ETH zürich

# Materialdiät

*Gründe für den Baustoff Lehm in der Bauwende*

*Prof. Dr. Guillaume Habert*

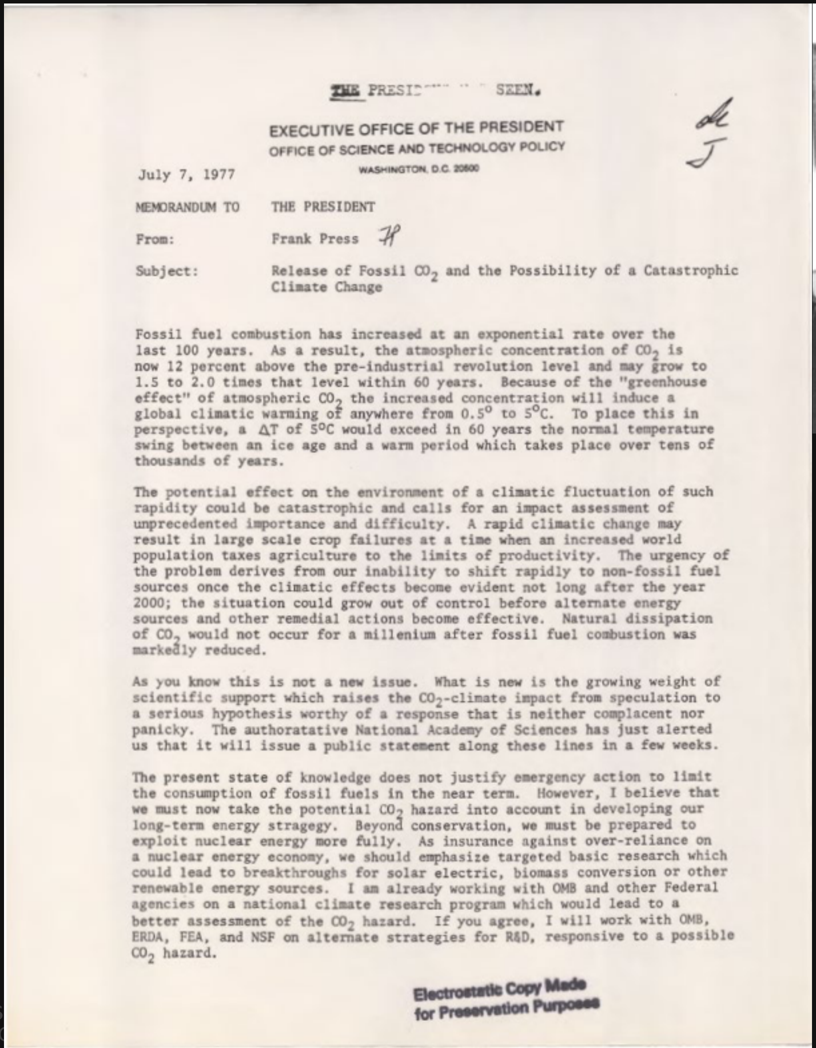
Amàco – tour de briques

# Reasons to build with clay…

1. Carbon and circularity

# So they knew…

1977



THE PRESI[illegible] SEEN.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

July 7, 1977

MEMORANDUM TO THE PRESIDENT

From: Frank Press

Subject: Release of Fossil $CO_2$ and the Possibility of a Catastrophic Climate Change

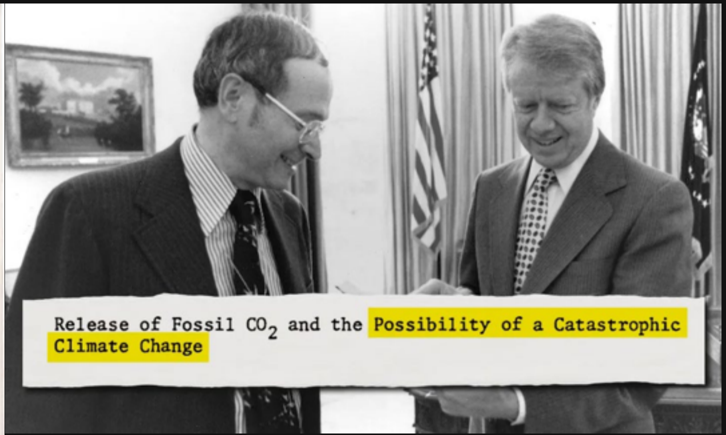
Fossil fuel combustion has increased at an exponential rate over the last 100 years. As a result, the atmospheric concentration of $CO_2$ is now 12 percent above the pre-industrial revolution level and may grow to 1.5 to 2.0 times that level within 60 years. Because of the "greenhouse effect" of atmospheric $CO_2$ the increased concentration will induce a global climatic warming of anywhere from 0.5° to 5°C. To place this in perspective, a $\Delta T$ of 5°C would exceed in 60 years the normal temperature swing between an ice age and a warm period which takes place over tens of thousands of years.

The potential effect on the environment of a climatic fluctuation of such rapidity could be catastrophic and calls for an impact assessment of unprecedented importance and difficulty. A rapid climatic change may result in large scale crop failures at a time when an increased world population taxes agriculture to the limits of productivity. The urgency of the problem derives from our inability to shift rapidly to non-fossil fuel sources once the climatic effects become evident not long after the year 2000; the situation could grow out of control before alternate energy sources and other remedial actions become effective. Natural dissipation of $CO_2$ would not occur for a millenium after fossil fuel combustion was markedly reduced.

As you know this is not a new issue. What is new is the growing weight of scientific support which raises the $CO_2$-climate impact from speculation to a serious hypothesis worthy of a response that is neither complacent nor panicky. The authoratative National Academy of Sciences has just alerted us that it will issue a public statement along these lines in a few weeks.

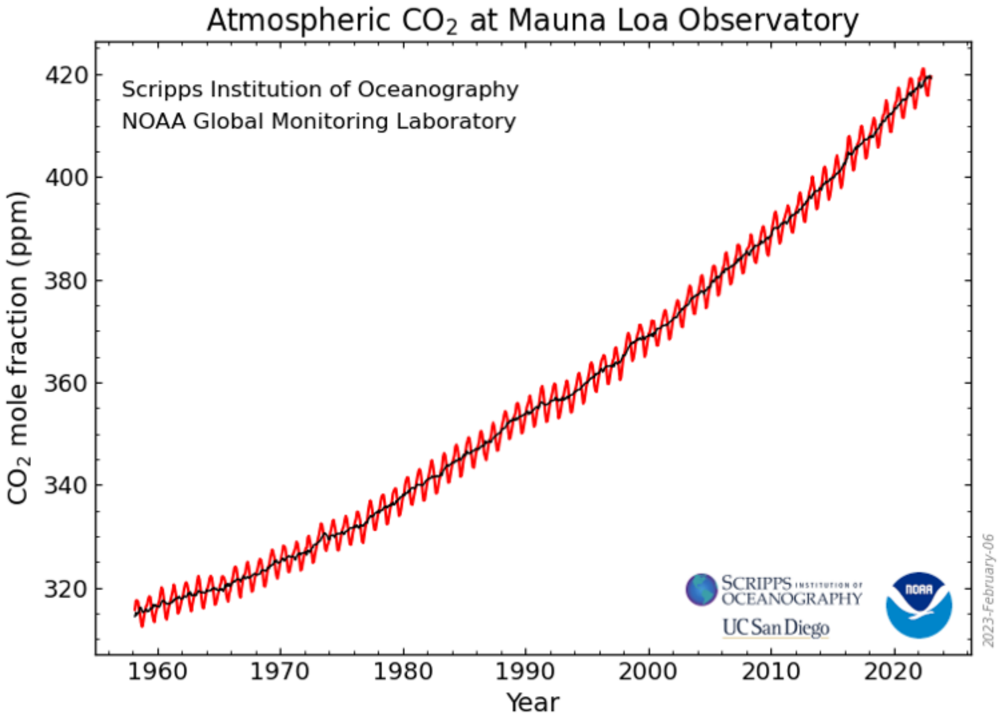
The present state of knowledge does not justify emergency action to limit the consumption of fossil fuels in the near term. However, I believe that we must now take the potential $CO_2$ hazard into account in developing our long-term energy stragegy. Beyond conservation, we must be prepared to exploit nuclear energy more fully. As insurance against over-reliance on a nuclear energy economy, we should emphasize targeted basic research which could lead to breakthroughs for solar electric, biomass conversion or other renewable energy sources. I am already working with OMB and other Federal agencies on a national climate research program which would lead to a better assessment of the $CO_2$ hazard. If you agree, I will work with OMB, ERDA, FEA, and NSF on alternate strategies for R&D, responsive to a possible $CO_2$ hazard.

