ETH zürich

ACV dynamique

Du bâtiment au stock bâti

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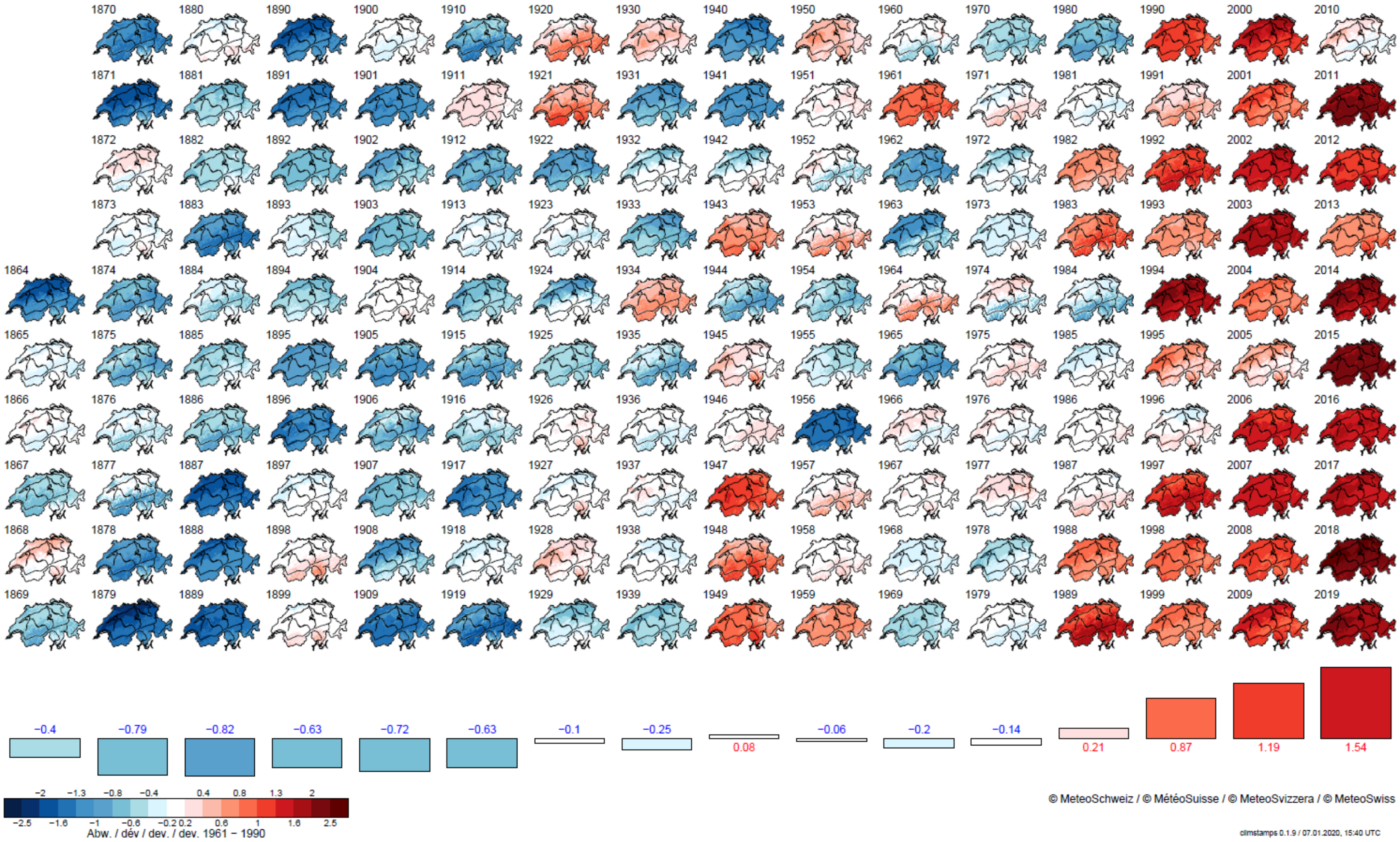
Chaire de Construction Durable

01.04.2021, Paris

Atba architecture, Soubeyran

TERRA FIBRA AWARD

1- Il y a une urgence climatique



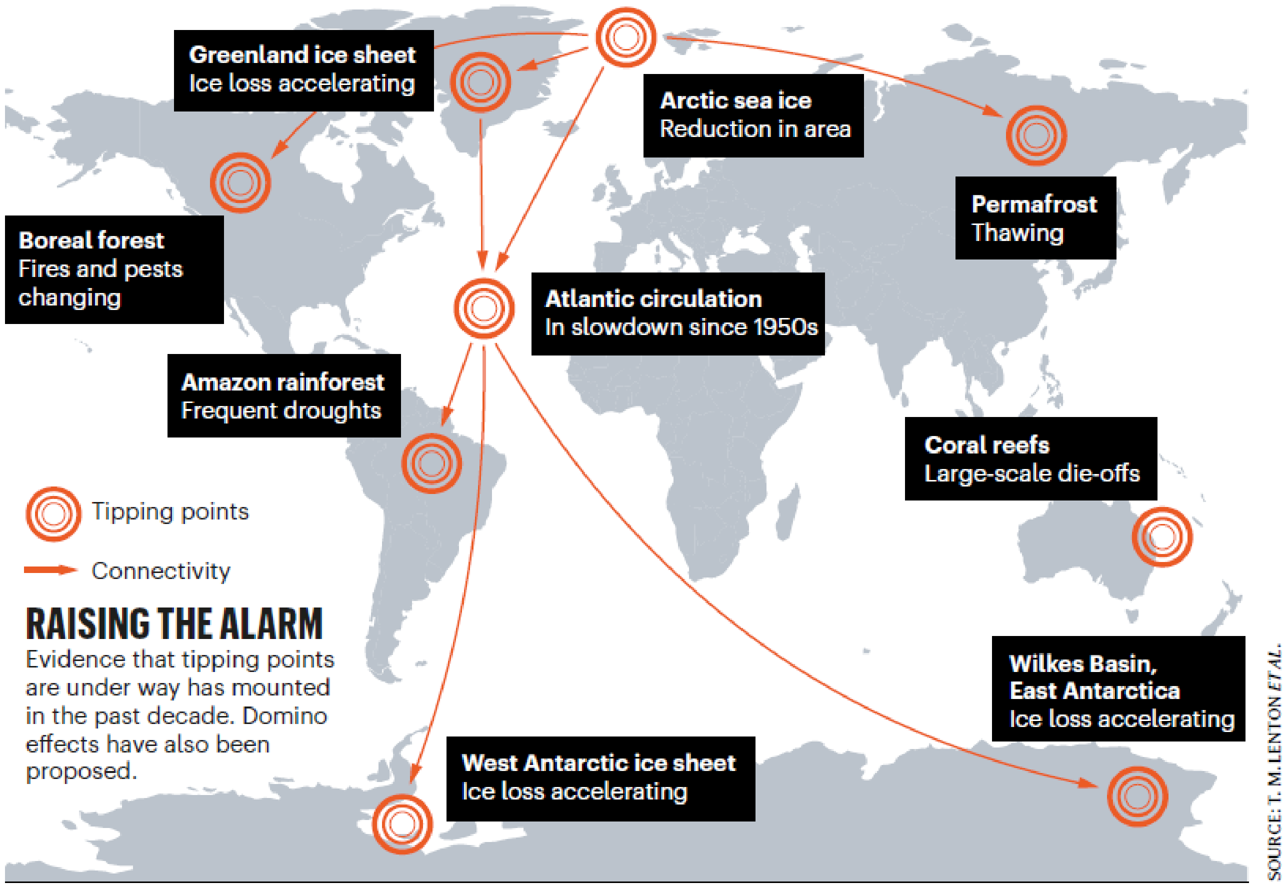
−0.4
−0.79
−0.82
−0.63
−0.72
−0.63
−0.1
−0.25
0.08
−0.06
−0.2
−0.14
0.21
0.87
1.19
1.54
Abw. / dév. / dev. 1961 − 1990
© MeteoSchweiz / © MétéoSuisse / © MeteoSvizzera / © MeteoSwiss
climstamps 0.1.9 / 07.01.2020, 15:40 UTC

January 2020, Lake Conjola, Australia
Photograph: Matthew Abbott

March 2021, Sidney, Australia
Photograph: J. Gourley / R.Shutterstock

1- Il y a une urgence climatique

We are very close to cross irreversible tipping points



Sce: Lenton et al. 2019. Climate tipping points, too risky to bet against. *Nature*

1- Il y a une urgence climatique

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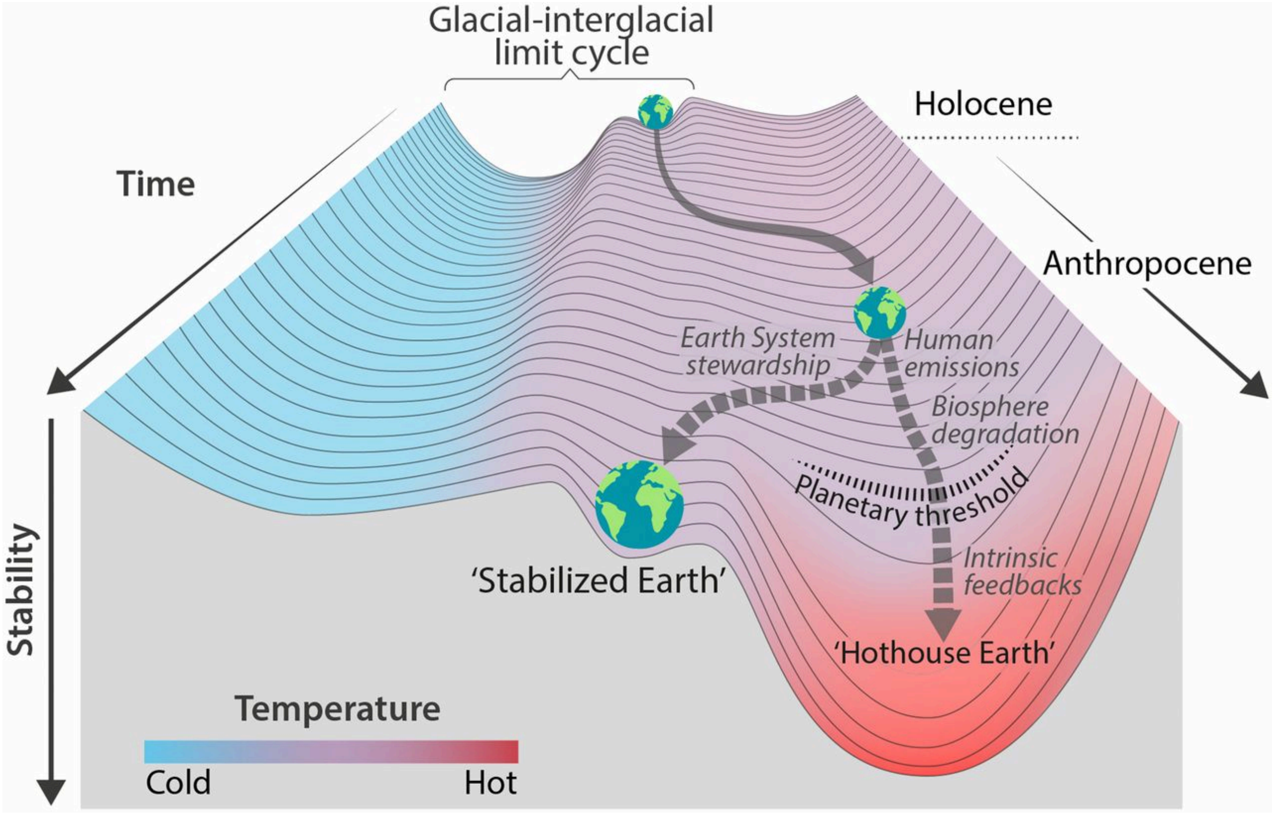


Here are the trajectories of the Earth System in the Anthropocene

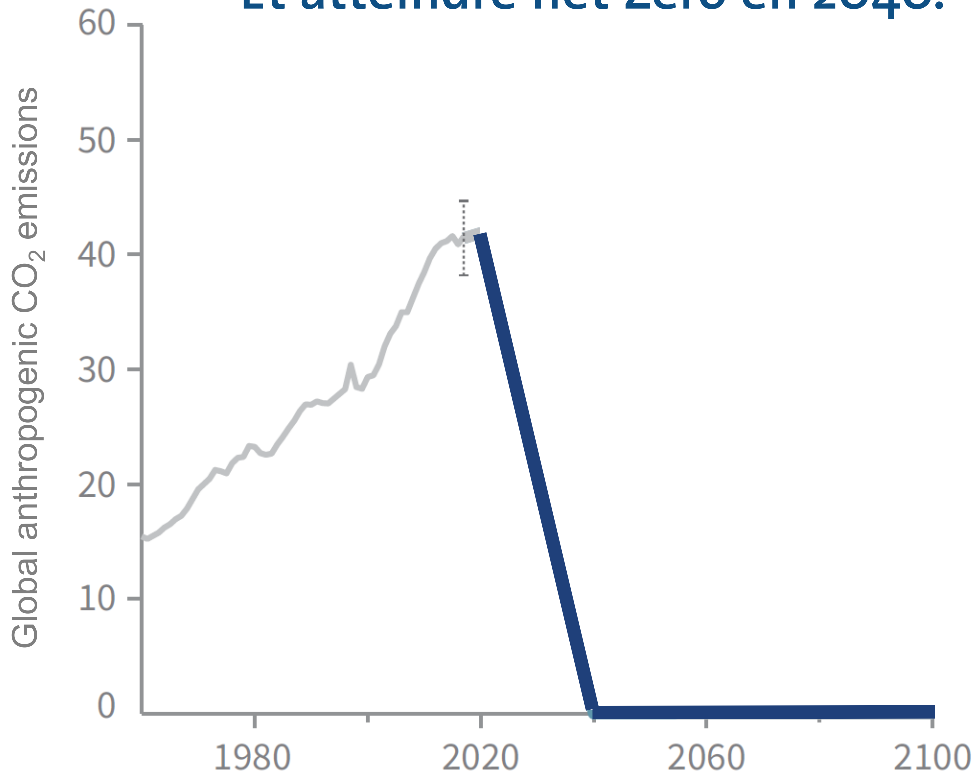
Sce: Steffen et al. 2019. Trajectories of the Earth System in the Anthropocene, *PNAS*

1- Il y a une urgence climatique

Une transformation radicale est nécessaire:

Réduire émissions de CO_2 emissions de 50% en 10 ans

Et atteindre net Zero en 2040.

