
SUSTAINABLE
REAL ESTATE
SOLUTIONS
WS
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BIO-BASED BUILDING MATERIALS, CONVENTIONAL MATERIALS AND CARBON STORAGE ASSESSMENT

Thibaut Lecompte, Enseignant Chercheur à l'Université de Bretagne Sud/IRDL

POWERED BY

CONTEXT

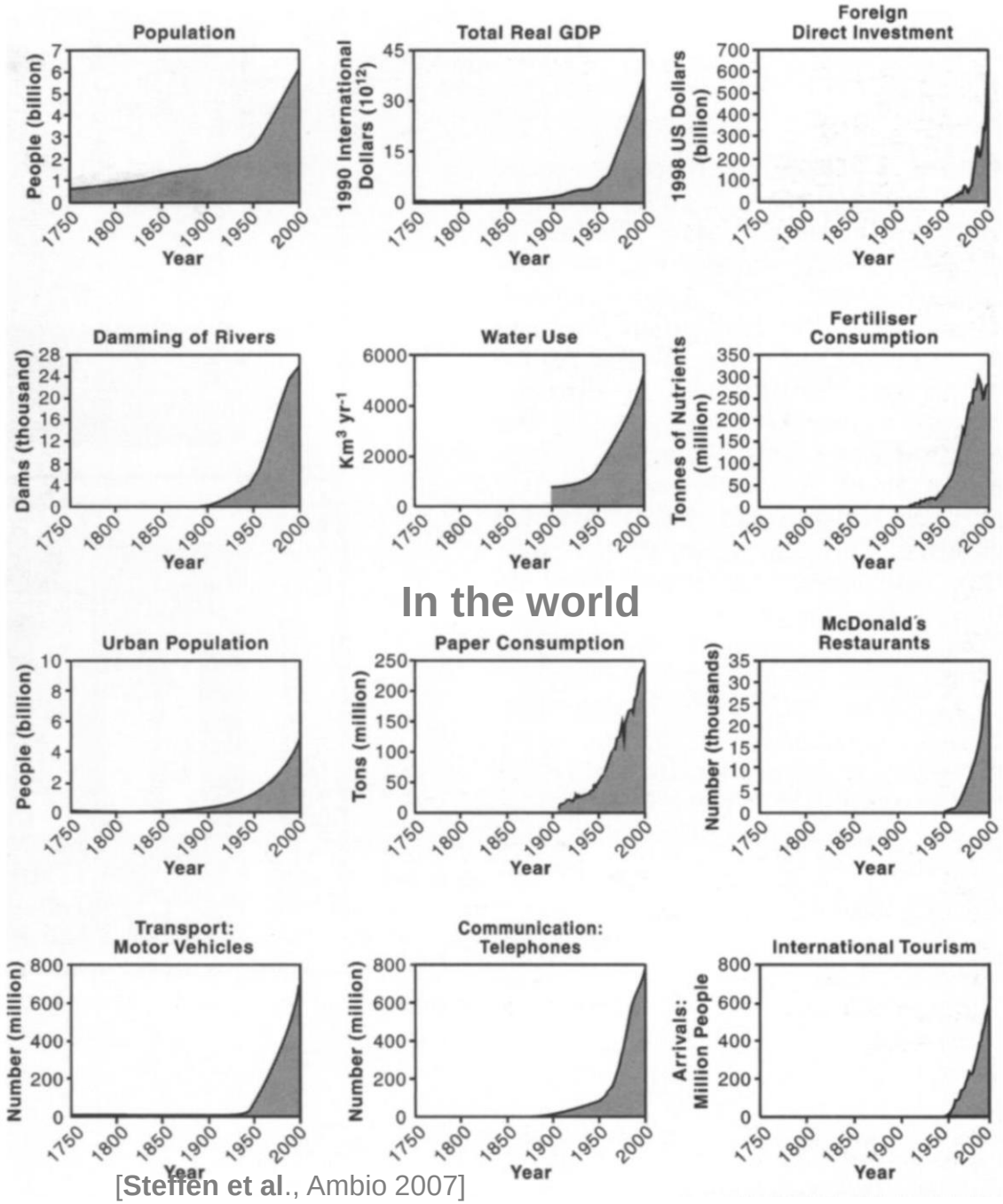
CONTEXT

In France

	Population	Electric consumption
1973	53 000 000	171 TWh
	x 1,3	x 2,8
2019	67 000 000	475 TWh

[**RTE**., Bilan Electrique 2019 ; **www.insee.fr**]

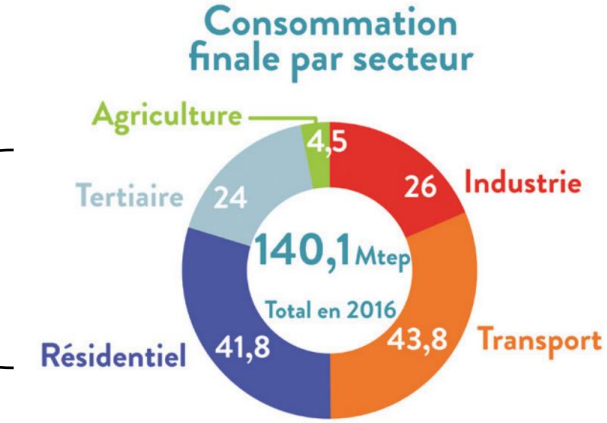
In the world



[**Steffen et al**., Ambio 2007]

CONTEXT

- **Environnemental Impact of building and construction sector**



47% of Energy consumption

In France

23% of Green-House Gases in France and about 40% in Europe (2017)

- **1er non-renewable raw materials consumer**
- **1er waste producer**

Energy consumption (current individual houses) :

- **about 85% for heating, cooling, lighting, hot water and ventilation (USAGE)**
- **about 15% for construction, material supplying and end of life**

[www.**insee.fr**, 2017 ; **statistiques.developpement-durable.gouv.fr**, 2016]

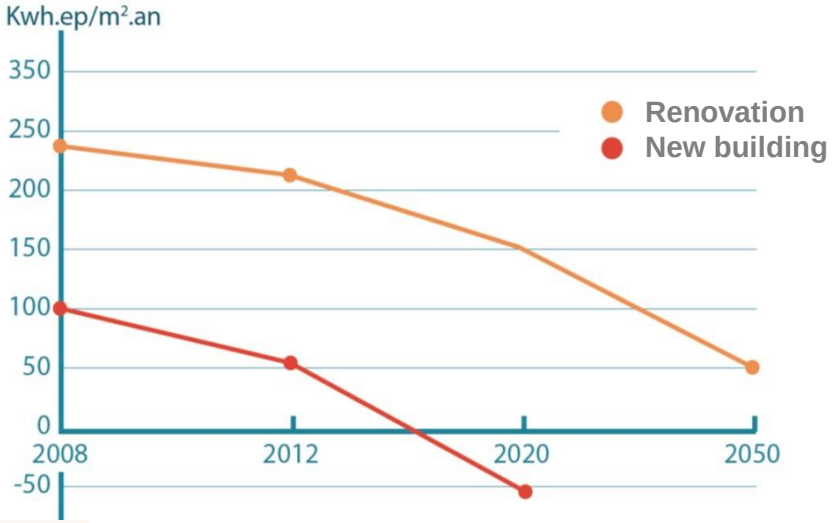
CONTEXT

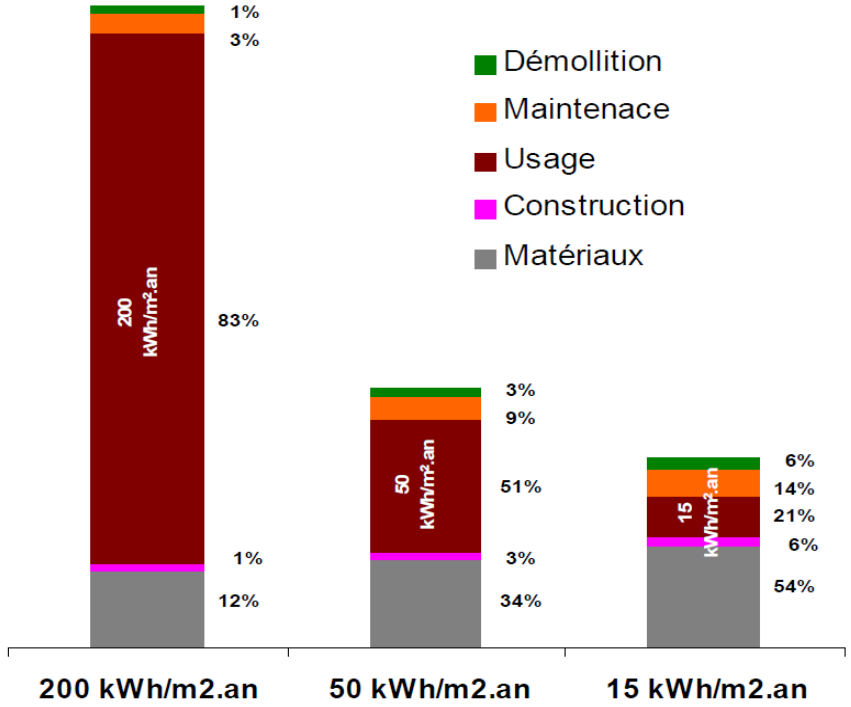
Current conventional buildings

	kgCO2eq / m2		kgCO2eq / m2	
Construction	250	11%	380	30%
End of life (EoL)	90	4%	130	10%
Service Life	25/an	85%	10 - 15/an	60%

