Biogenic carbon flows and assessments in building stocks, dynamic approach

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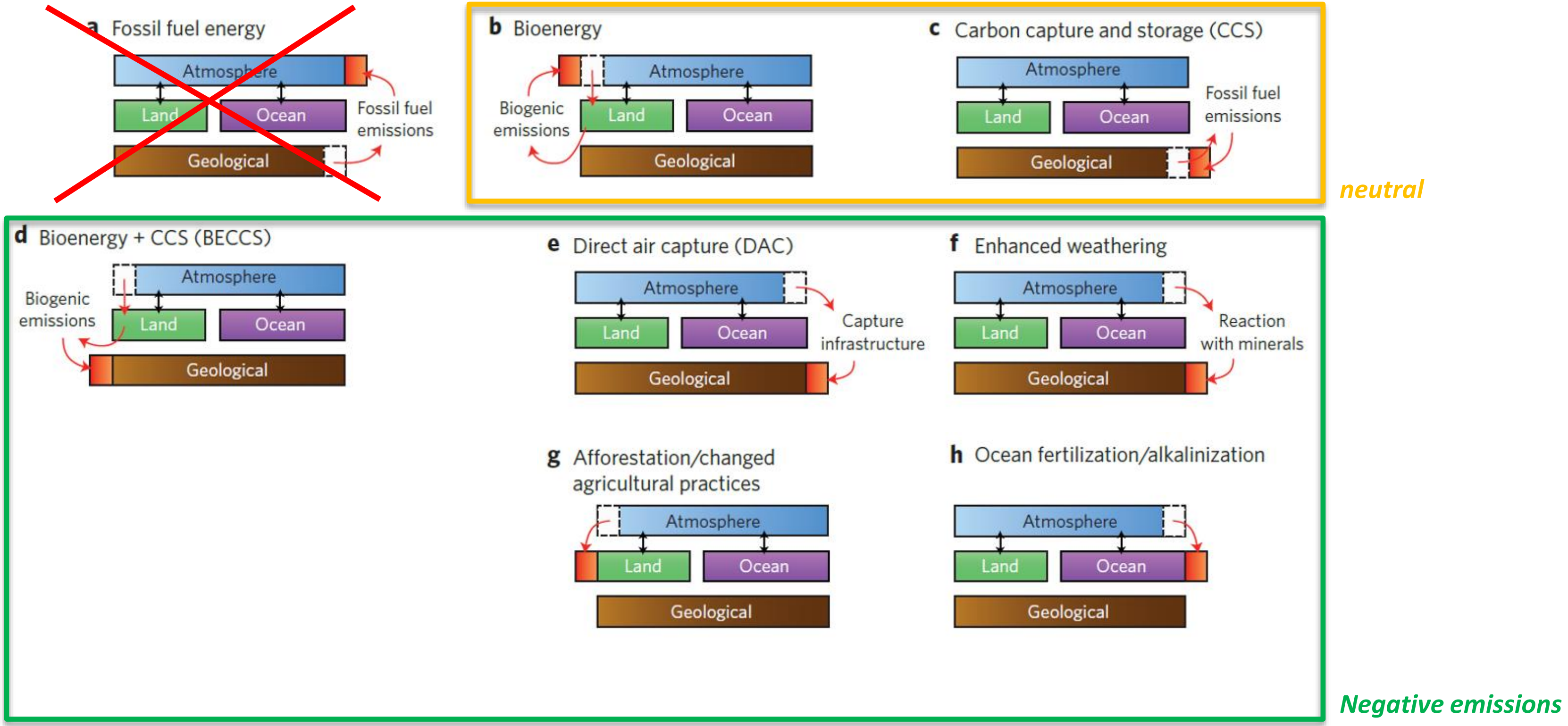
Professor for Sustainable Construction
09.06.2022

Atba architecture, Soubeyran

1. Carbon flows

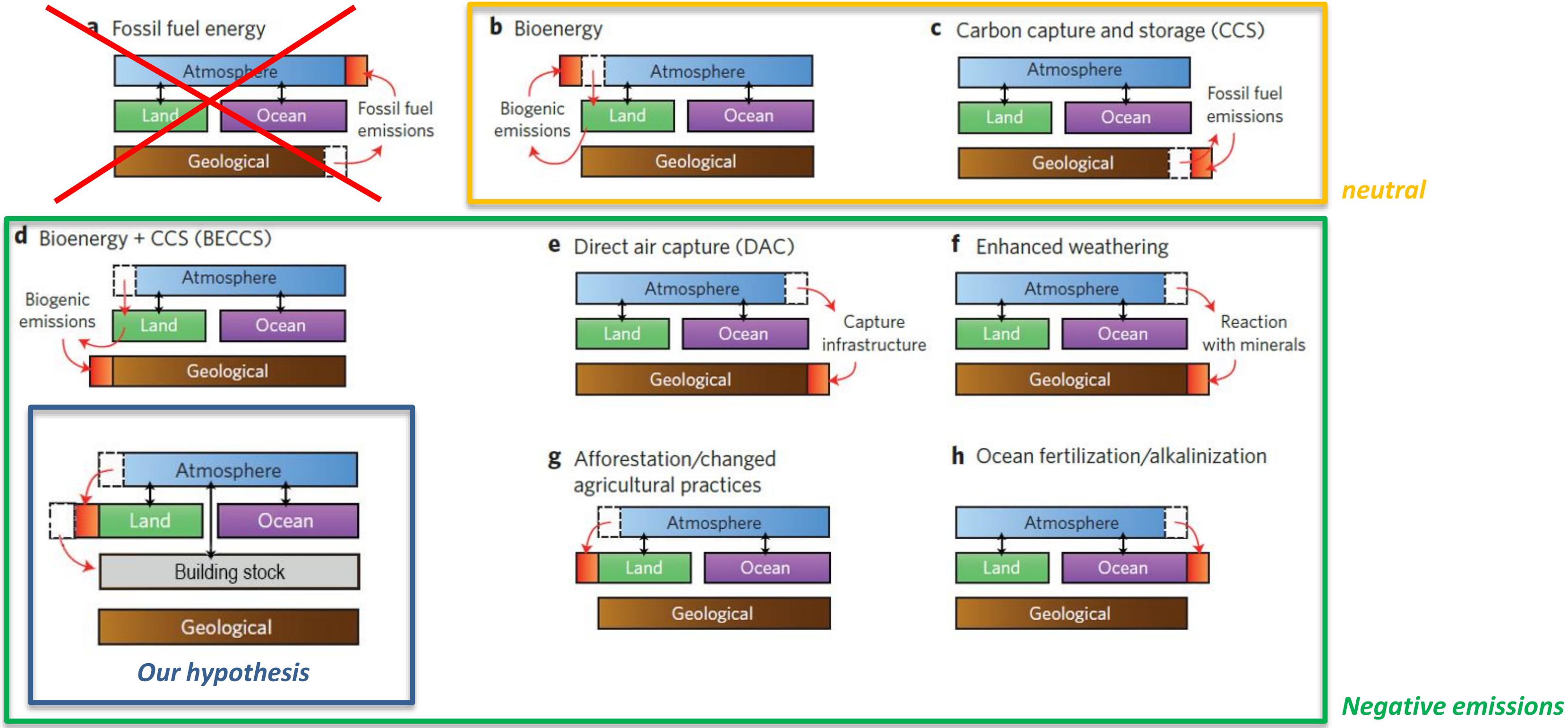
Schematic representation of carbon flows among atmospheric, land, ocean and geological reservoirs.