Electrostatic Copy Made
for Preservation Purposes




Frank Press with President Jimmy Carter.
Press wrote a letter to Carter warning of $CO_2$ emissions causing 'catastrophic climate change'.
Photograph: Emilio Segrè Visual Archives

# Climate change is here today




**2023 February 20: 420.58 ppm**

**2022 February 22: 419.26 ppm**

**2021 February 23: 416.33 ppm**

**2020 February 21: 414.36 ppm**

**2019 February 18: 411.86 ppm**

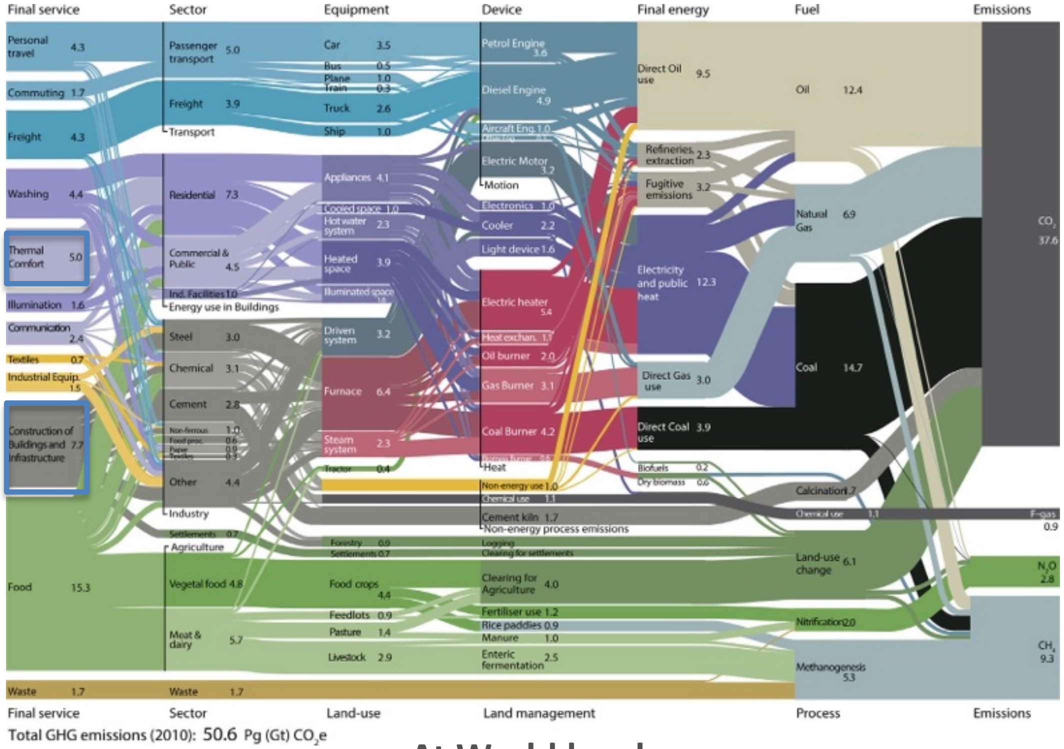
**2018 February 21: 408.53 ppm**

*born under 333 ppm*

**1.5°C scenario: 425 ppm**

**2°C scenario: 475 ppm**

# Who's responsible of emissions




## At World level:

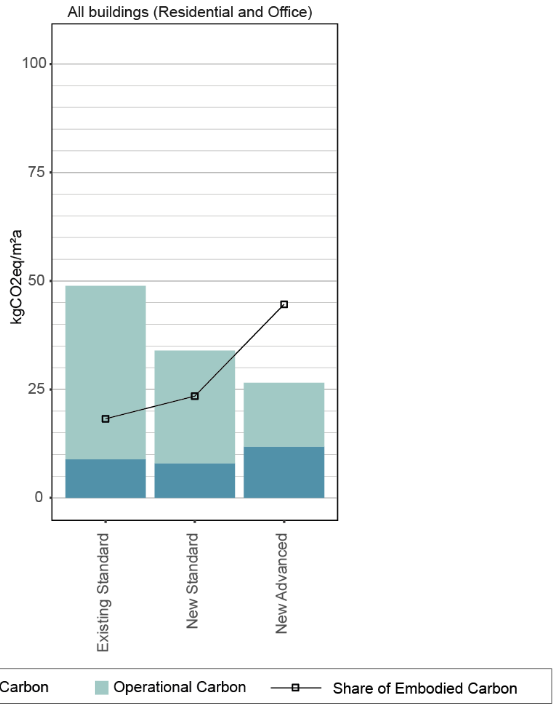
## GHG emissions from construction more important than emissions from building heating

*Construction in Global South & heating in Global North*

Sce: Bajželj et al. 2013. Designing Climate Change Mitigation Plans That Add Up. *Environmental Science & Technology.* DOI: 10.1021/es400399h

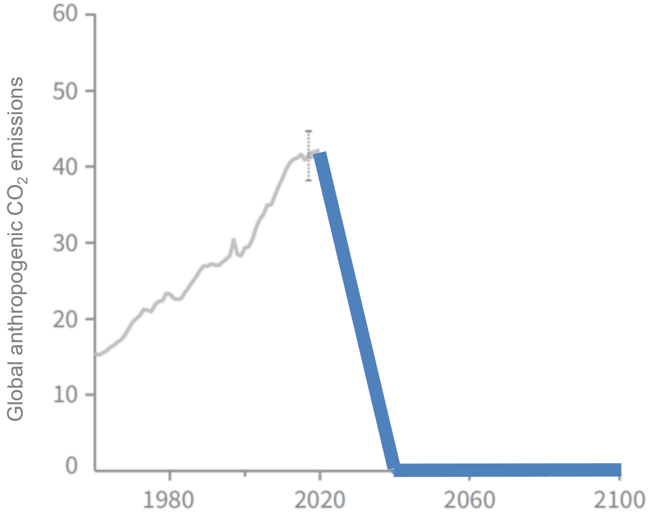
# Materials matter

## We have made progress for heating buildings
## We made NO significant progress for building them



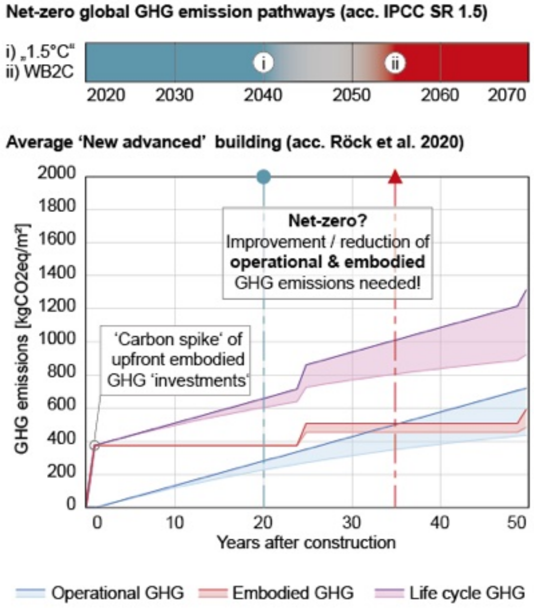

Sce: Röck et al. 2019. Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied energy*.

