ETH zürich

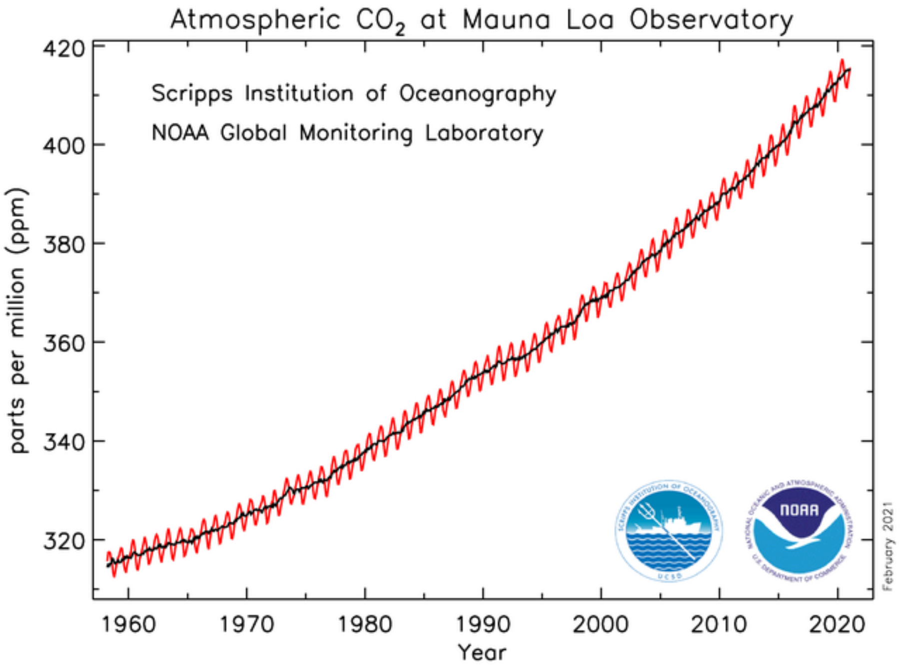
Bauen um zu heilen

Prof. Dr. Guillaume Habert
19.03.2022

Atba architecture, Soubeyran

1. Prioritäten festlegen

Climate change is here today



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

1.5°C scenario: 425 ppm

2°C scenario: 475 ppm

Dixie fire consumes a home in Plumas County (USA)
Photograph: Noah Berger/AP

The aftermath of a blaze in Old Bar, NSW. 15.11.19
Photograph: Peter Parks/AFP via Getty Images

02.01.2020. Eden residents
Photograph: Andrew Quilty/The Guardian

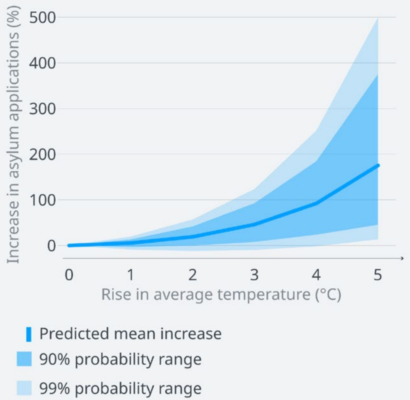
“CLIMATE CHANGE WOULD LEAVE THE LIVING ENVYING THE DEAD”.

Kofi Annan, 20 July 2015

January 2020, Mallacoota , Australia,
Allison Marion 11-year-old son, Finn.
Photograph: Dan Peled/AAP

Climate change will see an increase in asylum applications in the EU

Predicted changes to asylum applications under uniform climate change scenarios



Source: Modified from Anouch Missirian & Wolfram Schlenker *Science* 358:1610 (2017) | Reprinted with permission from AAAS

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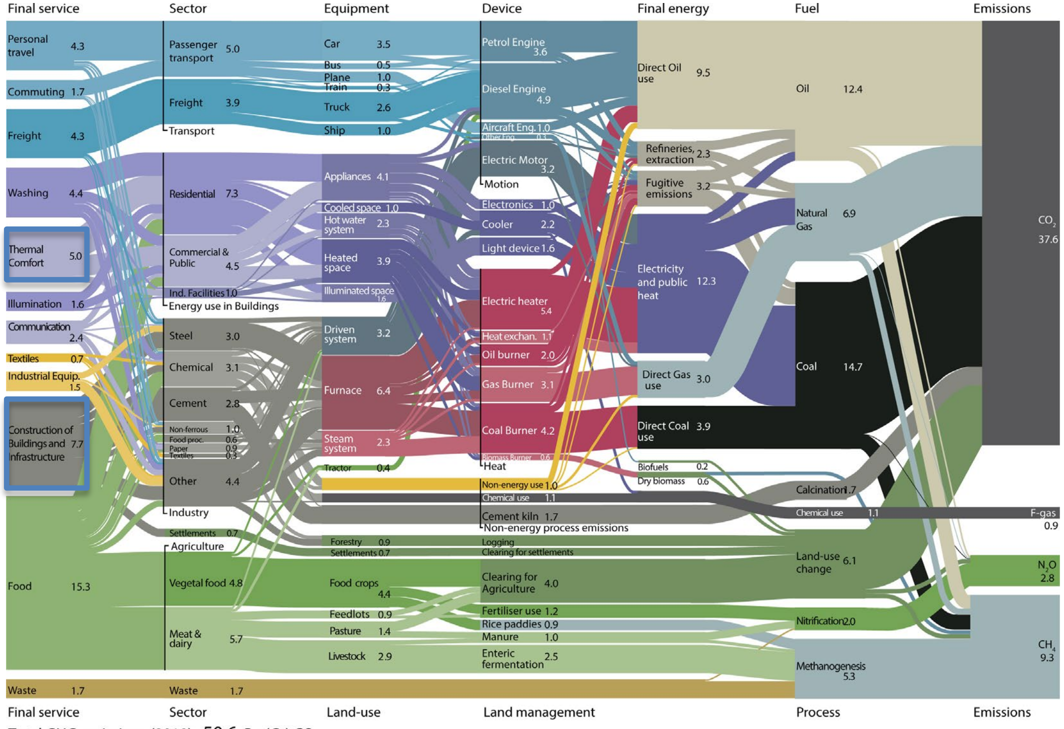
Who's responsible of emissions



At World level:

GHG emissions from construction more important than emissions from building heating

Construction in Global South & heating in Global North

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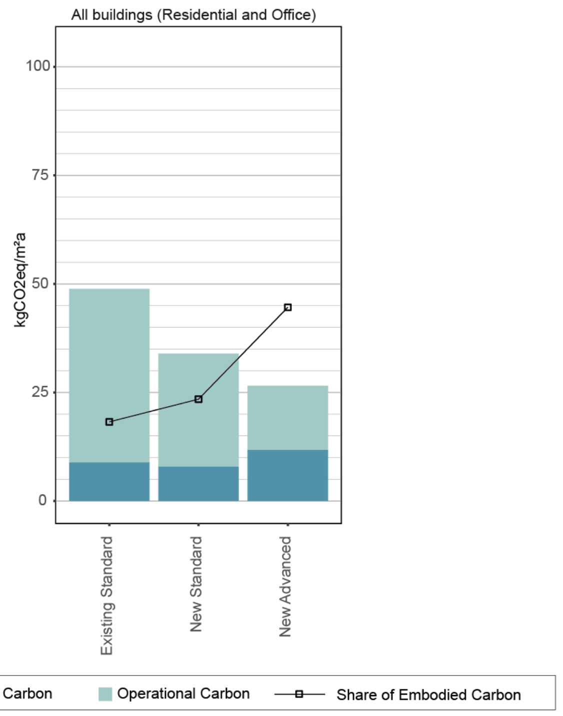
Sce: Bajželj et al. 2013. Designing Climate Change Mitigation Plans That Add Up. *Environmental Science & Technology.* DOI: 10.1021/es400399h

Materials matter

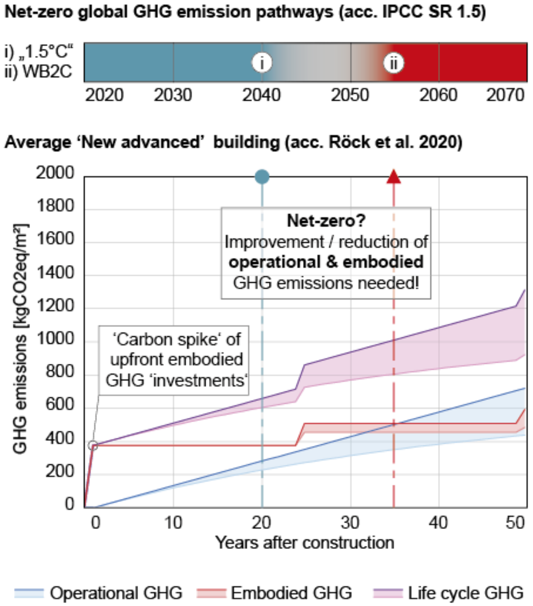
We have made progress for heating buildings

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*.

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



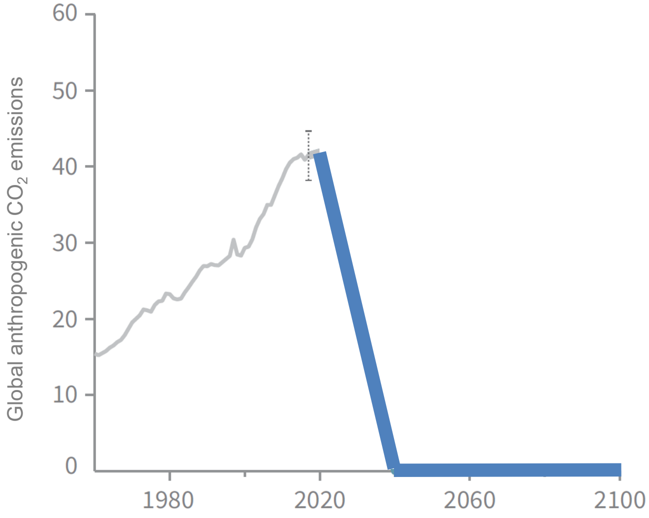
IPCC SR 1.5 net-zero GHG emissions pathways in relation to the temporal distribution of GHG emissions across the life cycle of an average 'New Advanced' building [Röck et al. 2020, Fig. 6 (c)].

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

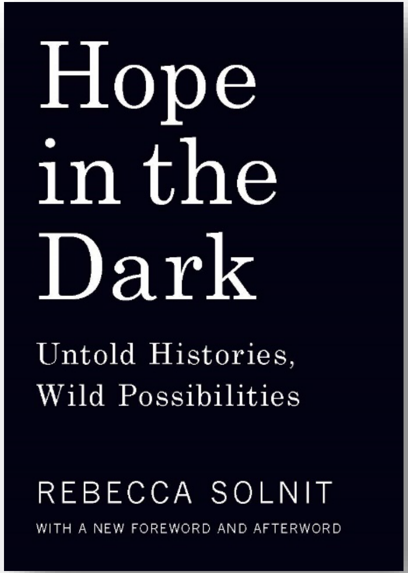
Sce: Röck et al. 2019. Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied energy*.