Sce: Smith et al., 2016. Biophysical and economic limits to negative CO_2 emissions. *Nature climate change*

1. Carbon flows

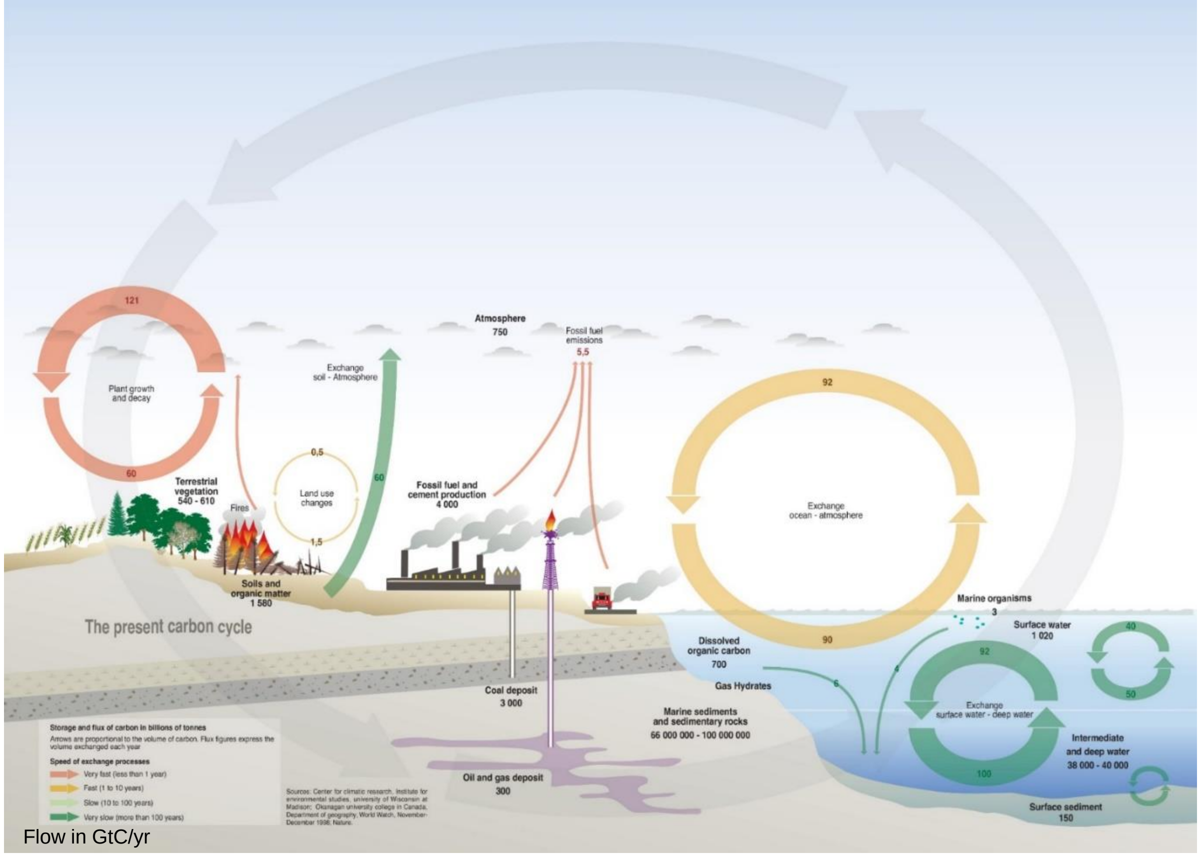
Schematic representation of carbon flows among atmospheric, land, ocean and geological reservoirs, with the addition of the building stock as a reservoir



Adapted from Smith et al., 2016. Biophysical and economic limits to negative CO2 emissions. Nature climate change

2. Carbon flows and their dynamic

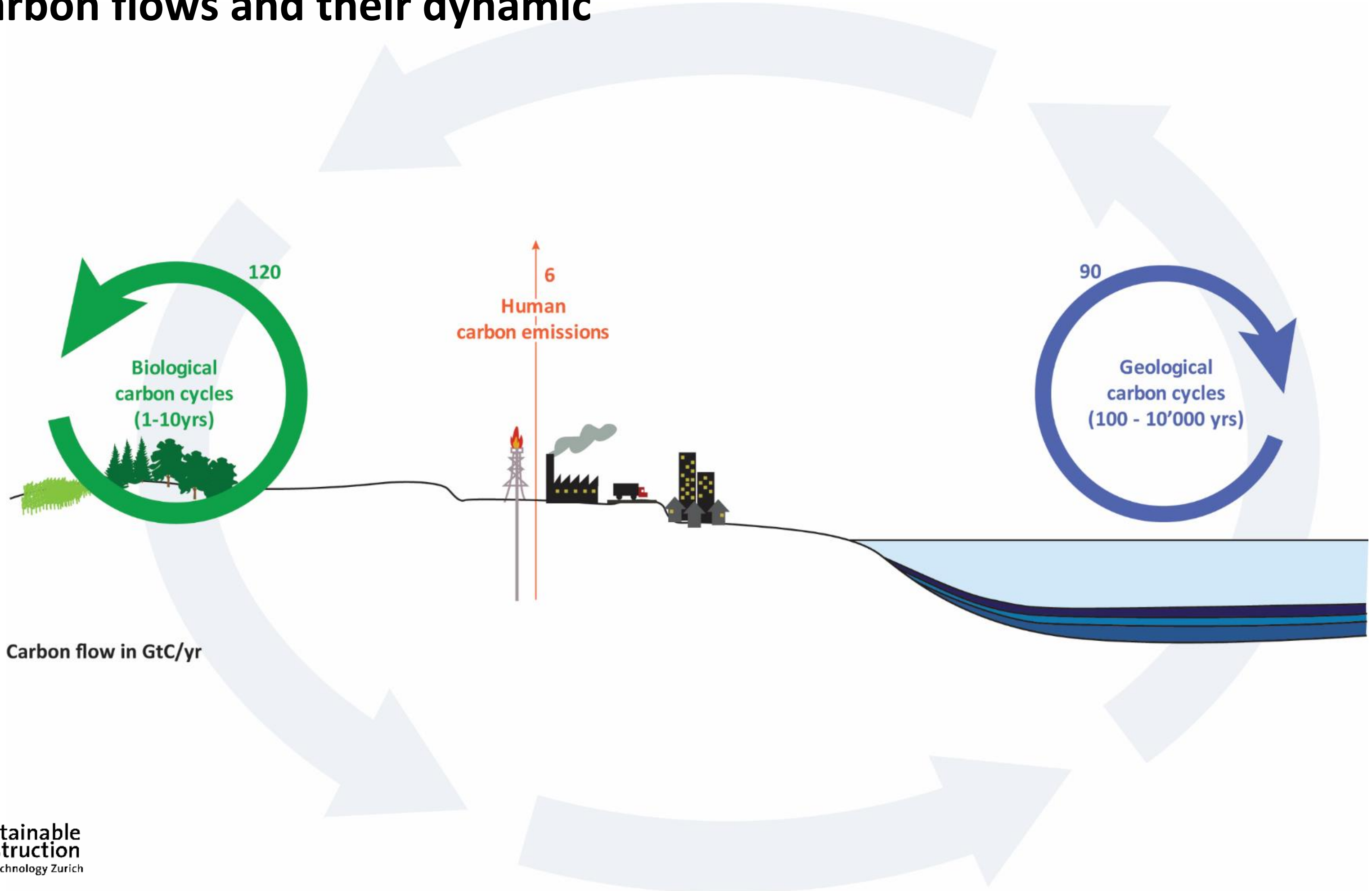
Schematic representation of carbon flows among atmospheric, land, ocean and geological reservoirs



Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Nature.