# A radical transition is needed: $CO_2$ emissions have to be reduced by 50% in the next 10 years and reach net Zero in 2040




Sce: IPCC. 2019. 1.5°C report

# Embodied emissions are released mainly in year one
# While operation emissions are released all along the life cycle




IPCC SR 1.5 net-zero GHG emissions pathways in relation to the temporal distribution of GHG emissions across the life cycle of an average 'New Advanced' building [Röck et al. 2020, Fig. 6 (c)].

**The carbon spike related with construction dominate the time period where action is required for climate mitigation...**

**Whatever the energy efficiency of the new building**

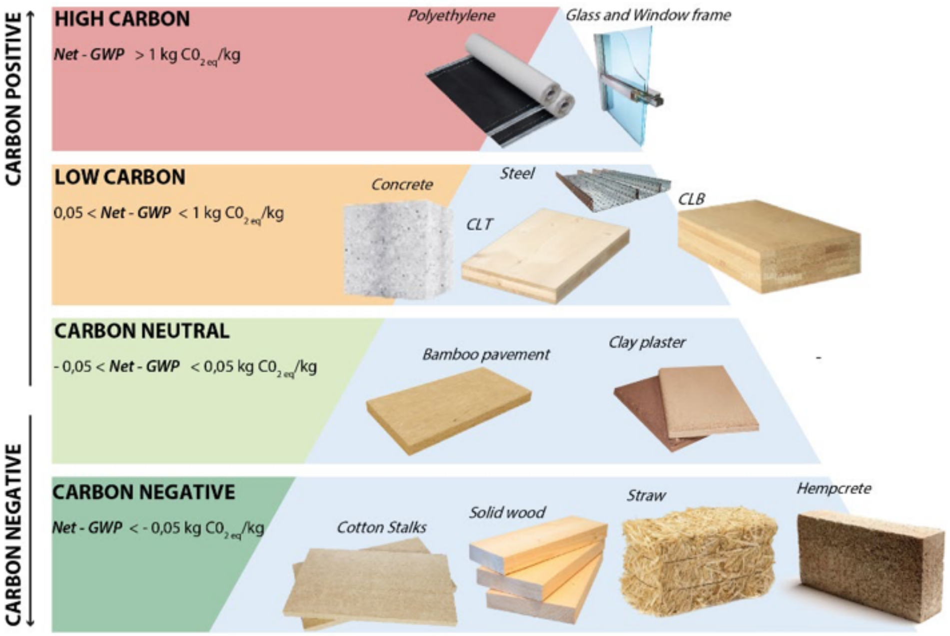
Sce: Röck et al. 2019. Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied energy*.

## It's possible to build climate neutral buildings

## We just have to change our material diet

*Less carbon intensive material, more vegetables..*

**Lehm**
**= Carbon neutral,**
**For indoor walls and finishing**
**+ Structure**




Openings
waterproofing

Structure

Interiors
& finishings

Insulation

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

# Carbon neutral vs climate neutral

| | FU | Mass of straw to compensate one FU | Mass of Solid softwood to compensate one FU | Mass of Solid hardwood to compensate one FU | Equivalent transport distance |
|---|---|---|---|---|---|
| **Concrete C30/37** | *kg* | 0.13 | 0.29 | 0.77 | 561 |
| **Concrete C25/30** | *kg* | 0.08 | 0.18 | 0.48 | 350 |
| **Steel reinforcement** | *kg* | 0.87 | 1.97 | 5.17 | 3,789 |
| **Reinforced concrete (slab)** | *kg* | 0.15 | 0.34 | 0.89 | 655 |
| **Waterproof membrane (PE)** | *kg* | 6.93 | 15.65 | 41.06 | 30,111 |
| **Mineral plaster** | *kg* | 0.34 | 0.76 | 2.00 | 1,467 |
| **Gypsum plasterboard** | *kg* | 0.36 | 0.82 | 2.16 | 1,582 |
| **EPS** | *kg* | 18.55 | 41.86 | 109.84 | 80,556 |
| **OSB** | *kg* | 0.18 | 0.41 | 1.06 | 779 |
| **PVC frame + Triple glazing** | $m^2$ | 145.39 | 328.09 | 860.81 | 12,627 |
| **Wood Aluminium frame + triple glazing** | $m^2$ | 129.24 | 291.65 | 765.21 | 10,793 |
| **PVC frame + double glazing** | $m^2$ | 111.03 | 250.56 | 657.38 | 12,053 |
| **Wood Aluminium frame + double glazing** | $m^2$ | 94.88 | 214.12 | 561.78 | 9,810 |
| **Rammed earth / earth plaster** | *kg* | 0.03 | 0.06 | 0.15 | 111 |

| | | | | | |
|---|---|---|---|---|---|
| **Gravel** | **kg** | 0.02 | 0.04 | 0.10 | 72 |
| **Regular Cement (CEM II A/LL)** | **kg** | 0.90 | 2.02 | 5.30 | 3,889 |
| **Low carbon cement (LC3)** | **kg** | 0.38 | 0.87 | 2.27 | 1,667 |

# Carbon neutral vs climate neutral

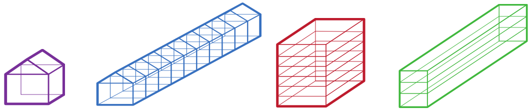
| | FU | Volume of straw to compensate one FU | Volume of Solid softwood to compensate one FU | Volume of Solid hardwood to compensate one FU |
|---|---|---|---|---|
| **Concrete C30/37** | $m^3$ | 1.38 | 1.38 | 2.50 |
| **Concrete C25/30** | $m^3$ | 0.86 | 0.86 | 1.56 |
| **Steel reinforcement** | $m^3$ | 31.86 | 31.87 | 57.52 |
| **Reinforced concrete (slab)** | $m^3$ | 1.65 | 1.65 | 2.98 |
| **Waterproof membrane (PE)** | $m^3$ | 32.25 | 32.26 | 58.24 |
| **Mineral plaster** | $m^3$ | 1.73 | 1.73 | 3.12 |
| **Gypsum plasterboard** | $m^3$ | 1.44 | 1.44 | 2.60 |
| **XPS** | $m^3$ | 3.02 | 3.02 | 5.45 |
| **OSB** | $m^3$ | 0.51 | 0.51 | 0.91 |
| **PVC frame + Triple glazing** | $m^2$ | 0.68 | 0.68 | 1.22 |
| **Wood Aluminium frame + triple glazing** | $m^2$ | 0.60 | 0.60 | 1.09 |
| **PVC frame + double glazing** | $m^2$ | 0.52 | 0.52 | 0.93 |
| **Wood Aluminium frame + double glazing** | $m^2$ | 0.44 | 0.44 | 0.80 |
| **Rammed earth / earth plaster** | $m^3$ | 0.27 | 0.27 | 0.49 |

