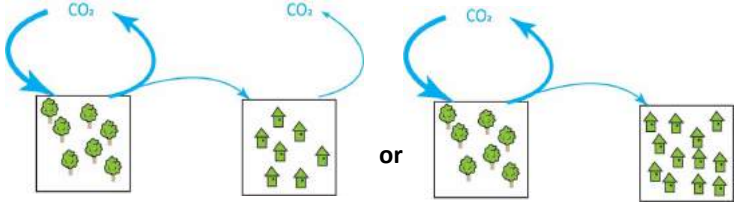
Thinking building stock as forests and building like a tree..
what's important is how many biobased buildings we have in the building stock





Time 1 **Time 2** **Time 3**

Time 1 to 3: biogenic carbon in building stock increases



Time 4

Time 4: Equilibrium of carbon stock in building stock
(new buildings replace old buildings) or building stock keeps increasing

Biobased – resource availability discussion?

Biobased – resource availability discussion?

There is extra straw available

(currently favoured use in agriculture and energy sector)

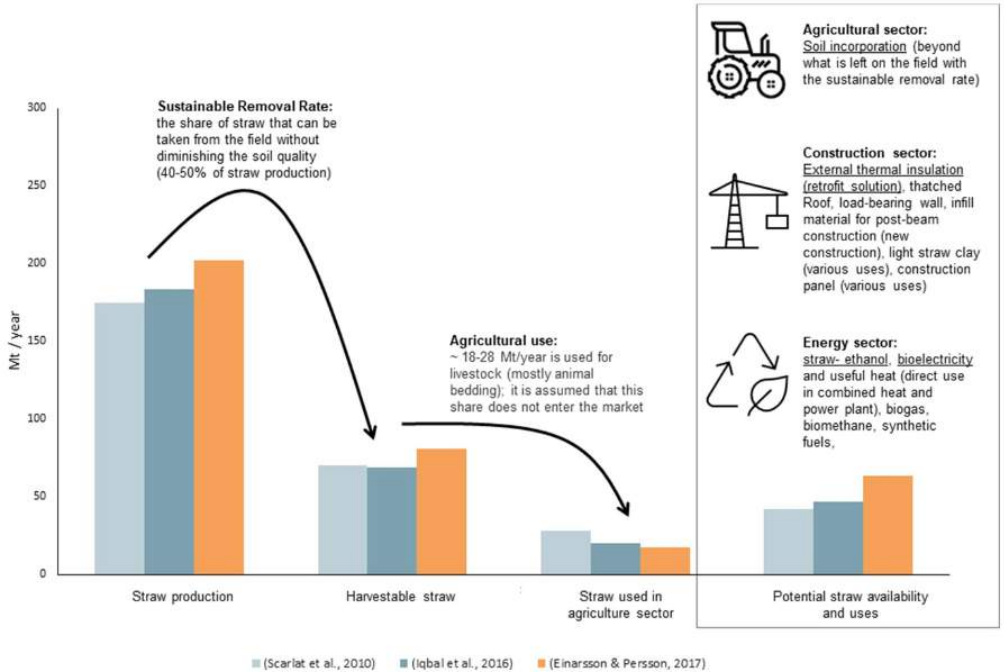
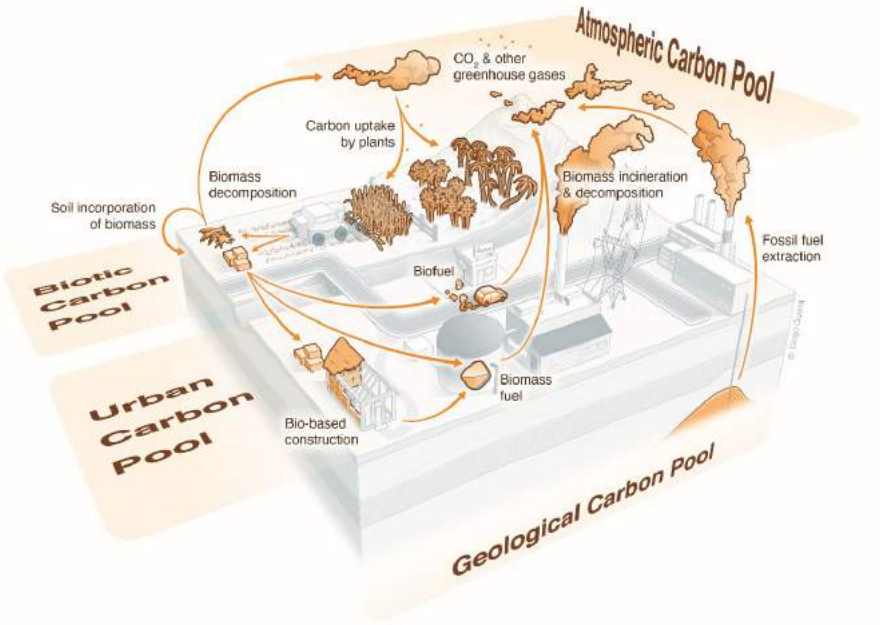