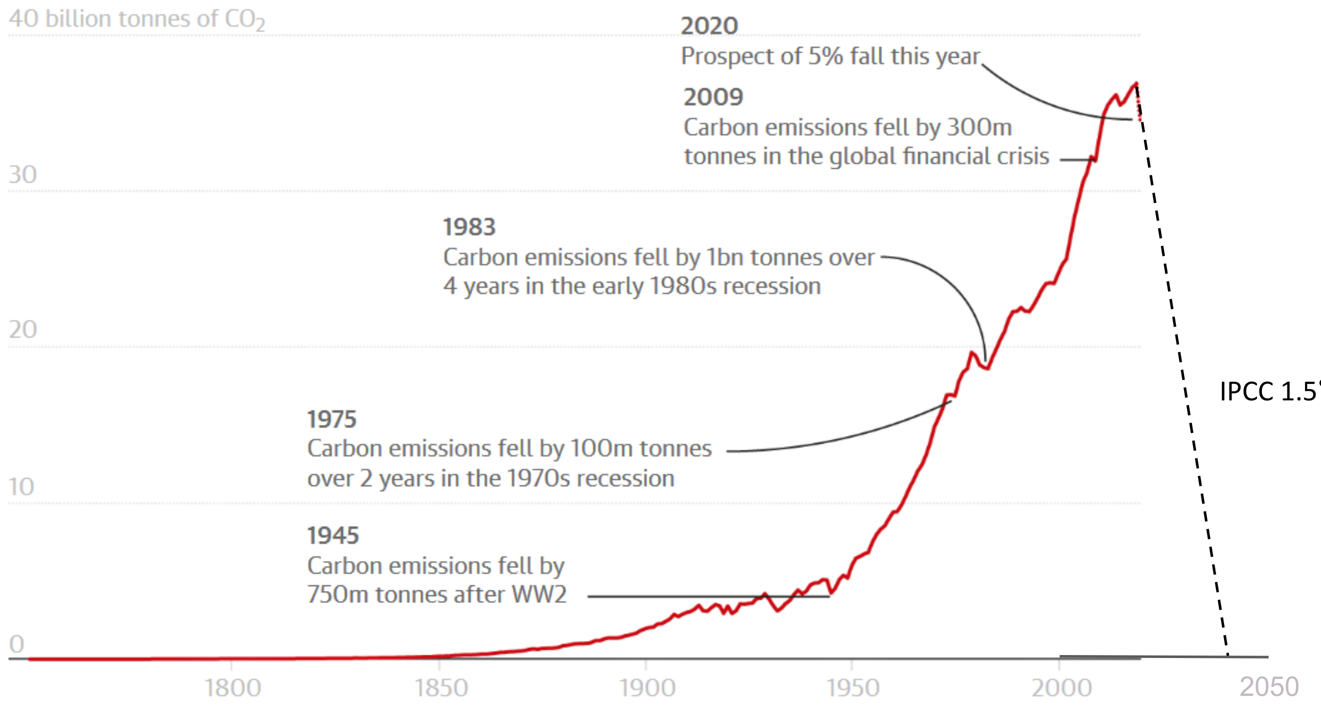


Sce: IPCC. 2019. 1.5°C report

1- Il y a une urgence climatique

Des leçons de la COVID

On observe une diminution de 4 to 5% des émissions CO_2 en 2020
cela respecte l'objectif climatique,
Mais à quel prix social et économique?..



Guardian graphic. Source: Global Carbon Project (GCP), Carbon Dioxide Analysis Center (CDIAC)

Sce: Le Quéré et al. 2020. Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. *Nature Climate Change*.

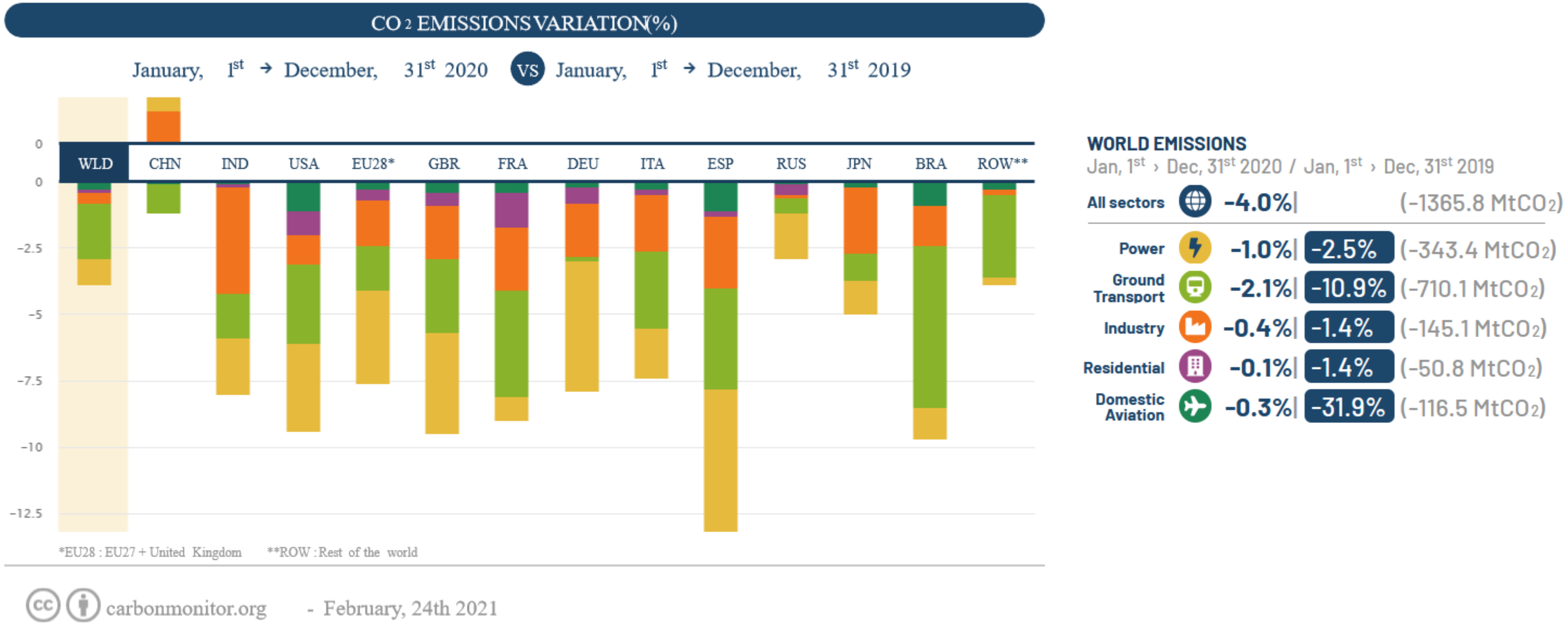
1- Il y a une urgence climatique

Des leçons de la COVID

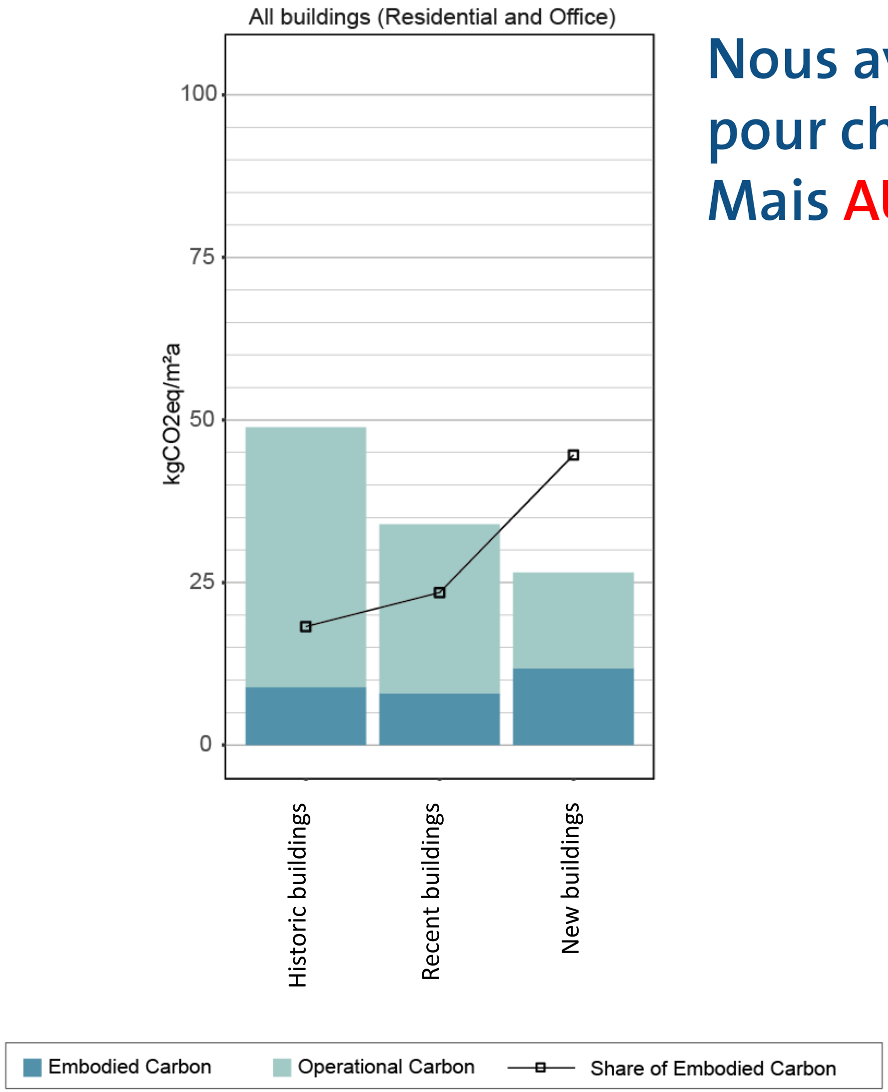
On observe une diminution de 4% des émissions CO_2 en 2020

→ La cohesion sociale ne consomme pas de CO_2

→ Réduire le CO_2 peut être fait en gardant une vie agréable avec interactions sociales, mais en diminuant les secteurs qui n'ont pas été touchés par la COVID (énergie, industrie, bâtiment)… en deux mots : L'environnement bâti



2- Méthode ACV classique ignore cette urgence climatique



Nous avons fait des progrès significatifs pour chauffer les batiments
Mais AUCUN progrès pour les construire

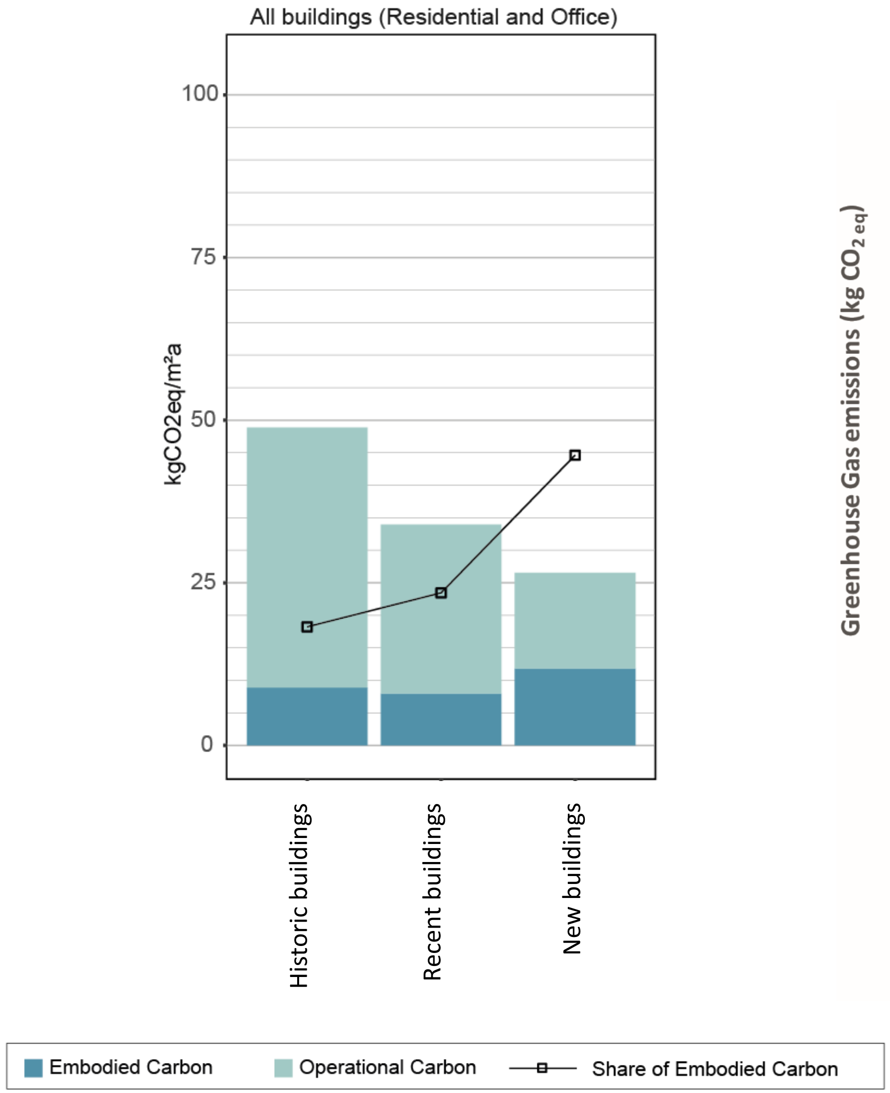
Les standards mêmes ambitieux prioritarisent la phase d'utilisation

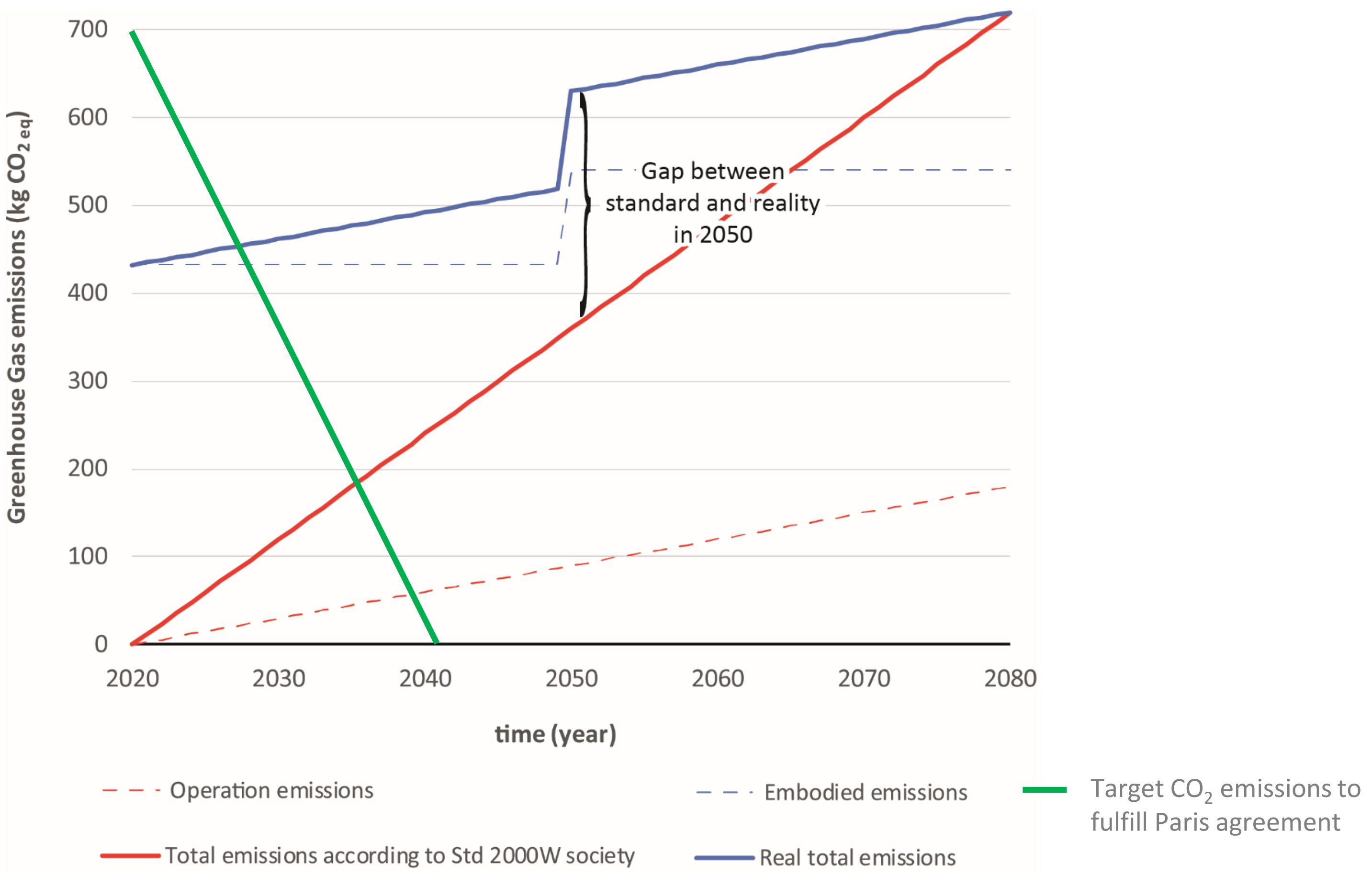
	Construction	Operation
For new buildings		
Guidance value (kg $CO_2/m^2.a$)	8.5	2.5
Service life of the building (yr)	60	60
Total (kg CO_2/m^2)	510	150
For renovation		
Guidance value (kg $CO_2/m^2.a$)	5	5
Service life of the building (yr)	60	60
Total (kg CO_2/m^2)	300	300

Société 2000Watt

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

Mais la réalité des émissions est bien différente de la vision statique de l'ACV





Sce: Röck et al. 2019. Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied energy*.
Habert et al. 2020. Carbon budgets for buildings: Harmonizing temporal, spatial and sectoral dimensions. *Buildings and cities*.