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

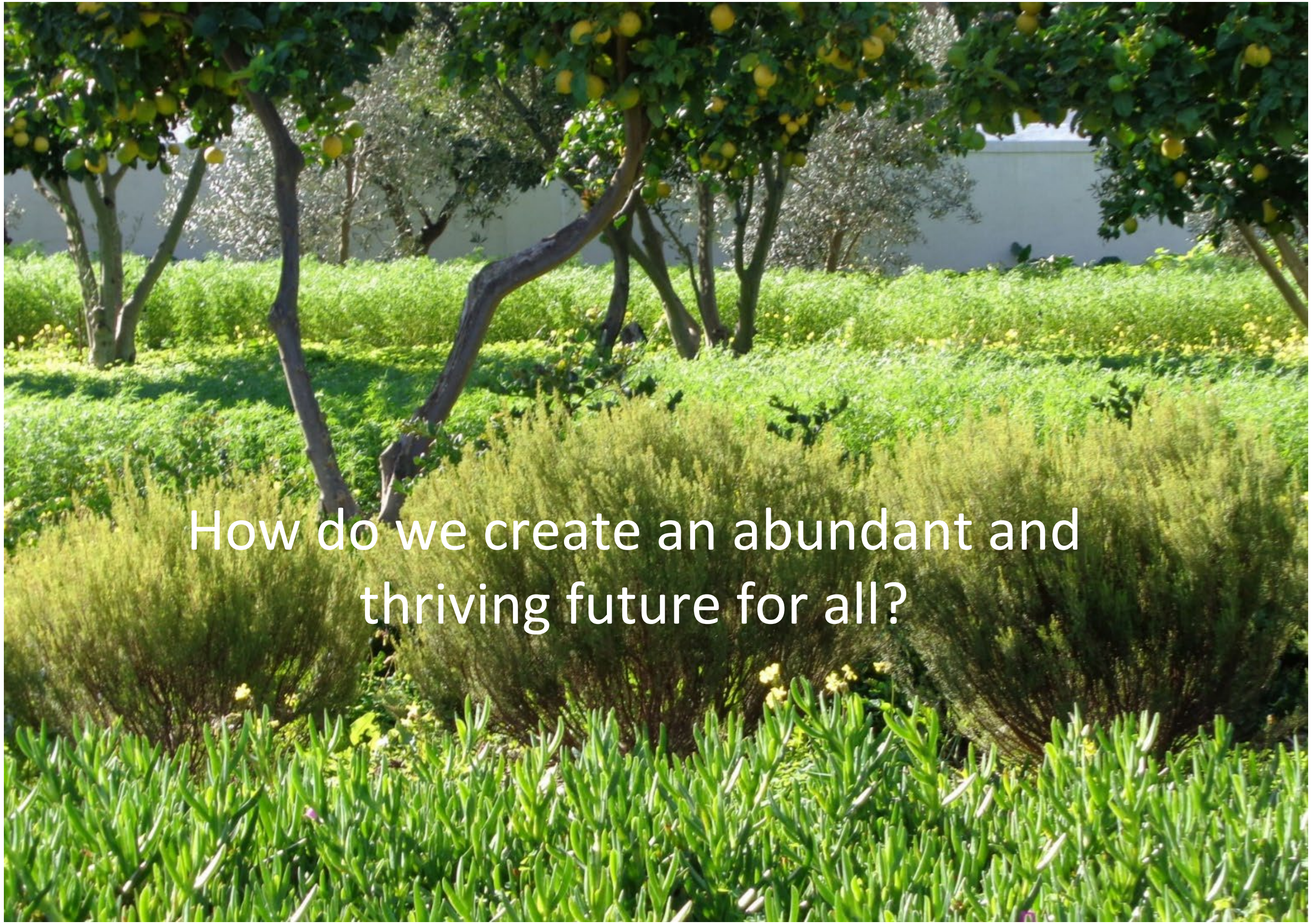
1. Prioritäten festlegen
2. Zeit zum Heilen



"Hope is an embrace of the unknown and the unknowable, an alternative to the certainty of both optimists and pessimists. Optimists think it will all be fine without our involvement; pessimists adopt the opposite position; both excuse themselves from acting. Hope is the belief that what we do matters even though how and when it may matter, who and what it may impact, are not things we can know beforehand."

Rebecca Solnit

Zwischen Verzweiflung, Fatalismus, Denialismus und naivem Optimismus wählen wir die Hoffnung, weil Gebäude das Potenzial haben, die Welt zu heilen *(wenn sie gut geplant sind...)*


How do we create an abundant and
thriving future for all?

Sustainability is just not good enough

	GOAL	APPROACH	
Regenerative ↑	Increase positive impact	Regenerative Restorative/net-positive	
	Adapt & transform	General Resilience	Step change
Neutral	Sustainability	Net-zero	
Degenerative ↓	Reduce negative impact	Green High performance Conservation	
	Follow code	Conventional building	

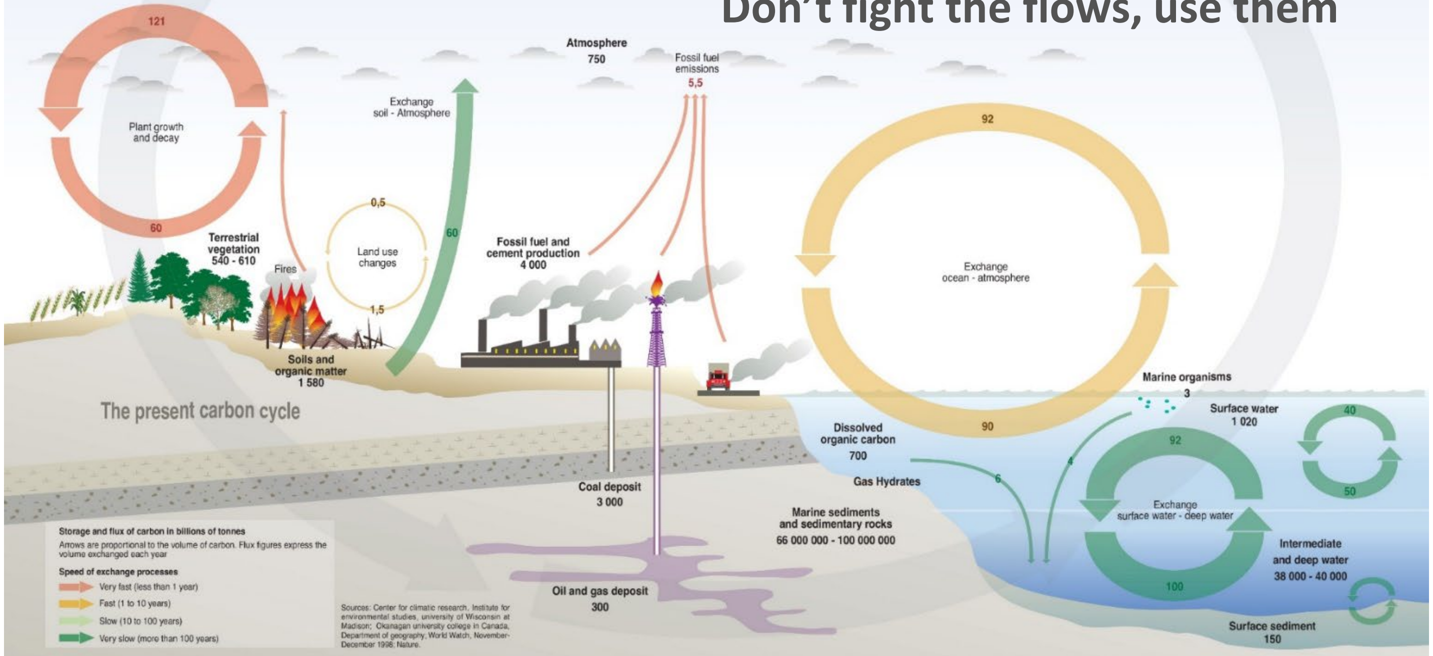
Developed from Reed, B. (2007) Shifting from 'sustainability' to regeneration. *Building Research & Information*, 35(6), 674–680.

1. **Prioritäten festlegen**
2. **Zeit zum Heilen**
3. **Werkstoffoptionen in einer fair und kohlenstofffrei Welt**

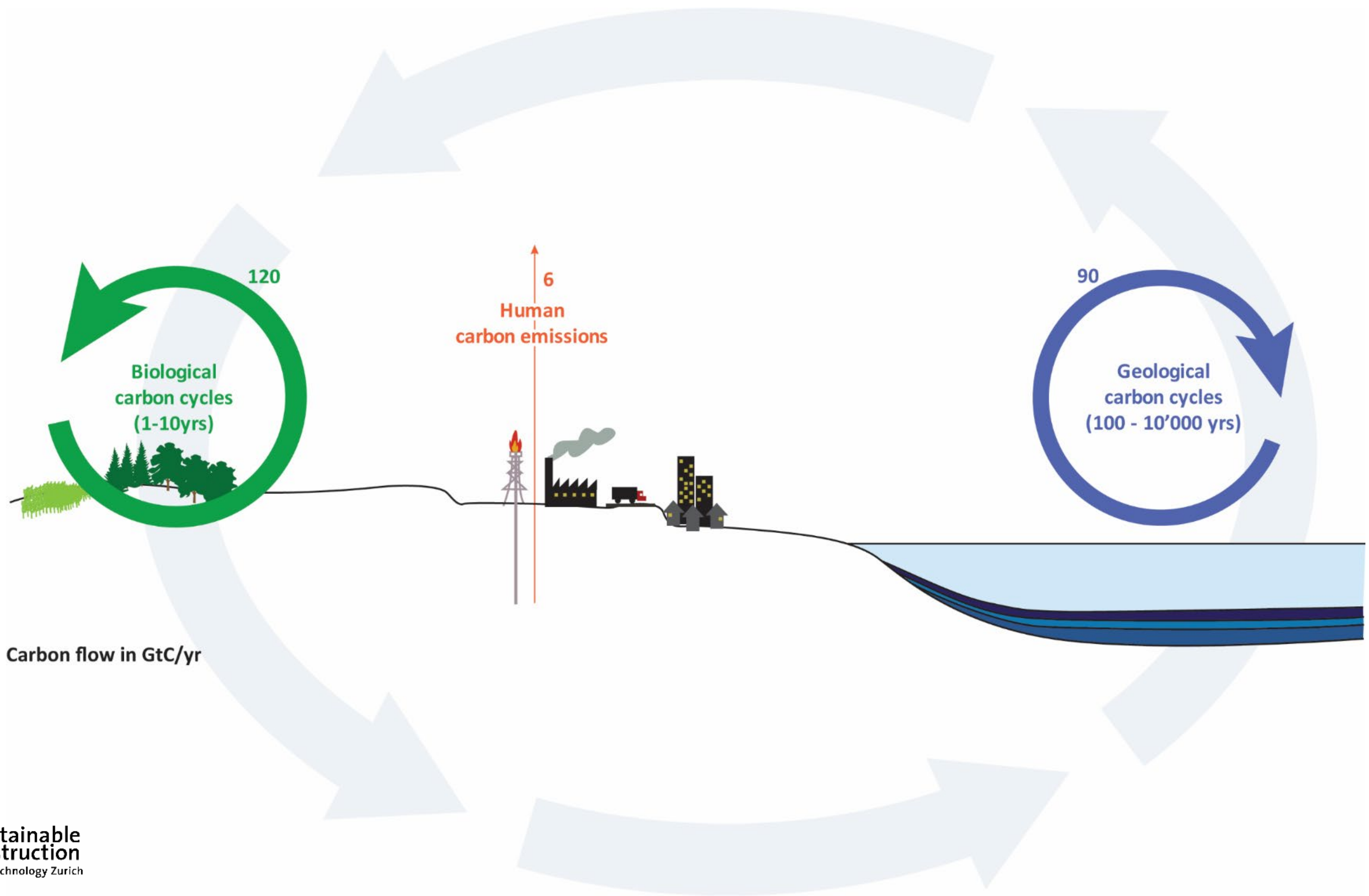
Don't fight forces, use them.