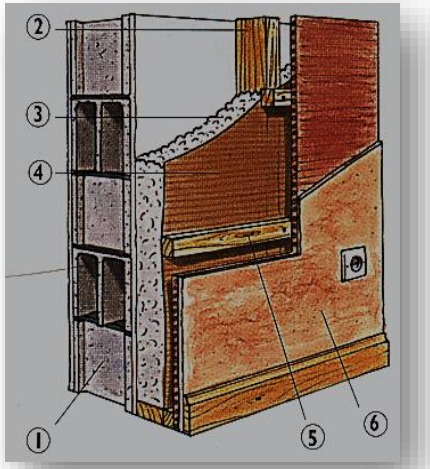
*DVR 75 ans

Thermal regulations in France





CONTEXT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3
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1
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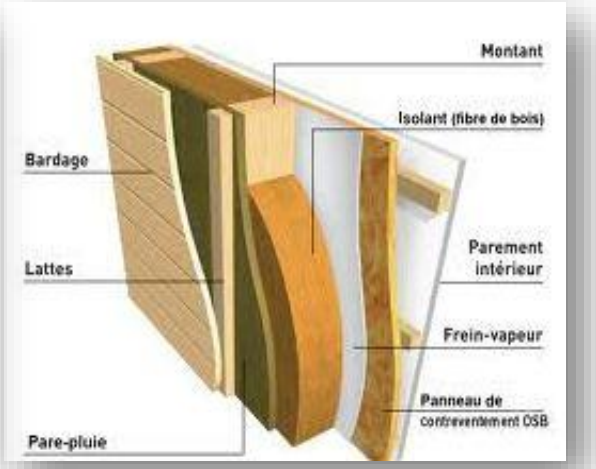
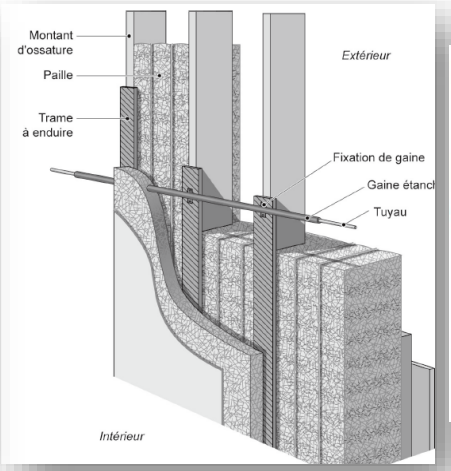
6

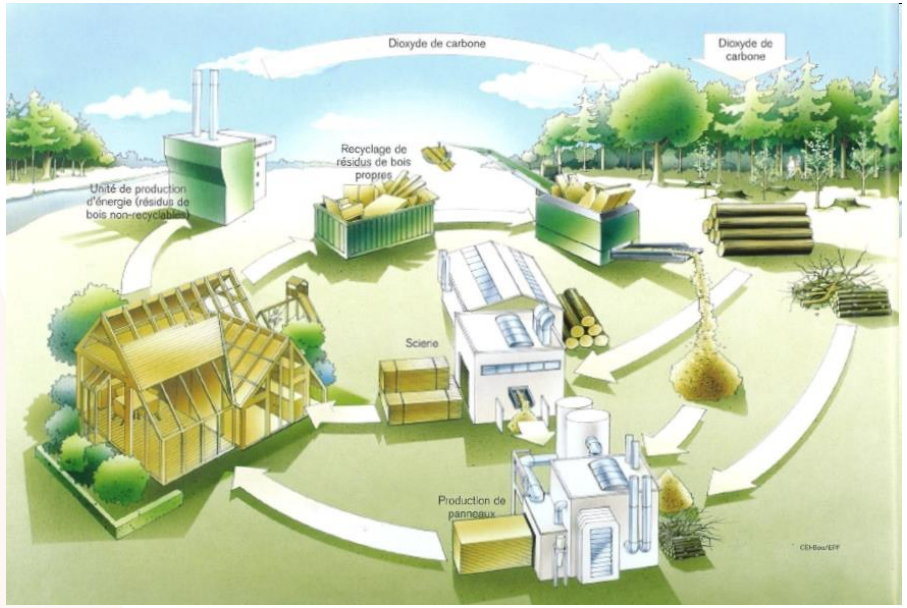

Montant
Isolant (fibre de bois)
Bardage
Lattes
Parement intérieur
Frein-vapeur
Panneau de contreventement OSB
Pare-pluie

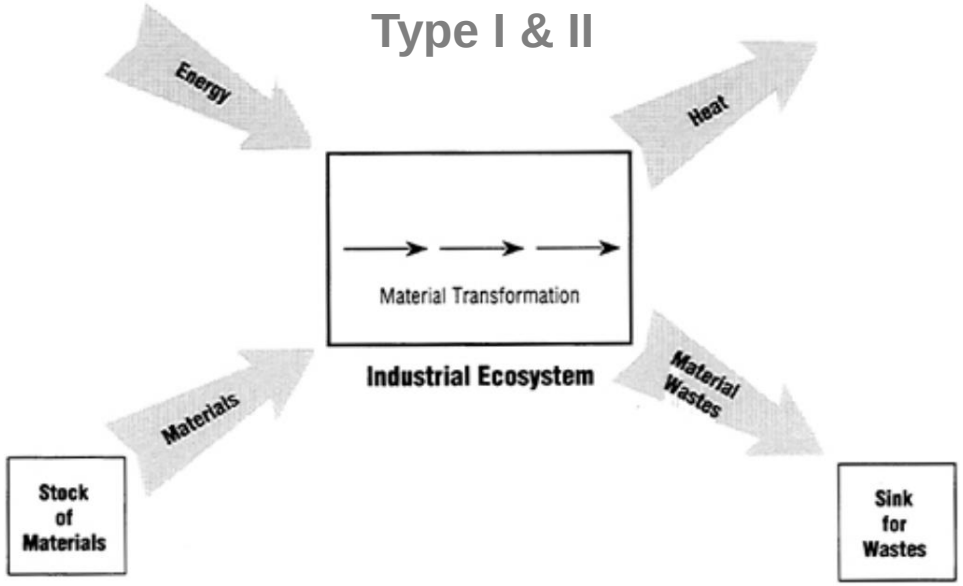

Montant d'ossature
Paille
Trame à enduire
Extérieur
Fixation de gaine
Gaine étanch
Tuyau
Intérieur

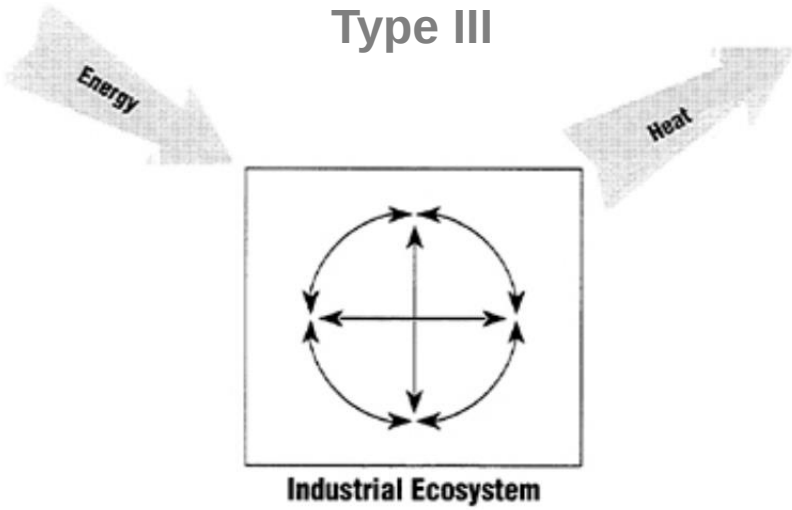

Règles professionnelles de construction en paille
Remplissage isolant et support d'enduit
Règles CP 2012 révisées
RFCP
Isolation
Technique
Mise en œuvre
Enduit
Étanchéité
Remplissa
LE MONITEUR