3- La méthode dynamique

3- Méthode dynamique

Dynamique technologique

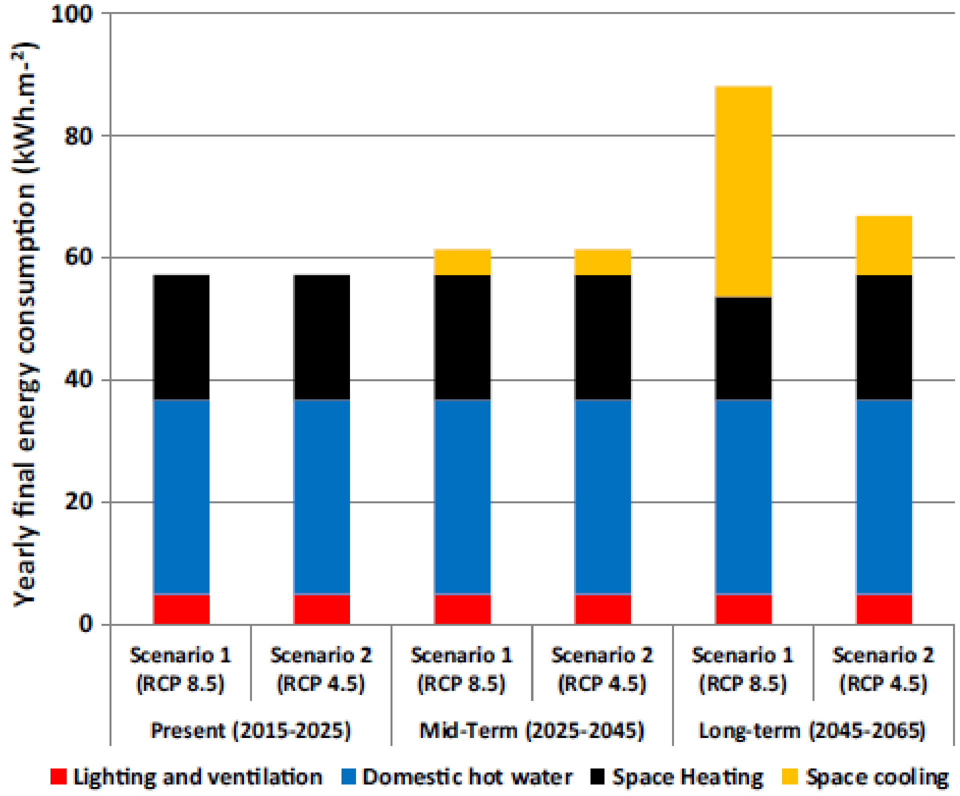
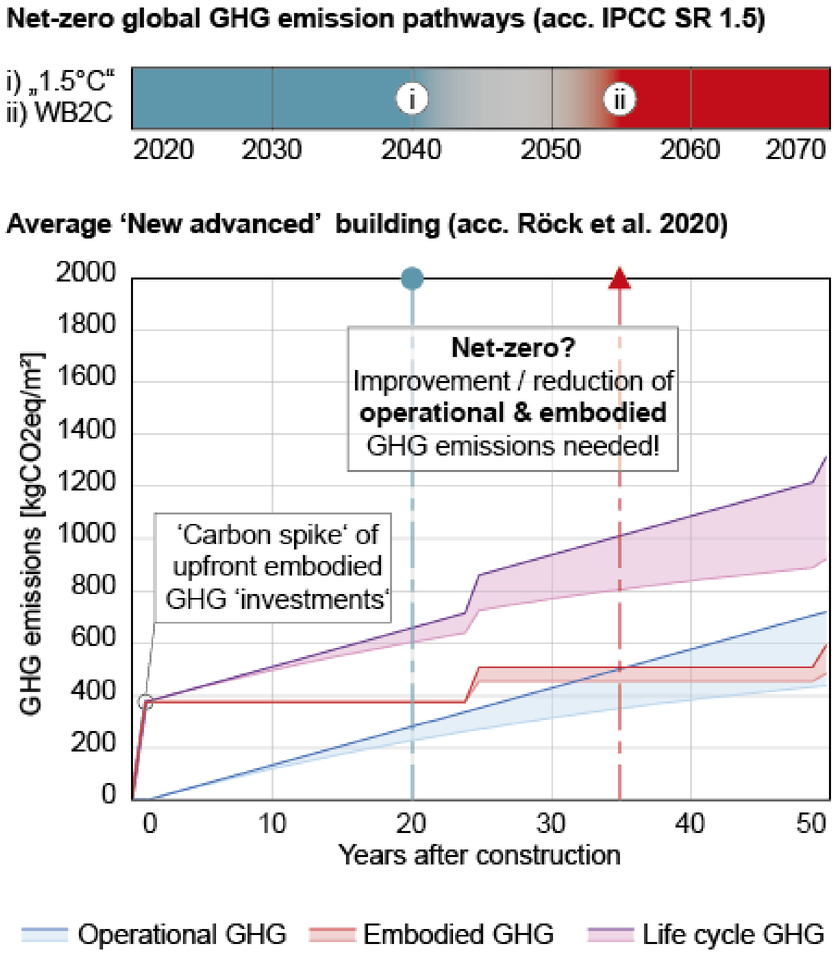


Fig. 4. Total annual energy consumption per square metre (heated and cooled area of the house) in the different scenarios.



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)].

Sce: Roux et al., 2016. Integrating Climate change and energy mix scenarios in LCA of buildings and districts. *Applied energy*
Röck et al. 2019. Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation. *Applied energy*.

3- Méthode dynamique

Dynamique méthodologique

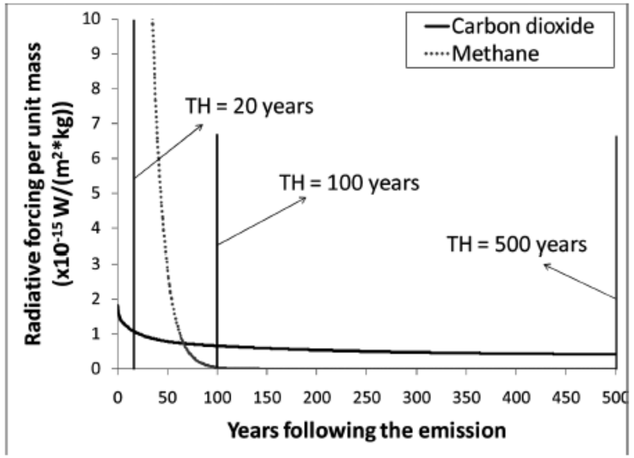


FIGURE 1. Radiative forcing of a unit mass pulse emission at time zero for carbon dioxide and methane with the three time horizons proposed by IPCC.

TABLE 1. GWP Values for CO_2, CH_4, and N_2O for Time Horizons of 20, 100, and 500 Years As Published by IPCC in the Fourth Assessment Report (7)

	20 years	100 years	500 years
CO_2	1	1	1
CH_4	72	25	7.6
N_2O	289	298	153

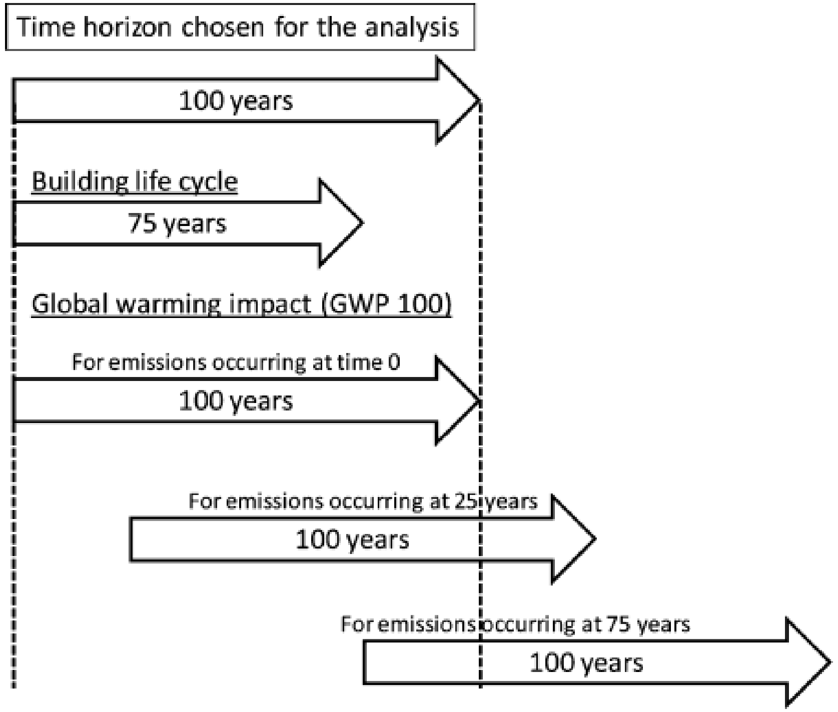


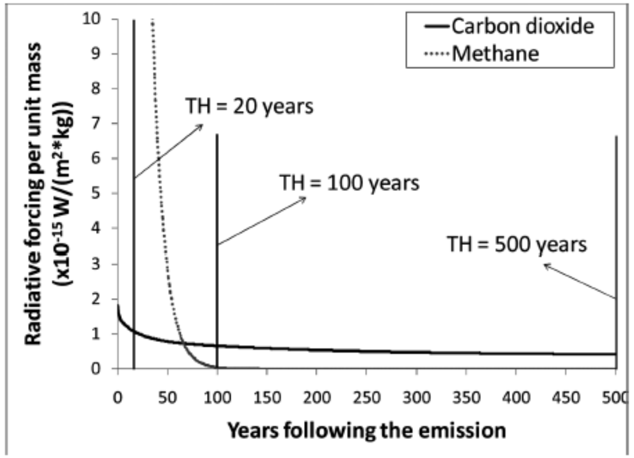
FIGURE 2. Illustration of the inconsistency in time frames for global warming LCIA with the example of a 75-year lifetime building.

TERRA FIBRA AWARD ETH sustainable construction Swiss Federal Institute of Technology Zurich

Sce: Levasseur et al., 2010. Considering time in LCA: Dynamic LCA and its application to Global Warming impact assessments. *Environmental Science and Technology*
Levasseur et al., 2012. Valuing temporary carbon storage. *Nature climate change*

3- Méthode dynamique

Dynamique méthodologique



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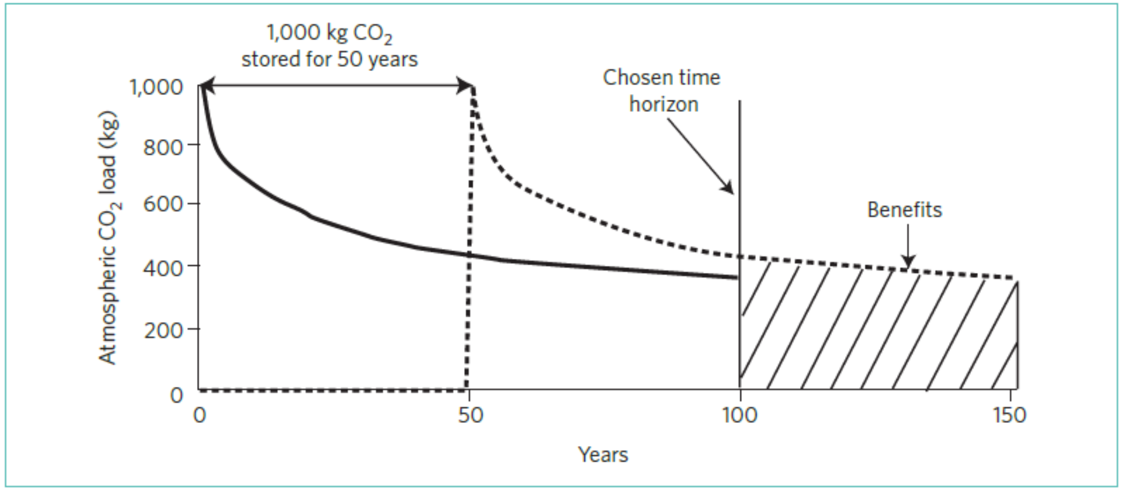

Figure 1 | Temporary carbon storage assessed with the Lashof method[12]. The cumulative radiative forcing of a 1,000 kg CO_2 pulse-emission is given by the integral over the chosen time horizon (100 years) of the atmospheric load curve (continuous line, given by the revised Bern carbon-cycle-climate model), multiplied by the instantaneous radiative forcing of a unit mass of CO_2 in the atmosphere. The benefits of delaying release are thus given by the portion of the cumulative atmospheric load that is pushed back beyond the chosen time horizon of 100 years (hatched area). In the case shown, according to the Lashof method, storing 1,000 kg CO_2 over a period of 50 years is equivalent to delaying a 1,000 kg CO_2 pulse-emission by 50 years (dotted line).

Sce: Levasseur et al., 2010. Considering time in LCA: Dynamic LCA and its application to Global Warming impact assessments. *Environmental Science and Technology*
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Dynamique méthodologique

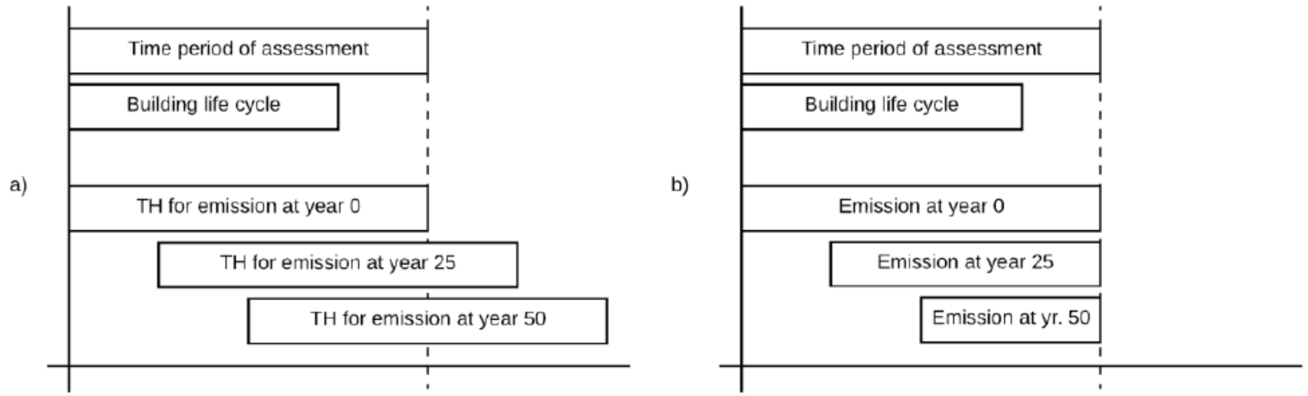


Table 4. Synthesis of the four main approaches for biogenic carbon assessment in attributional LCA.