## It's possible to build climate neutral buildings

## We just have to change our material diet

*Less carbon intensive material, more vegetables..*

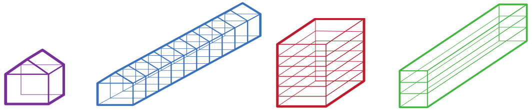
= Climate neutral building



optimised
Reinforced concrete

+ 50 - 100 cm
Straw walls

= Climate neutral building

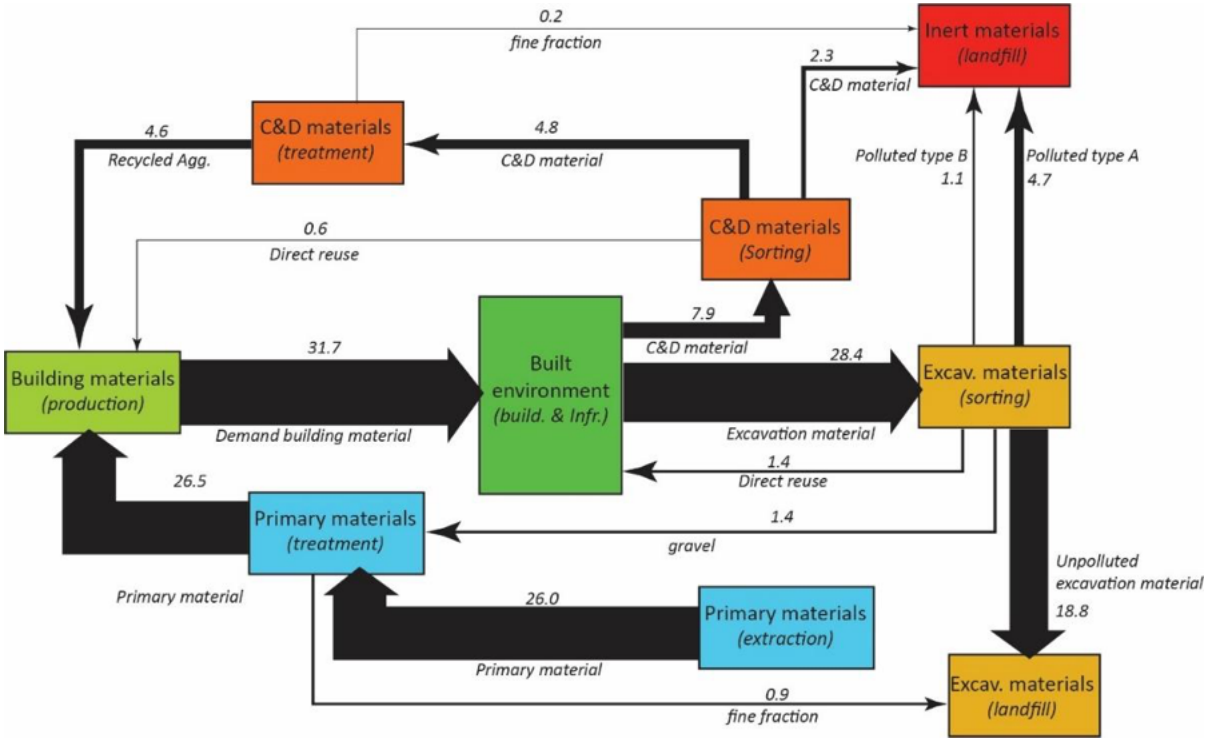


Timber
structure

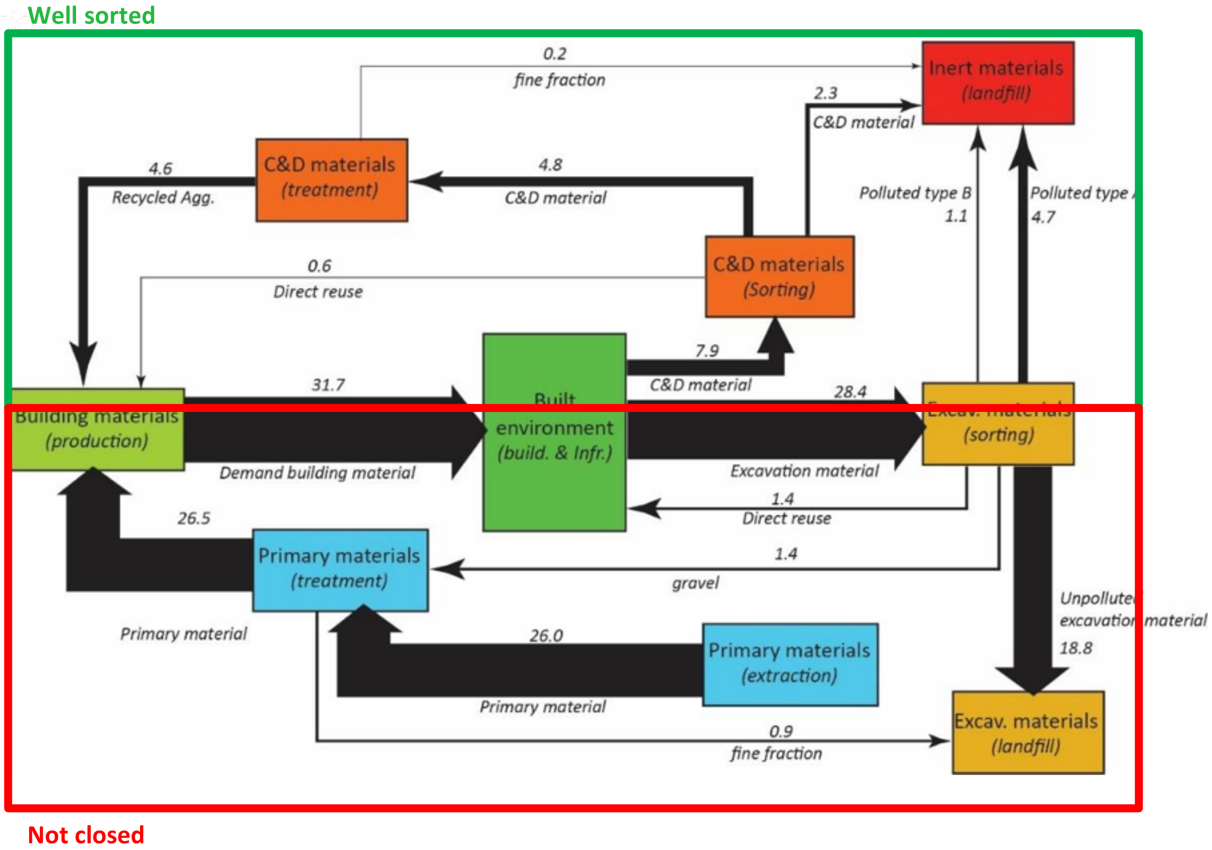
+ 30 - 60 cm
Straw walls

Adapted from: Carcassi et al., 2022. Material diets for Climate-Neutral construction. *Environmental Science and technology*

## Earth is carbon neutral construction & Circular



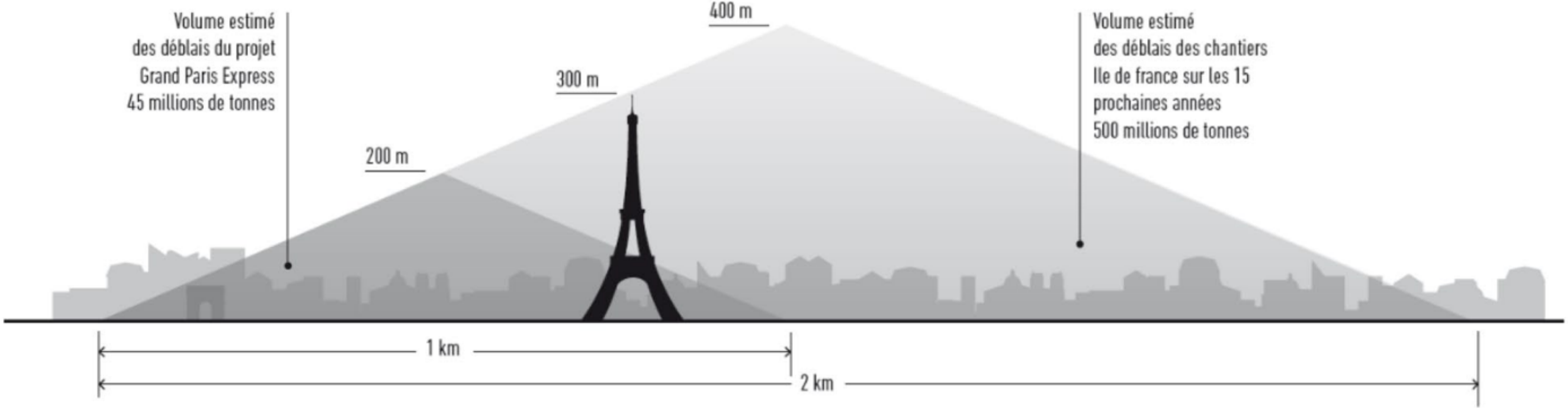

Sce: Das KAR-Modell für die Schweiz. CH2018
www.kar-modell.ch




Sce: Das KAR-Modell für die Schweiz. CH2018
www.kar-modell.ch

# To close material loop, we need to use excavation materials in construction

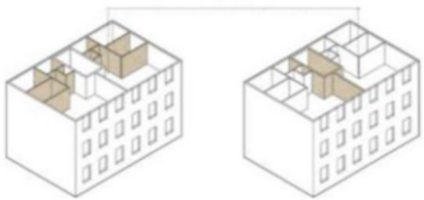
# To close material loop, we need to use excavation materials in construction