CONTEXT

- Bio-based materials benefits:
  - Carbon sinks
  - Local, renewable and available
  - Agro by-products valorisation

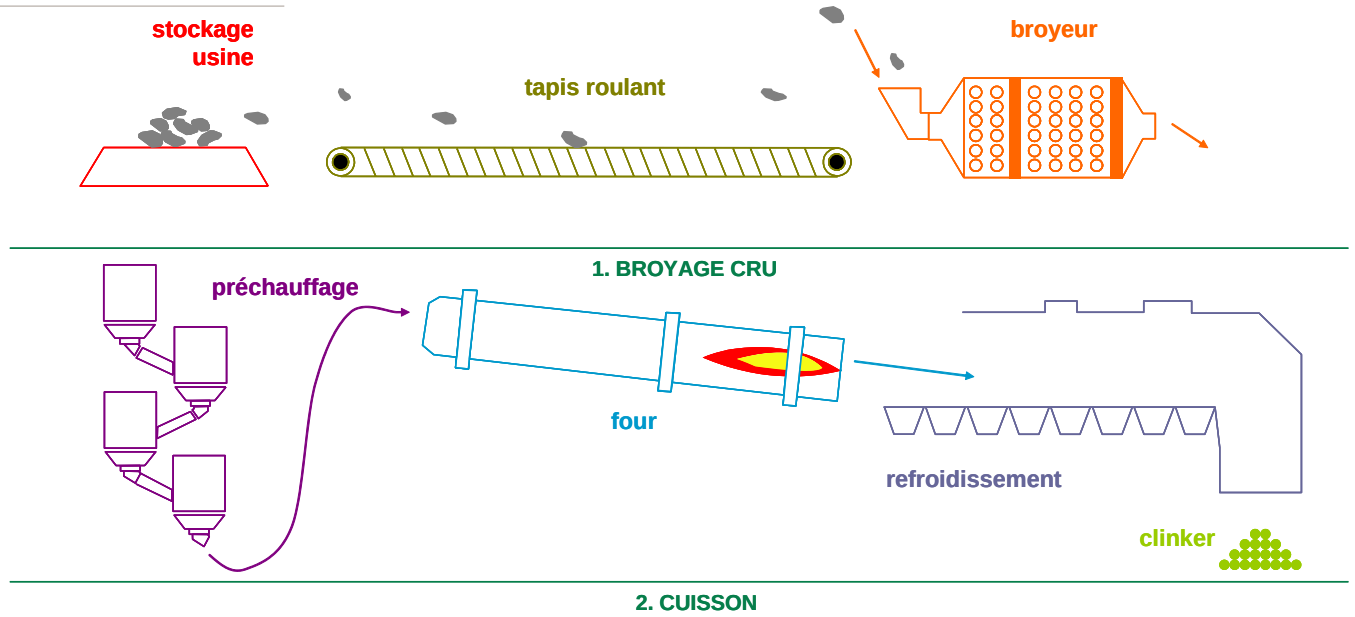






[**Richards, Allenby, Frosch**, The greening of industrial ecosystems, 1994]

CONTEXT



Main reaction during cement production:

$$CaCO_3 \Rightarrow CaO + CO_2$$

Limestone => Clinker + Carbon Dioxyde in atmosphere

[www.lafarge.fr]

CONTEXT

PRODUCTION PHASE

EMISSION of about 700 kg CO_2 by ton of pure cement

EMISSION of about 100 kg CO_2 by ton of concrete

SEQUESTRATION of more than 1500 kg CO_2 by ton of wood

LIFE CYCLE ASSESSMENTS (LCA) IN BUILDING SECTOR

LIFE CYCLE ASSESSMENTS

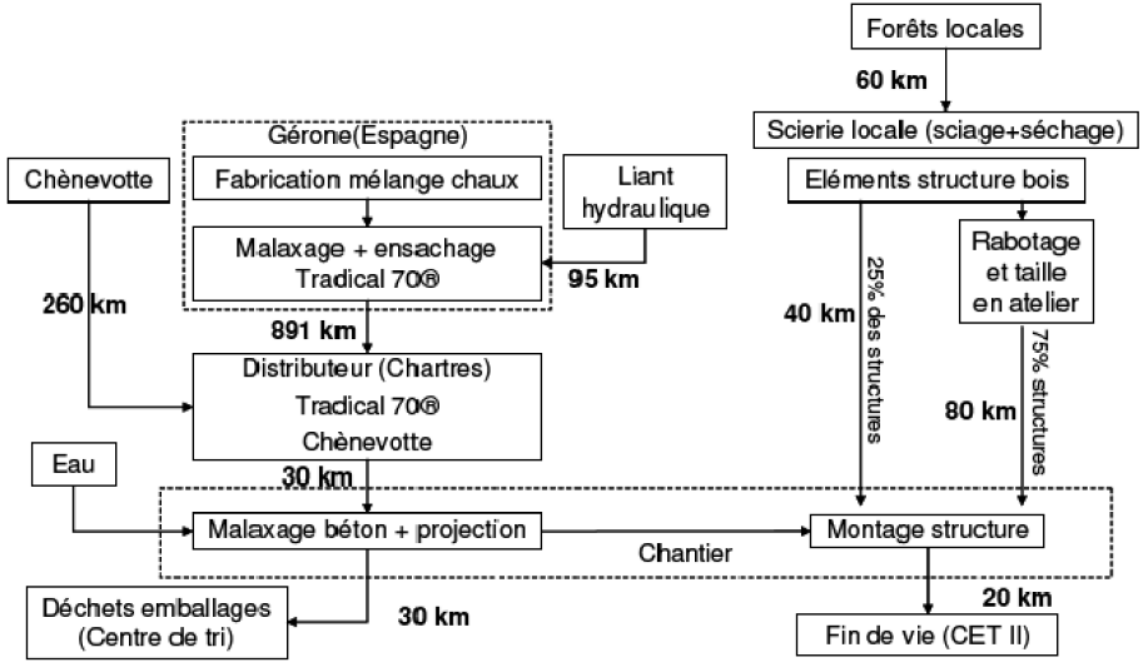
STANDARDS: ISO 14 040 AND ISO 14 044

⇒ LIFE CYCLE INVENTORY

⇒ FUNCTIONAL UNIT

⇒ A LOT OF IMPACTS

LIFE CYCLE ASSESSMENTS



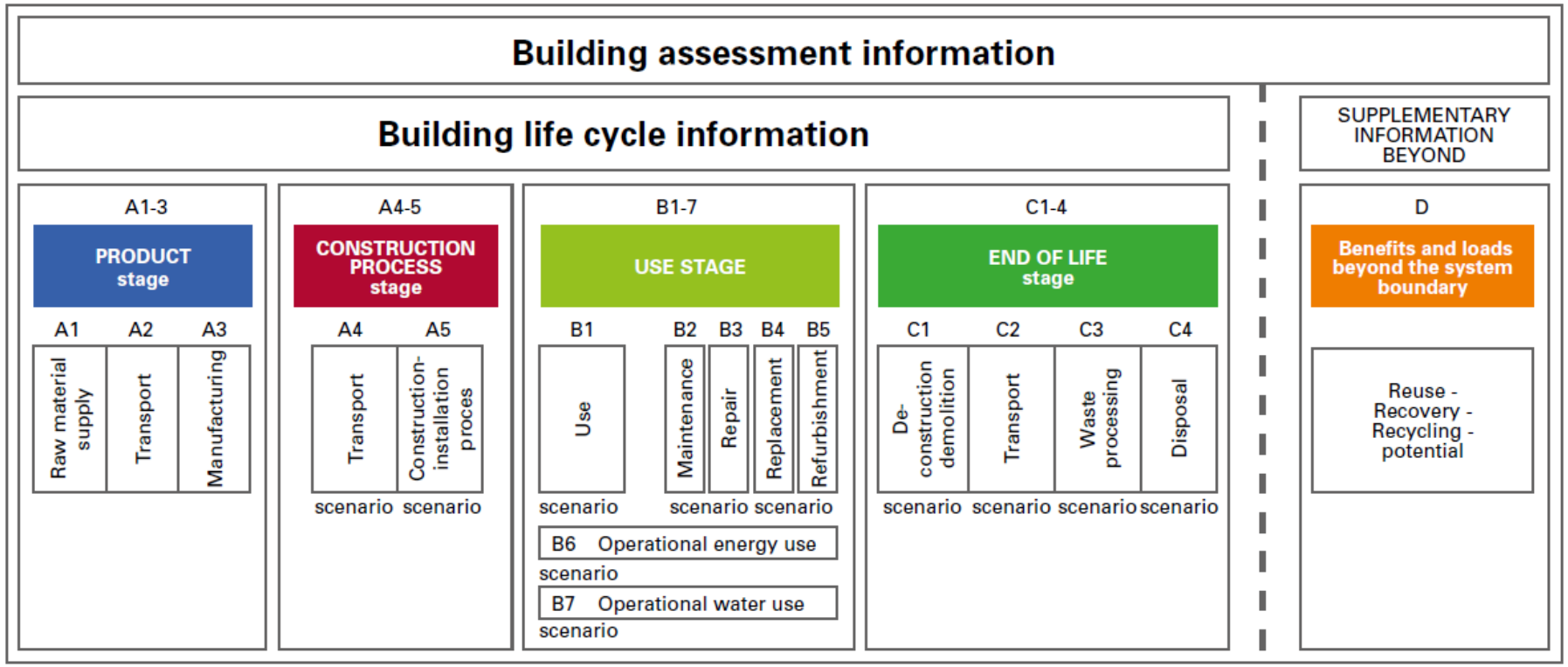
Source : BCB-Lhoist, Construire en chanvre