	1. Static LCI and LCIA	2. Static LCI and LCIA, with Credits	3. Dynamic LCI and Static LCIA	4. Dynamic LCI and LCIA
Assumption of Carbon Neutrality	Yes	No	No	No
Assumption of Emission at Harvest	Yes	No	No	No
Credits for Temporary Carbon Storage	No	Yes	No Sequestration and temporary storage are considered in the dynamic LCI.	No Sequestration and temporary storage are considered in the dynamic LCI.
Treatment of Time in LCI	Aggregated as a pulse emission at time 0.	Aggregated as a pulse emission at time 0.	Dynamic	Varies. Some approaches use a dynamic LCI, other include time considerations directly in LCIA.
Treatment of Time in LCIA	Fixed time horizon	Fixed time horizon	Fixed time horizon	Fixed endpoint

ACVs dynamiques

Au niveau du temps des émissions (LCI)

Au niveau de l'horizon temporel (LCIA)

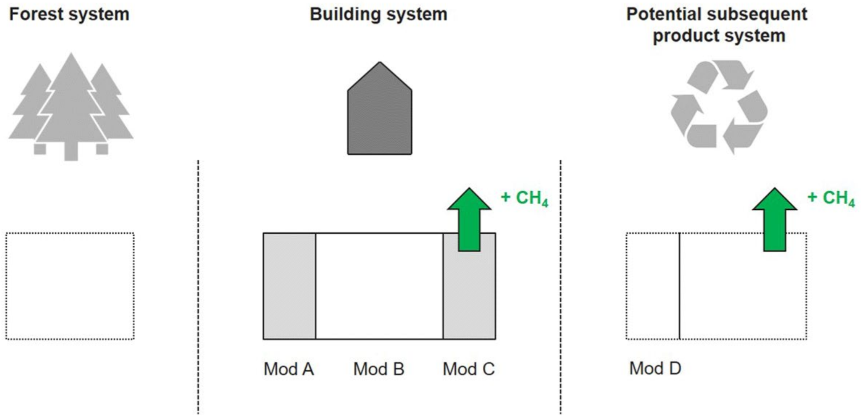
Sce: Breton et al., 2020. Assessing the Climate Change Impacts of Biogenic Carbon in Buildings: A Critical Review of Two Main Dynamic Approaches. *Sustainability*

4- Dynamique combinée de la nature et des bâtiments

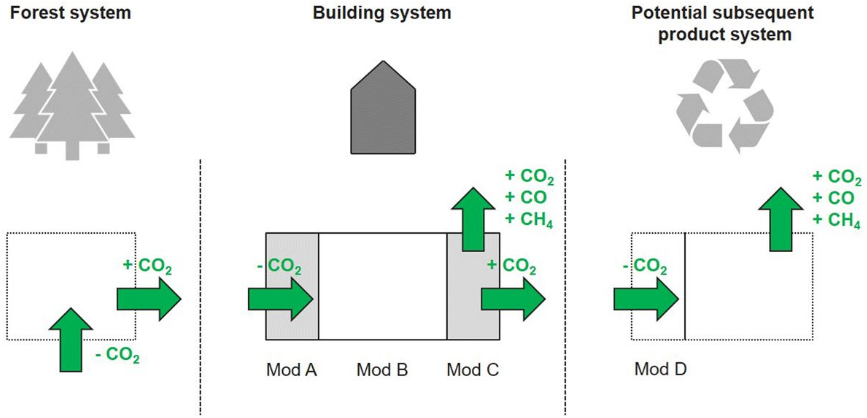
Prise en compte du stockage carbone dans le bâtiment

© Kees Hageman Living on the Edge 2010 / Arch. Arjen Reas – HOLLAND

4- Prise en compte du stockage carbone en ACV



Méthode classique : 0/0

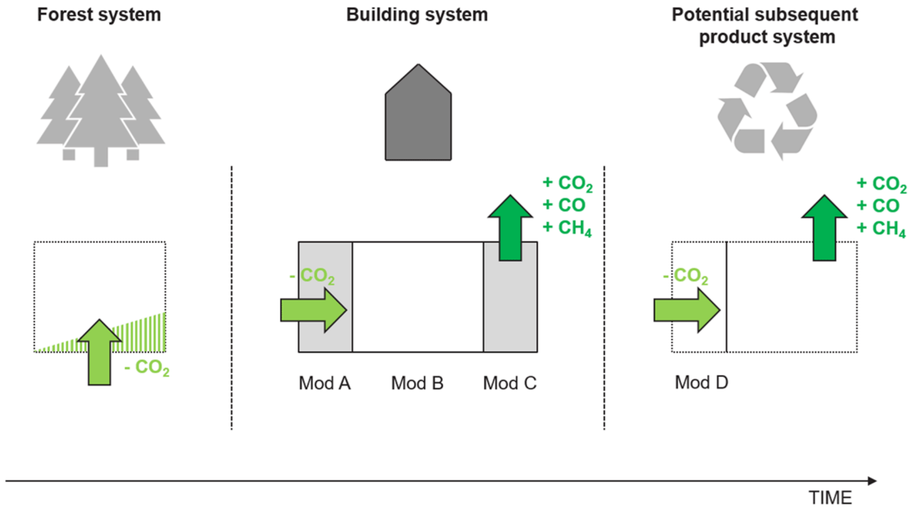


Méthode EN-15804 : -1/+1

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

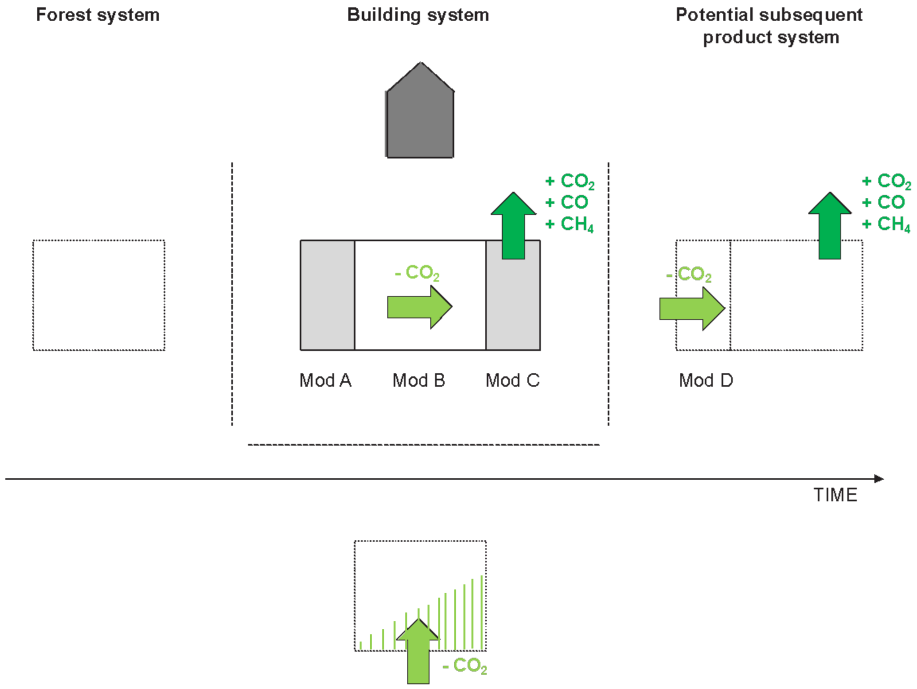
4- Prise en compte du stockage carbone en ACV

Stockage avant ou après le début de la construction



Dynamic LCA

Carbon removal **BEFORE** construction



Dynamic LCA

Carbon removal **AFTER** construction

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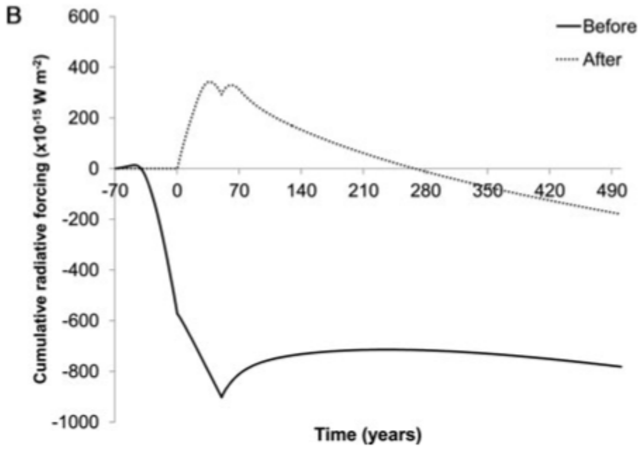
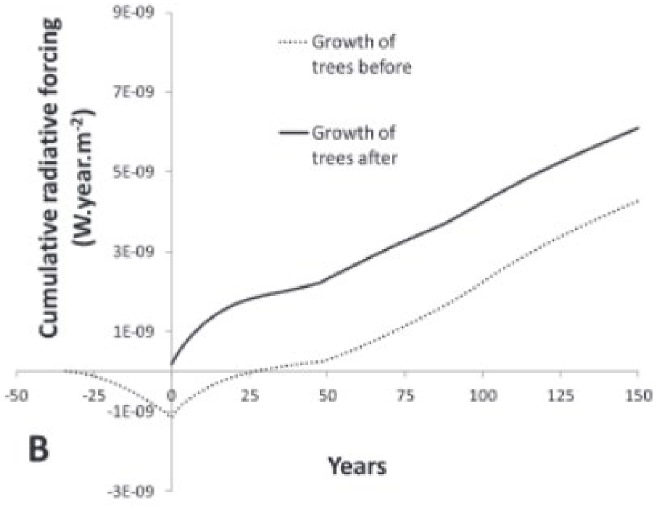




Question principale de nombreuse études:

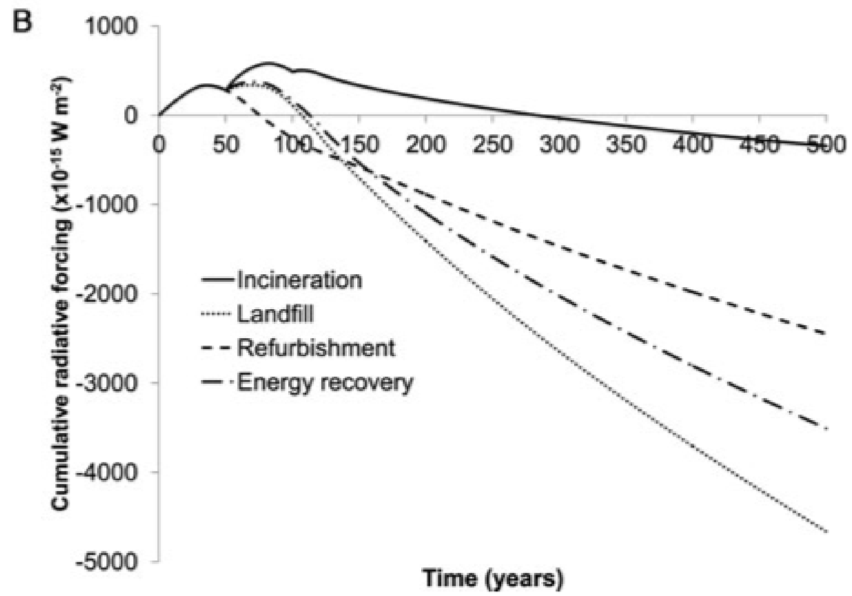
Est ce que la dynamique de croissance de la plante est considérée pendant l'ACV du produit ou non..

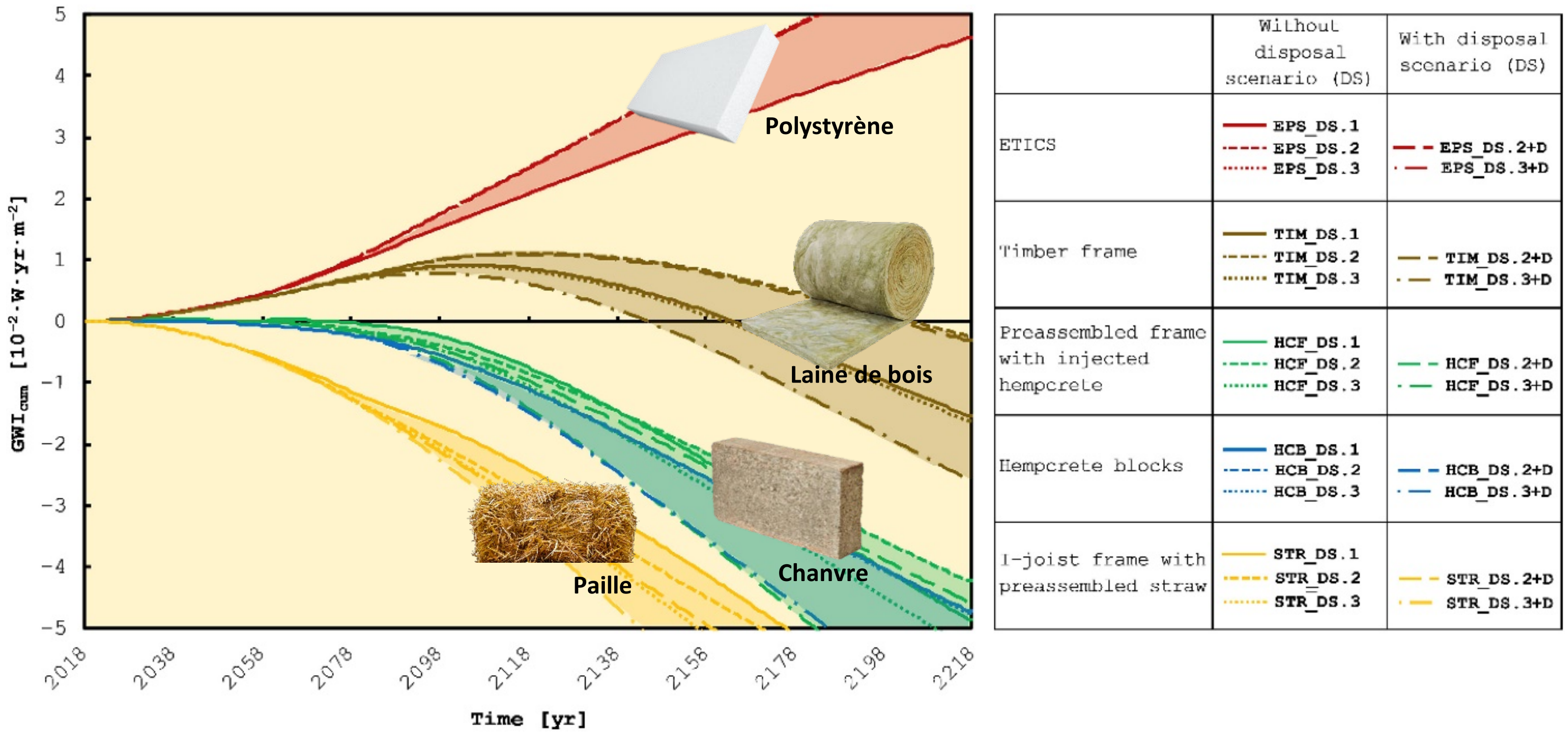
Sce: Levasseur et al., 2012. Biogenic carbon and temporary storage addressed with dynamic Life Cycle Assessment. *Journal of industrial ecology*

Fouquet et al., 2015. Methodological challenges and developments in LCA of low energy buildings: Application to biogenic carbon and global warming assessment. *Building and environment*