Flow in GtC/yr

2. Carbon flows and their dynamic



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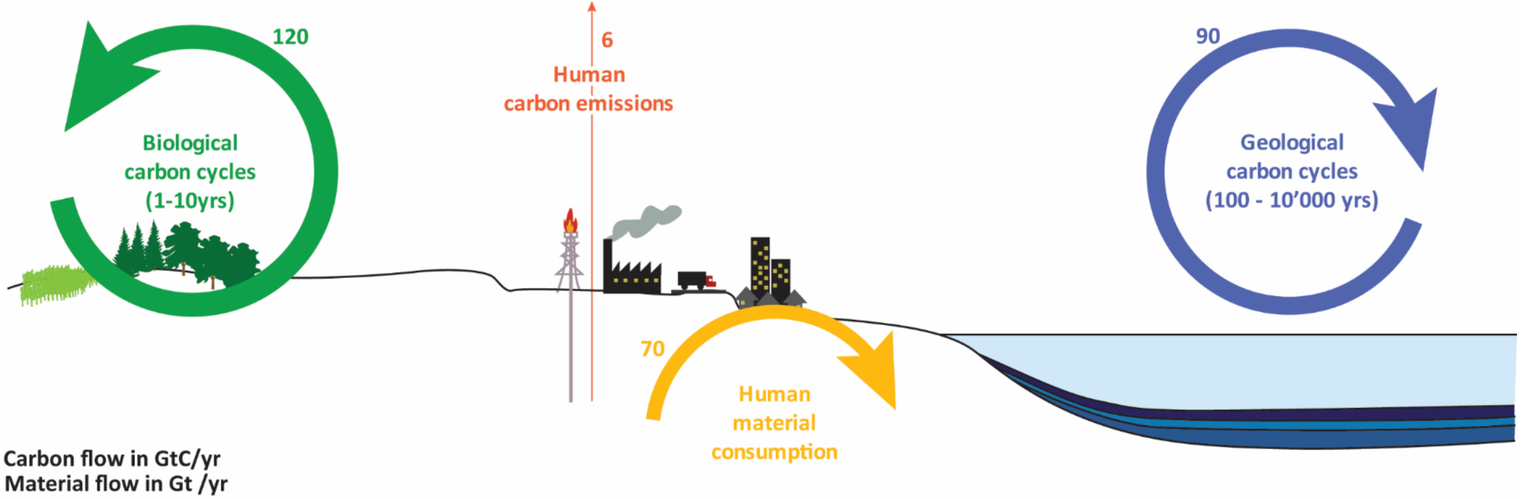
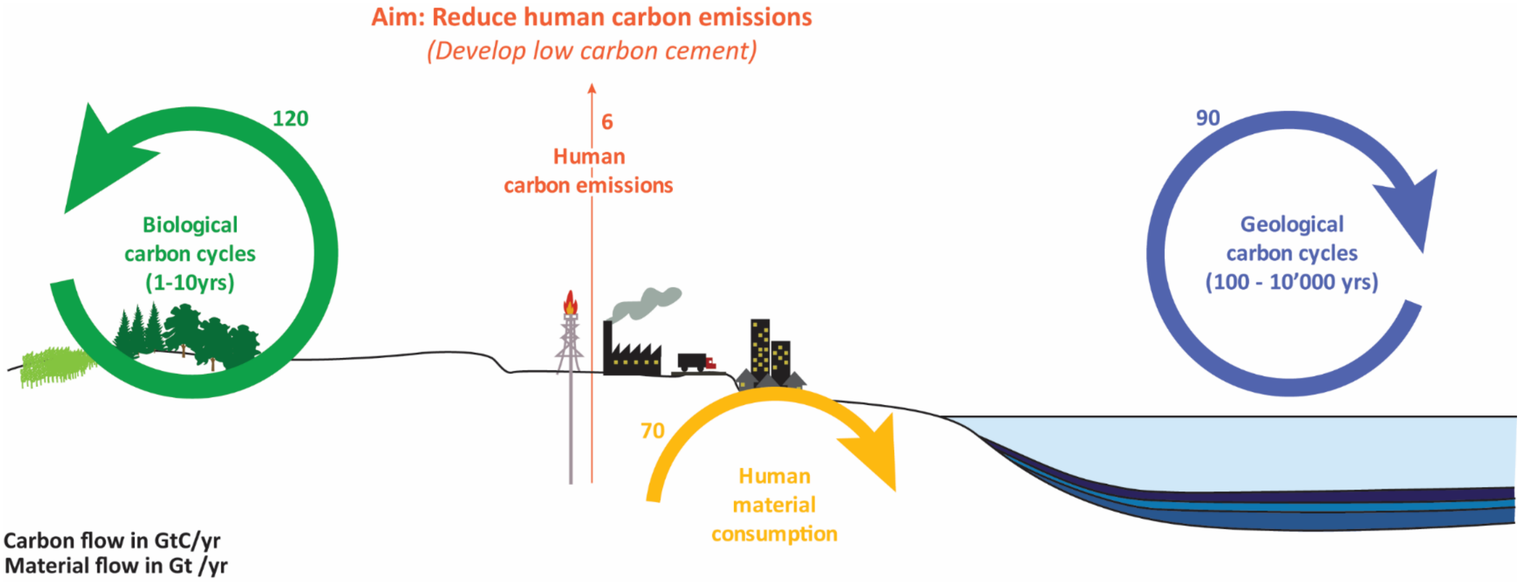


ETH sustainable construction
Swiss Federal Institute of Technology Zurich

2. Carbon flows and their dynamic



Sce: Habert et al. 2020. Environmental impacts and decarbonization strategies in the cement and concrete industries. *Nature Reviews Earth & Environment.*

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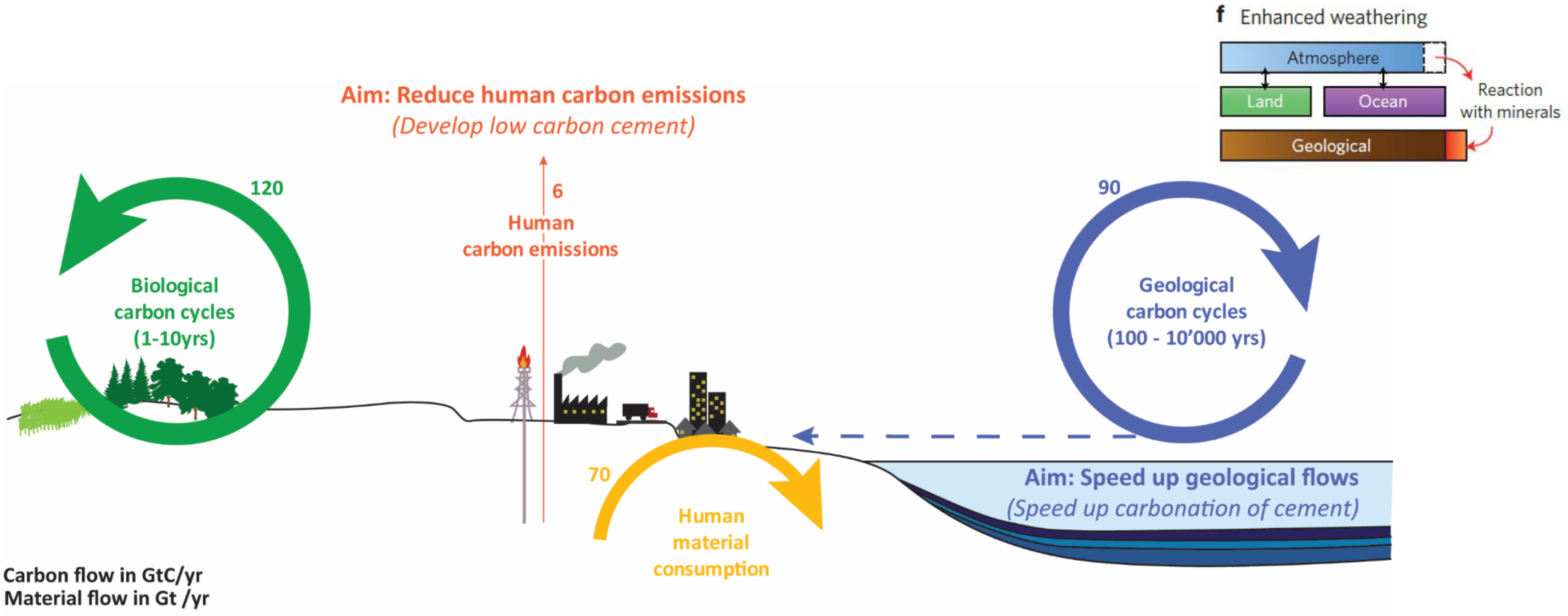

Sce: Soja W., Georget F., Scrivener K. 2020. Evolution of microstructural changes in cement paste during environmental drying. *Cement and Concrete Research*