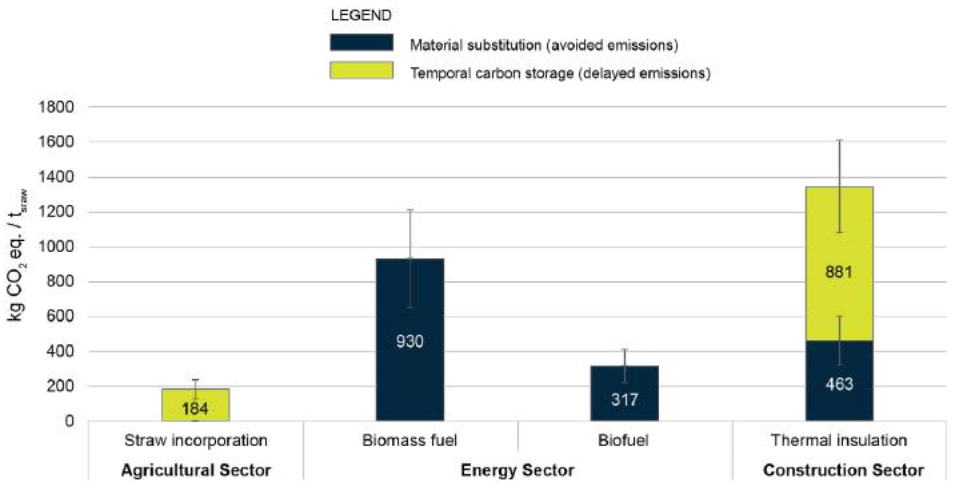
Figure 1. Straw availability in the EU based on different studies.
Notes: Values are taken from Einarsson and Persson (2017), Iqbal et al (2016), and Scarlat et al (2010). Only straw from wheat, barley, rye and oats are considered, in the EU-27 (2010 composition), to ensure comparability between studies. The underlined straw uses in the right box are analyzed in this study.

Sce: Phan-huy et al. 2023. Climate-effective use of straw in the EU bioeconomy—comparing avoided and delayed emissions in the agricultural, energy and construction sectors. *Environmental Research Letters*

Biobased – resource availability discussion?

A switch to biobased insulation
is the most efficient way of valorizing agriculture waste
(compared to use in agriculure or energy sectors)

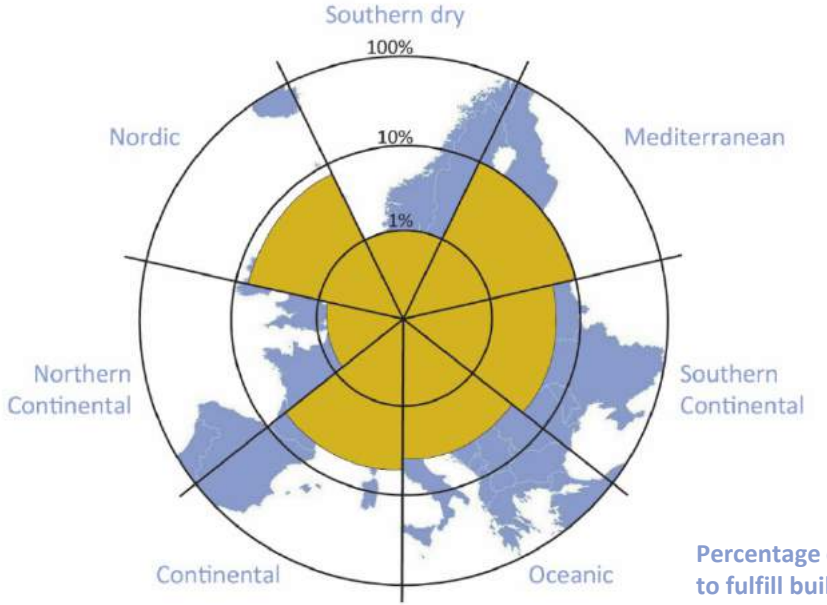




Sce: Phan-huy et al. 2023. Climate-effective use of straw in the EU bioeconomy - Comparing avoided and delayed emissions in the agricultural, energy and construction sectors. *Environment Research Letters*

Biobased – resource availability discussion?