Questions:

- System boundaries
- Allocation or consequential approach**?**

[**Henry et al.** *Impacts environnementaux et sanitaires des matériaux Chanvre ;* Séminaire Scientifique, 2008]

LIFE CYCLE INVENTORY



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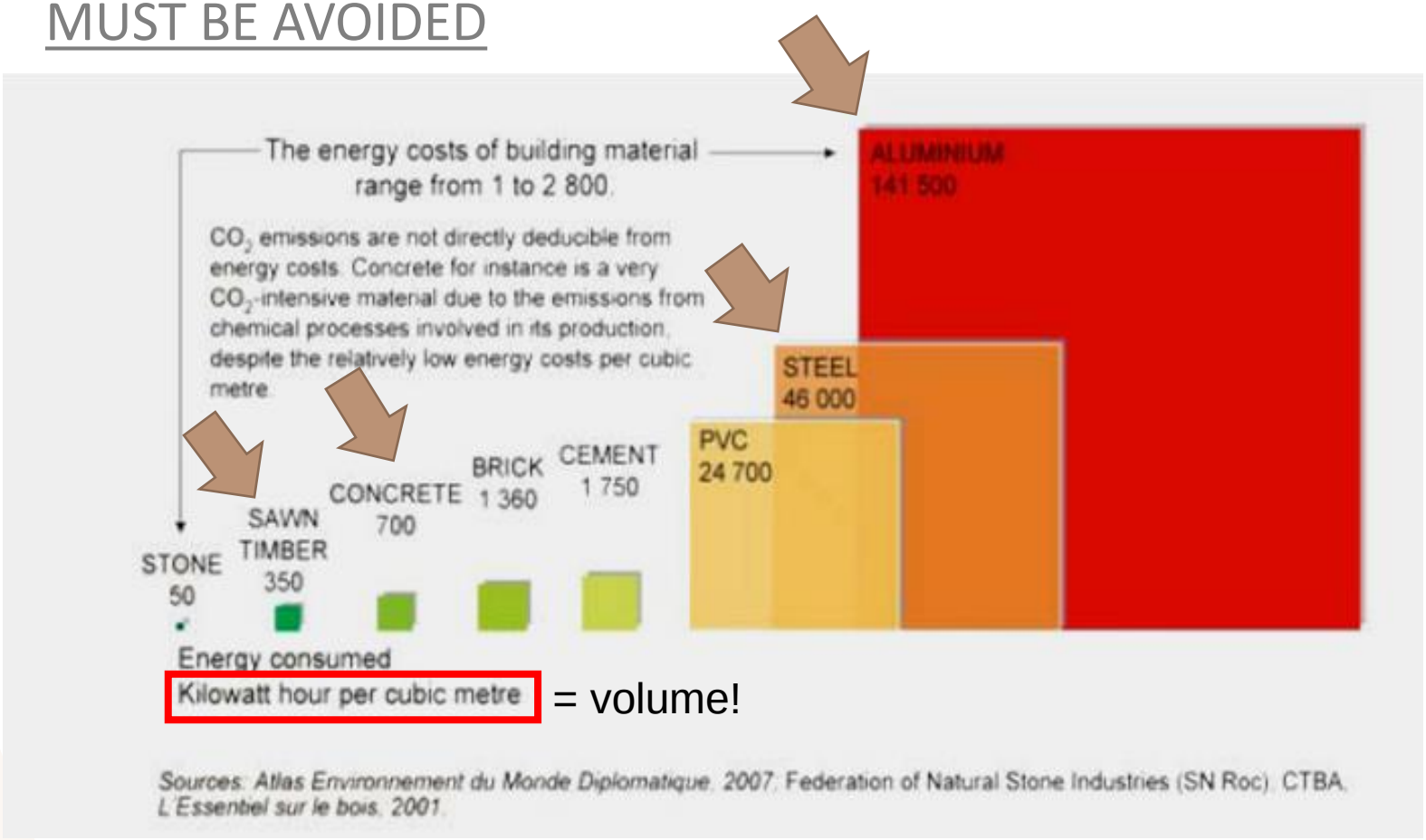
FUNCTIONAL UNIT

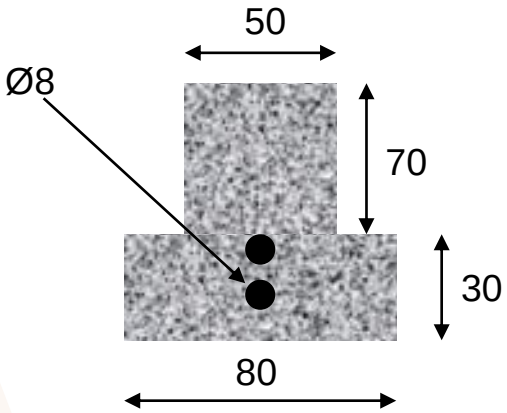
COMPARISON FOR A GIVEN MASS OR A GIVEN VOLUME MUST BE AVOIDED



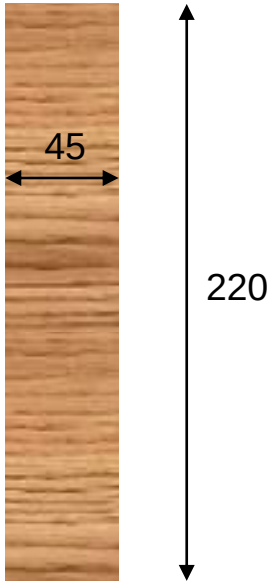
FUNCTIONAL UNIT

FUNCTION + PERFORMANCE + QUANTITY + TIME

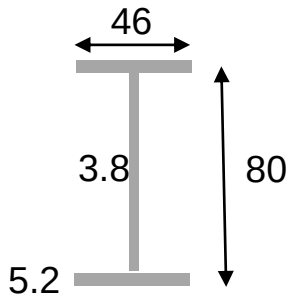
Ex: A structural beam, able to bear a floor with a load of 1kN by linear meter, with a span of 4 m, during 50 years