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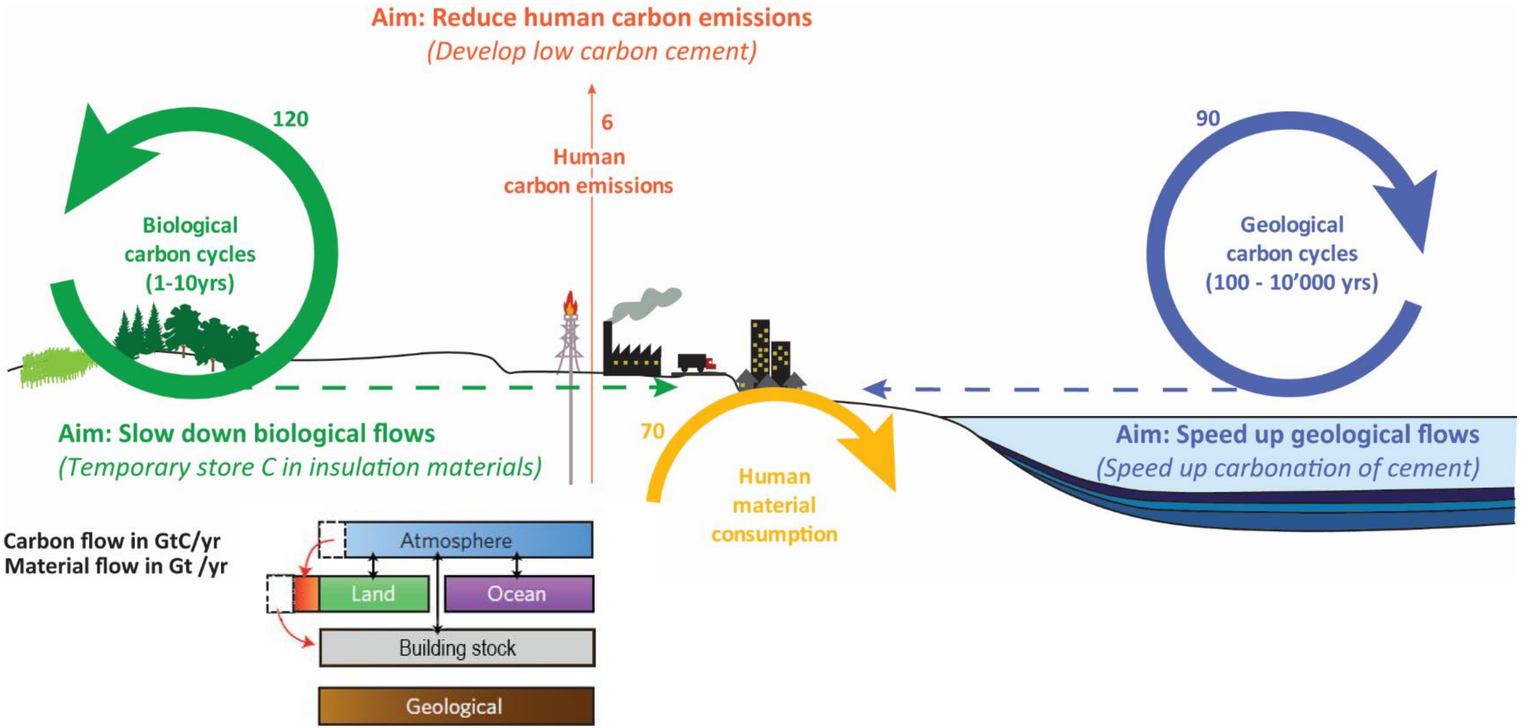

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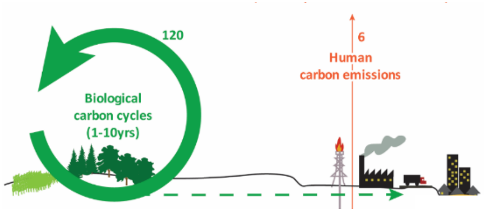
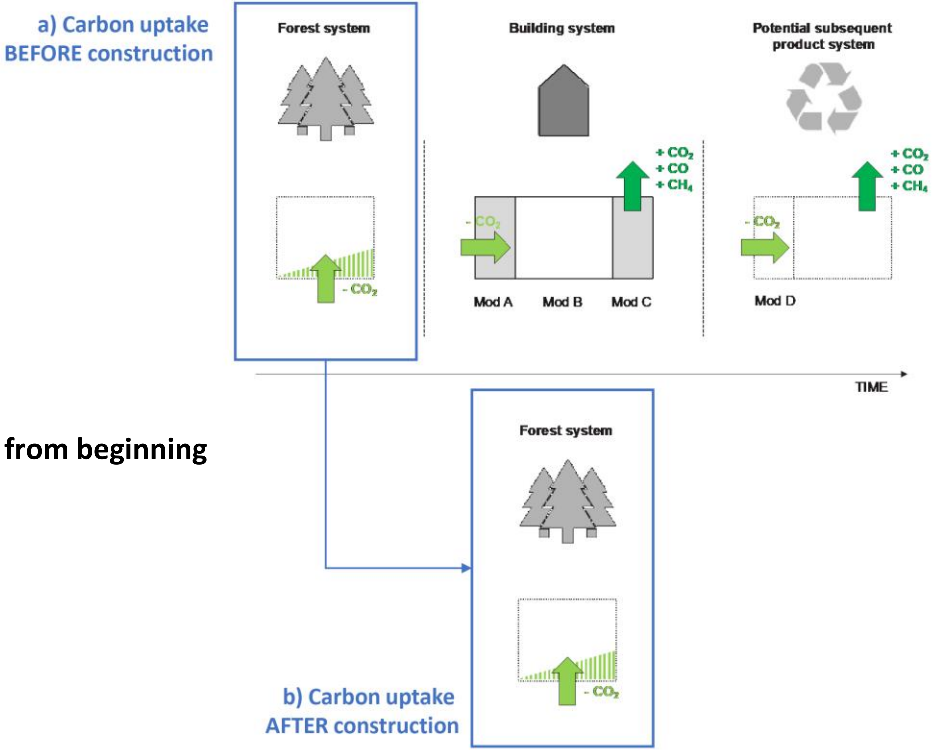
3. Modelling of carbon flows and their dynamic at building scale





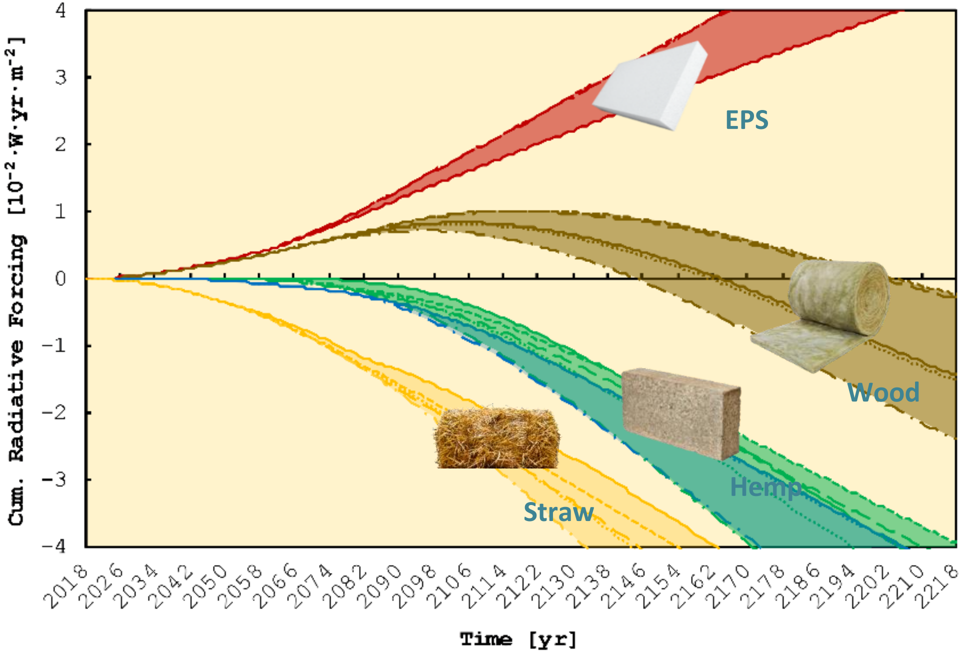
<u>Before construction</u>:
It assumes biogenic cycle belongs to technosphere from beginning

<u>After construction</u>:
It assumes it is the replantation that absorbs CO$_2$

Sce: Hoxha et al., 2020. Biogenic carbon in buildings: a critical overview of LCA methods. *Buildings and Cities*