R. Buckminster Fuller (1895-1983)

Don’t fight the flows, use them



Flow in GtC/yr



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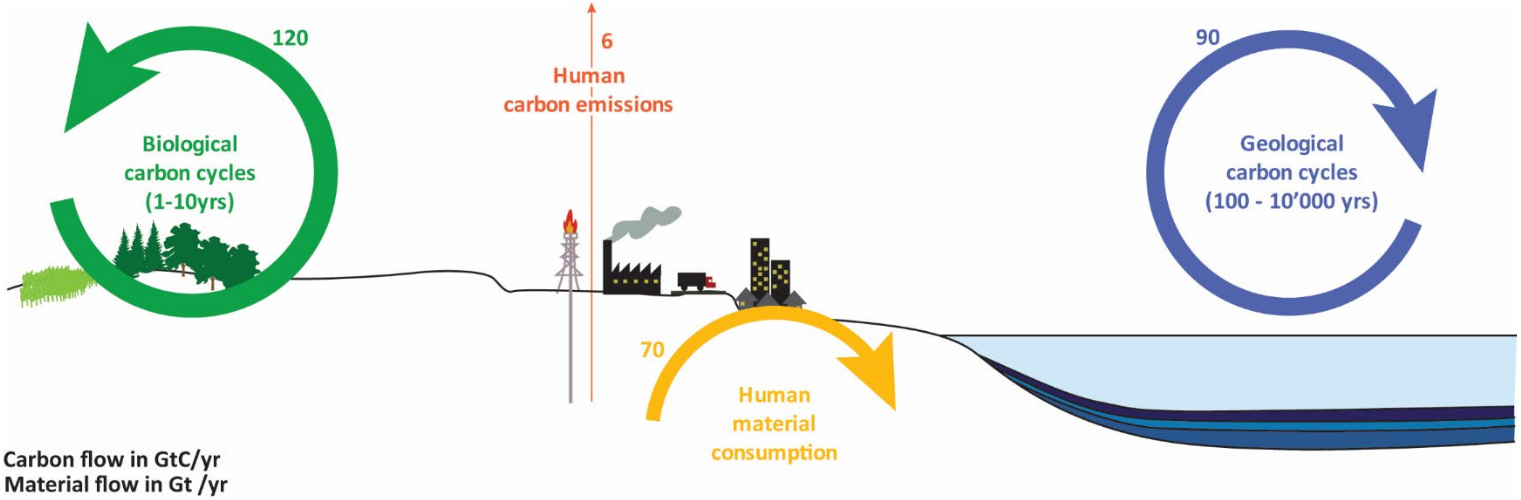
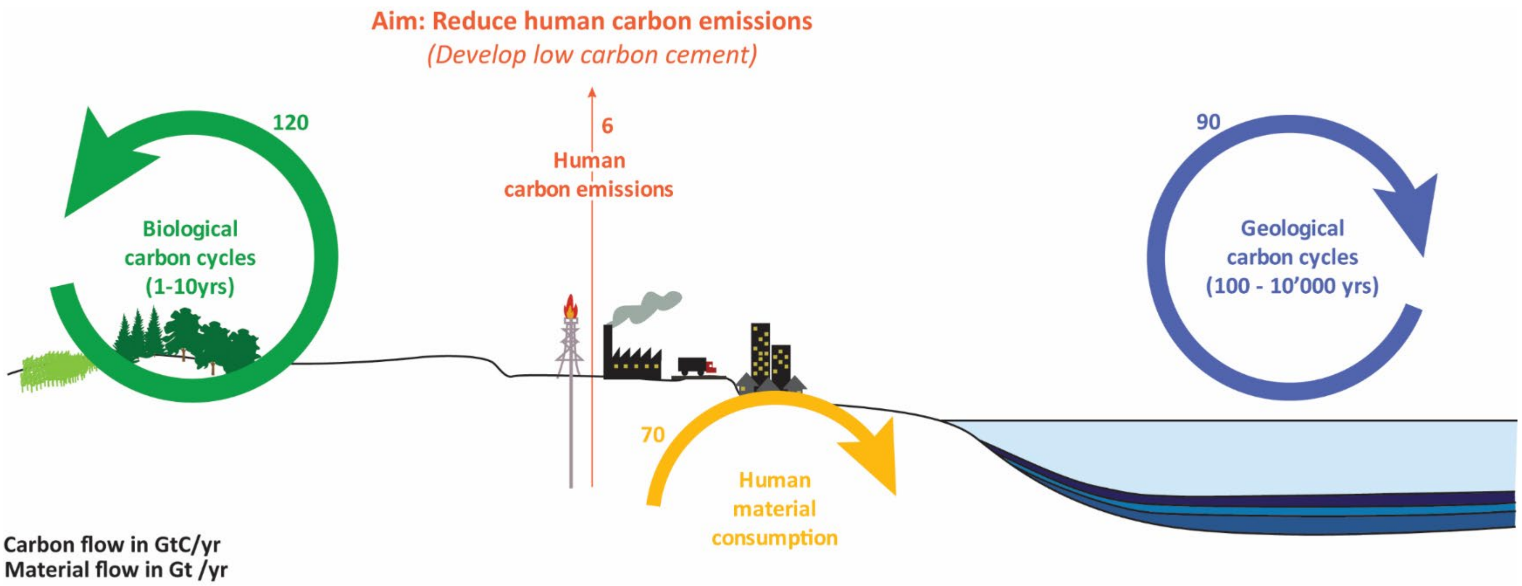

120
Biological
carbon cycles
(1-10yrs)
6
Human
carbon emissions
70
Human
material
consumption
90
Geological
carbon cycles
(100 - 10'000 yrs)
Carbon flow in GtC/yr
Material flow in Gt /yr



Aim: Reduce human carbon emissions
(Develop low carbon cement)
120
Biological
carbon cycles
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Human
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Geological
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(100 - 10'000 yrs)
70
Human
material
consumption
Carbon flow in GtC/yr
Material flow in Gt /yr


REVIEWS

Check for updates

Environmental impacts and decarbonization strategies in the cement and concrete industries

G. Habert[1]✉, S. A. Miller[2], V. M. John[3], J. L. Provis[4], A. Favier[1,5], A. Horvath[6] and K. L. Scrivener[5]

Abstract | The use of cement and concrete, among the most widely used man-made materials, is under scrutiny. Owing to their large-scale use, production of cement and concrete results in substantial emission of greenhouse gases and places strain on the availability of natural resources, such as water. Projected urbanization over the next 50–100 years therefore indicates that the demand for cement and concrete will continue to increase, necessitating strategies to limit their environmental impact. In this Review, we shed light on the available solutions that can be implemented within the next decade and beyond to reduce greenhouse gas emissions from cement and concrete production. As the construction sector has proven to be very slow-moving and risk-averse, we focus on minor improvements that can be achieved across the value chain, such as the use of supplementary cementitious materials and optimizing the clinker content of cement. Critically, the combined effect of these marginal gains can have an important impact on reducing greenhouse gas emissions by up to 50% if all stakeholders are engaged. In doing so, we reveal credible pathways for sustainable concrete use that balance societal needs, environmental requirements and technical feasibility.

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https://doi.org/10.1038/s43017-020-0093-3

Concrete, a synthetic rock composed of cement, sand, gravel and water, is the fundamental building block of the urbanizing world, and by far the most widely used man-made material in the construction industry. Concrete is a critical component in the construction of our modern, industrialized society[1]. For example, energy systems, water and wastewater systems, buildings — from single-floor houses to high-rise buildings — and transportation networks all rely on concrete.

Cement, the mineral glue that binds sand and gravel together in concrete, represents around 10% of concrete mass and is currently produced at a rate of around 4 gigatonnes (Gt) per year, a rate comparable to global food production[2]. Over the last 65 years, cement consumption has increased tenfold[3], a huge change considering steel production has only increased by a factor of three and timber construction has stayed nearly constant in the same time frame[3]. Indeed, cement accounted for 36% of the 7.7 Gt of CO_2 released globally by construction activities in 2010 (REF.[4]), while steel accounted for 25% (REF.[5]), plastics 8% (REF.[4]), aluminium <4% (REF.[6]) and brick <1% (REFS[7,8]). It is important to note that only half of cement is used for concrete[9], with the rest being used for blocks, mortar and plaster. Nevertheless, owing to the large-scale use of concrete in our modern society, concrete production represents a substantial proportion of global CO_2 emissions associated with construction.

Concrete accumulates in the Earth's crust and is now considered to be one of the markers of the Anthropocene[10], with an estimated 900 Gt added since the beginning of the industrial revolution[10,11]. The rate of concrete accumulation is due to the rapid urbanization of the global population. The global urban population is forecasted to increase by 2.5 billion by 2050, with the majority of this increase occurring in Asia and Africa[12]. Together with the pressure to fill the already sizeable housing deficit and the lack of reliably functioning infrastructure, it is anticipated that this population growth will cause a surge in demand for building materials, including concrete. After 2050, the demand for construction materials is expected to reduce in most regions of the world[13], owing to the achievement of urban transition and the stabilization of the population[13].

It is crucial to act now to reduce the environmental impact of construction within the next few decades. New buildings are designed with better energy performance than existing buildings, which reduces the energy need during operation to around 50% of emissions over the full life cycle (FIG. 1) and increases the focus on emissions related to concrete production[14]. For a typical multifamily residential building, steel-reinforced

Die Zusammenarbeit aller Akteure entlang der gesamten Wertschöpfungskette ermöglicht eine sofortige Senkung der Kohlenstoffemissionen von Zement um 50 %. Ohne massive Investitionen und ohne groundbreaking technologie.

Table 2 | **Stakeholder attributes**

Stakeholder	Number of actors	Available investment	Action(s)	Market penetration and/or applicability (%)	Benefits (% CO_2 reduction for the technology)	Potential (benefit × market)
Alternative-fuel producer	XXX	$$	Collecting and sorting of alternative fuel for clinker kiln	85	14	12
Clinker producer	X	$$$$$	Kiln efficiency	15	1	0.15
			Carbon capture and storage	15	100	15
Cement producer	XX	$$$$	Increased degree of substitution	17	45	8
			Alternative cements	15	41	6
Concrete producer	XXXXXX	$$	Optimize concrete mix	25	17	4
Construction company	XXXXXXXXX	$$	Waste control, low-carbon-concrete use	NA	NA	NA
Engineering office	XXXX	$	Lower exposure class prescription, structural optimization	25	25	6
Architect office	XXXX	$	Optimized design	70	13	9
Demolition company	XXXXXXX	$	Fines and waste recycling	20	8	2
Client	XXXXXXXXXXX	$$	Integration of all actions	100	62	62

Summary of the actions that can be taken by stakeholders to reduce the CO_2 budget of concrete production. The potential of each action from a particular stakeholder is calculated as the product of the benefit of the technology (measured as the percent CO_2 reduction) and its market penetration. '$' symbols represent a qualitative assessment of the economic benefits and investment possibilities for the different stakeholders. Cement and clinker producers are the most concentrated actors and generate the largest benefit. Similarly, the number of actors involved in developing or implementing each technology is represented by 'X' symbols. The fastest and easiest implementation possibilities happen when small numbers of actors with high investment capabilities can have large saving potentials at low costs (such as for the increase of supplementary cementitious materials in cement). The other actions will require incentive and/or regulation constraints from national authorities to motivate the actors to engage in the transition. NA, not applicable.