There is enough straw in all european regions to renovate the existing building stock and build the new buildings to fulfil housing demand



Percentage of land supply required to fulfill building insulation demand
(Ecosystem needs already withdrawn)

Sce: Göswein et al. 2021. Land availability in Europe for a radical shift toward bio-based construction. *Sustainable Cities and Society*

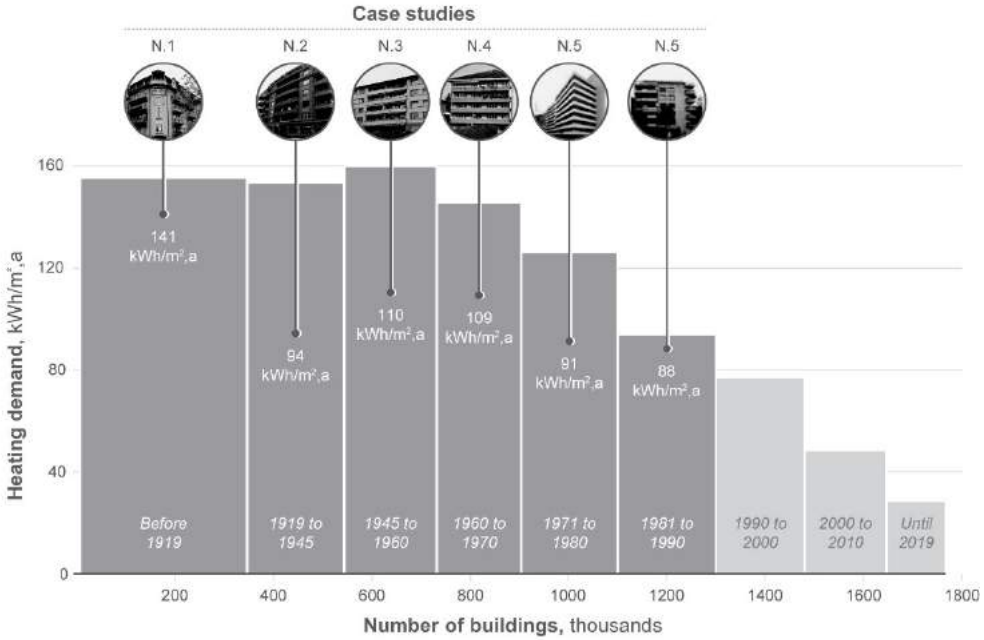
Biobased – resource availability discussion?

Thank you

Prof. Dr. Guillaume Habert
habertg@ethz.ch

Maison Feuillette, Strawbale house, built 1920

Robust renovation

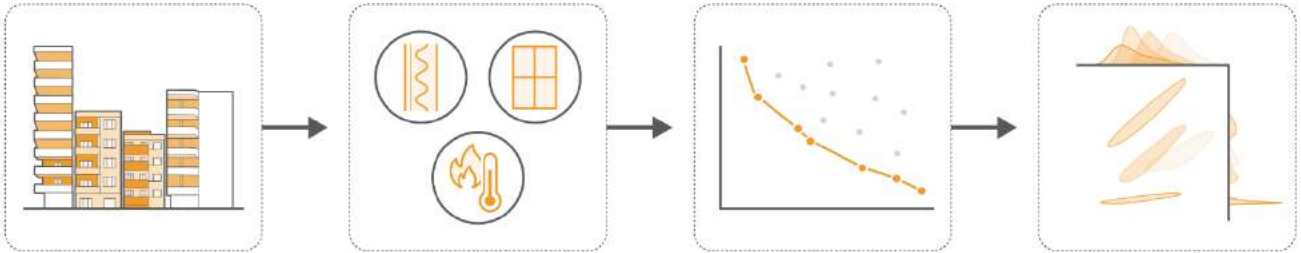


In Switzerland:

Building stock mainly composed of energy inefficient buildings.

Renovation rate in Switzerland is small (0.8-1.8%)

Robust renovation



Possible solutions:

- Thermal envelope renovation (insulation, windows)
- Heating system replacement
  - Gas boiler
  - Wood pellets boiler
  - Heat pump