3. Modelling of carbon flows and their dynamic at building scale

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*

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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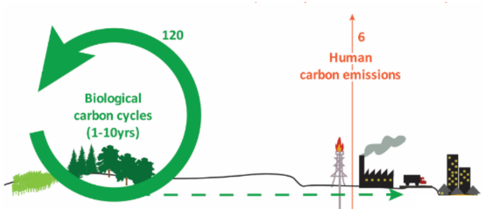
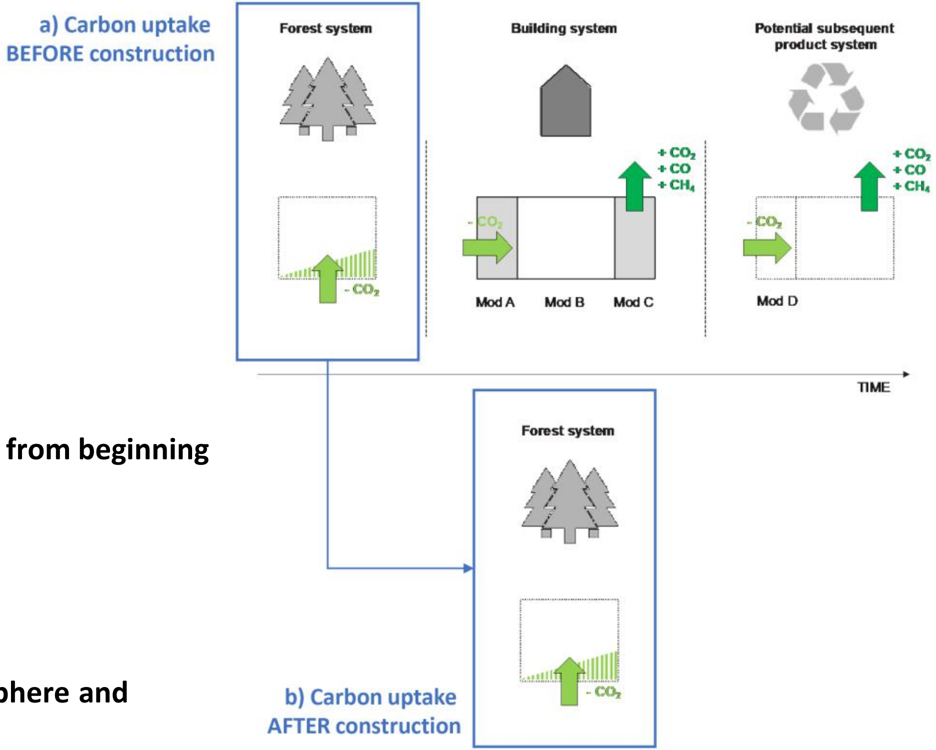




<u>Before construction</u>:
It assumes biogenic cycle belongs to technosphere from beginning

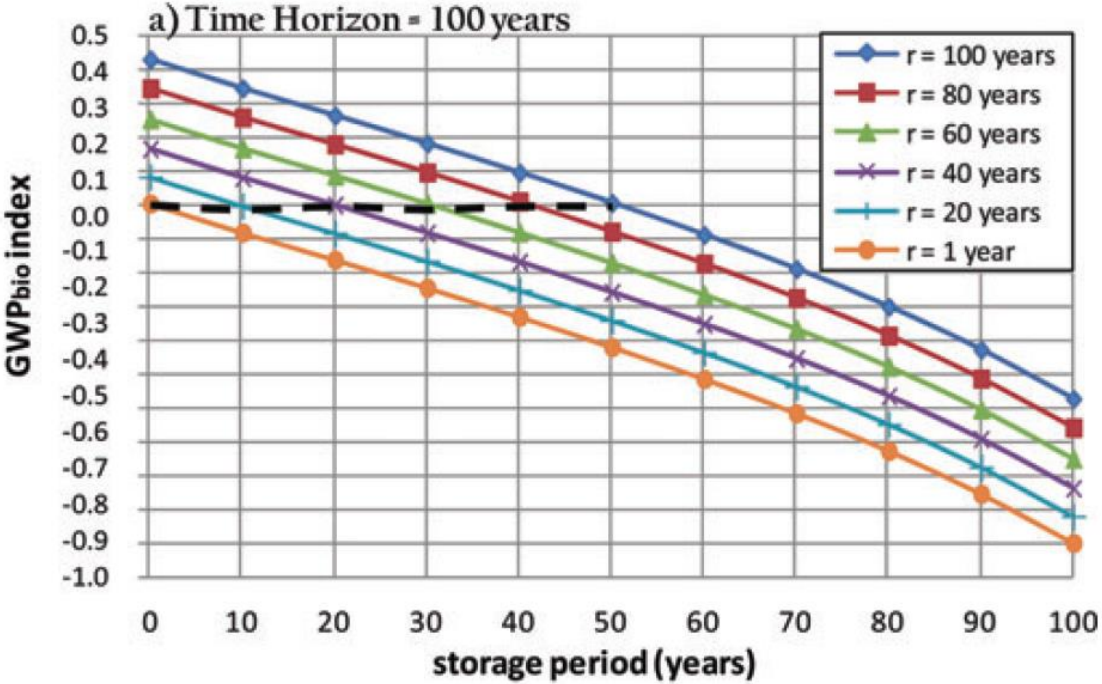
<u>After construction</u>:
It assumes it is the replantation that absorbs CO_2

<u>«Real pump»</u>:
It considers the dynamic difference between biosphere and technosphere

Sce: Hoxha et al., 2020. Biogenic carbon in buildings: a critical overview of LCA methods. *Buildings and Cities*

3. Modelling of carbon flows and their dynamic at building scale

Semi-static approach considering discrepancy between rotation period (in biosphere) and storage period (in technosphere)



Sce: Guest et al., 2012. GWP of CO_2 emissions from biomass stored in the anthroposphere and used for bioenergy at end of life. Journal of Industrial ecology

3. Modelling of carbon flows and their dynamic at building scale

Semi-static approach considering discrepancy between rotation period (in biosphere) and storage period (in technosphere)

Finishing

Insulation
Windows/doors

Structures

Growing seasonal crops (straw, cotton, flax, etc.)

Coniferous forests – softwoods (fir, nordic spruce, pine, larch, etc.)

Broad-leaved trees – hardwoods (beech, oak, birch, etc.)

	Storage period									
Rotation	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
1	-0.07	-0.15	-0.23	-0.32	-0.4	-0.5	-0.6	-0.71	-0.84	-0.99
10	-0.04	-0.12	-0.2	-0.28	-0.37	-0.46	-0.57	-0.68	-0.8	-0.96
20	0	-0.08	-0.16	-0.24	-0.33	-0.42	-0.53	-0.64	-0.76	-0.92
30	0.04	-0.04	-0.12	-0.2	-0.29	-0.38	-0.48	-0.6	-0.72	-0.88
40	0.09	0.01	-0.08	-0.16	-0.25	-0.34	-0.44	-0.55	-0.68	-0.84
50	0.13	0.05	-0.03	-0.12	-0.21	-0.3	-0.4	-0.51	-0.64	-0.8
60	0.17	0.09	0.01	-0.07	-0.16	-0.26	-0.36	-0.47	-0.59	-0.75
70	0.22	0.14	0.06	-0.03	-0.12	-0.21	-0.31	-0.42	-0.55	-0.71
80	0.26	0.18	0.1	0.02	-0.07	-0.17	-0.27	-0.38	-0.5	-0.66
90	0.31	0.23	0.15	0.06	-0.03	-0.12	-0.22	-0.33	-0.46	-0.62
100	0.37	0.29	0.21	0.12	0.032	-0.06	-0.16	-0.27	-0.4	-0.56

Remark:

Most common use of biobased materials:

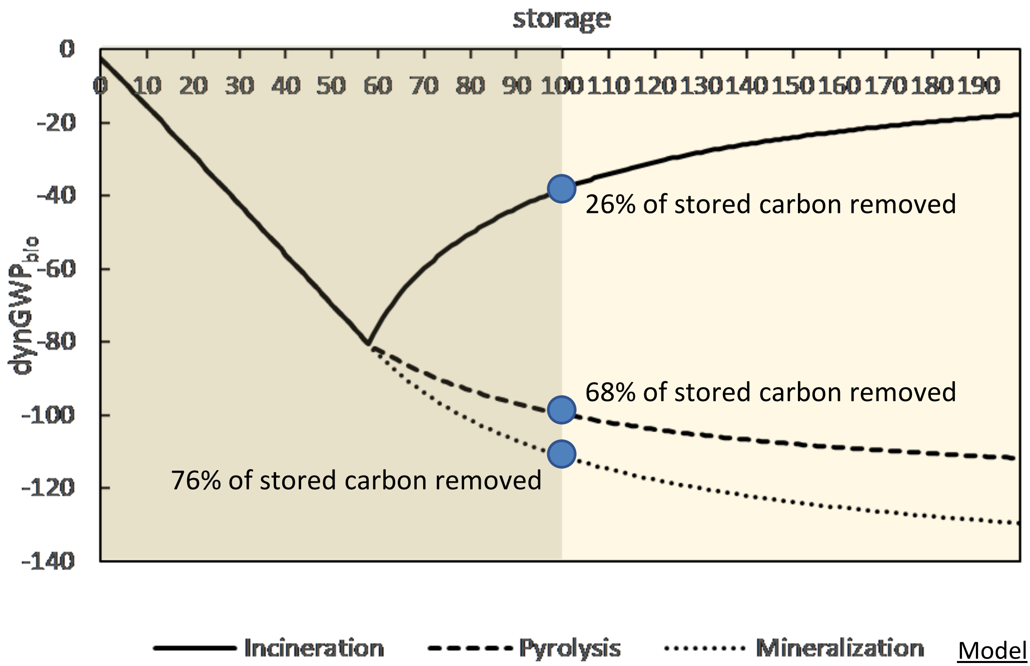
- GWP bio for Straw insulation = - 0.23
- GWP bio for softwood structure = - 0.26

Having a characterisation factor of - 0.25 for biogenic CO_2 can be a way to avoid the need to define a function...

Sce: Adapted from Guest et al., 2012. Journal of Industrial ecology

3. Modelling of carbon flows and their dynamic at building scale

Figure is completely different if one consider that at the end of life of building element, it will not be allowed to do aerobic combustion of biogenic material and release CO_2, but that anaerobic combustion will be the standard (pyrolysis)

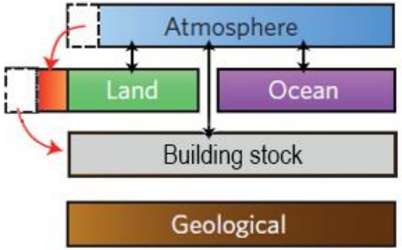


Ex: Biochar starts to be used in concrete (Klark from LogBau) and green waste from cities starts to be pyrolysed (Basel)

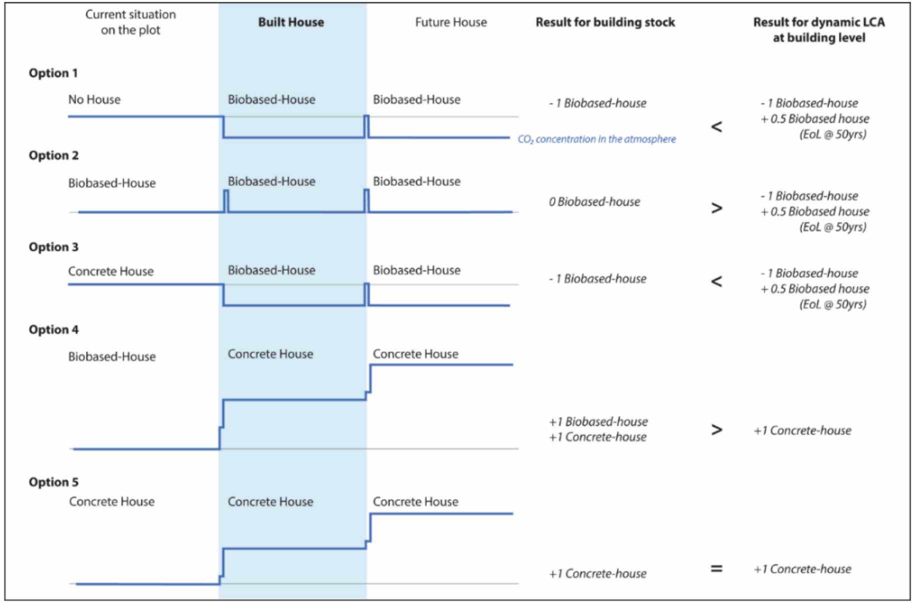
Model: Dynamic GWP results from equivalent biogenic CO_2 emissions of treating 100 kg of wood according to 3 different post-use process: incineration, pyrolysis and mineralization. Assumptions: Storage=60 years; Regrowth=60 years.

Sce: Pittau et al., 2022. Methodology for biogenic carbon accounting and carbonation in LCA of buildings and construction products. *Stadt Zurich report*

4. Assessing carbon content in building stock



There is a short term *(decades)* dynamic flow question.
But in the long term *(centuries)*, what counts is the total content of the building stock reservoir



	Current situation on the plot	Built House	Future House	Result for building stock		Result for dynamic LCA at building level
Option 1	No House	Biobased-House	Biobased-House	*- 1 Biobased-house*	<	*- 1 Biobased-house* *+ 0.5 Biobased house* *(EoL @ 50yrs)*
Option 2	Biobased-House	Biobased-House	Biobased-House	*0 Biobased-house*	>	*- 1 Biobased-house* *+ 0.5 Biobased house* *(EoL @ 50yrs)*
Option 3	Concrete House	Biobased-House	Biobased-House	*- 1 Biobased-house*	<	*- 1 Biobased-house* *+ 0.5 Biobased house* *(EoL @ 50yrs)*
Option 4	Biobased-House	Concrete House	Concrete House	*+1 Biobased-house* *+1 Concrete-house*	>	*+1 Concrete-house*
Option 5	Concrete House	Concrete House	Concrete House	*+1 Concrete-house*	=	*+1 Concrete-house*

Maybe the most important would be to integrate the carbon content on the plot before construction and insure that this carbon content is at least preserved and at best increased through new construction.

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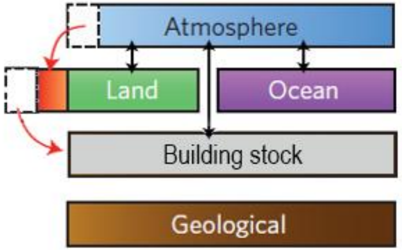

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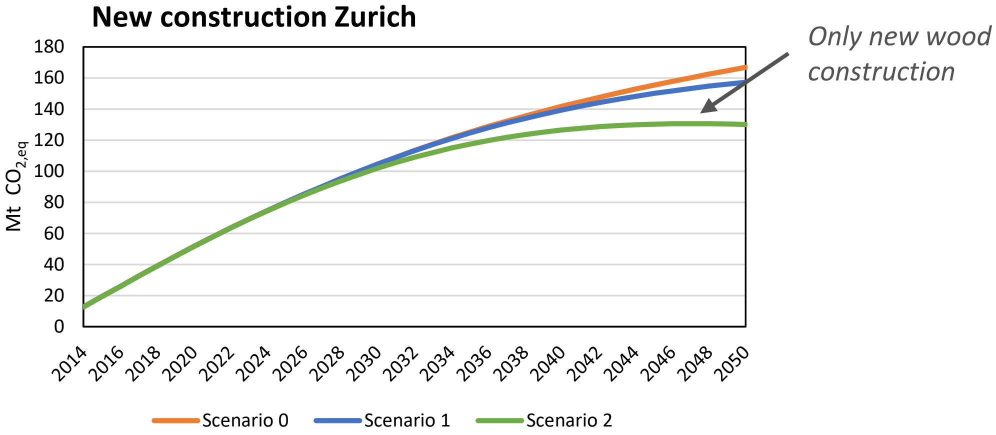
The increase of building stock reservoir could represent around 3 to 5% of yearly GHG emissions[1]. Adding the carbon substitution effect (switch from concrete to wood and from Polystyrene/rockwool to straw/cellulose); it starts to be possible to reach climate neutrality for built environment WITHOUT carbon capture and storage technology

[1] Arehart et al., 2021. Carbon sequestration and storage in the built environment. *Sustainable production and consumption*



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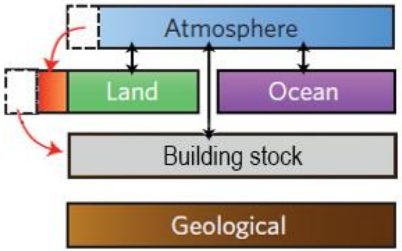