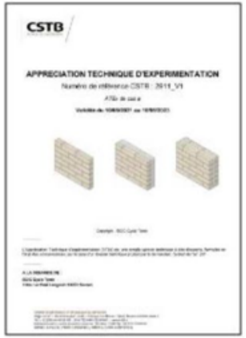


## To close material loop, we need to use excavation materials in construction

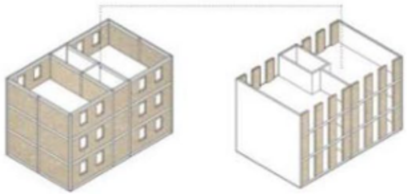
# Trois ATEx obtenus

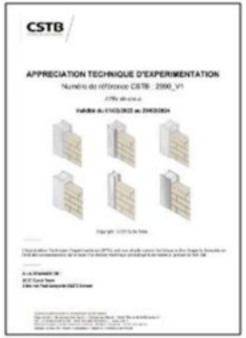
En cloison distributives ou séparatives



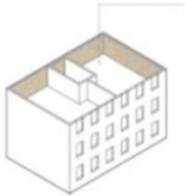


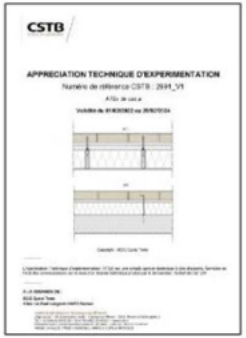

En remplissage d'ossature avec ITE et bardage



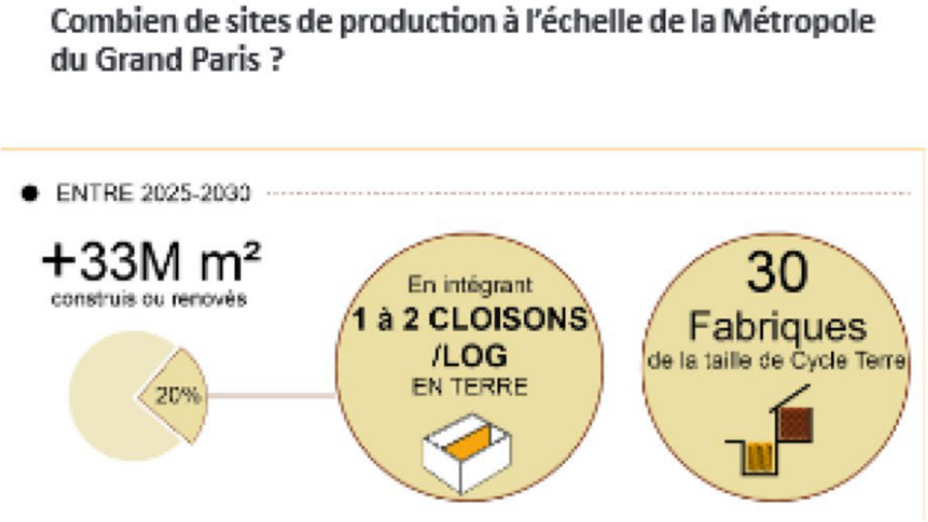



En parement intérieur





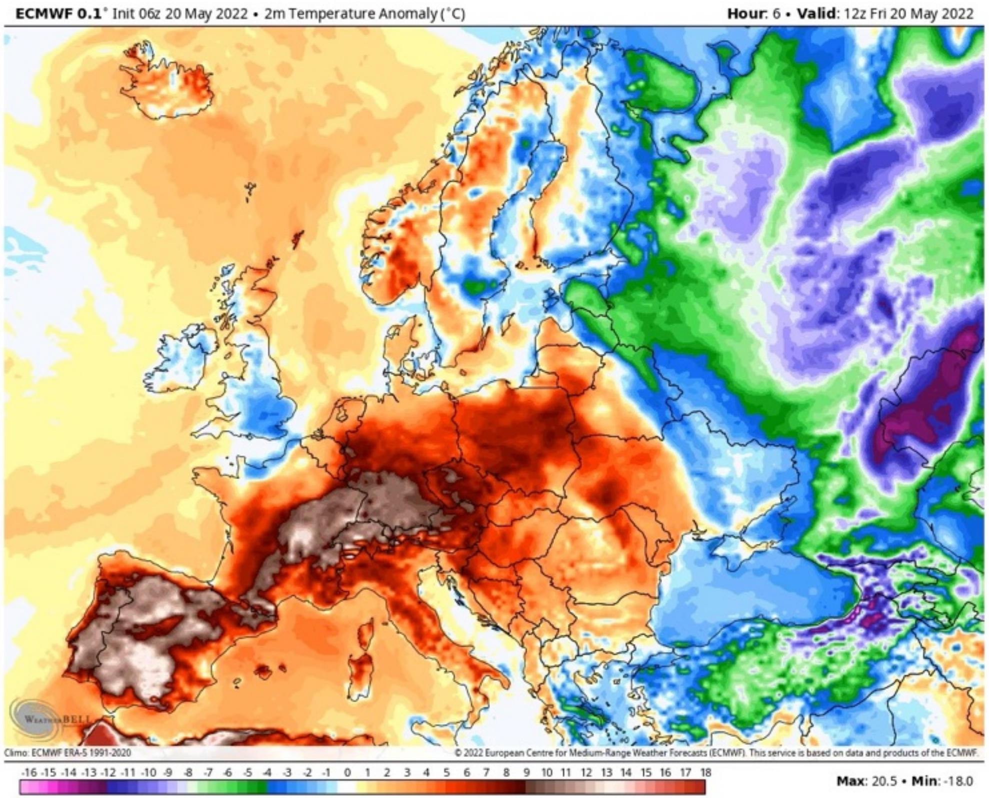
# To close material loop, we need to use excavation materials in construction