4- Prise en compte du stockage carbone en ACV

Quel scenario de fin de vie pour les matériaux biosourcés





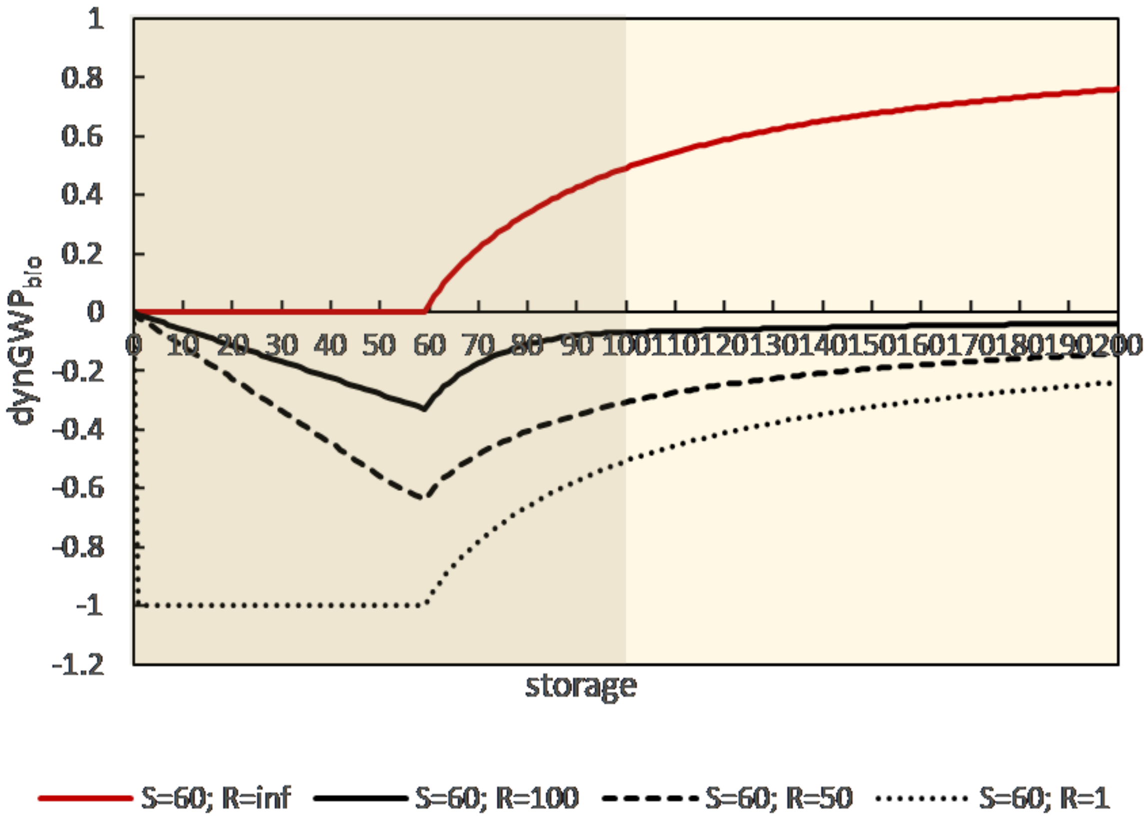
Question principale de nombreuse études:

La fin de vie des matériaux biosourcés (comme pour ACV statique) ont une influence majeure sur impact à long terme.

Sce: Levasseur et al., 2012. Biogenic carbon and temporary storage addressed with dynamic Life Cycle Assessment. *Journal of industrial ecology*
Pittau et al., 2019. Retrofit as a carbon sink: the carbon storage potentials of the EU housing stock. *Journal of Cleaner Production*

4- Prise en compte du stockage carbone en ACV

Ma méthode préférée… Le GWP_{bio}…



Effet sur Changement climatique
Selon vitesse de croissance

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*

4- Prise en compte du stockage carbone en ACV

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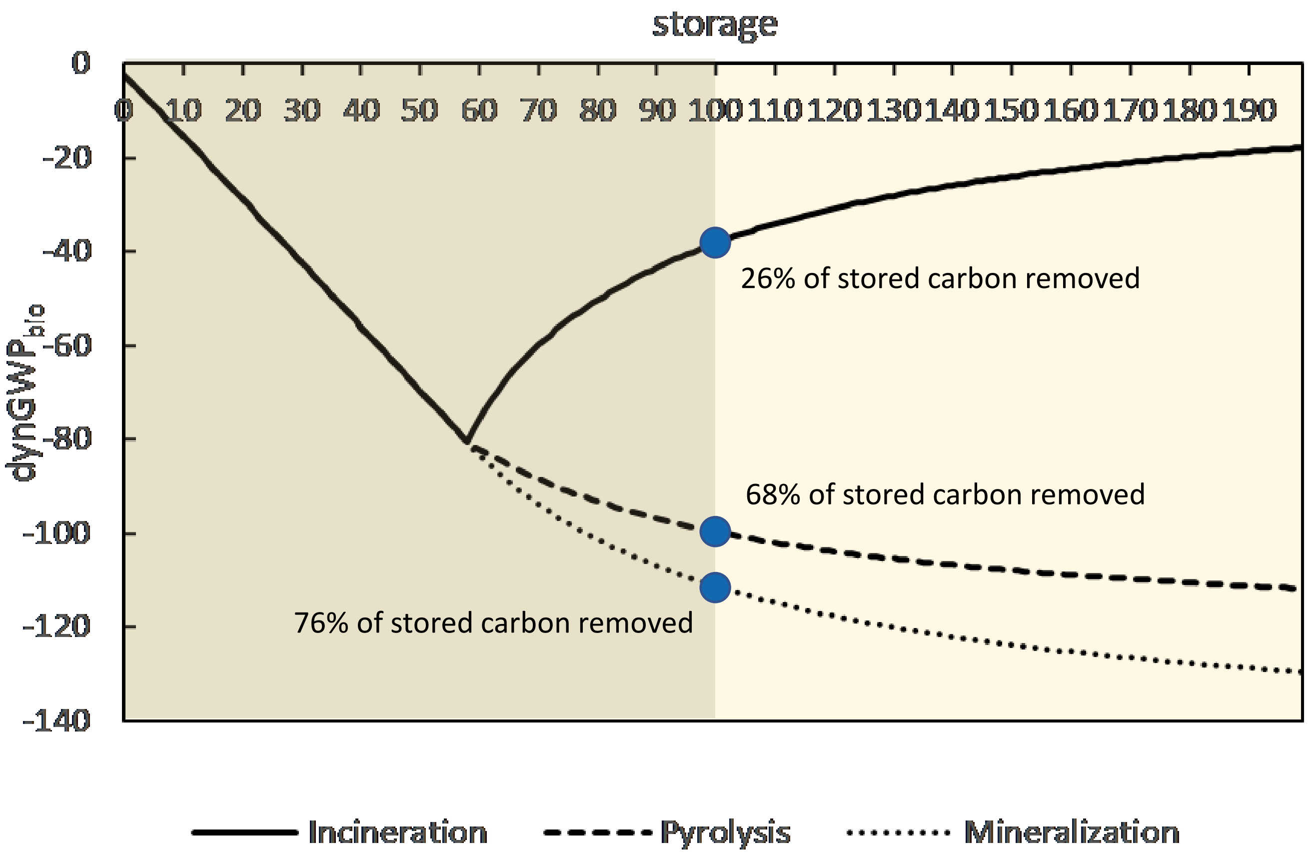


Effet sur Changement climatique

Selon fin de vie

Dynamic GWP results from equivalent biogenic CO_2 emissions of treating 100 kg of wood according to three different post-use process: incineration, pyrolysis and mineralization. Assumtions: S=60 years; R=60 years.

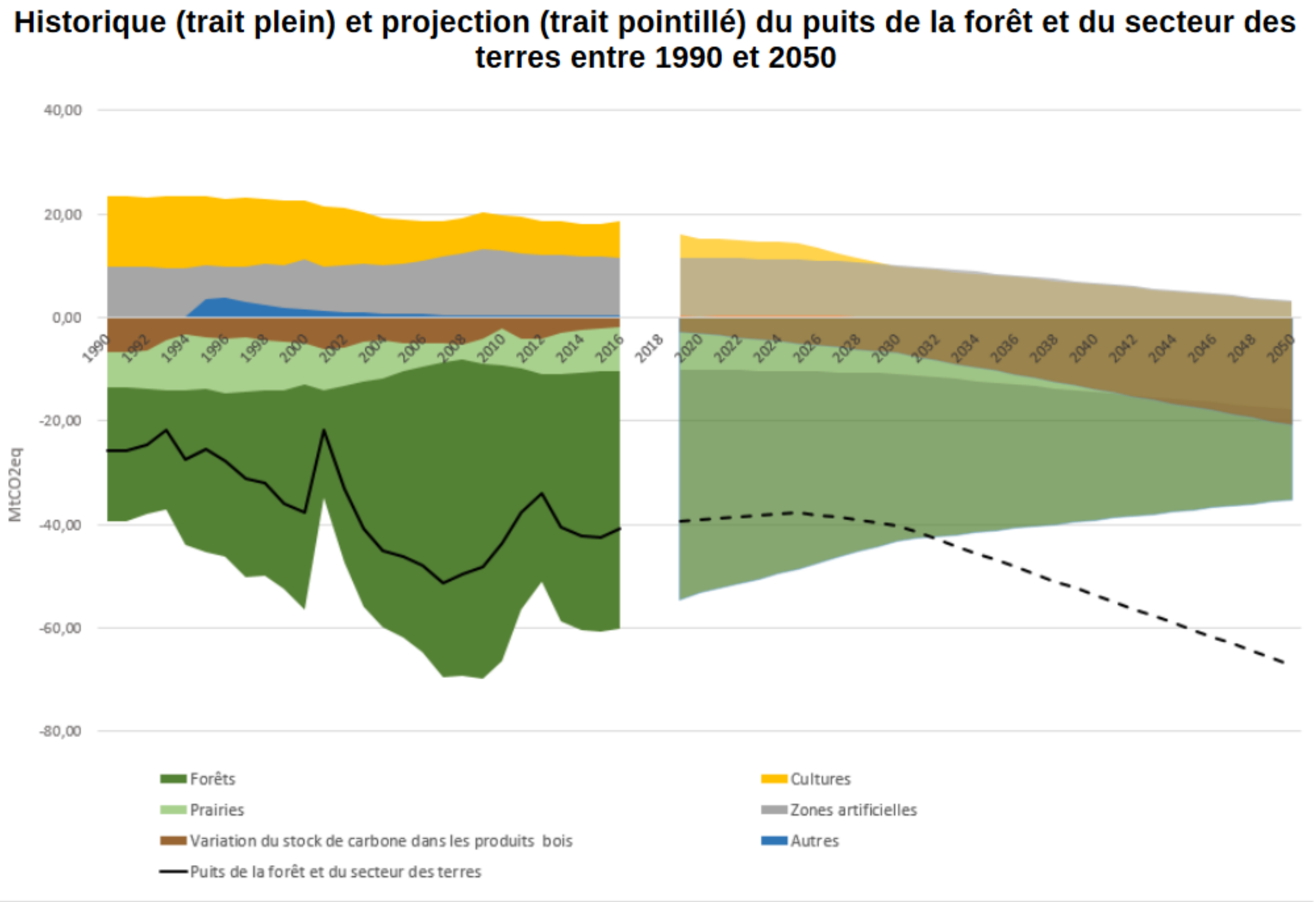
Sce: Guest et al., 2012. GWP of CO_2 emissions from biomass stored in the anthroposphere and used for bioenergy at end of life. *Journal of Industrial ecology*

5- Du bâtiment au stock bâti

Stockage temporaire pour un bâtiment mais permanent pour l'environnement construit

5- Du bâtiment au stock bâti

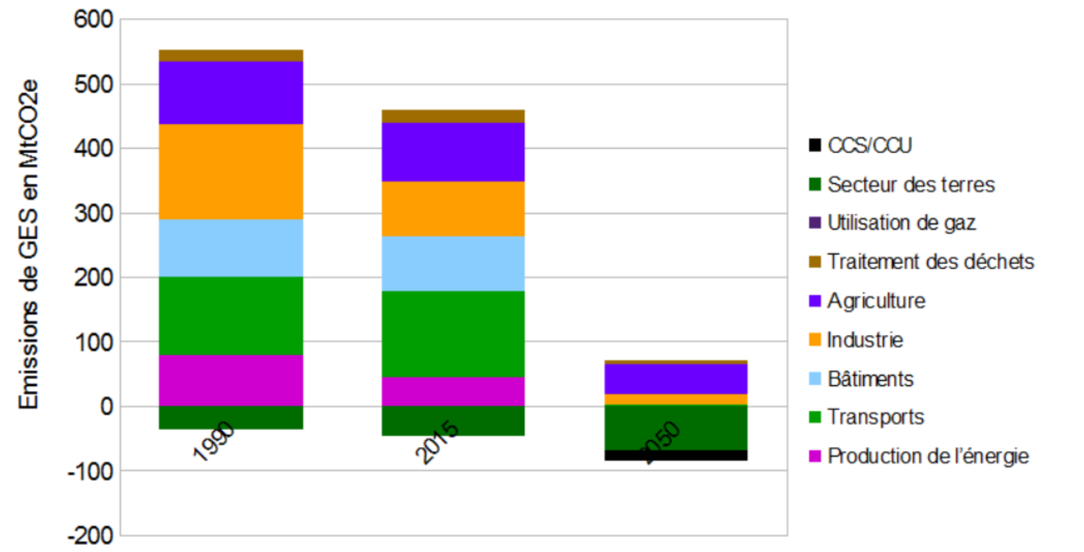
Utiliser l'environnement construit comme puit de carbone

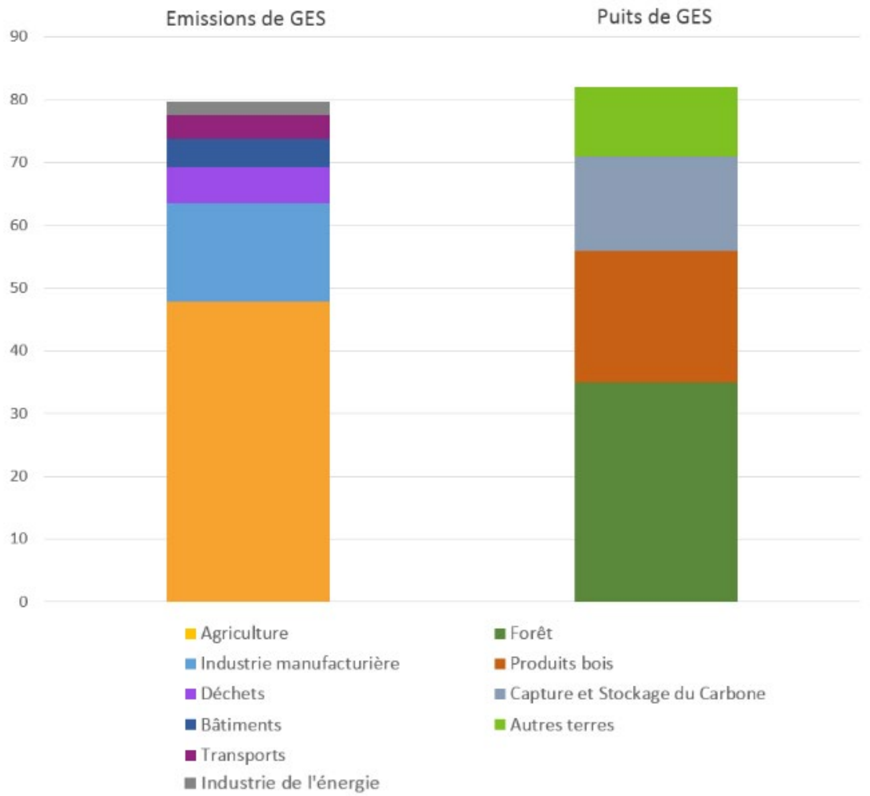


Sce: Stratégie Nationale Bas Carbone, Ministère de l'environnement 2019

5- Du bâtiment au stock bâti

Utiliser l'environnement construit comme puit de carbone





Il faut augmenter le temps de résidence des produits bois dans la «technosphère»