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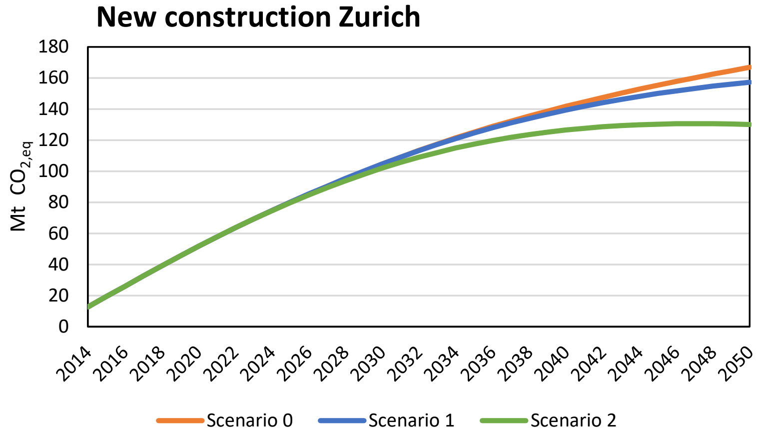
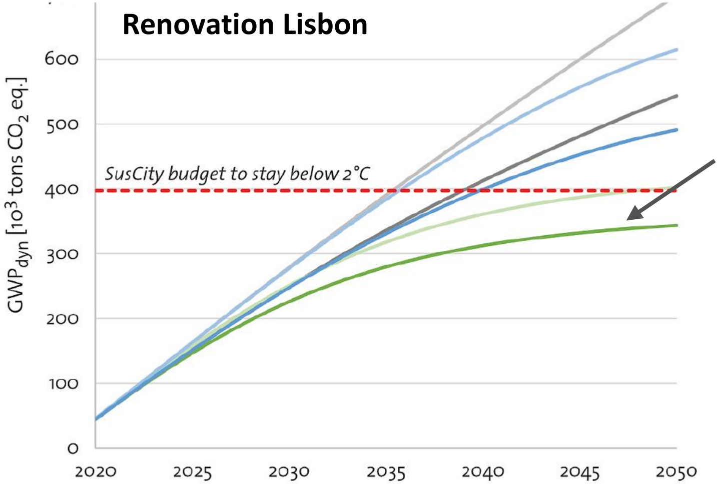

New construction Zurich

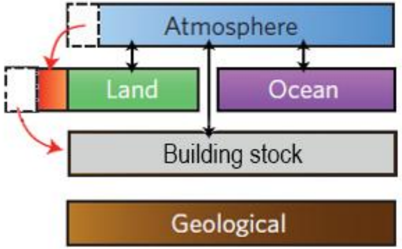
Sce: Pittau et al., 2022. Methodology for biogenic carbon accounting and carbonation in LCA of buildings and construction products. Stadt Zurich report


Renovation Lisbon

High renovation rate
+ Biobased insulation

Sce: Göswein et al. 2021. Influence of materials choice, renovation rate, and electricity grid to achieve a Paris agreement-compatible building stock: A Portuguese case study. *Building and Environment*

4. Assessing carbon content in building stock



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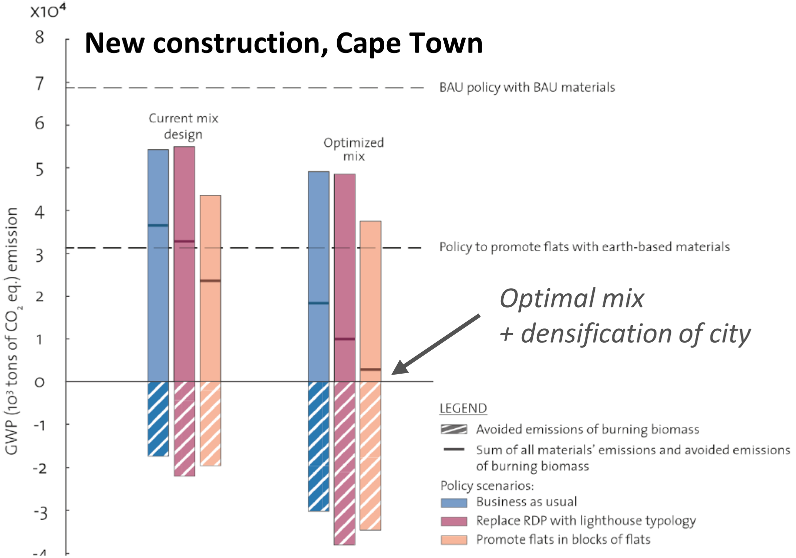
S. Lamb


New construction, Cape Town

Optimal mix
+ densification of city

Sce: Göswein et al. 2021. Invasive alien plants as an alternative resource for concrete production - Multi-scale optimization including carbon compensation, cleared land and saved water runoff in South Africa. *Resources, Conservation & Recycling*

ETH zürich

Thank you for your attention

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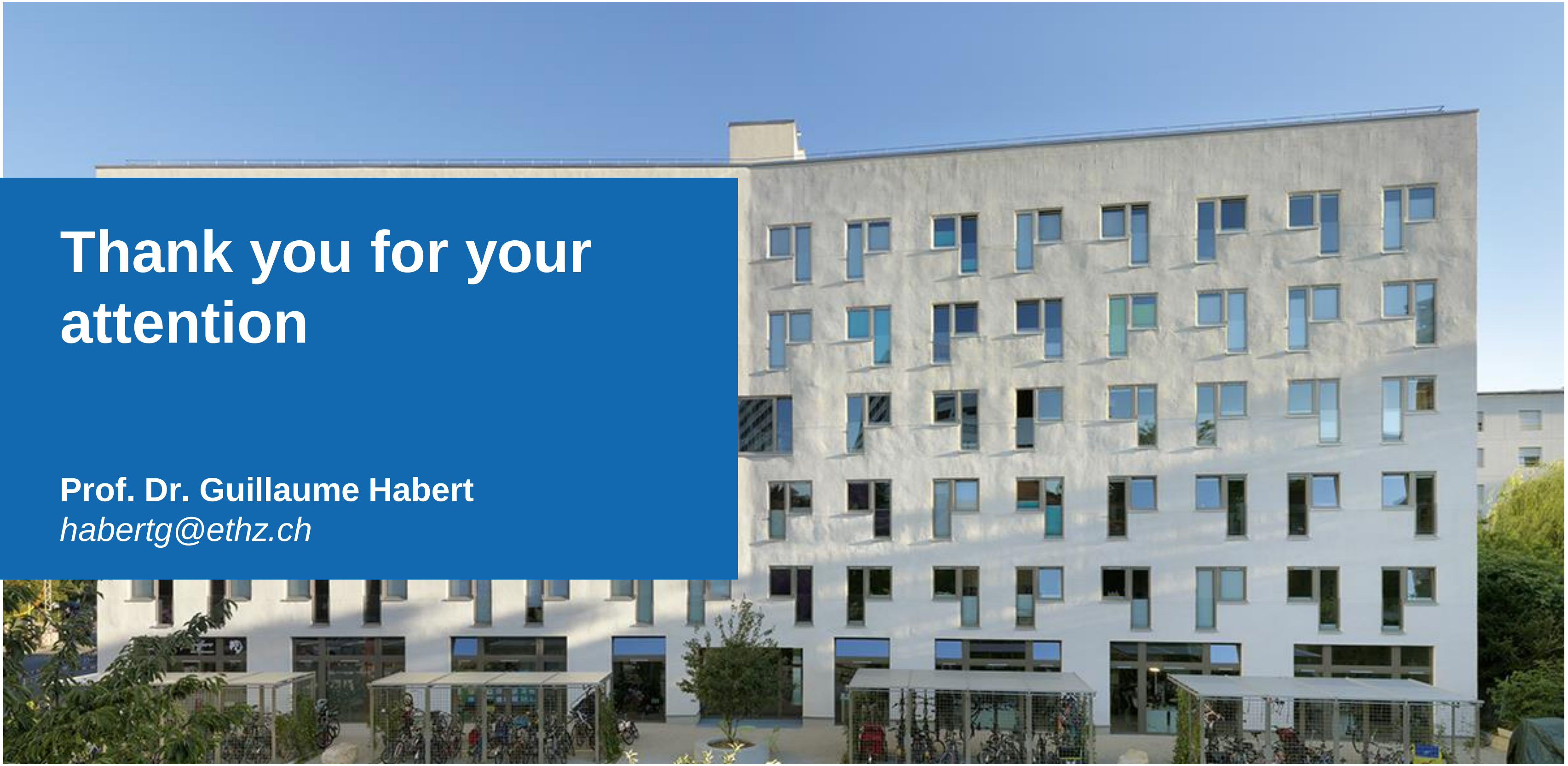
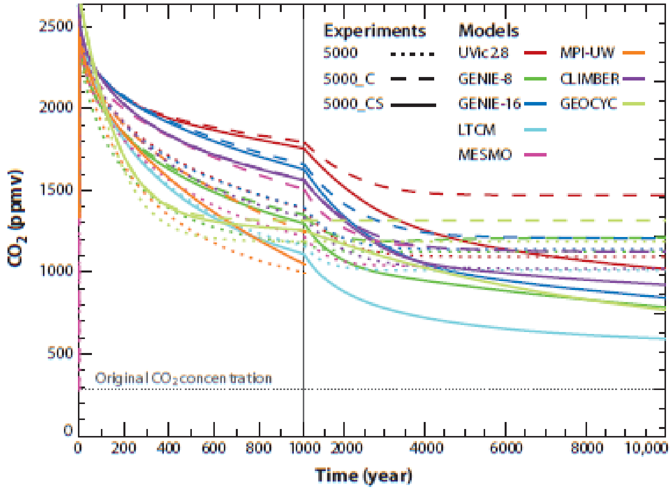