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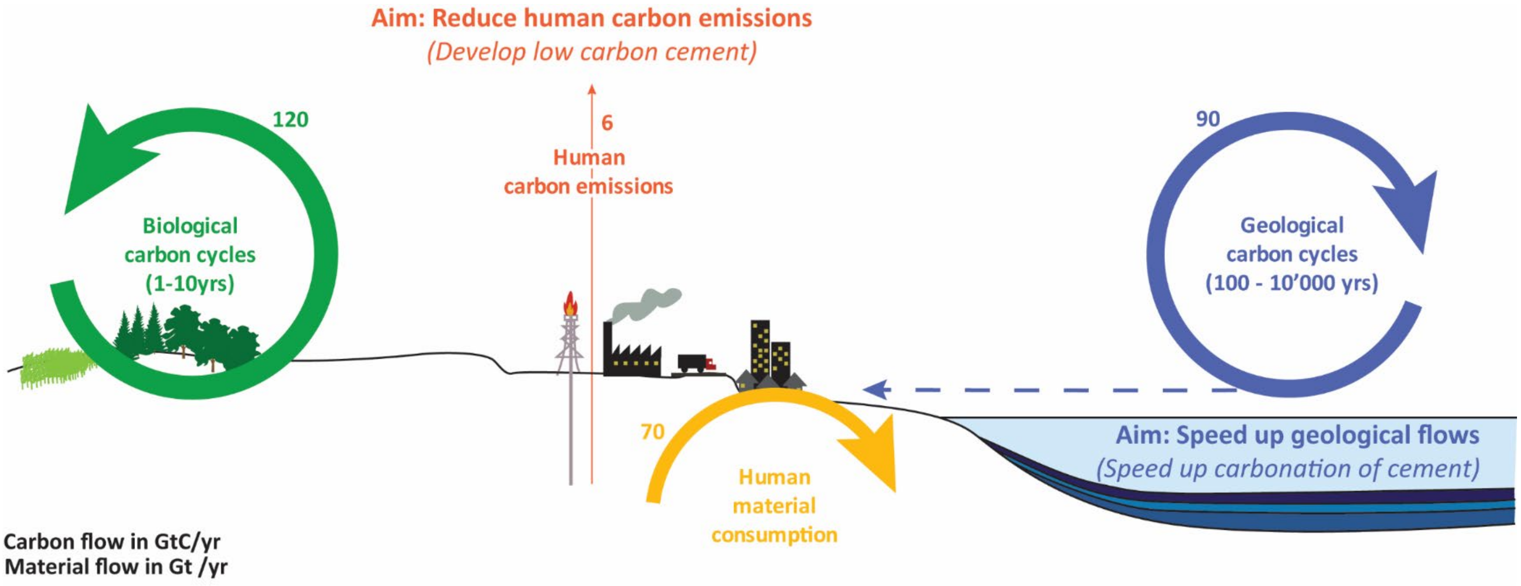
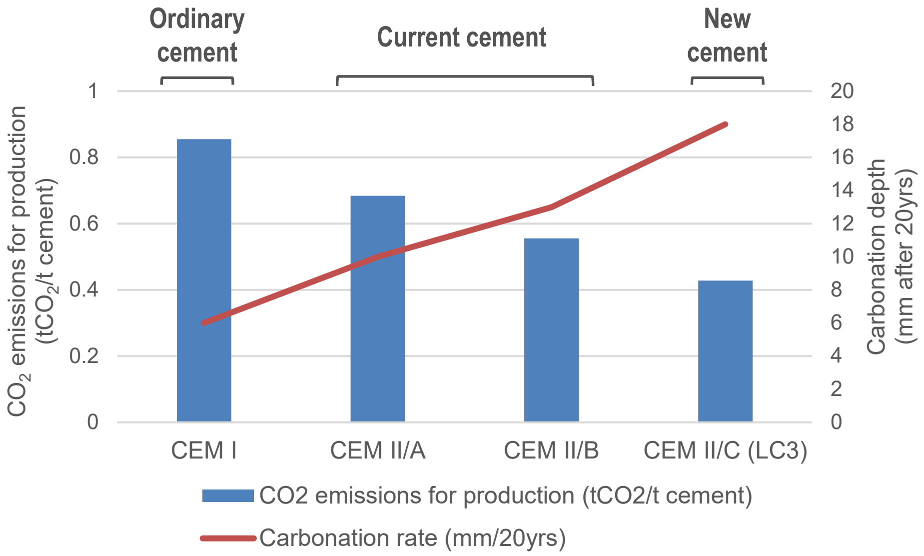

Aim: Reduce human carbon emissions
(Develop low carbon cement)
120
Biological
carbon cycles
(1-10yrs)
6
Human
carbon emissions
90
Geological
carbon cycles
(100 - 10'000 yrs)
70
Human
material
consumption
Aim: Speed up geological flows
(Speed up carbonation of cement)
Carbon flow in GtC/yr
Material flow in Gt /yr

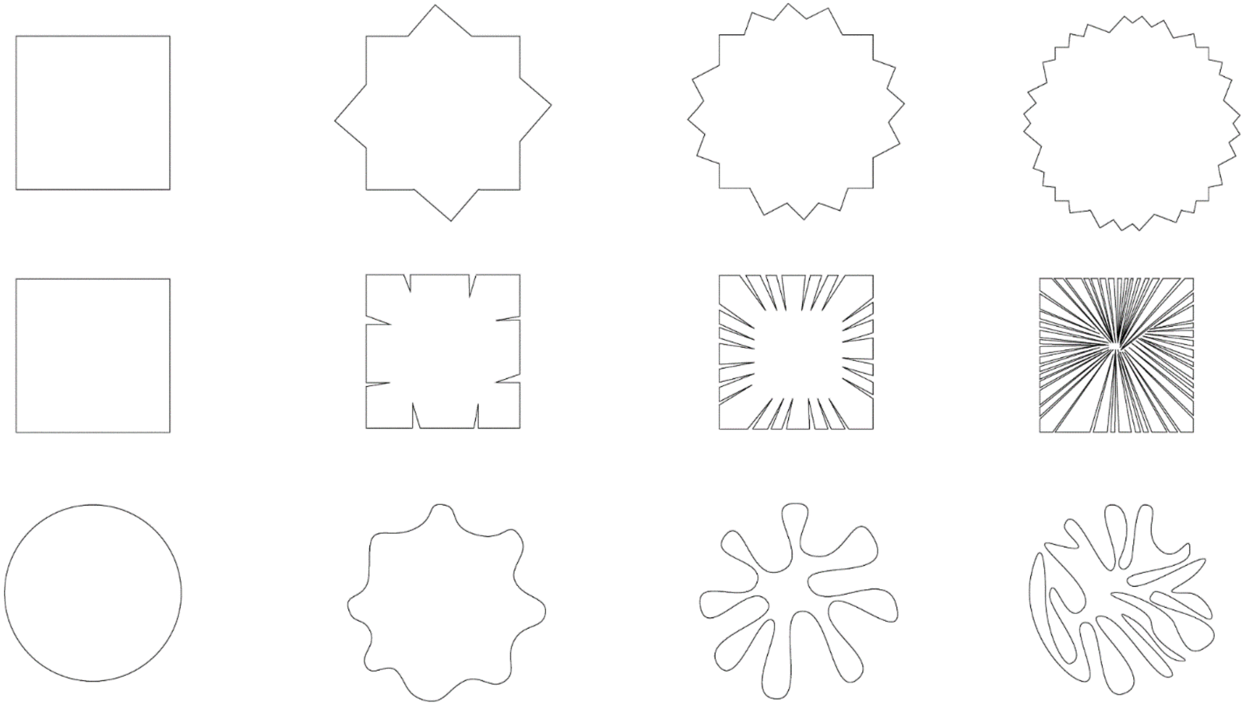
New cement, with high amount of clinker substitution have the capacity to reabsorb faster CO_2

It reduces the time the fossil CO_2 is in the atmosphere and therefore the risk of crossing irreversibly a tipping points



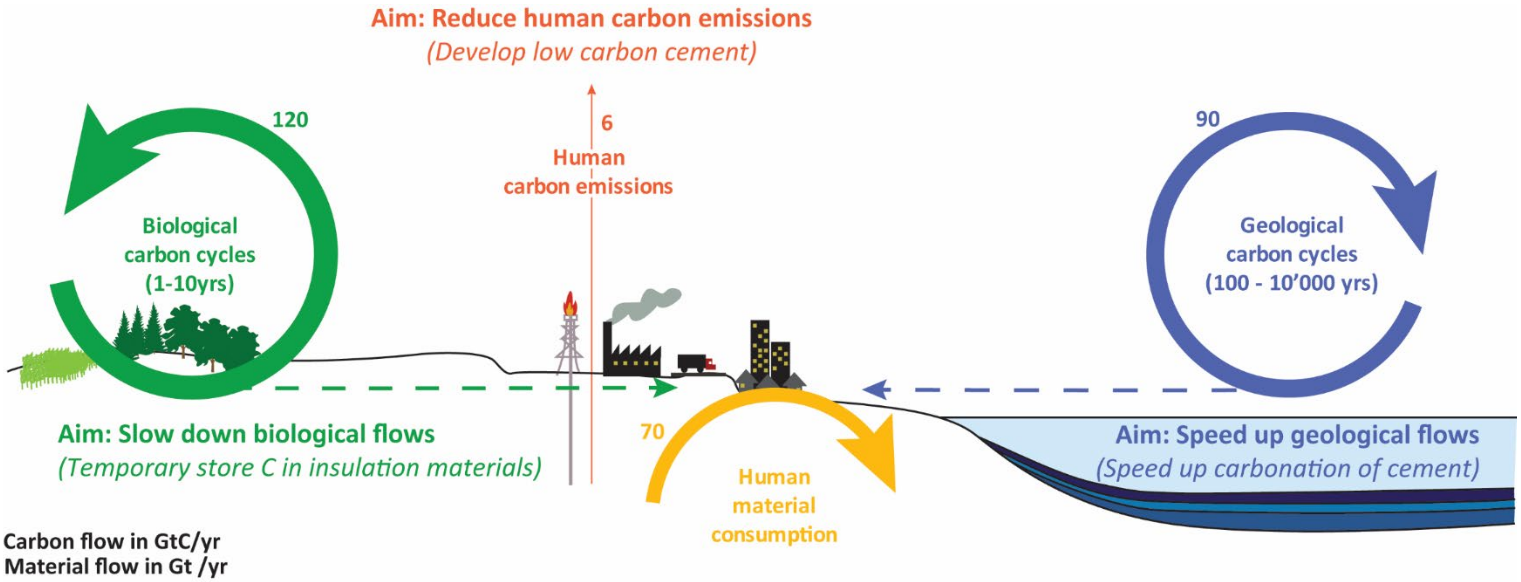
Quelle: Soja W., Georget F., Scrivener K. submitted. Effect of Microstructure Changes after Carbonation on diffusivity in Cement Paste made with Low Carbon Binders. *Cement and Concrete Research*

Could we design for fast carbonation?
Increase surface exposure for reduced volume..



Can *design for carbonation* help digital fabrication and form finding design to get a sustainable purpose?