*Du bois énergie (temps de résidence 1 an) au bois construction (temps de résidence 40 ans)**

** Valeur de temps de résidence utilisées en Suisse*

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Sce: Stratégie Nationale Bas Carbone, Ministère de l'environnement 2019

5- Du bâtiment au stock bâti

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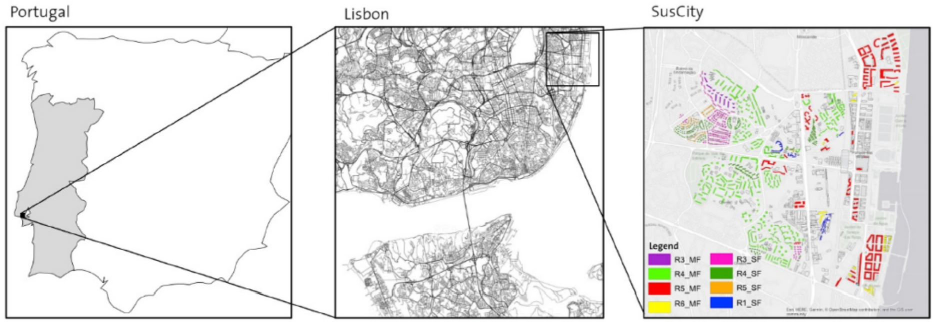
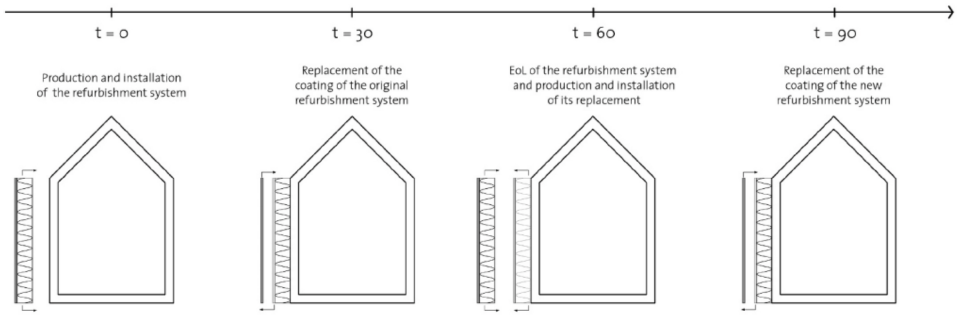
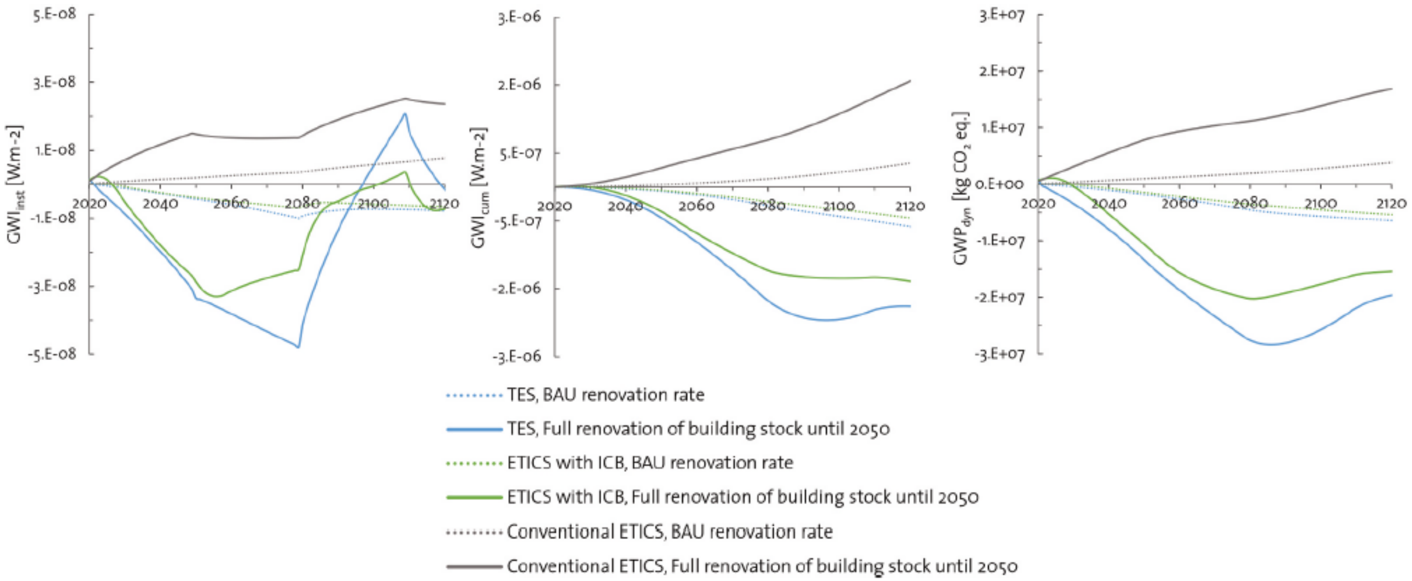


Archetype ID	R1_SF	R2	R3_SF	R3_MF	R4_SF	R4_MF	R5_SF	R5_MF	R6_MF
Construction period	before 1919	1920–1945	1946–1960	1946–1960	1961–1990	1961–1990	1991–2005	1991–2005	2006–2011
Size class	single family	–	single family	multi family	single family	multi family	single family	multi family	multi family
Share archetype	1%	0%	3%	1%	3%	38%	1%	47%	6%
U-value exterior walls [W/(m²K)]	2.38	–	2.38	1.01	1.89	0.96	1.02	0.63	0.56
Annual electricity consumption [kWh/m²]	57.2	–	46.9	36.4	44.5	36.2	43.8	34.3	34.5
Number of floors	1	–	2	4	2	6	2	8	7
Window to wall ratio	10%	–	8%	19%	8%	27%	8%	31%	29%



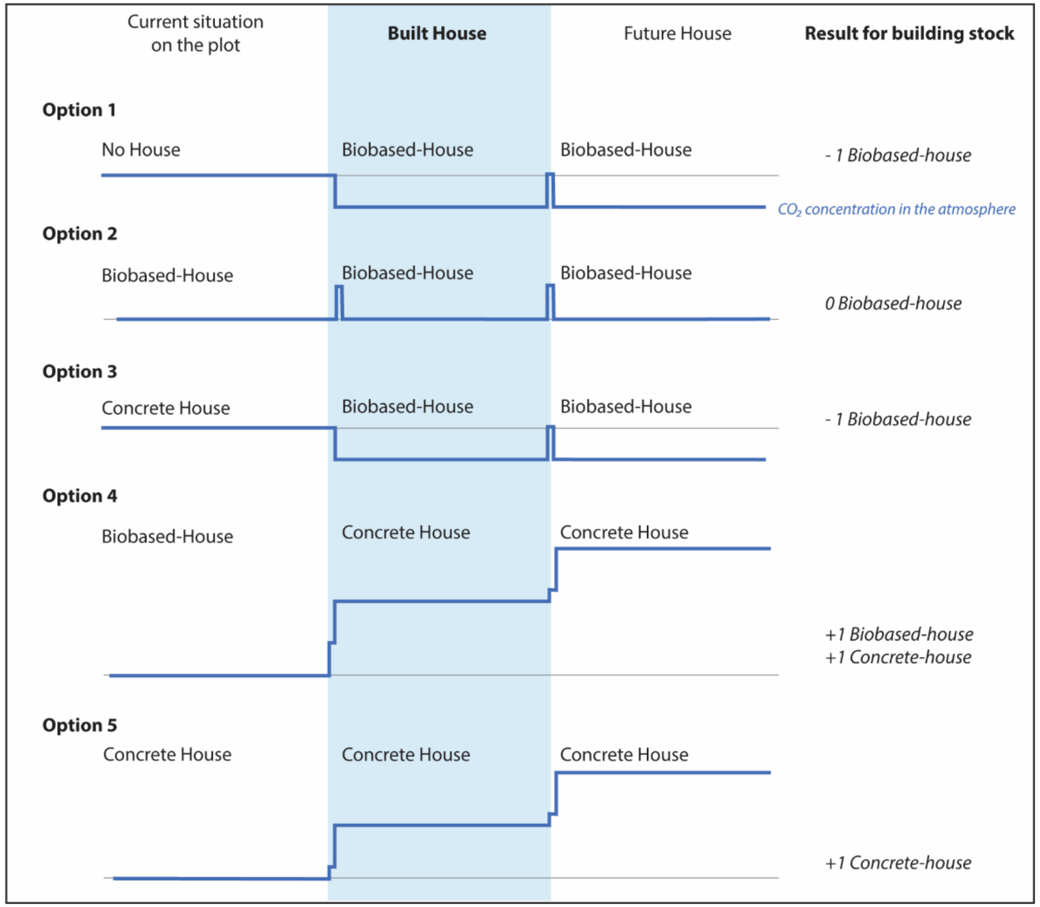


À l'échelle du batiment,
on observe fin de vie des matériaux, remplacement.
Mais à l'échelle du stock,
on observe de façon permanente une diminution de l'effet de serre

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

5- Du bâtiment au stock bâti

Comment motiver un acteur individuel, lors de la construction d'un bâtiment de l'intérêt plus général pour la société d'élargir le puit naturel du l'environnement construit?



Ce qui compte:

1) Qu'est ce qui est présent avant la construction?

C'est la transformation d'un environnement minéral à un environnement biosourcé qui aggrandit le stock

(Comme pour la forêt, c'est l'extension de la forêt qui agrandi le stock)

2) Avec quels matériaux biosourcés je construits?

Il ne faut pas que la construction soit un transfert de stock entre un stock naturel *(la forêt)* **et un stock artificiel** *(les bâtiments)*. **Avec matériaux à croissance rapide** *(paille, chanvre…)*, **cet aspect est évident car cycle naturel est plus court que le bâtiment. Pour le bois, il faut veiller à ce qu'il y ait une transformation des filières entre produits à courte durée de vie** *(bois-énergie)* **et produits à longue durée de vie** *(bois-construction)*; **mais pas qu'il y ait une exploitation supplémentaire d'une forêt existante**

5- Du bâtiment au stock bâti

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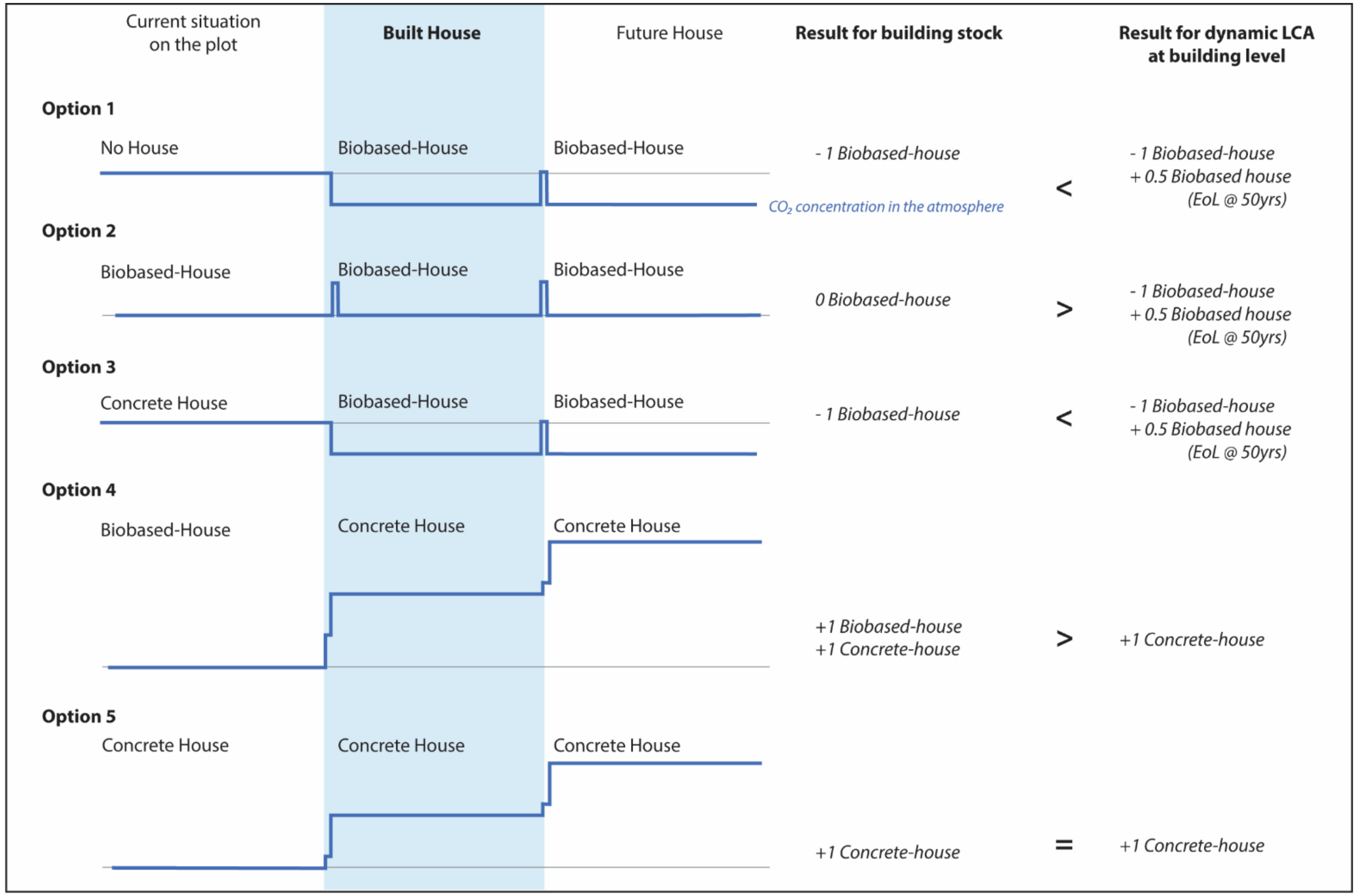

ACV dynamique permet d'avantager l'utilisateur de produits biosourcés.