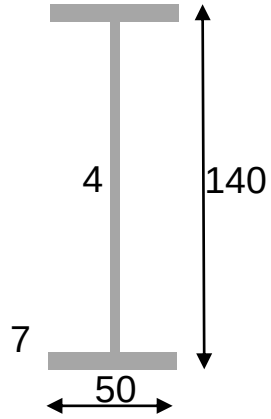
Reinforced concrete beam



Epicea



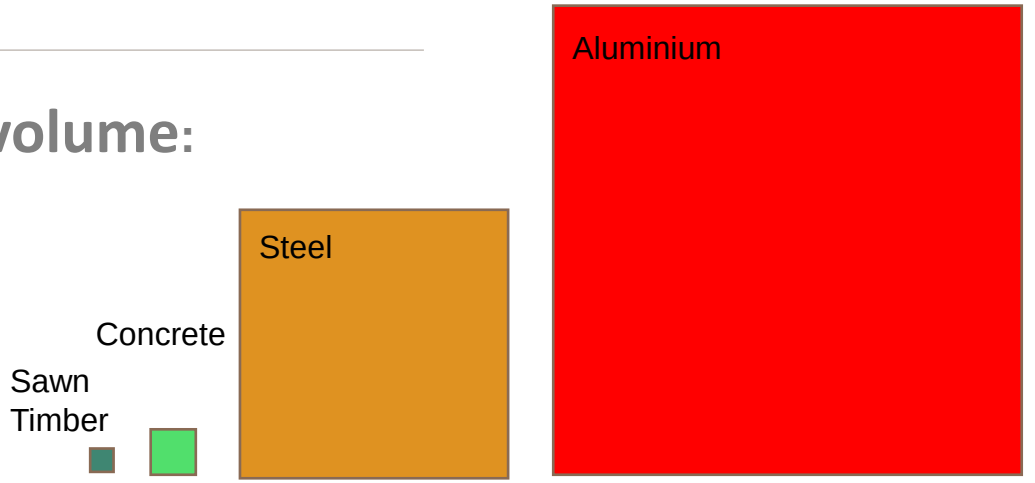
IPE 80



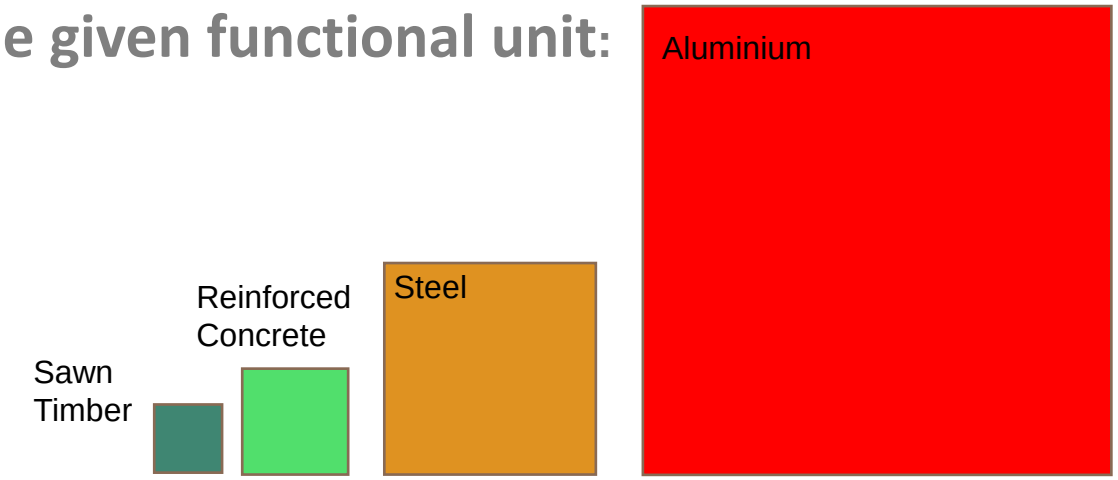
Aluminium beam

FUNCTIONAL UNIT

Compared in volume:



Compared for the given functional unit:



EMBODIED ENERGY

A LOT OF IMPACTS

EMBODIED ENERGY

AIR POLLUTION

WATER POLLUTION

GLOBAL WARMING POTENTIAL

WASTE PRODUCTIONS

NON RENEWABLE RESSOURCES

OZONE LAYER DESTRUCTION

SOILS ACIDIFICATION

EUTROPHICATION

...

WEIGHT OF EACH IMPACT?

A LOT OF IMPACTS

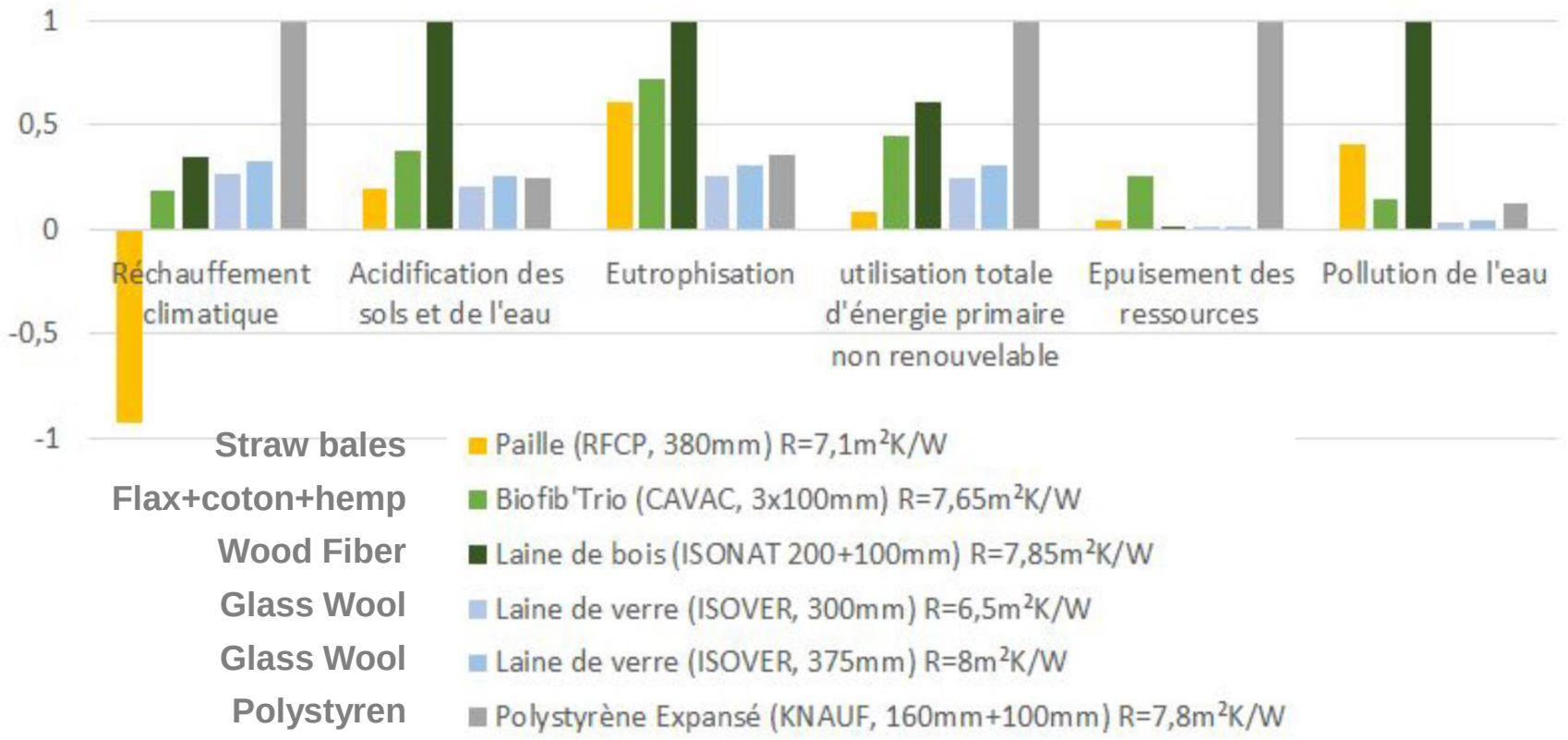
Impacts environnementaux	Etape de fabrication			Etape de mise en œuvre		Etape de vie en œuvre							Etape de fin de vie				D Bénéfices et charges au-delà des frontières du système
	A1 Approvisionnement en matières premières	A2 Transport	A3 Fabrication	A4 Transport	A5 Installation	B1 Usage	B2 Maintenance	B3 Réparation	B4 Remplacement	B5 Réhabilitation	B6 Utilisation de l'énergie	B7 Utilisation de l'eau	C1 Déconstruction/ démolition	C2 Transport	C3 Traitement des déchets	C4 Décharge	
Réchauffement climatique kg CO_2 eq/UF	-7,05E+02	8,71E+00	3,30E+01	4,92E+01	6,22E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,32E+00	4,18E+00	4,30E+02	2,42E+02	-3,07E+01
Appauvrissement de la couche d'ozone kg CFC 11 eq/UF	2,19E-06	1,51E-06	7,77E-06	1,10E-05	1,53E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,08E-07	7,91E-07	1,32E-06	4,73E-07	-1,74E-05
Acidification des sols et de l'eau kg SO_2 eq/UF	1,46E-01	3,44E-02	1,09E-01	1,46E-01	4,19E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,54E-02	1,64E-02	5,49E-02	2,52E-02	-1,20E-01
Eutrophisation kg $(PO_4)^{3-}$ eq/UF	3,04E-02	5,65E-03	2,42E-02	2,12E-02	1,50E-05	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,42E-03	2,92E-03	1,17E-02	8,30E-03	-6,52E-03
Formation d'ozone photochimique Ethene eq/UF	1,11E-01	4,62E-03	1,60E-02	3,75E-02	1,56E-05	4,89E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,80E-03	1,86E-03	6,07E-03	8,84E-03	-1,62E-02
Epuisement des ressources abiotiques (éléments) kg Sb eq/UF	5,59E-05	1,80E-05	1,36E-05	1,39E-04	8,39E-09	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,20E-06	1,30E-05	2,61E-06	4,96E-06	-1,22E-05
Épuisement des ressources abiotiques (fossiles) MJ PCI/UF	5,75E+02	1,34E+02	5,08E+02	8,70E+02	1,45E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	4,80E+01	6,39E+01	1,04E+02	4,32E+01	-4,56E+02
Pollution de l'air m^3/UF	9,29E+03	1,11E+03	2,95E+03	8,18E+03	8,91E-01	1,18E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	4,06E+02	4,54E+02	8,79E+02	4,91E+02	-1,84E+03
Pollution de l'eau m^3/UF	2,35E+01	3,73E+00	1,28E+01	2,10E+01	6,23E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,12E+00	1,52E+00	2,42E+00	1,85E+00	-4,84E+00