## Reasons to build with clay…

1. Carbon and circularity
2. Health

# With climate change, extreme events (hot, cold, wind, rain..) will become more regular



# With climate change, extreme events (hot, cold, wind, rain..) will become more regular

# These events have health consequences

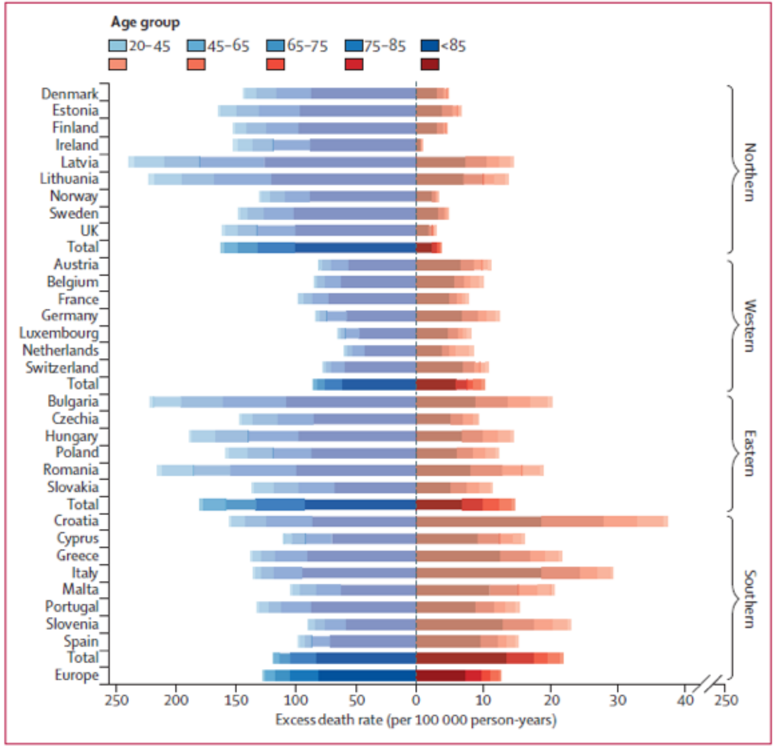


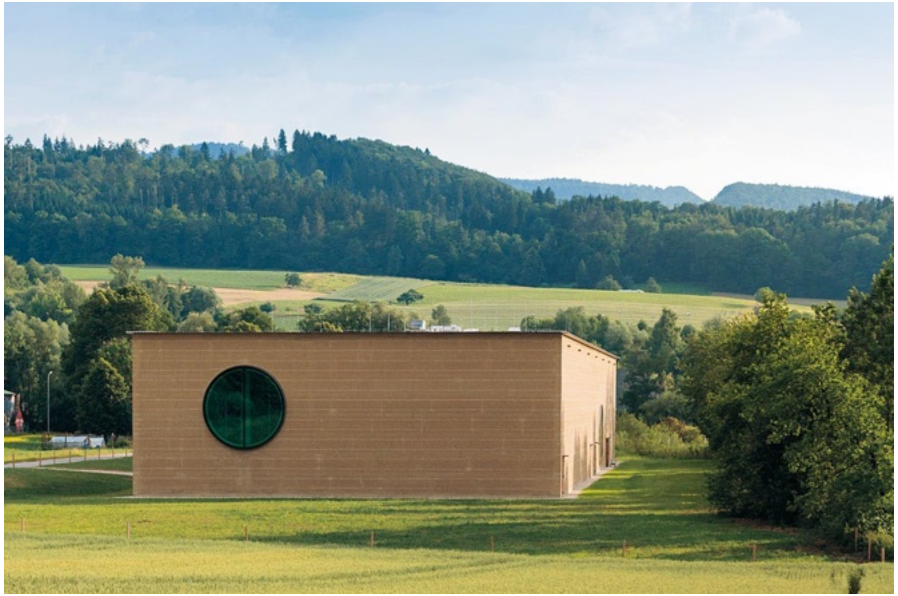

***Figure 3:* Country-level cold (in blue) and heat (in red) annual raw death rates broken down by age group**

Sce: Masselot et al. 2023. Excess mortality attributed to heat and cold: a health impact assessment study in 854 cities in Europe *The Lancet*

# We can use of moisture permeable materials to improve the indoor comfort

*Venice Bienale, Rem Koolas*

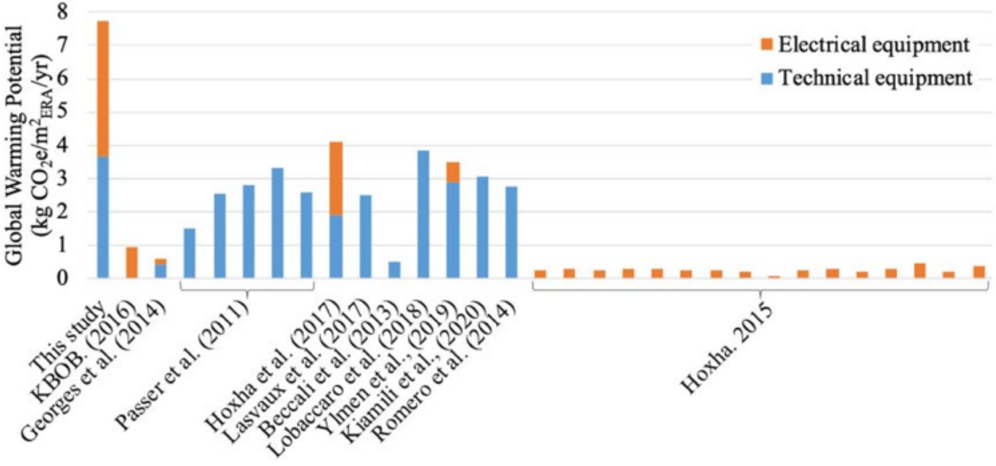
VS

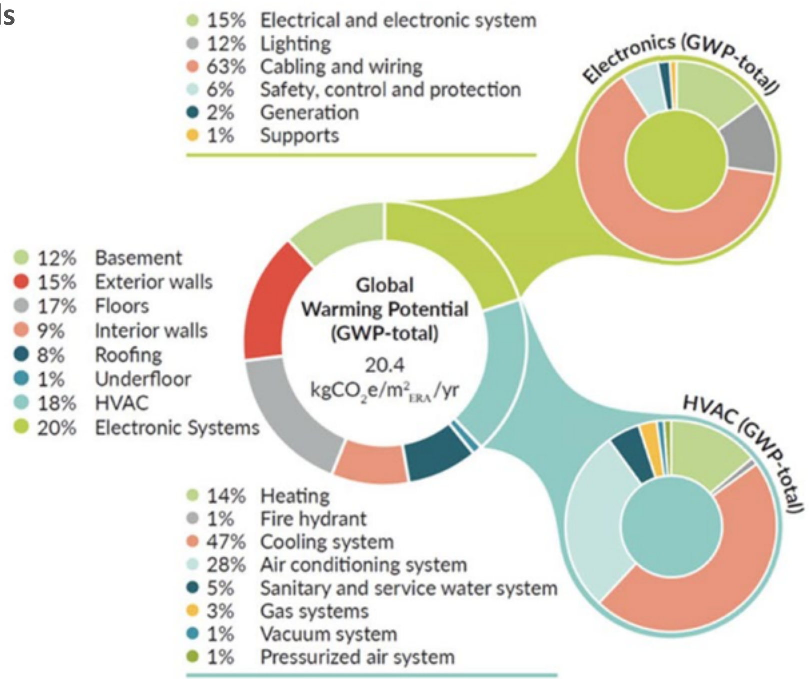


*Ricola herb storage, Hertzog & Demeuron*

# Technical systems seems to be massively underestimated in LCA

## So reducing the need for using them and quantifying their impact accurately will show the potential of using biobased and earth materials as interior materials




Sce: Hoxha et al. 2021. Influence of technical and electrical equipment in life cycle assessments of buildings: case of a laboratory and research building. *The International Journal of Life Cycle Assessment* 26:852–863