- Quelque soit la transformation réalisée sur site

5- Du bâtiment au stock bâti

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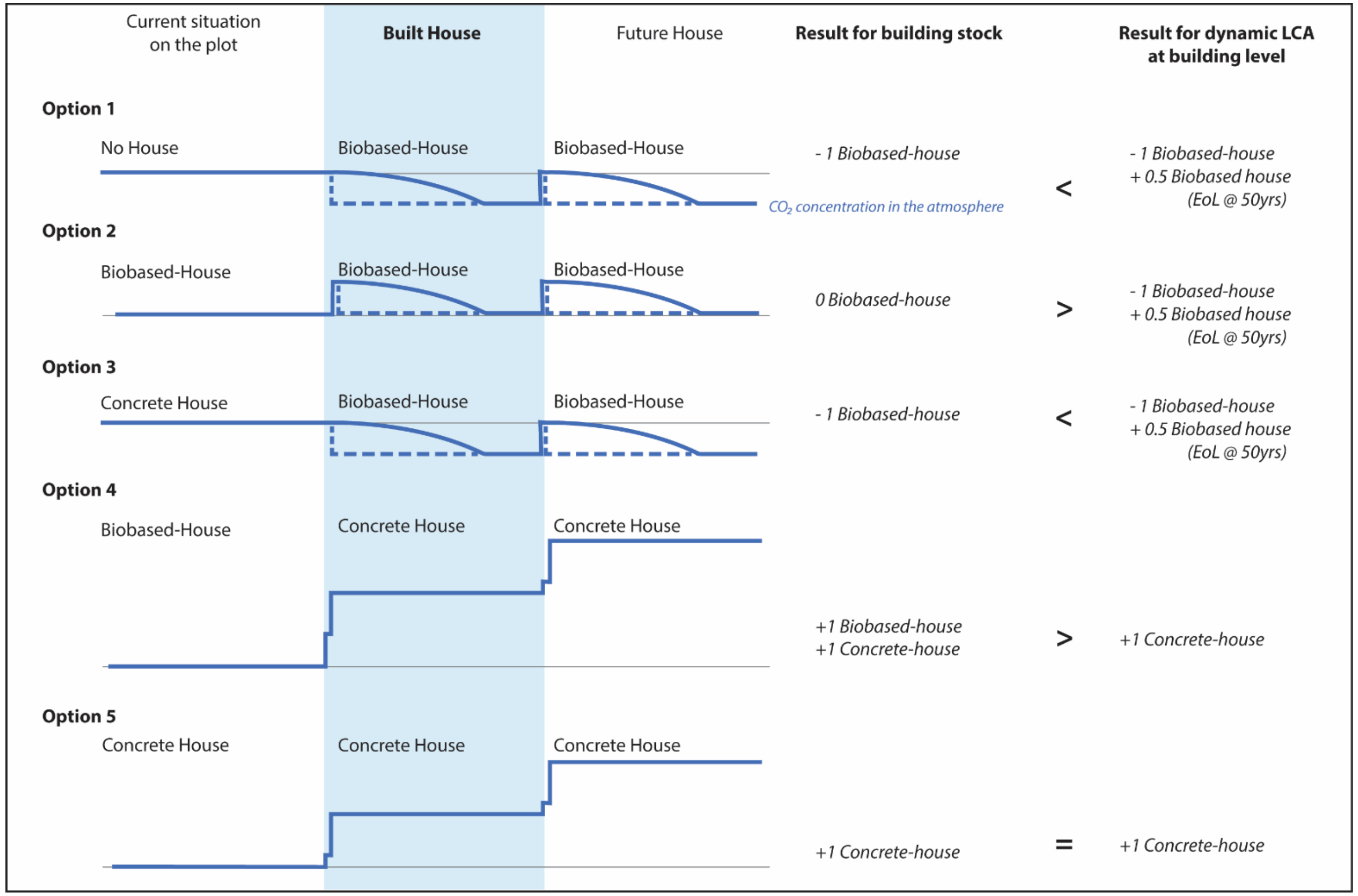
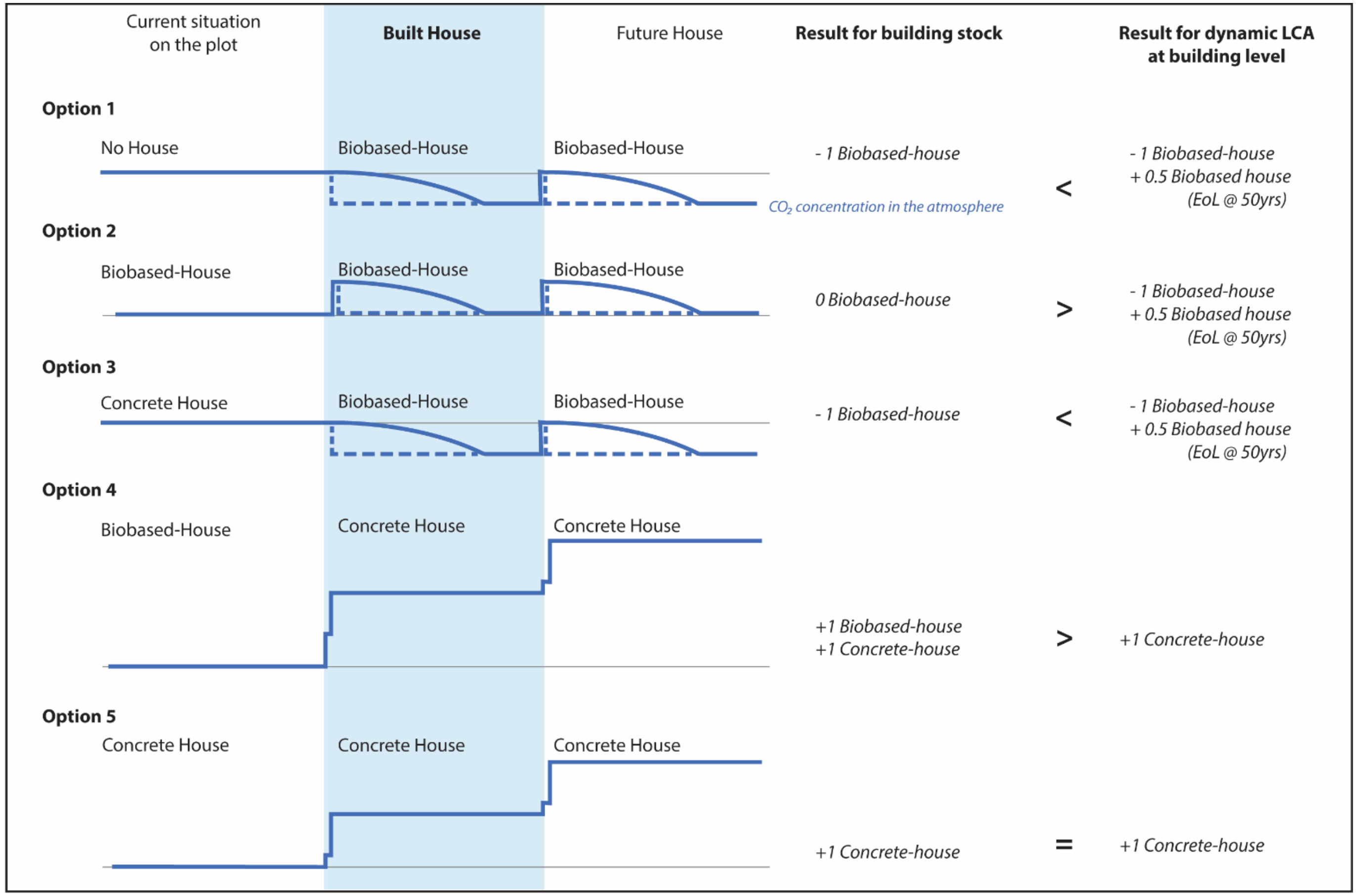


ACV dynamique permet d'avantager l'utilisateur de produits biosourcés.

- *Quelque soit la transformation réalisée sur site*
- *Quelque soit la vitesse de croissance de la plante dans la nature*

5- Du bâtiment au stock bâti

Comment motiver un acteur individuel, lors de la construction d'un bâtiment de l'intérêt plus général pour la société d'élargir le puit naturel du l'environnement construit?



Suggestions

1) Prise en compte de l'existant dans le calcul ACV du bâtiment.

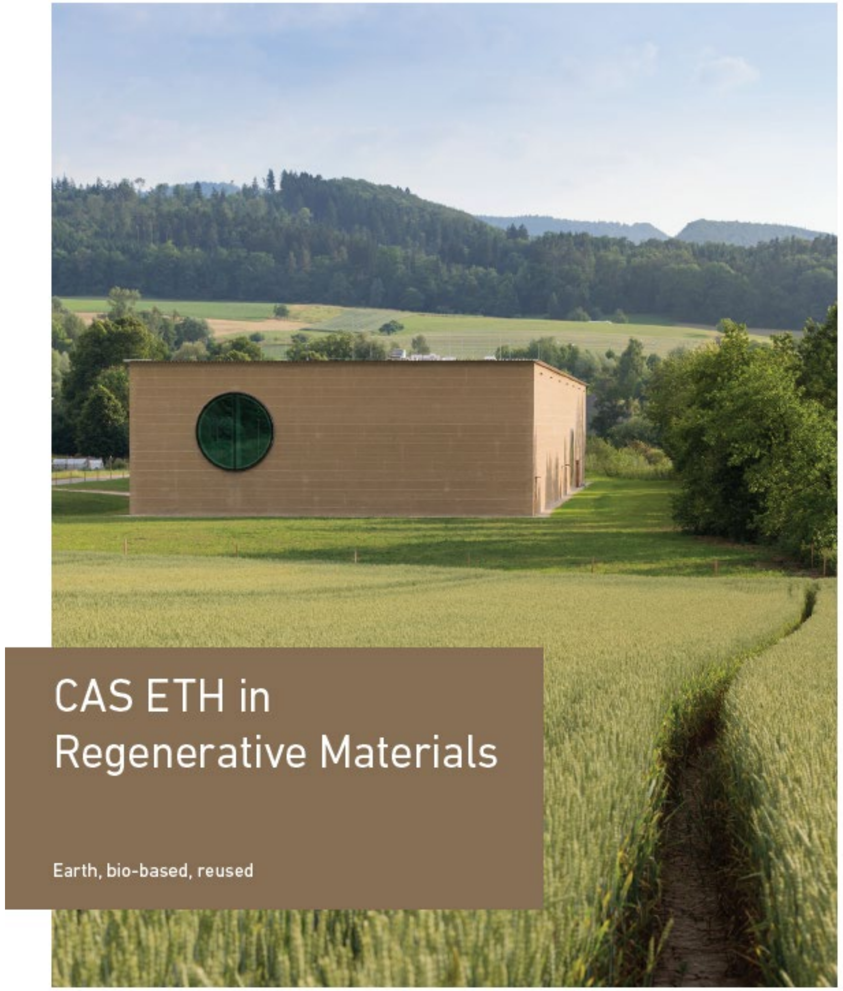
(on ne part pas d'un terrain vierge)

2) Prise en compte de la différence entre vitesse de croissance de la plante dans la biosphère et temps de stockage dans la technosphère

(pour éviter un transfert entre stock naturel et stock bâti)

Habitat social, rue Myrha, Paris
Str. Acier / Isolation chaux chanvre
North by Northwest architectes

Besoin de promotion des matériaux régénératifs



Module 1 : Discovering Regenerative Materials — Week 1 18.01-22.01.21

- Discovery (composition, implementation, LCA analysis, aesthetic)
- Inspiration from vernacular and contemporary architecture: think local - adopt a territory approach
- Social and ecological transition through Regenerative Materials
- Innovative project setting up to overcome legislative barriers

Module 2 : Earth construction — Week 2 01.03-05.03.21

- Construction techniques
- Focus on the structural behaviour and durability
- Cost and planning, existing standards
- Innovative processes: Prefabrication and production line

Module 3 : Bio-based construction — Week 3 12.04-16.04.21

- Construction techniques
- Focus on the thermal and hygrothermal behaviour
- Cost and planning, existing standards
- Recent development with lightweight materials

Module 4 : Re-valuing the building stock — Week 4 17.05-21.05.21

- Methodology for energy retrofit of existing buildings (historic to 80's)
- Refurbishment technique with Regenerative Materials
- Advantages of RM as finishing (air quality, acoustic, moisture regulation)
- Deconstruction: from dismantling to reuse
- Re-think modern building conception for future reuse

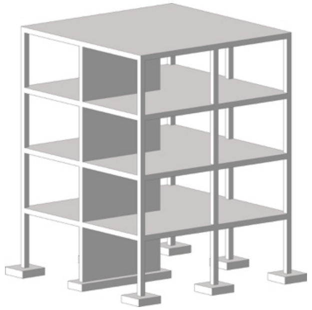
Module 5 : Individual project exercise — Week 5 14.06-18.06.21

- Analysis of the local resources, the regional know-how and the social challenges of the project to tend towards a regenerative architecture
- Definition of a pre-programme with cost and planning
- Formulation of a strategy to overcome blockages

Merci

Es ist möglich, jetzt schon klimaneutrale Gebäude zu bauen.

wir müssen unsere material Diät ändern.
Weniger kohlenstoffintensive Materialien und mehr Gemüse!!!



Optimierte Stahlbeton Structur

+ 45 - 70 cm Strohwände

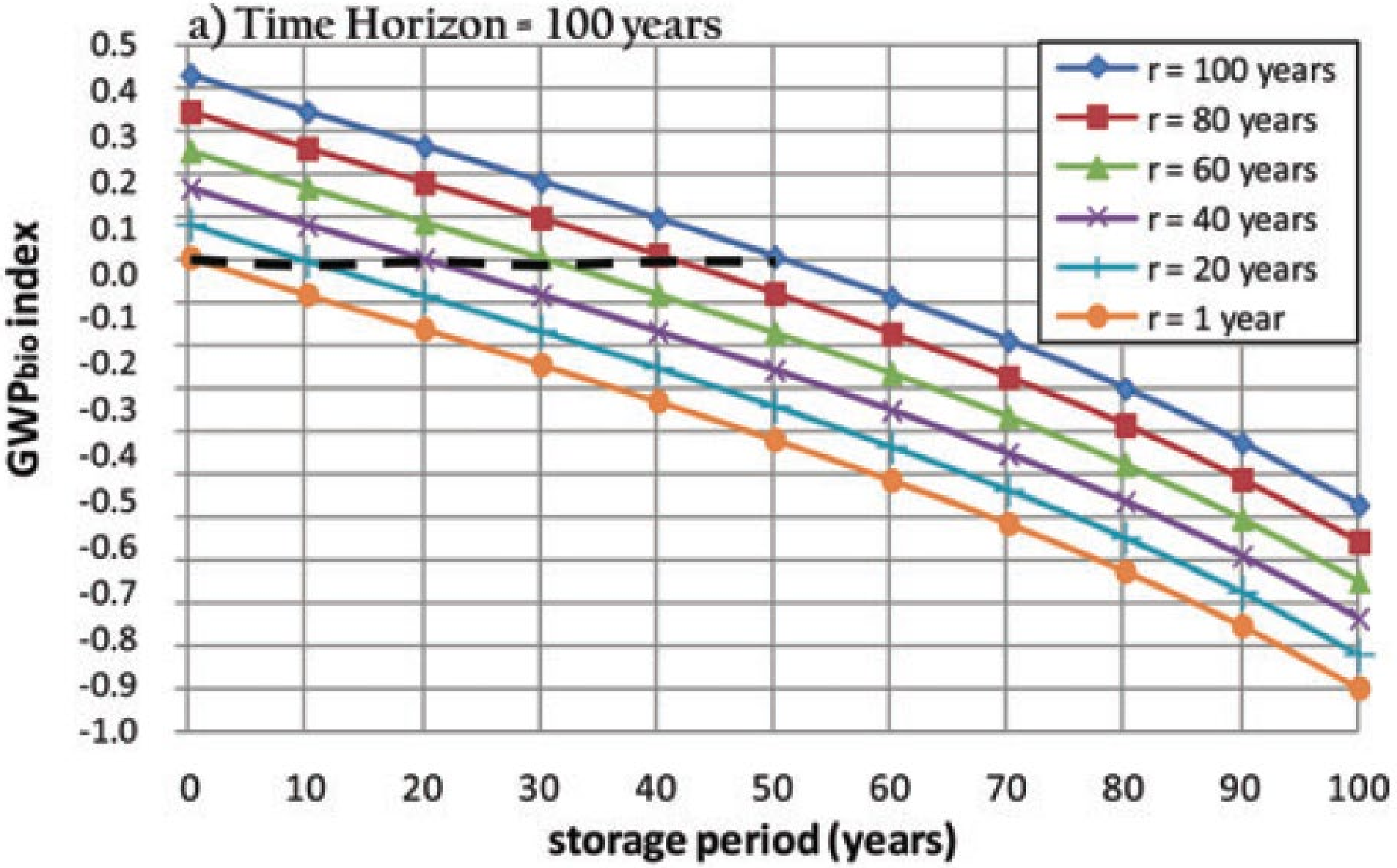
= Netto-Null-Treibhausgasemissionen
+ Gute Raumluftqualität