[www.**inies.fr** ; **ACV CLT Stora Enso**]

A LOT OF IMPACTS

IN FRANCE BUILDING SECTOR: FDES (ENVIRONMENTAL AND HEALTH DECLARATION FORMS)

FU: 1m² wall insulation, R of about 7 m²K/W, lifespan of 50 years



[www.**inies.fr**, consulted in 2020]

A LOT OF IMPACTS

THE ECO-BUILDER « MANTRA »

« THE BEST ENERGY IS THE NOT-CONSUMED ONE

&

THE BEST MATERIAL IS THE NOT-USED ONE »

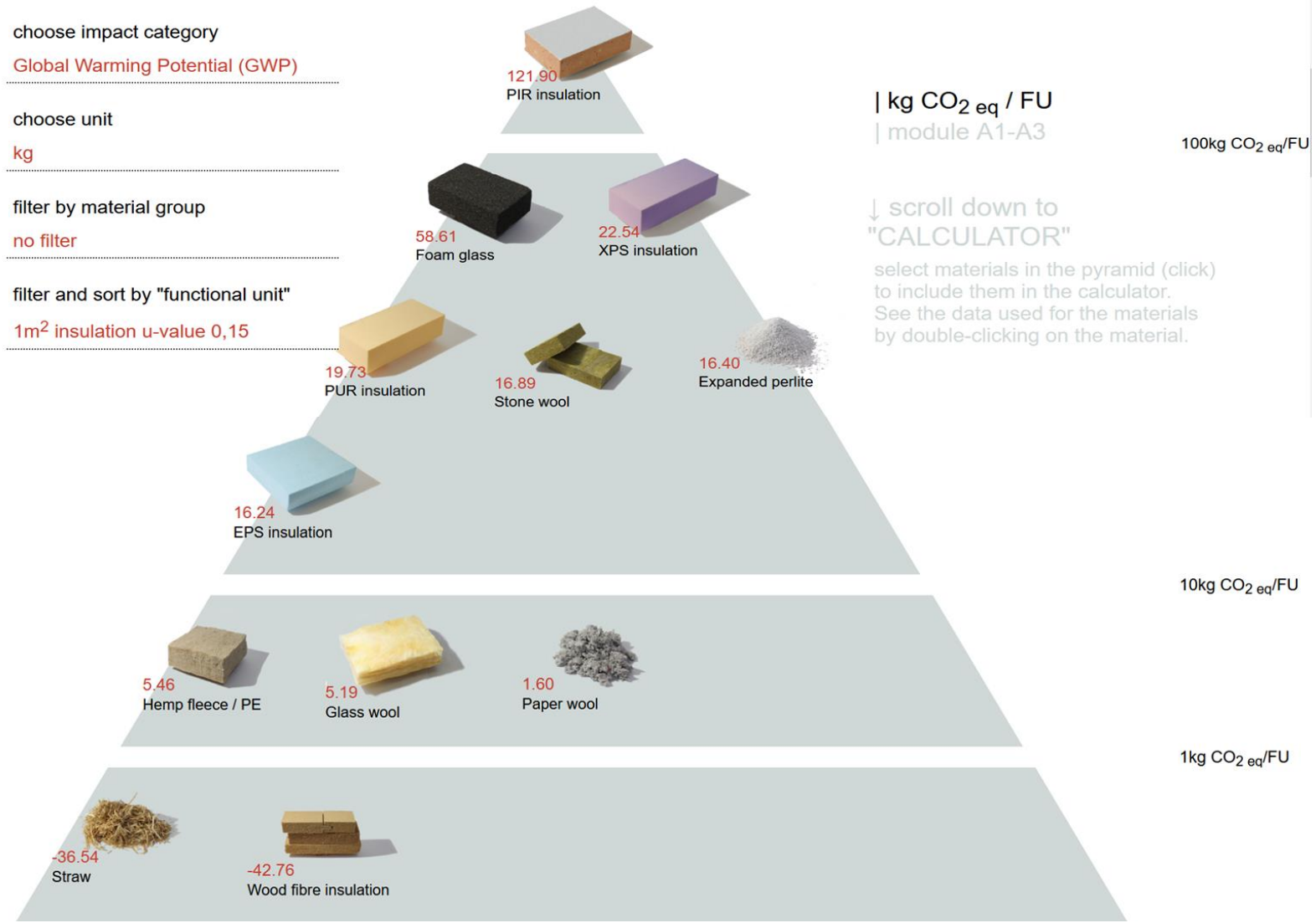
CARBON UPTAKES AND EMISSIONS: THE IMPORTANCE OF TIMMING

BIOGENIC AND ANTHROPIC GHG

Carbon Storage (biogenic)

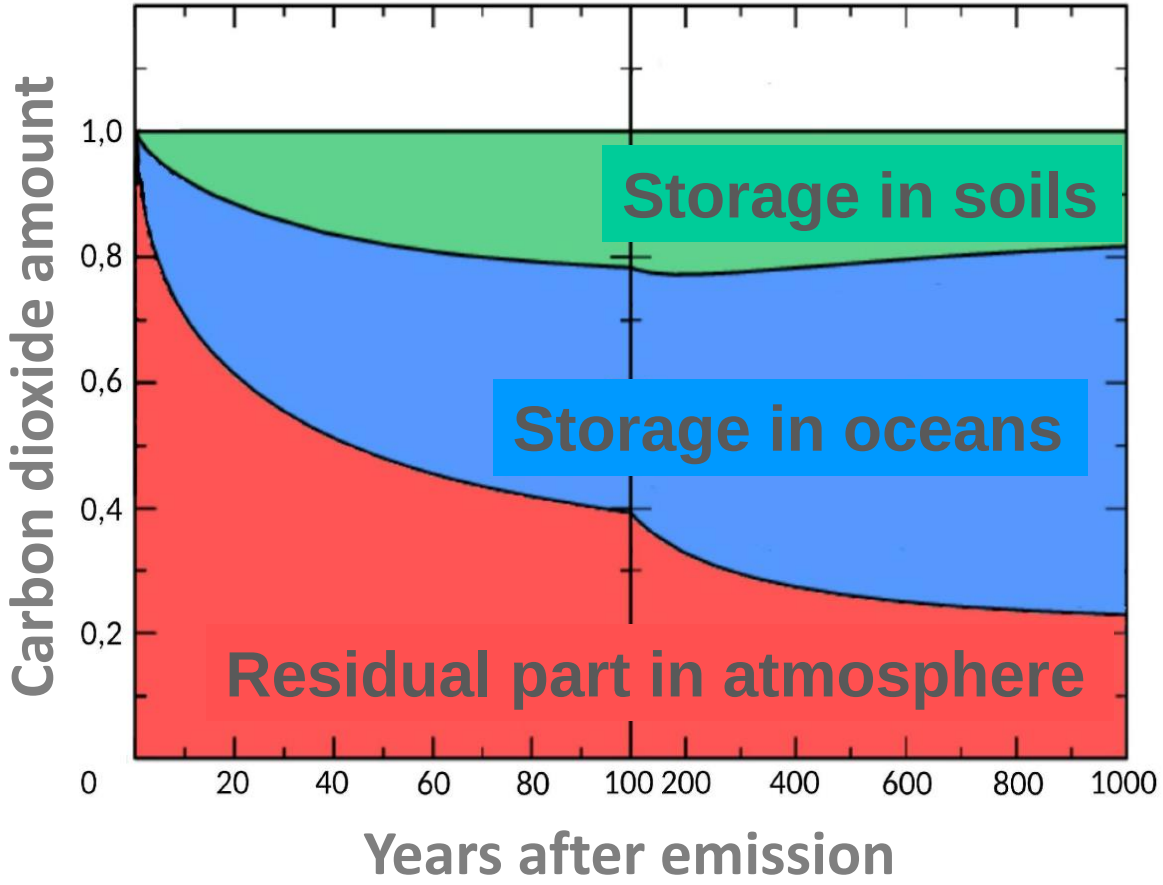
GHG emissions (anthropic)