Climate mitigation

## Earth is carbon neutral construction & Circular

Climate adaptation

**It provides moisture buffer capacity. It increases indoor air quality & reduce needs for ventilation**

## Reasons to build with clay…

1. Carbon and circularity
2. Health
3. **Beauty**

# Reasons to build with clay…

1. Carbon and circularity
2. Health
3. Beauty
4. **economy**

# Prefabrication as a one solution to reduce costs and increase speed

# Poured earth as a one solution to reduce costs and increase speed

Sce: G. Landrou 2018. Poured earth technology. *PhD, ETH*

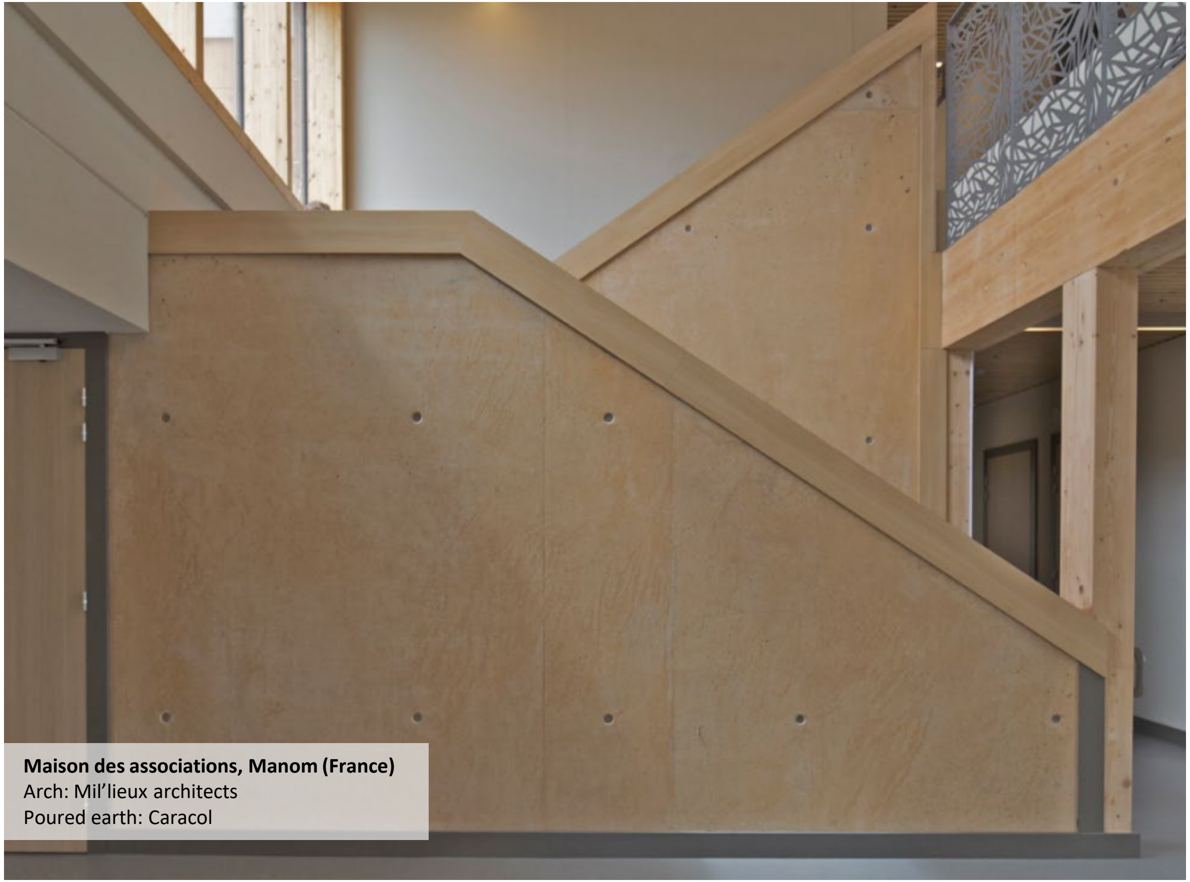
# Excavation materials used for compressed earth bricks

**Renovation, Grand théatre, Geneva**
CEB: TERRABLOC

# Excavation materials used for prefabricated rammed earth

**Office building, Lyon (France)**
Arch: Clément Vergely architectes
Rammed earth: Nicolas Meunier.

# Excavation materials used for poured earth



**Maison des associations, Manom (France)**
Arch: Mil'lieux architects
Poured earth: Caracol

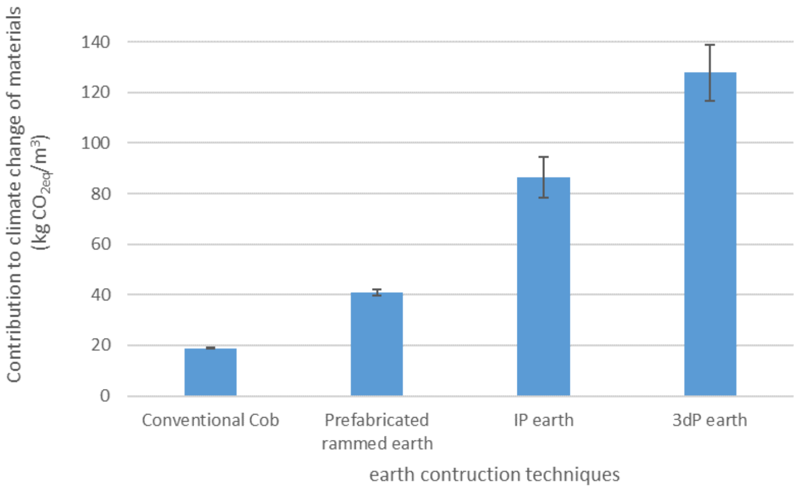
# Excavation materials used for poured earth

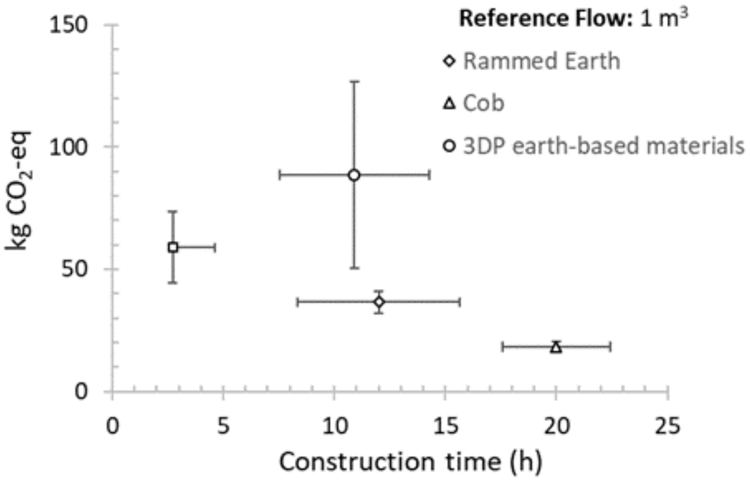
Tecla 3D printed hause model
Poured earth: WASP

Sce: Perrot et al. 2018. 3D printing of earth-based materials: Processing aspects. *Construction and Building Materials*

## When does economic reality
## Costs environmental impact reduction?

## The faster we implement the more environmental impact we have (per $m^3$)

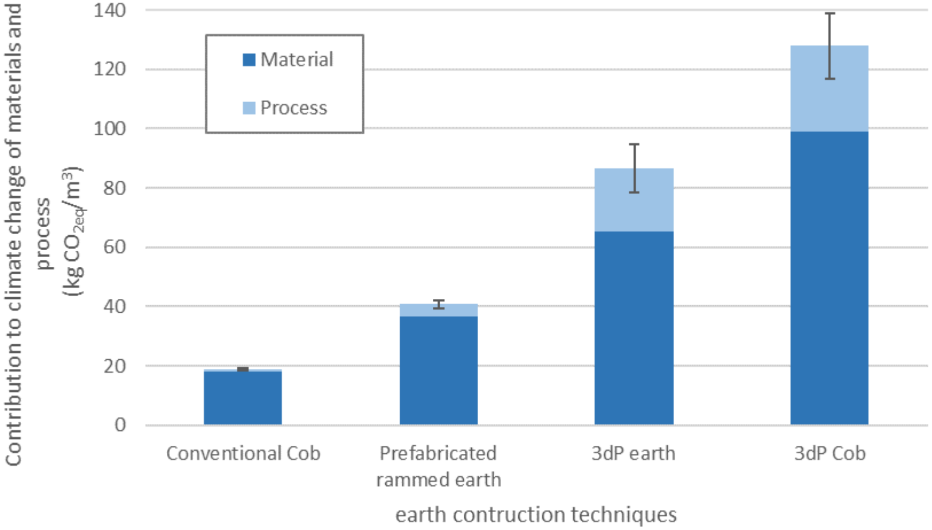



Sce: Assenção et al., 2023. Can digital fabrication meet low-carbon materials? 3DPrint or not 3DPrint, that's the question! *ICBBM, Vienna*