Concrete choreography, NCCR Dfab, Benjamin Dillenburger, ETH Zurich


Aim: Reduce human carbon emissions
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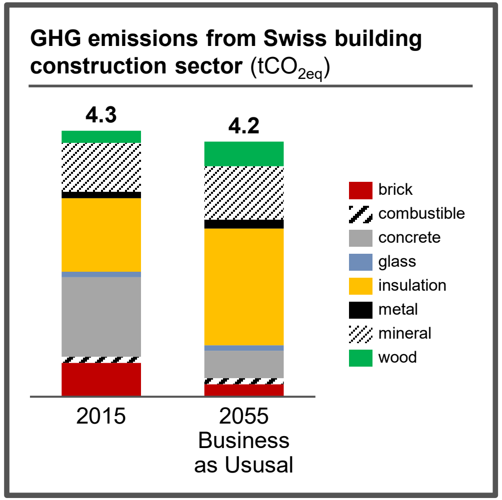
120
6
Human
carbon emissions
90
Biological
carbon cycles
(1-10yrs)
Geological
carbon cycles
(100 - 10'000 yrs)
Aim: Slow down biological flows
(Temporary store C in insulation materials)
70
Human
material
consumption
Aim: Speed up geological flows
(Speed up carbonation of cement)
Carbon flow in GtC/yr
Material flow in Gt /yr

In Switzerland *(and similarly to all countries with an already well established building stock)*

Half of emissions from material production will come from insulation materials in 2050

(if fossil based insulation are used)



Sce: Heeren & Hellweg. 2019. Tracking Construction Material over Space and Time: Prospective and Geo-referenced Modeling of Building Stocks and Construction Material Flows. *Journal of Industrial ecology*

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

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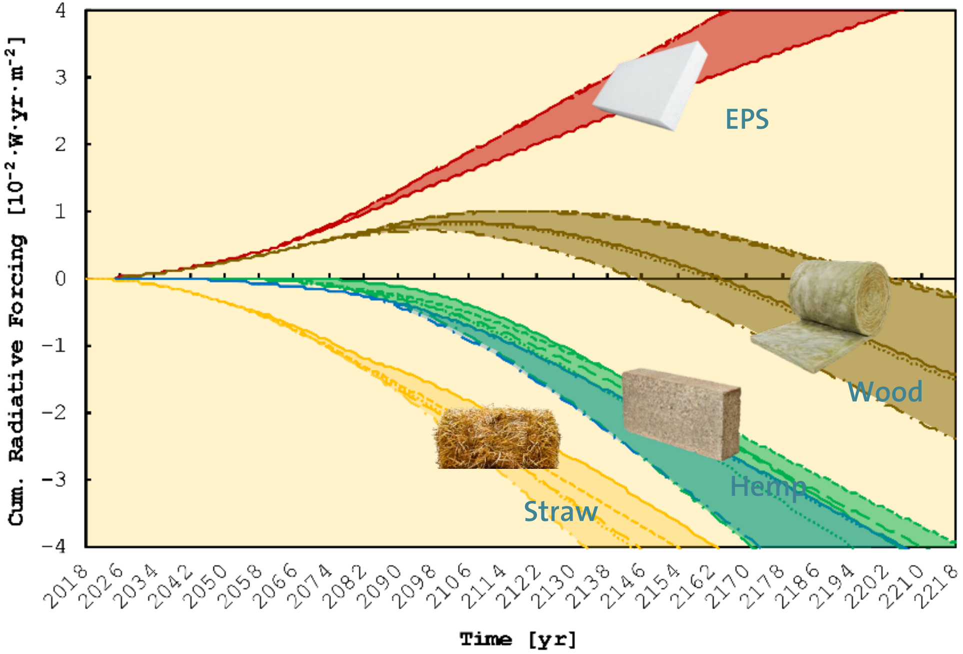
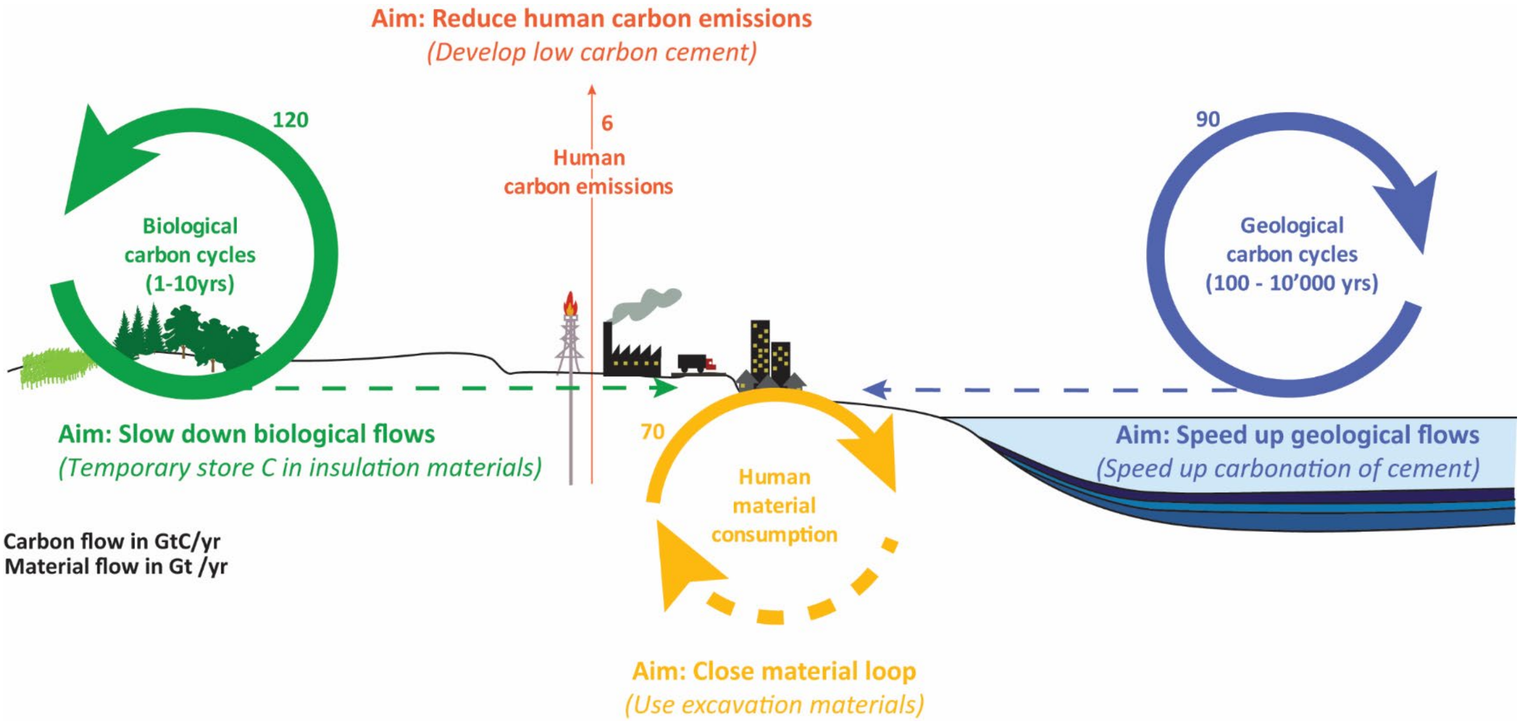
atba 20 ans

Renovation of the built environment with biobased insulation reduces immediately the radiative forcing from GHGs in the atmosphere



Sce: Pittau et al. 2018. Fast-growing bio-based materials as an opportunity for storing carbon in exterior walls. *Building and Environment*, 129, 117-129



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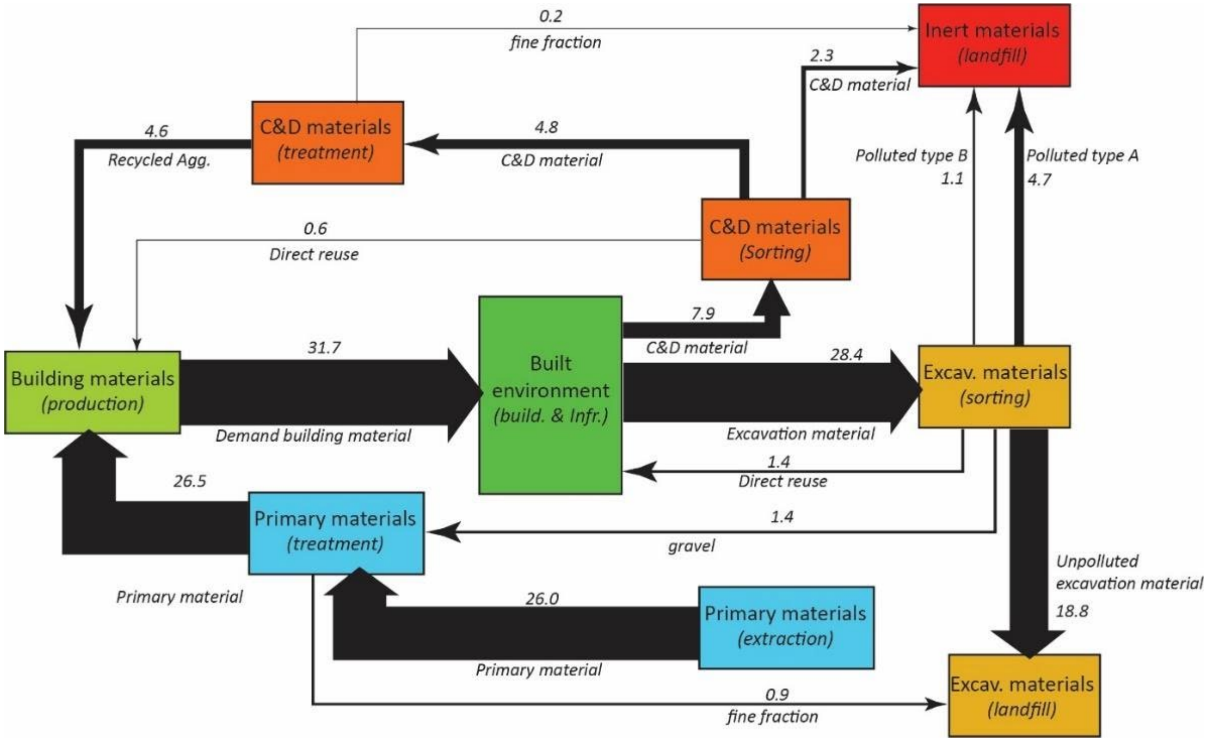
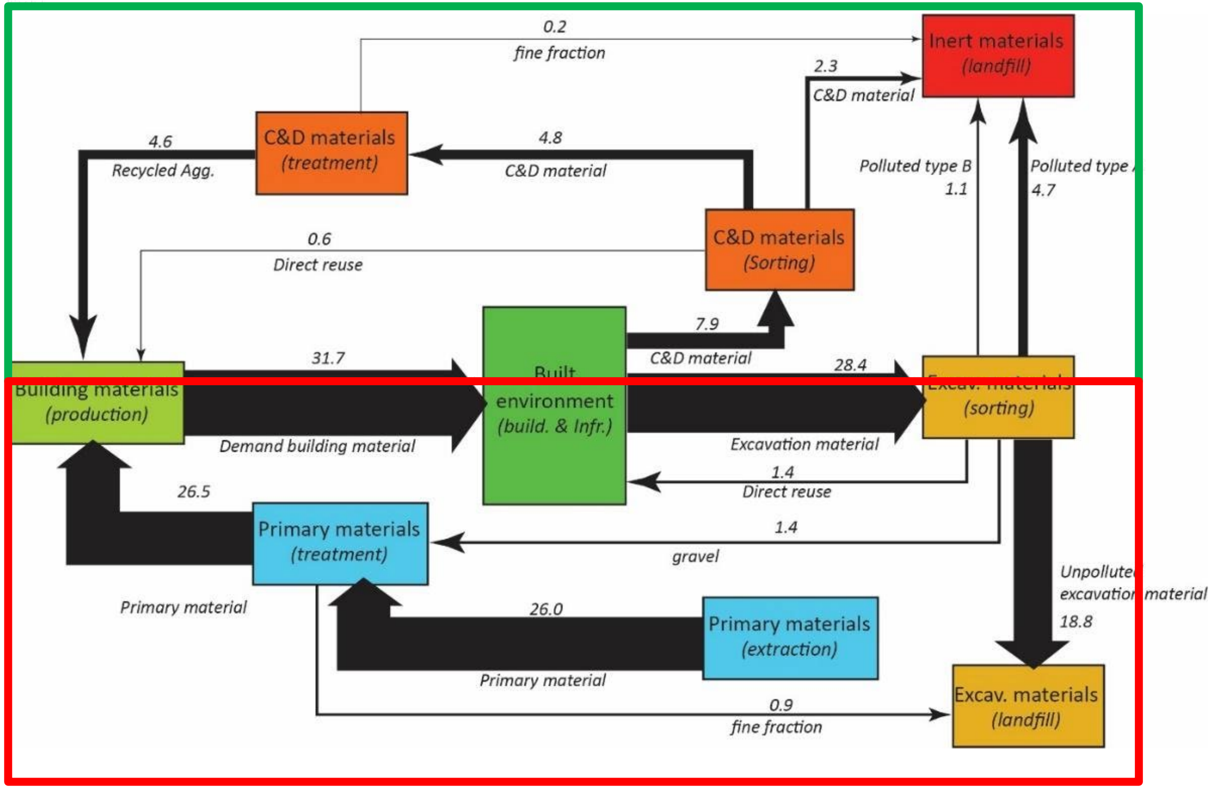