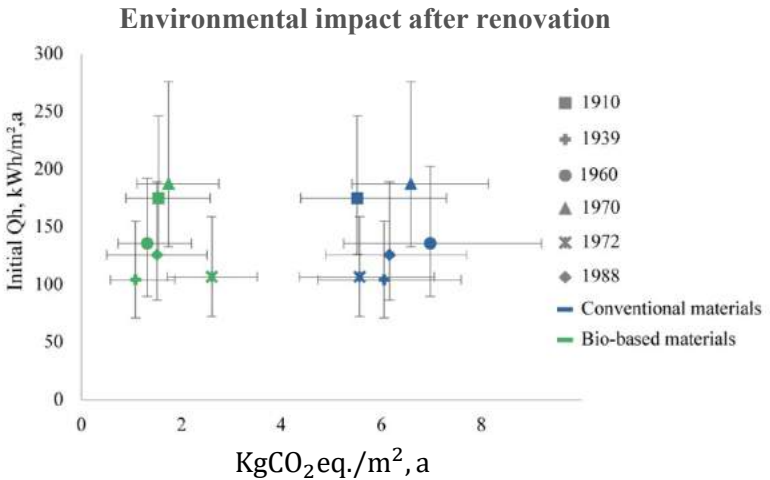
Uncertainties on future

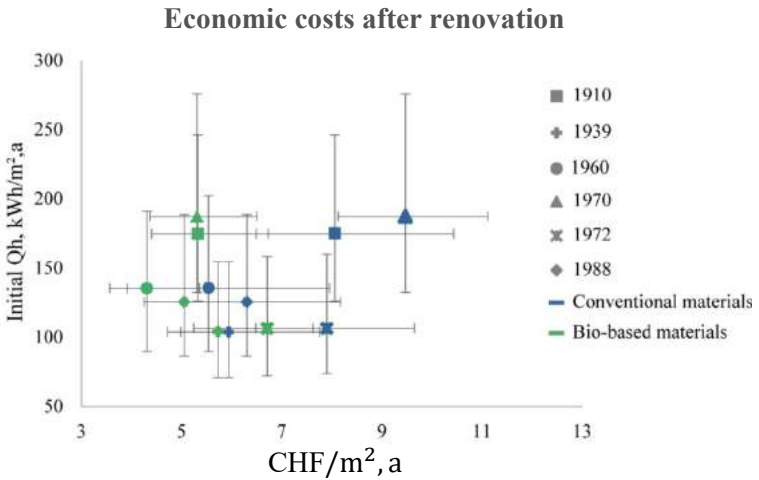
- Climate, material service life, energy mix, occupancy behaviour, inflation rate, energy prices

Sce: Alina Galimshina. 2022. ETH PhD

Robust renovation

Results – Conventional renovation solution



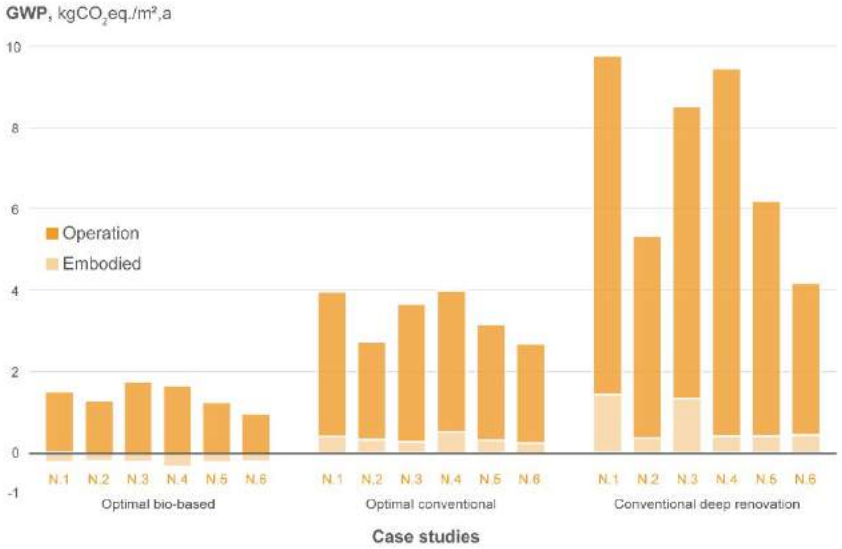


Wichtigste Ergebnisse:

Für alle Gebäude, die für den Schweizer Gebäudepark repräsentativ sind,
bedeutet die Benutzung von Dämmstoffen auf Biobasis eine deutlich geringere Umweltbelastung
ohne signifikant höhere Lebenszykluskosten.

Sce: Galimshina et al. 2024. Strategies for robust renovation of Swiss residential buildings. *Nature communications*

Robust renovation



Summary

1) Lowest LCC and carbon footprint for optimal biobased (high amount of biobased insulation + change heating system)
2) Worst option (both economic and environment) is conventional deep renovation of enveloppe (high amount of insulation, no heating change)
3) Lowest initial investment but not best carbon footprint is optimal conventional (small amount of fossil based insulation + change heating systems)

Sce: Galimshina et al. 2024. Strategies for robust renovation of Swiss residential buildings. *Nature communications*