BIOGENIC AND ANTHROPIC GHG



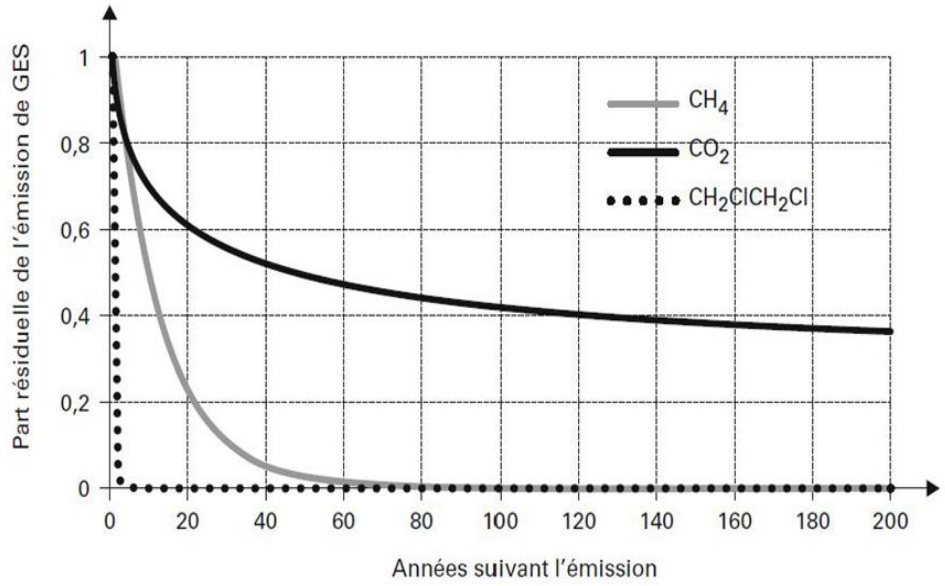
https://www.materialepyramiden.dk/

WOOD AS A CARBON SINK



[after **Strassman**, 2018]

WOOD AS A CARBON SINK



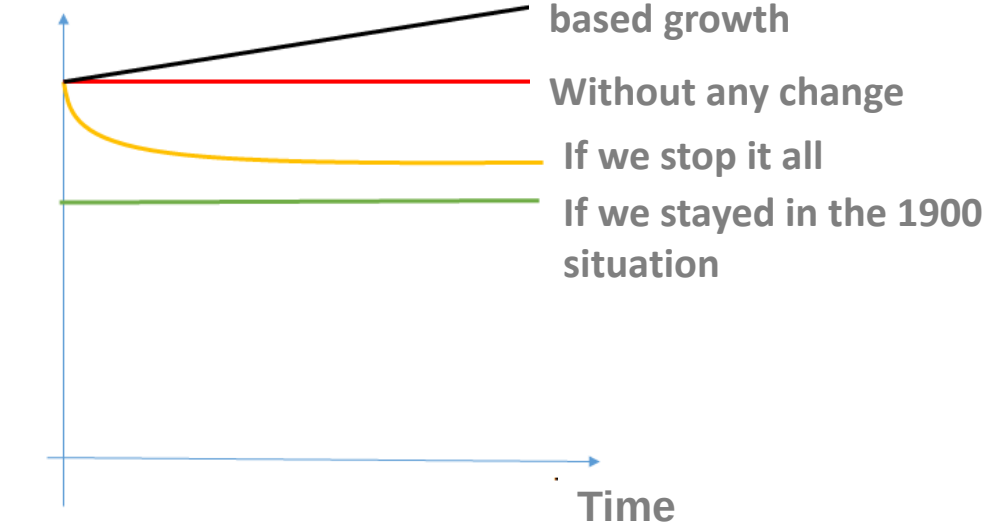
x

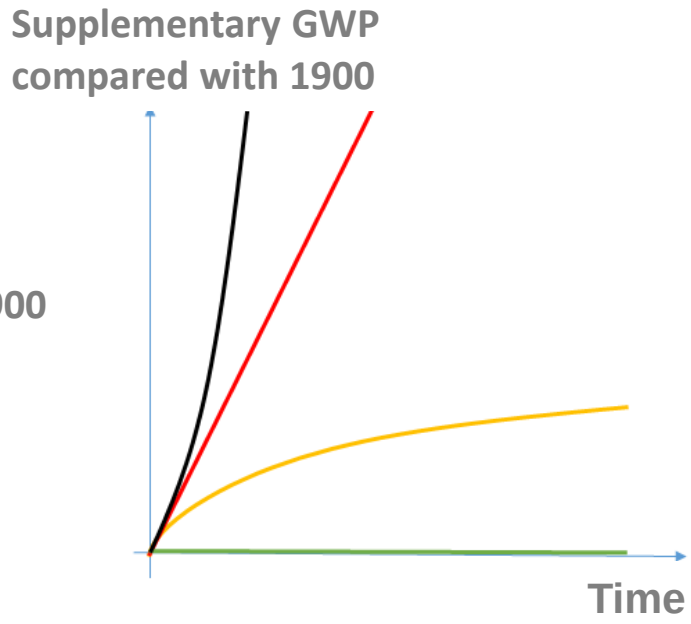
Radiative Forcing of Each GHG (Green House Gas)

= GWP : Global Warming Potential (instantaneous or cumulative)

[**Lecompte**, Techniques de l'ingénieur, 2019]

WOOD AS A CARBON SINK





WOOD AS A CARBON SINK

Photosynthesis:

$$2n\ \mathbf{CO_2} + 4n\ H_2O + photons \rightarrow \mathbf{2(CH_2O)_n} + 2n\ O_2 + 2n\ H_2O.$$

=> Cellulose, hemi-cellulose, pectin, lignin

Material	Carbon Content, in mass	CO_2 sequestration, in 1kg of wood (12% water content)
Wheat Straw	44%	1,44
Flax and hemp fibers		
Hemp Shiv	47%	1,54
Hard Wood	48%	1,57
Conifers	50%	1,63

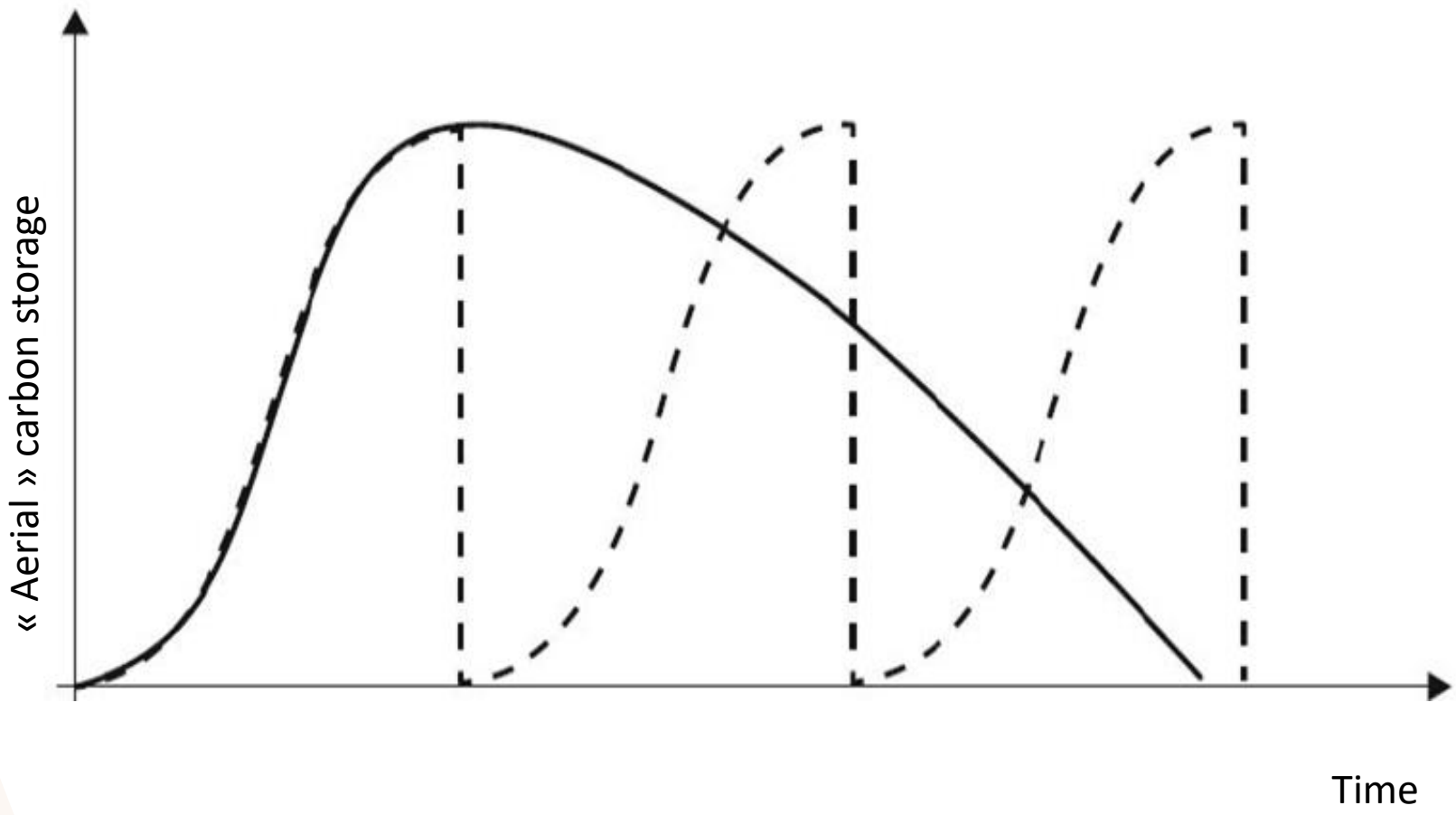
[**Lecompte**, Techniques de l'ingénieur, 2019]