0.2
fine fraction
Inert materials
(landfill)
2.3
C&D material
C&D materials
(treatment)
4.6
Recycled Agg.
4.8
C&D material
Polluted type B
1.1
Polluted type A
4.7
0.6
Direct reuse
C&D materials
(Sorting)
7.9
C&D material
31.7
Building materials
(production)
Demand building material
Built
environment
(build. & Infr.)
28.4
Excavation material
Excav. materials
(sorting)
1.4
Direct reuse
26.5
Primary materials
(treatment)
1.4
gravel
Unpolluted
excavation material
18.8
Primary material
26.0
Primary materials
(extraction)
Primary material
0.9
fine fraction
Excav. materials
(landfill)

Well sorted



Not closed

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

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

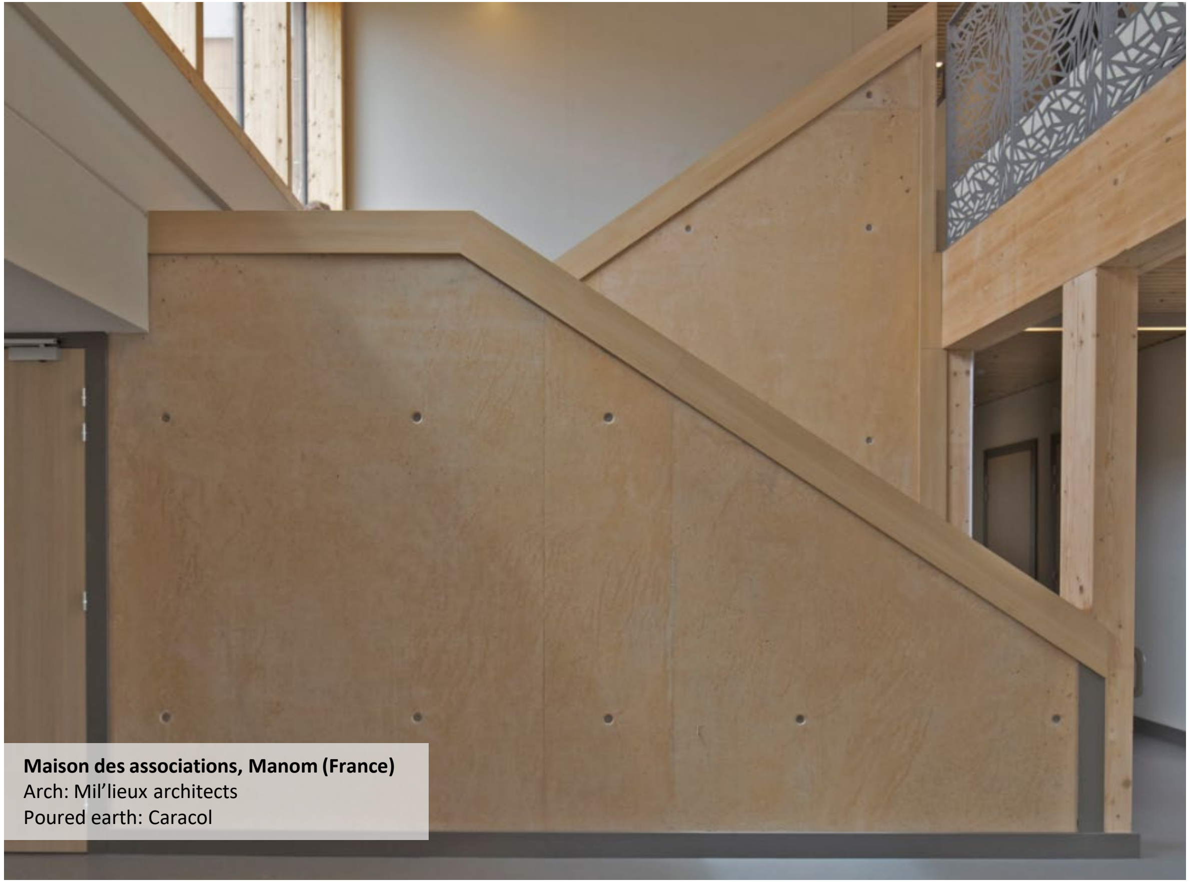
Excavation materials used for compressed earth bricks

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



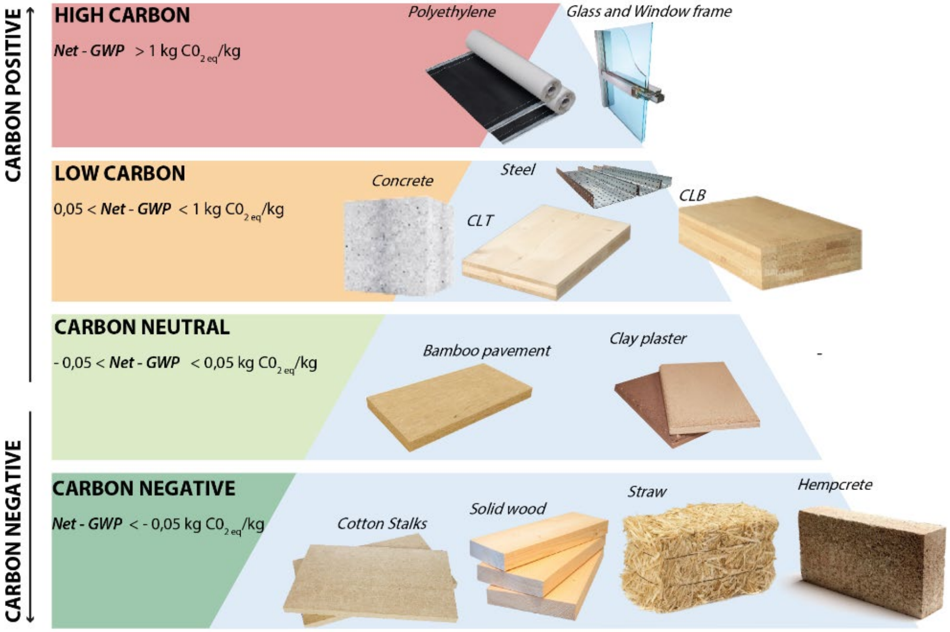
Maison des associations, Manom (France)
Arch: Mil'lieux architects
Poured earth: Caracol

1. Prioritäten festlegen
2. Zeit zum Heilen
3. Werkstoffoptionen in einer fair und kohlenstofffrei Welt
4. Eine neue Materialdiät

Es ist möglich, klimaneutrale Gebäude zu bauen

Wir müssen nur unsere materielle Diät ändern

Weniger kohlenstoffintensives Material, mehr Gemüse...



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

Es ist möglich, klimaneutrale Gebäude zu bauen

Wir müssen nur unsere materielle Diät ändern

Weniger kohlenstoffintensives Material, mehr Gemüse...

optimised
Reinforced concrete

+ 45 - 70 cm
Straw walls

= Climate neutral building
+ good indoor comfort

Timber
structure

+ 30 - 45 cm
Straw walls

= Climate neutral building
+ good indoor comfort

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

1. Prioritäten festlegen
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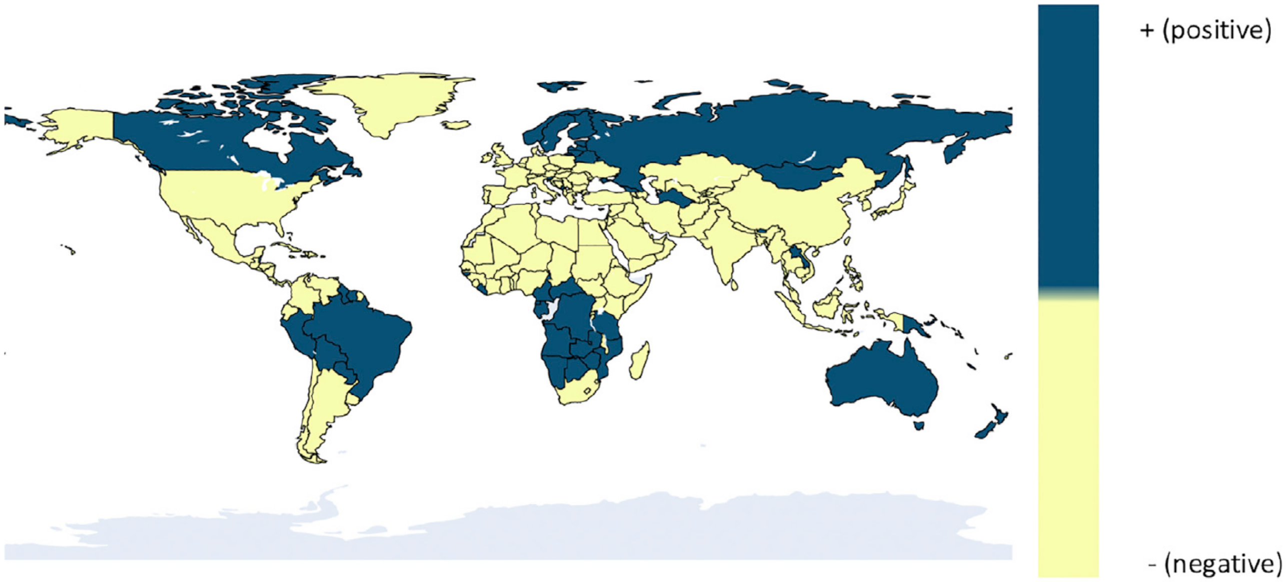
3. Werkstoffoptionen in einer fair und kohlenstofffrei Welt
4. Eine neue Materialdiät
5. Die Zeit der Konsequenzen

1. **Prioritäten festlegen**
2. **Zeit zum Heilen**
3. **Werkstoffoptionen in einer fair und kohlenstofffrei Welt**
4. **Eine neue Materialdiät**
5. **Die Zeit der Konsequenzen**

   Landnutzung

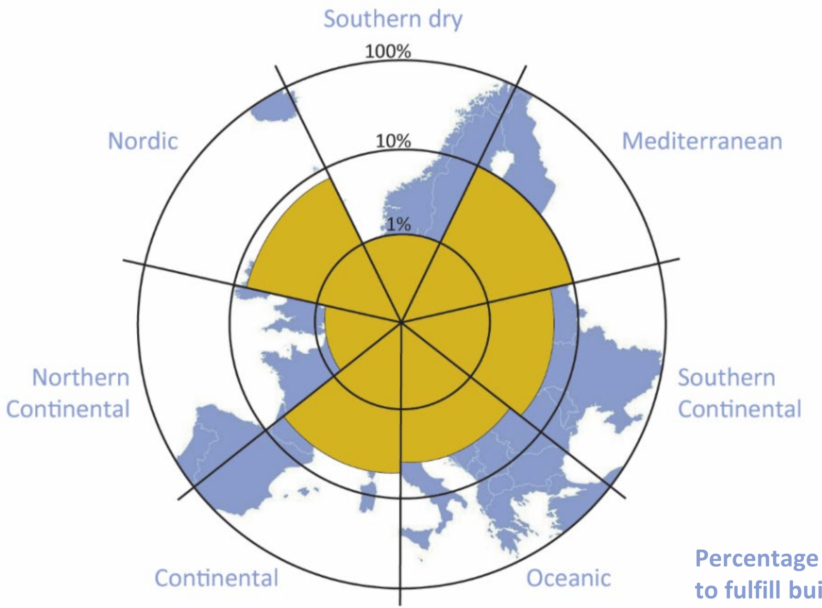
There is not enough timber



Simplified Supply-Demand Model for Timber-Based Floor Area Globally by 2050

Sce: Pomponi et al. 2020. Buildings as a Global Carbon Sink? A Reality Check on Feasibility Limits, *One Earth*, 3, 157–161

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)