Holz Structur

+ 30 - 45 cm Strohwände

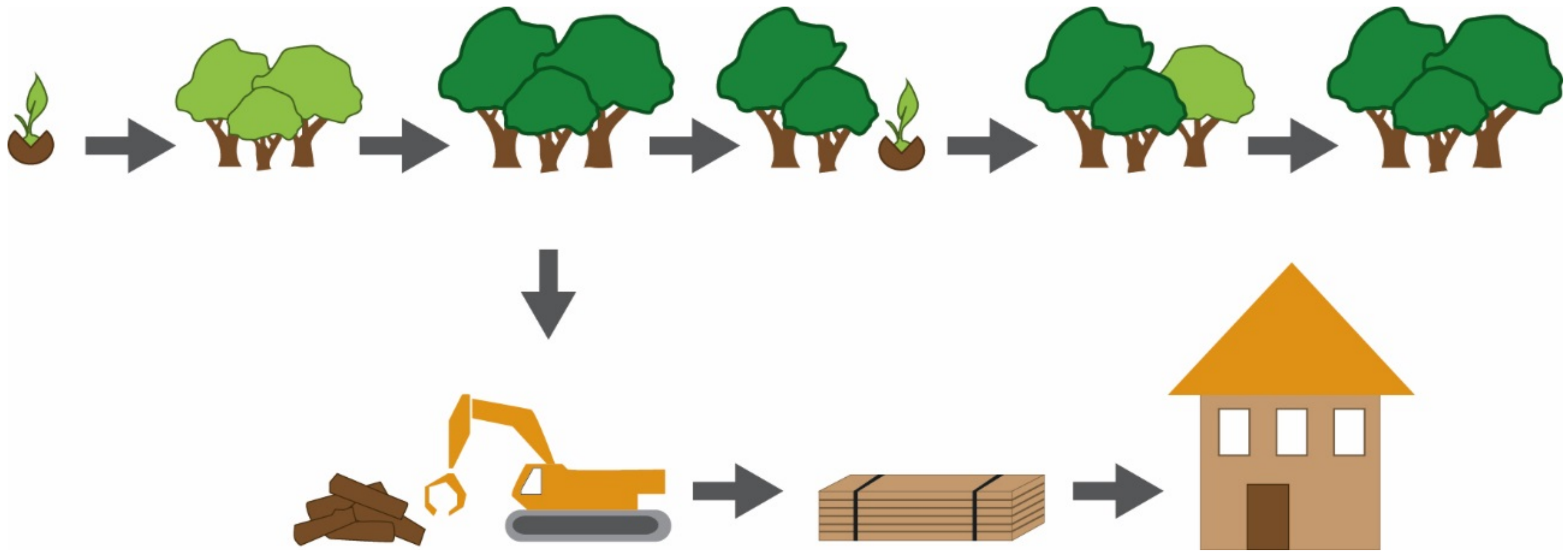
= Netto-Null-Treibhausgasemissionen
+ Gute Raumluftqualität

Quelle: Carcassi et al., submitted. Material diets for Climate-Neutral Buildings.

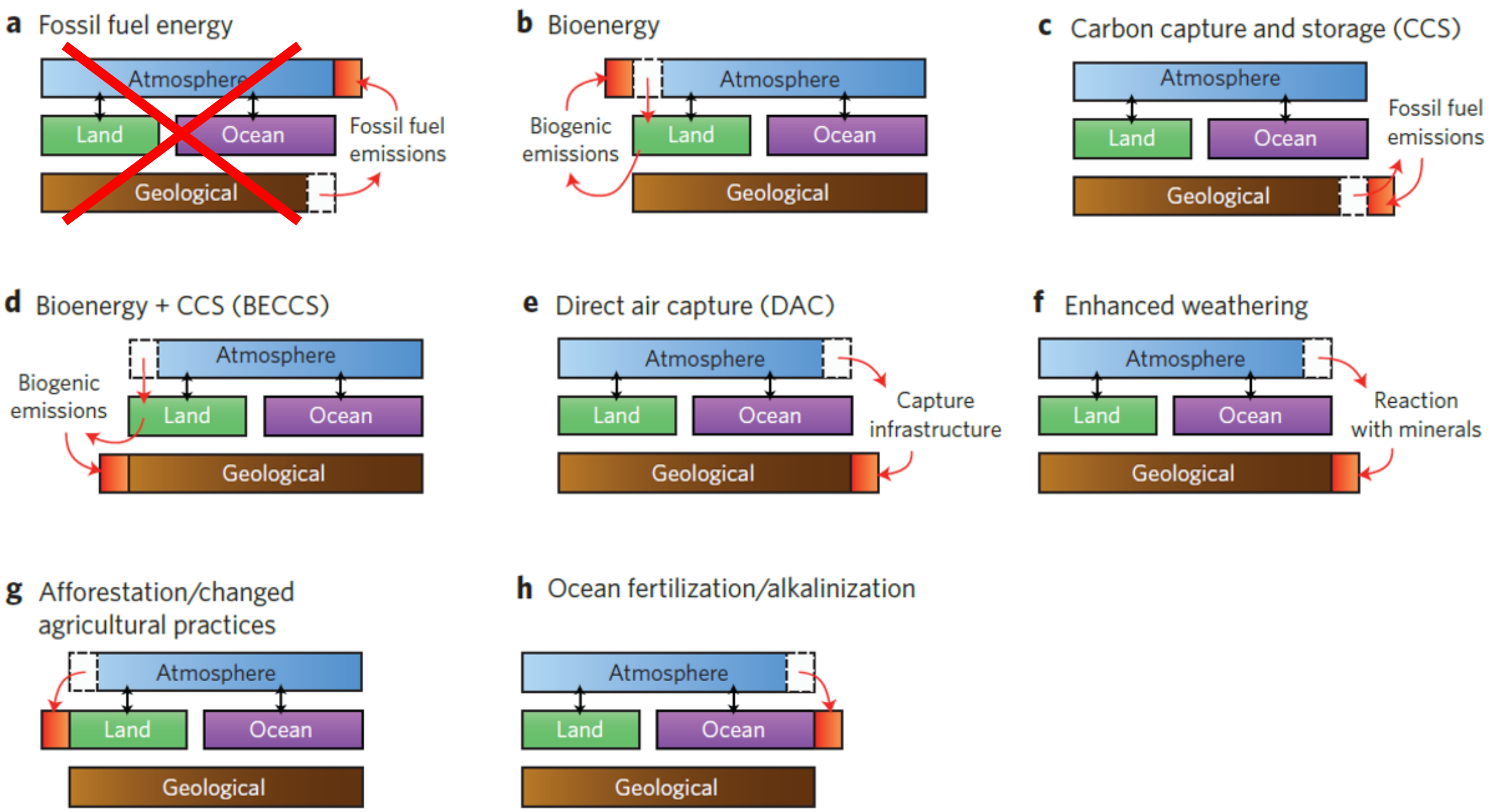


Fast growing plants stored a long time outside the natural carbon cycle can cool the atmosphere

Sce: Guest et al., 2012. GWP of CO2 emissions from biomass stored in the anthroposphere and used for bioenergy at end of life. *Journal of Industrial ecology*, 17, 20-30



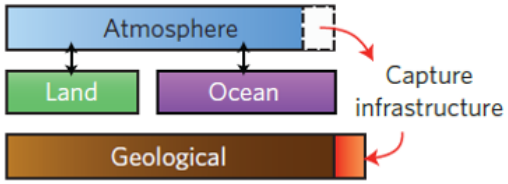
Carbon storage in the Biosphere…



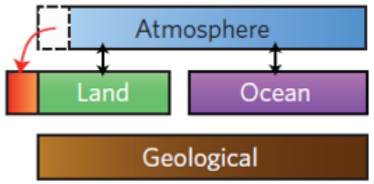
Source: Smith et al. Nature (2016)

Carbon storage in the Built Environment

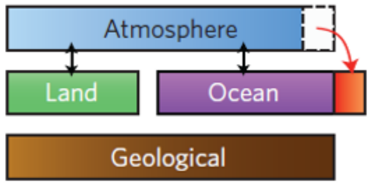
Direct air capture (DAC)



Afforestation/changed agricultural practices

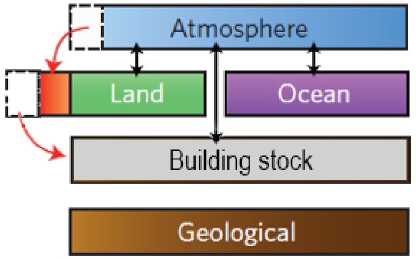


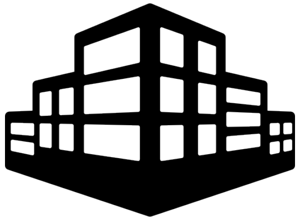
Ocean fertilization/alkalinization



Source: Smith et al. Nature (2016)

Building materials storage





Our hypothesis

GWPbio index (100 years)

based on Guest et al. method

Growing seasonal crops (straw, cotton, flax, 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

GWPbio index (100 years)

Fast-growing forests (bamboo, Eucalyptus, 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
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GWPbio index (100 years)

Exotic cohort-agroforestry plantations (palms, coffee, cacao trees, 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
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GWPbio index (100 years)

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

GWPbio index (100 years)

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…										

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

GWPbio index (100 years)

Finishing

	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
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100	0.37	0.29	0.21	0.12	0.032	-0.06	-0.16	-0.27	-0.4	-0.56

GWPbio index (100 years)

Insulation
Windows/doors

	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
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GWPbio index (100 years)

Structures

	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
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100	0.37	0.29	0.21	0.12	0.032	-0.06	-0.16	-0.27	-0.4	-0.56

GWPbio index (SIA compatible)

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									
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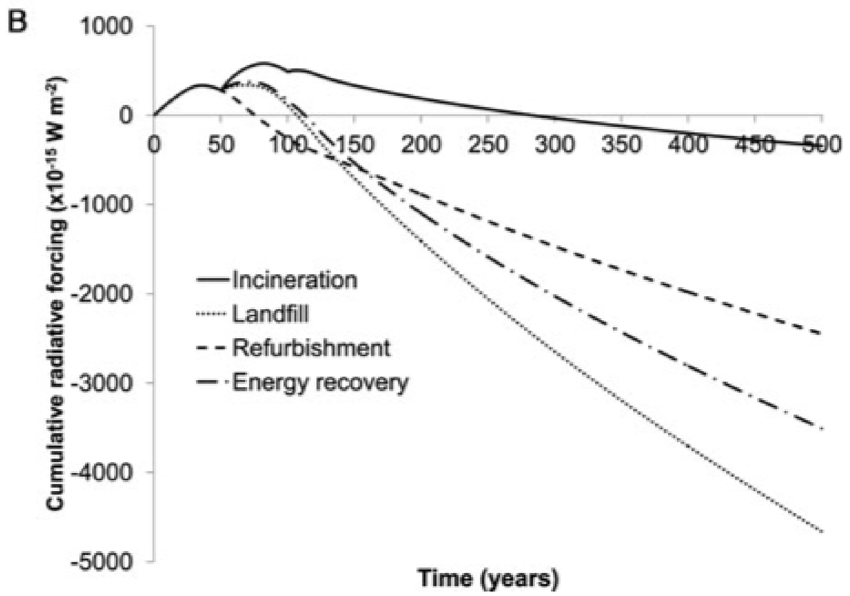
100	0.37	0.29	0.21	0.12	0.032	-0.06	-0.16	-0.27	-0.4	-0.56

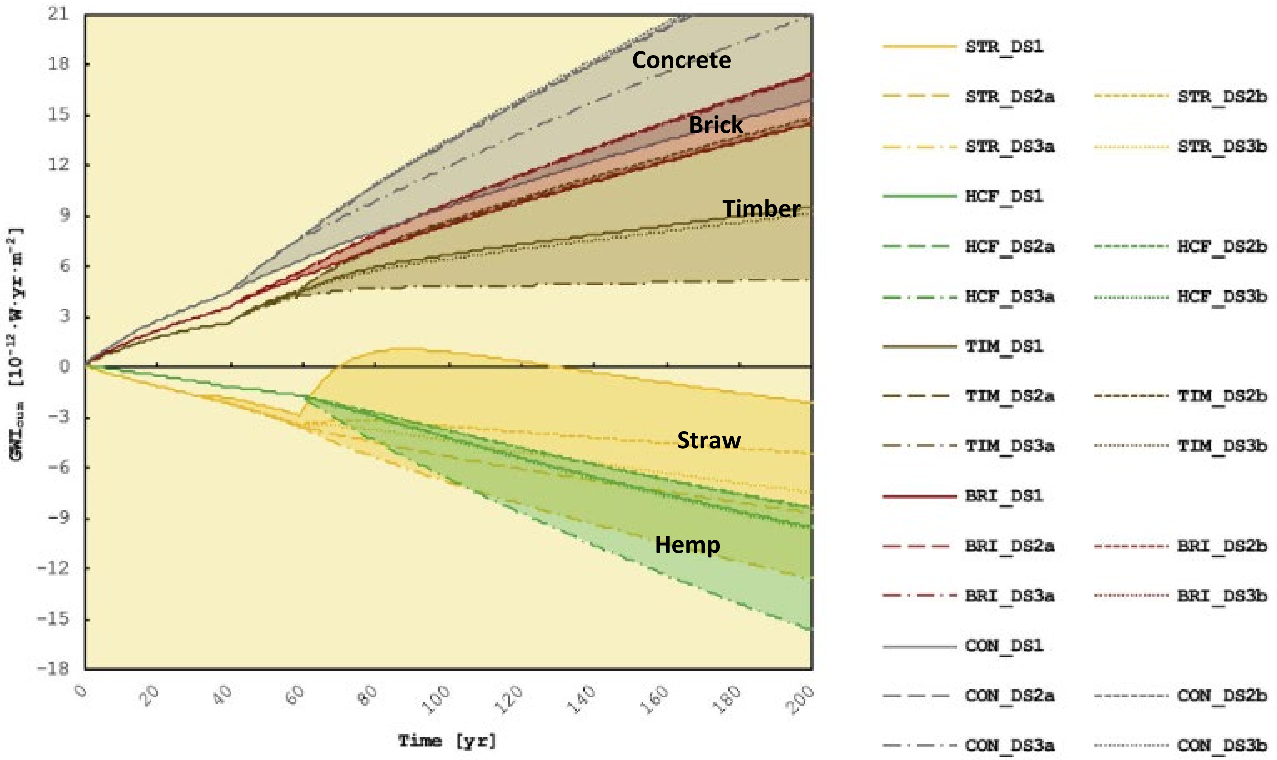
Remark:
Most common use of biobased materials:
- GWP bio for Straw insulation = 0.23
- GWP bio for softwood structure = 0.26

Having a characterisation factor of 0.25 for biogenic CO2 can be a way to avoid the need to define a function in KBOB database...

4- Prise en compte du stockage carbone en ACV

Quel scenario de fin de vie pour les matériaux biosourcés





Question principale de nombreuse études:

La fin de vie des matériaux biosourcés (comme pour ACV statique) on une influence majeure sur impact à long terme

Sce: Levasseur et al., 2012. Biogenic carbon and temporary storage addressed with dynamic Life Cycle Assessment. *Journal of industrial ecology*
Pittau et al., 2019. Retrofit as a carbon sink: the carbon storage potentials of the EU housing stock. *Journal of Cleaner Production*