Atba architecture, Soubeyran

Atmospheric life time of fossil fuel carbon dioxide.

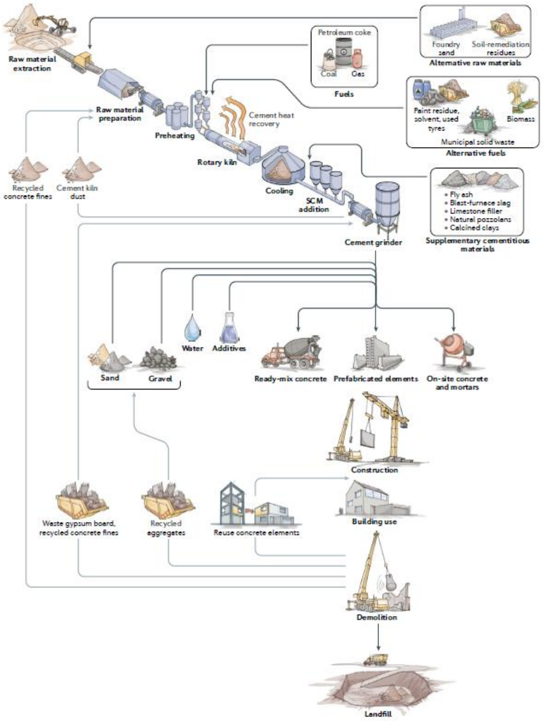
Archer et al. 2009. *Annual Review of Earth and Planetary Sciences*. 37:117–34.
DOI: 10.1146/annurev.earth.031208.100206



When CO_2 is released in the atmosphere.
65% is reabsorbed by ocean after 200 to 2’000 years
Remaining 35% will be neutralized thanks to mineral weathering in 3’000 to 7’000 years

CO_2 resulting from roman lime production is still in the air…

The involvement of all stakeholders along the value chain allow to cut immediately by 50% carbon emissions from cement Without massive investment and without changing current standards



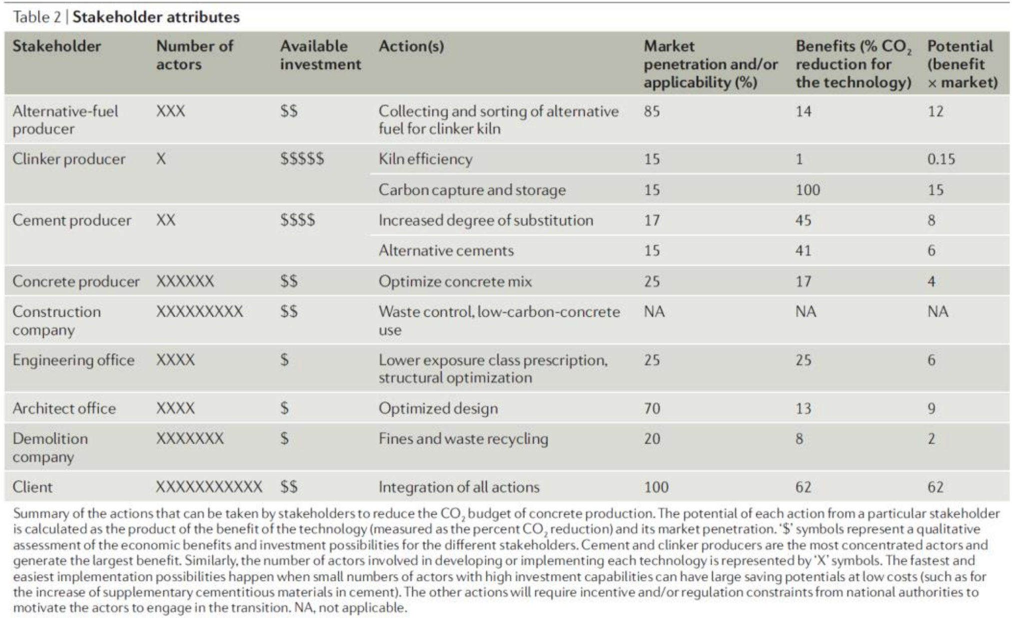


Table 2 | **Stakeholder attributes**

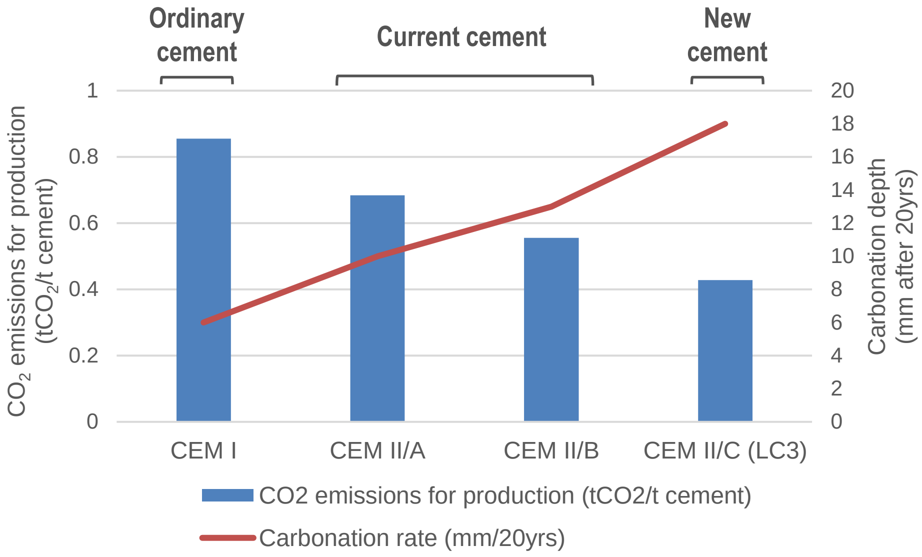
Stakeholder	Number of actors	Available investment	Action(s)	Market penetration and/or applicability (%)	Benefits (% CO_2 reduction for the technology)	Potential (benefit × market)
Alternative-fuel producer	XXX	$$	Collecting and sorting of alternative fuel for clinker kiln	85	14	12
Clinker producer	X	$$$$$	Kiln efficiency	15	1	0.15
			Carbon capture and storage	15	100	15
Cement producer	XX	$$$$	Increased degree of substitution	17	45	8
			Alternative cements	15	41	6
Concrete producer	XXXXXX	$$	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.

Sce: Habert et al. 2020. Environmental impacts and decarbonization strategies in the cement and concrete industries. *Nature Reviews Earth & Environment.*

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



Sce: Soja W., Georget F., Scrivener K.. Evolution of microstructural changes in cement paste during environmental drying. *Cement and Concrete Research*

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

Concrete choreography, NCCR Dfab, Benjamin Dillenburger, ETH Zurich