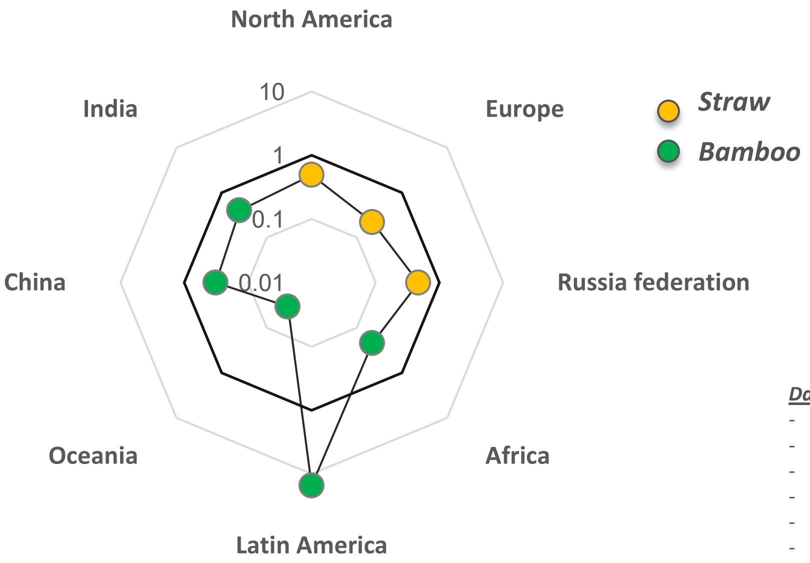
Sce: Göswein et al. 2021. Land availability in Europe for a radical shift toward bio-based construction. *Sustainable Cities and Society*

Bamboo grows naturally where most of the urbanization boom is happening

Grows naturally in America, Africa and Asia, introduced in Europe

Wir können die Nachfrage nach biobasierten Materialien fast überall auf der Welt erfüllen
Stroh zur Isolierung im globalen Norden
Bambus für Bauzwecke im globalen Süden

Ratio between Demand and Supply



Data from:

- BPIE, 2021. Policy Brief, Buildings Performance Institute Europe
- Dai et al. 2016. Biomass and Bioenergy. 85, 223–227
- FAO, 2019. Data for crops
- FAO, 2007. World bamboo resources
- Güneralp et al., 2017. Proc Natl Acad Sci USA. 114, 8945–8950
- Lesschen et al., 2013. Rice straw and wheat straw - Potential feedstocks for the biobased economy
- Xu et al., 2019. Forest Resources in China - The 9th National Forest Inventory

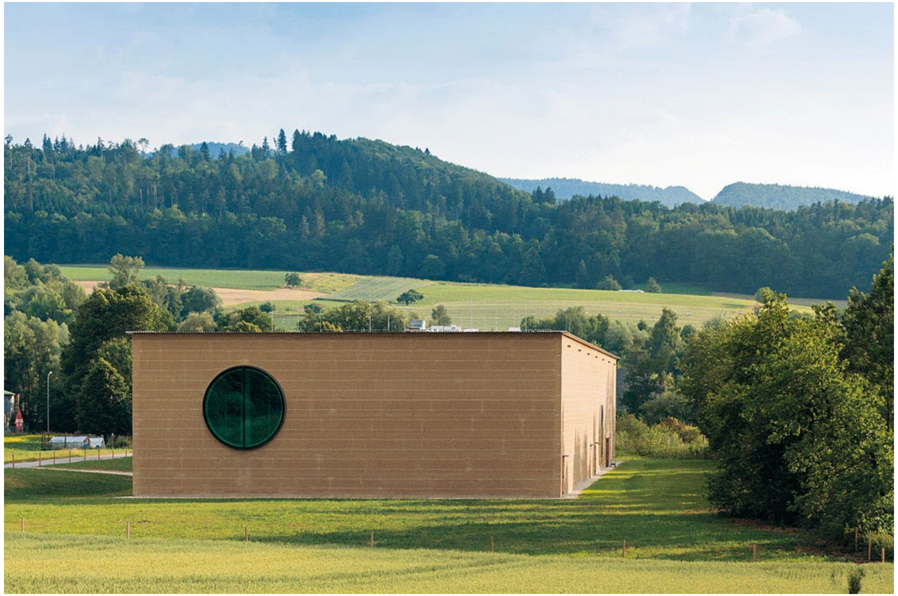
Sce: Göswein et al. Submitted. Buildings of the future – Vegan and biodiverse.

1. **Prioritäten festlegen**
2. **Zeit zum Heilen**
3. **Werkstoffoptionen in einer fair und kohlenstofffrei Welt**
4. **Eine neue Materialdiät**
5. **Die Zeit der Konsequenzen**
   - ***Landnutzung***
   - ***Gebäudenutzer***

Use of straw, earth and hemp improves the indoor comfort

Venice Bienale, Rem Koolas

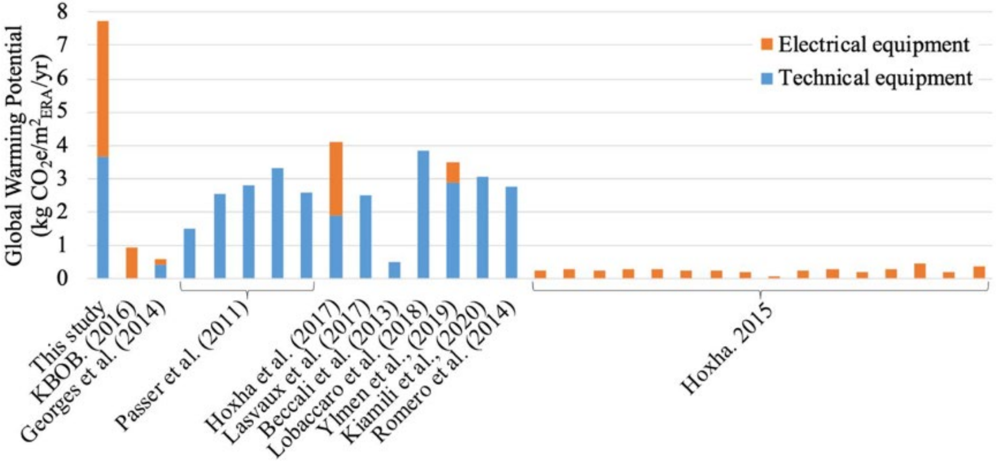
vs

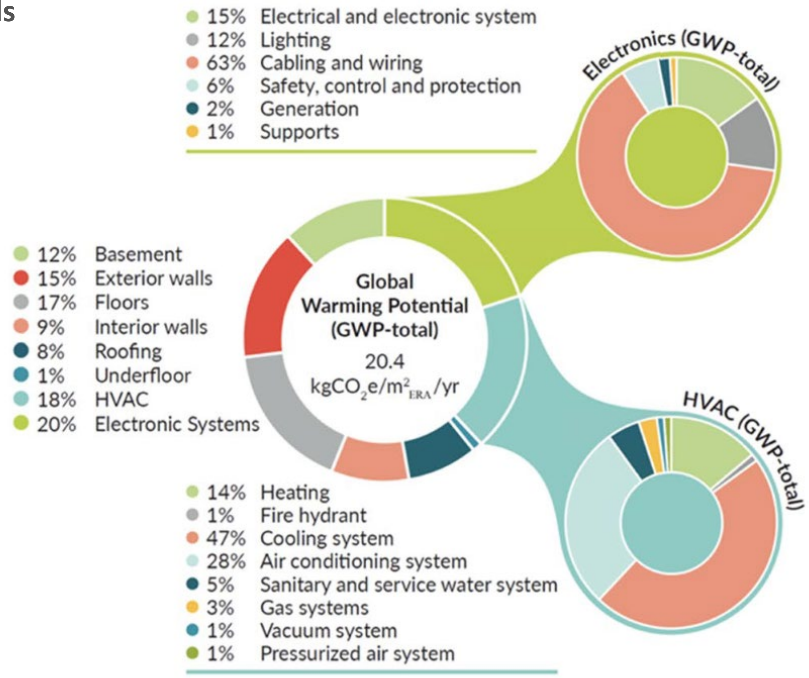


Ricola herb storage, Hertzog & Demeuron

Technical systems seems to be massively underestimated in LCA

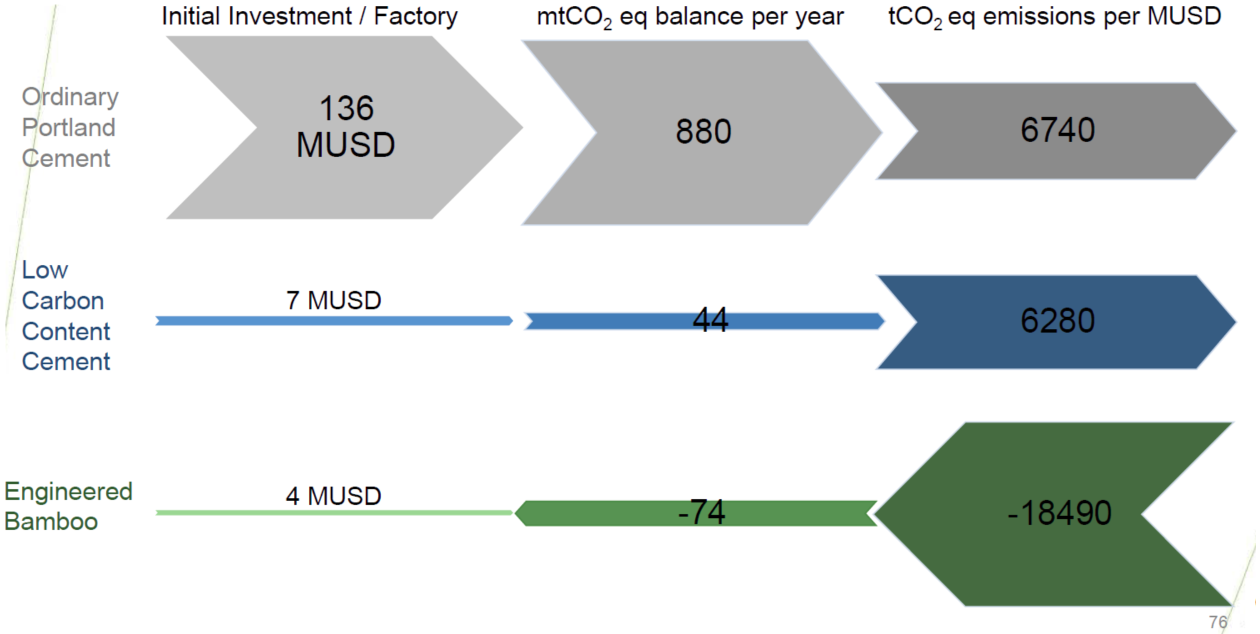
So reducing the need for using them and quantifying their impact accurately will show the potential of using biobased and earth materials as interior materials