# When does economic reality
# Costs environmental impact reduction?

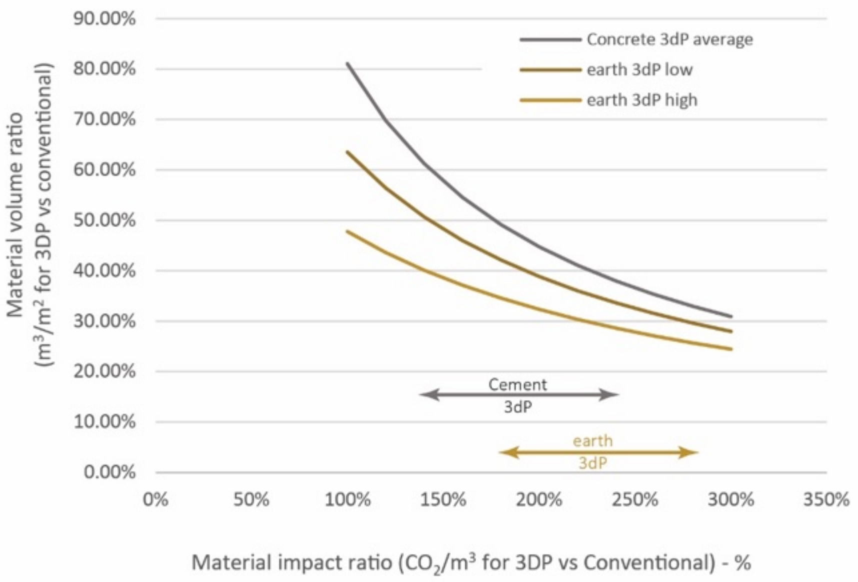
## The faster we implement the more environmental impact of process is important




Sce: Assenção et al., 2023. Can digital fabrication meet low-carbon materials? 3DPrint or not 3DPrint, that's the question! *ICBBM, Vienna*

# When does economic reality
# Costs environmental impact reduction?

## To be economically and environmentally relevant
## Technologies with higher processing requires material savings




**3dP cement is more environmentally friendy when around 40 to 50% materials can be saved**

**When a low carbon material is 3d printed, like earth, 60 to 70% of materials has to be saved!**

Sce: Assenção et al., 2023. Can digital fabrication meet low-carbon materials? 3DPrint or not 3DPrint, that's the question! *ICBBM, Vienna*

| Conventional construction | Engineered natural materials | Vernacular construction |
| --- | --- | --- |
| Engineered building materials | Engineered building materials | Natural building materials |
| High $CO_2$ | Low $CO_2$ | Low $CO_2$ |
| Monofunctional | Multifunctional | Hygrometric control of indoor air |
| High strength | Good strength | Low strength |
| Cheap | Cheap | Labour intensive (expensive) |
| Fast | Fast | Time consuming (expensive) |
| Scientific construction | Scientific construction | Empiric construction |
| Rely on engineering knowledge | Rely on engineering knowledge | Rely on skilled workers |

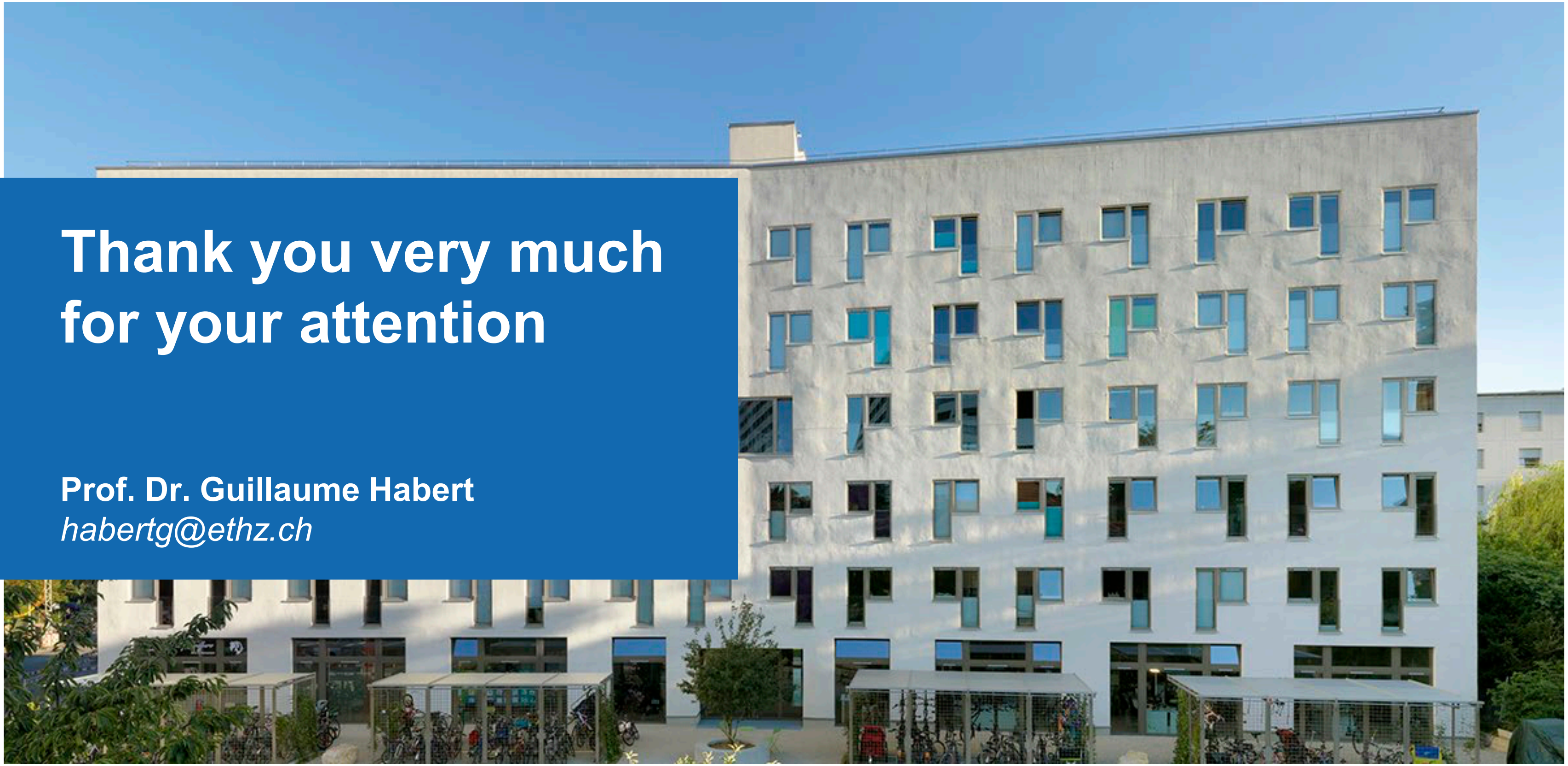
# Reasons to build with clay

- Earth is carbon neutral construction & Circular (climate mitigation)
- It improves indoor comfort and reduces ventilation needs (climate adaptation and Social justice)
- It creates an emotional relation with users (sensorial and aesthetic)
- By reducing ventilation needs, it reduces maintenance costs but construction costs are still high
- Mechanisation speeds up construction and reduces costs.. But increase environmental impact.
- Synergies can be found if new techniques allow enough material savings
- But too much technology might bring this material saving quantity out of reach (higher than 60-70%)

ETH zürich

# Thank you very much for your attention

**Prof. Dr. Guillaume Habert**
*habertg@ethz.ch*



Atba architecture, Soubeyran