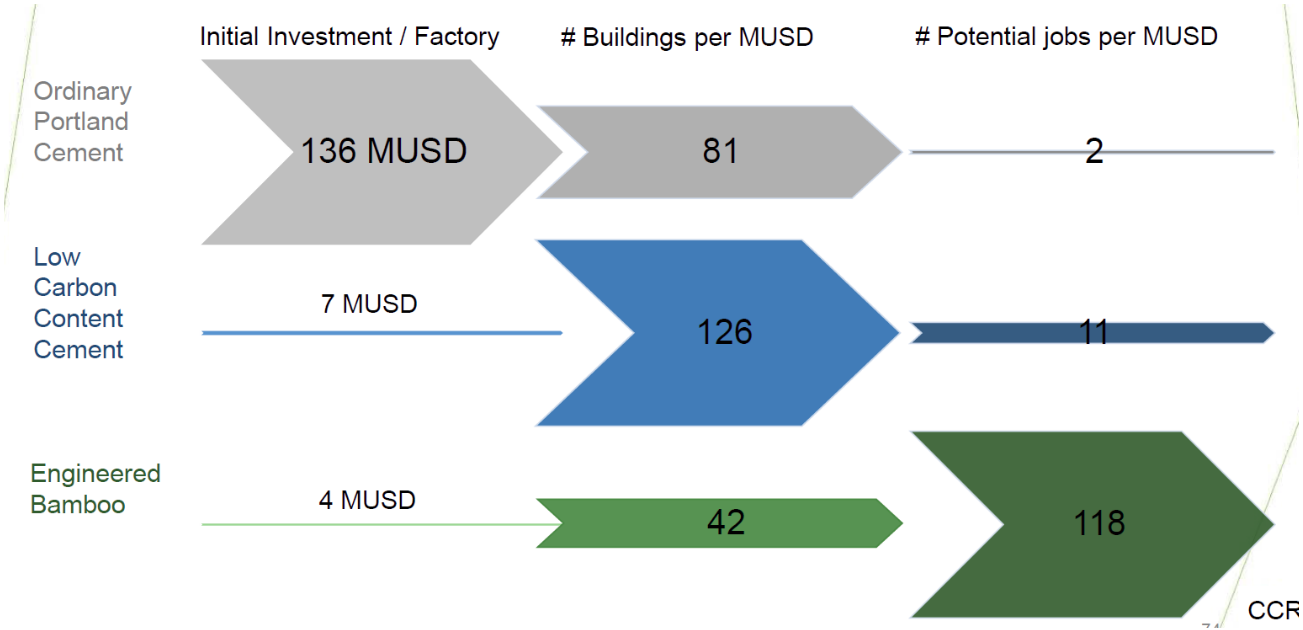


Sce: Hoxha et al. 2021. Influence of technical and electrical equipment in life cycle assessments of buildings: case of a laboratory and research building. *The International Journal of Life Cycle Assessment* 26:852–863

1. **Prioritäten festlegen**
2. **Zeit zum Heilen**
3. **Werkstoffoptionen in einer fair und kohlenstofffrei Welt**
4. **Eine neue Materialdiät**
5. **Die Zeit der Konsequenzen**
   - ***Landnutzung***
   - ***Gebäudenutzer***
   - ***Sozio-ökonomische***



Sce: Zea et al. 2017. Investing in alternative construction materials as a sustainable path towards the reduction of global CO_2 emissions.
A comparative case study of industrialized bamboo and low carbon content cement. *International Symposium on Bamboo in Urban environment*



Bambus als Baumaterial ermöglicht
die Speicherung von CO2 im Gebäudebestand
und schafft Geschäftsmöglichkeiten für kleine Werkstätten *(finanziert durch Carbon credits)*

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The challenge of urbanisation:

Time	GDP (trillion 2012 USD)	Population (billion)	Households (million)	Average persons per household	Residential floor area (billion m^2)	Average m^2 per person
2011	80.8	6.95	1894	3.6	164	24
2030	161.4	8.36	2840	2.9	266	30
2050	272.7	9.48	3518	2.7	354	37

The challenge of urbanisation:

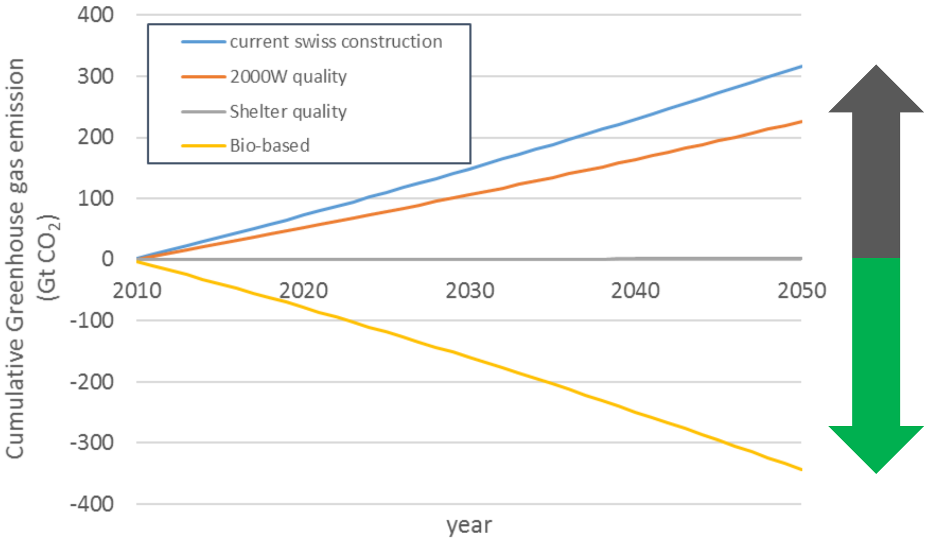
2000W society standard

	Construction	Operation
For new buildings		
Guidance value (kg $CO_2/m^2.a$)	8.5	2.5
Service life of the building (yr)	60	60
Total (kg CO_2/m^2)	510	150
For renovation		
Guidance value (kg $CO_2/m^2.a$)	5	5
Service life of the building (yr)	60	60
Total (kg CO_2/m^2)	300	300

For Bamboo House

	Average
Construction (kgCO2/m2)	37.1
Stored biogenic CO2 (kgCO2/m2)	614.9
Surface (m^2)	20
TOTAL CO_2 emissions (ton/m2)	**-0.6**
TOTAL CO_2 emissions (ton/cap)	**-11.6**

The challenge opportunity of urbanisation:



Consume 40% of global budget only for construction

Gain 45% additional budget thanks to construction

Conclusion

Lehm und Fasern haben die Kapazität, die Welt zu heilen

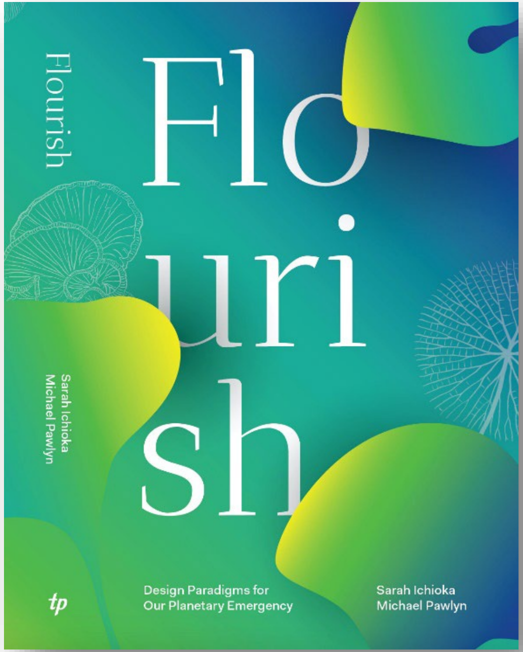
- Schnell wachsende biobasierte Materialien reinigen die Atmosphäre (entfernen CO2)

- Lehm und biobasierte Materialien reinigen die Innenraumluft (ohne zusätzliche graue Emissionen)

- die Verwendung von Aushubmaterial entlastet unsere Mülldeponien (durch Verwendung für neue Gebäude)

- Lehm und biobasierte Materialien schaffen eine lokale Wertschöpfungskette
  Verbindung von städtischen und ländlichen Gebieten
  und generieren Einnahmen an Orten oder Aktivitäten, die in der Regel einen geringen Wert haben.

Conclusion



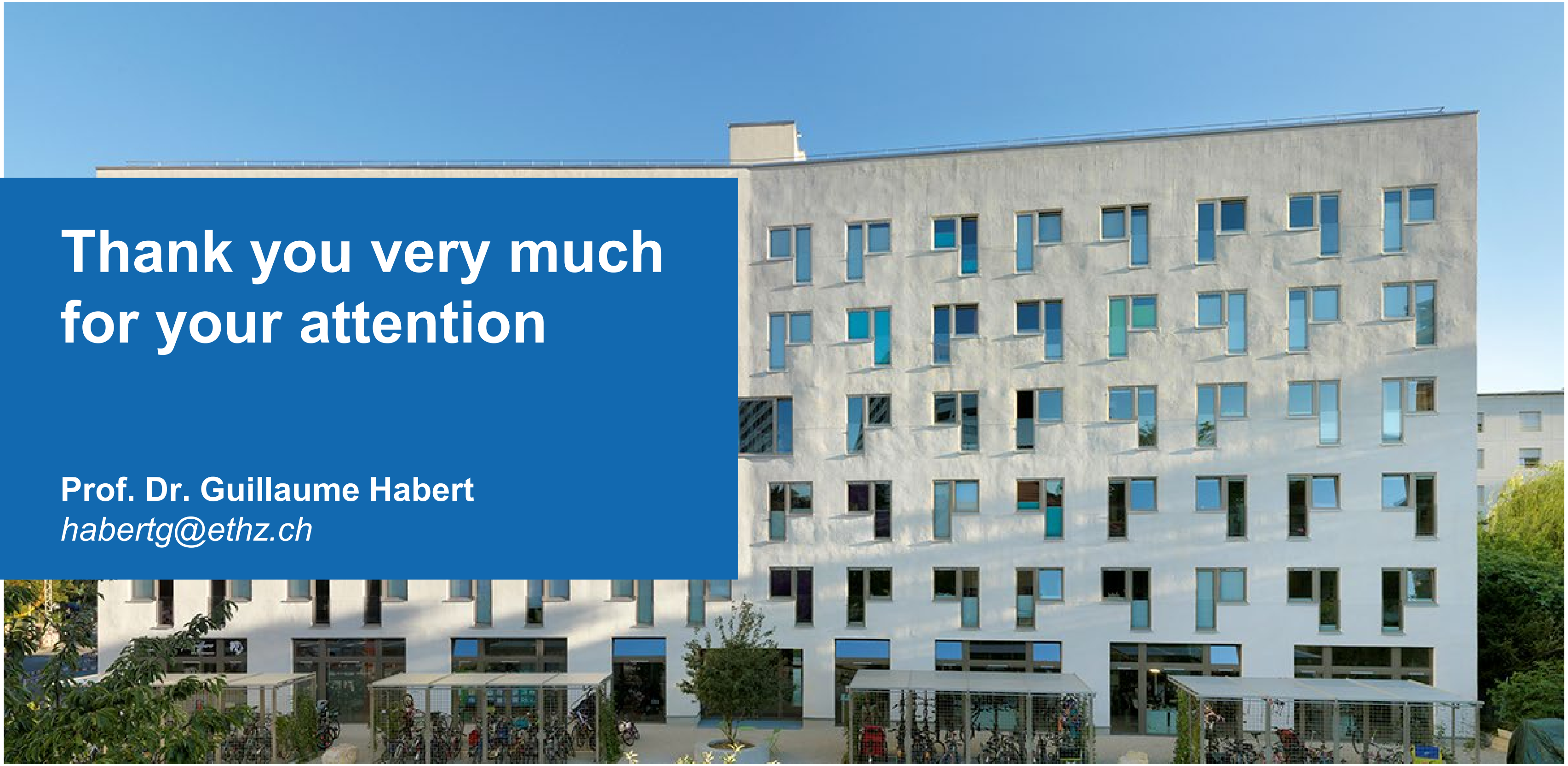
“the fossil age has been in many respects, a massive distraction from humanity ingenuity. Thousands of years ago, people in the middle East knew how to make ice in the desert. One of the exciting aspects about the age we are entering is that we could see a massive reawakening of place based ingenuity”.

“A holistic transformation of modern industrialised human consciousness may induce feelings of overwhelm. And we acknowledge that some argument may look arrogant, naïve or hypocritical to be so ambitious. The chief law of the hypocrisy critique is its implication that unless someone is perfect, they don’t have a right to suggest how things could improve. As Rebecca Solnit has written “Perfection is a stick with which to beat the possible”.

Sarah Ichioka & Michael Pawlyn, Flourish, Triarchy press

ETH zürich

Thank you very much for your attention



Prof. Dr. Guillaume Habert
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Atba architecture, Soubeyran