WOOD AND FAST GROWING PLANTS

FOREST
&CULTIVATED
AREAS IN FRANCE

Permanent carbon storage	41,5 tC/ ha	190 tC/ ha
Average Yields	4 à 6 t/ha/an	3 t/ha/an
Areas	9,3 millions d'hectares	17 millions d'hectares

WOOD AND FAST GROWING PLANTS

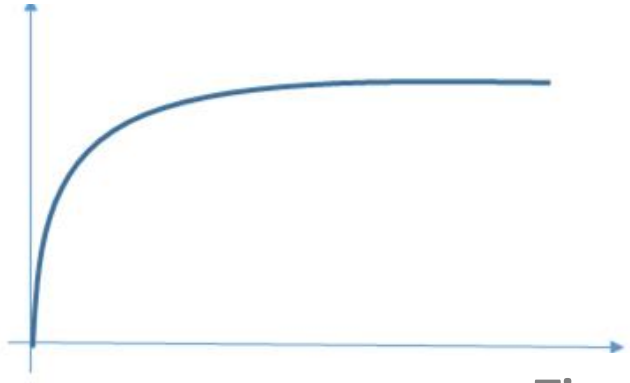


[**Lecompte**, Techniques de l'ingénieur, 2019]

WOOD AS A CARBON SINK

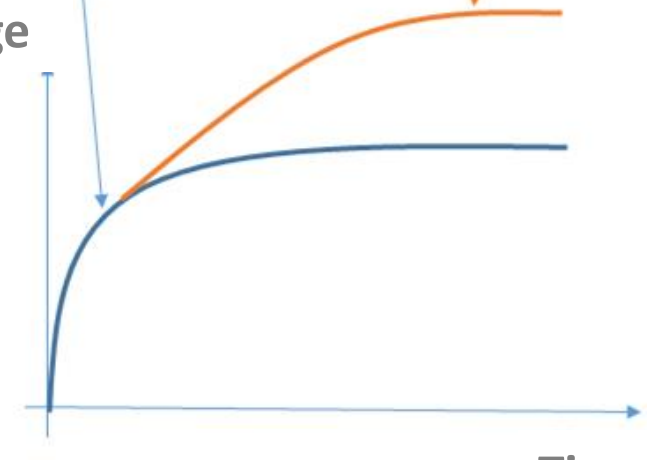
Natural Forest

Carbon storage

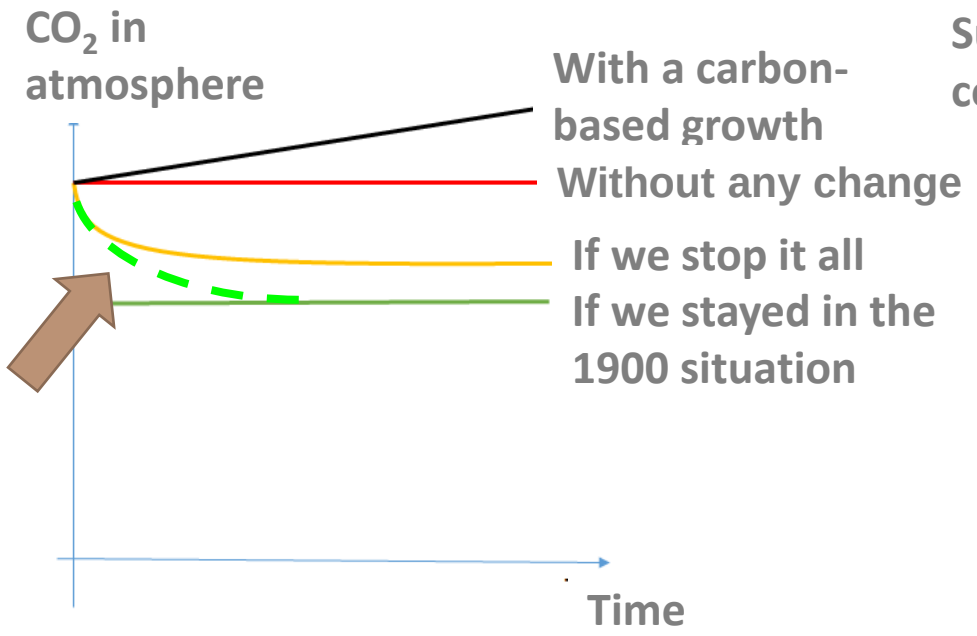


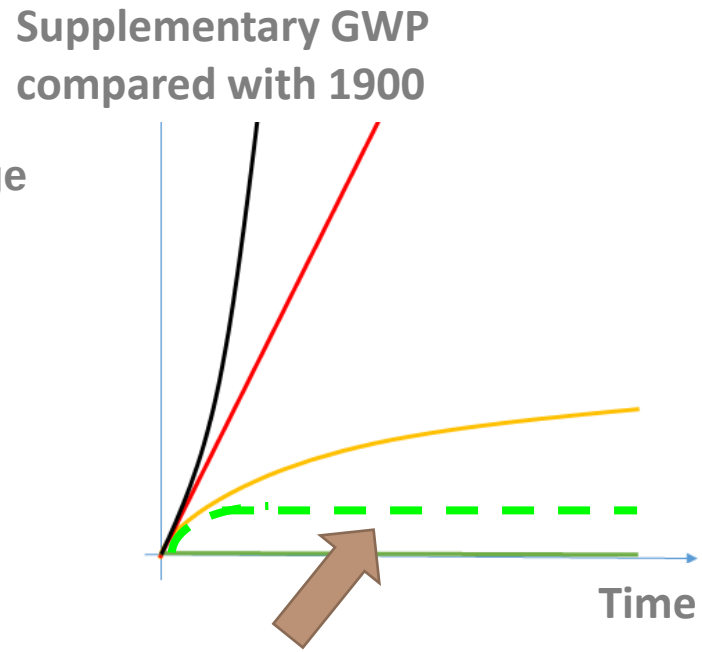
Sustainable forest management and storage in buildings

Carbon storage



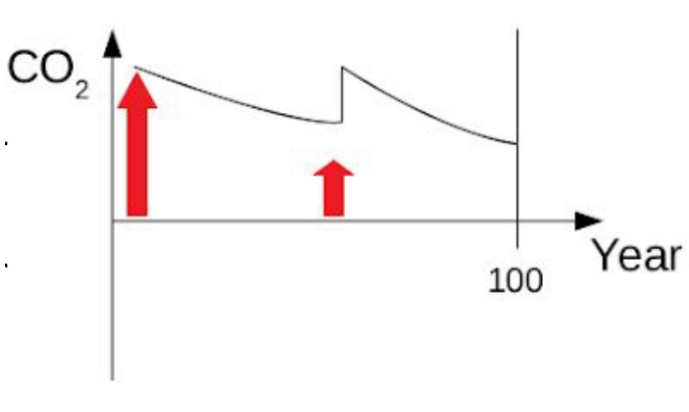
WOOD AS A CARBON SINK



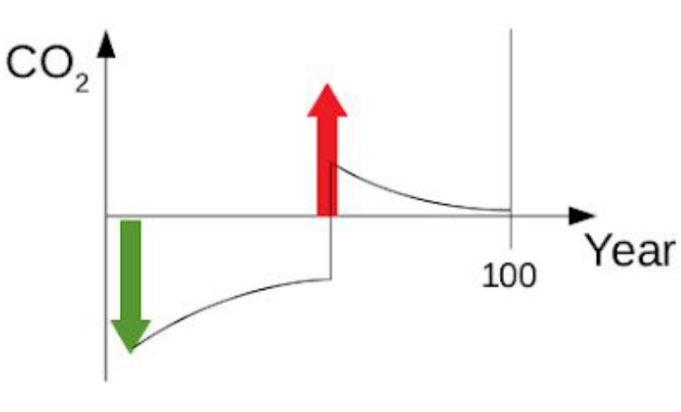


WOOD AS A CARBON SINK

Emission

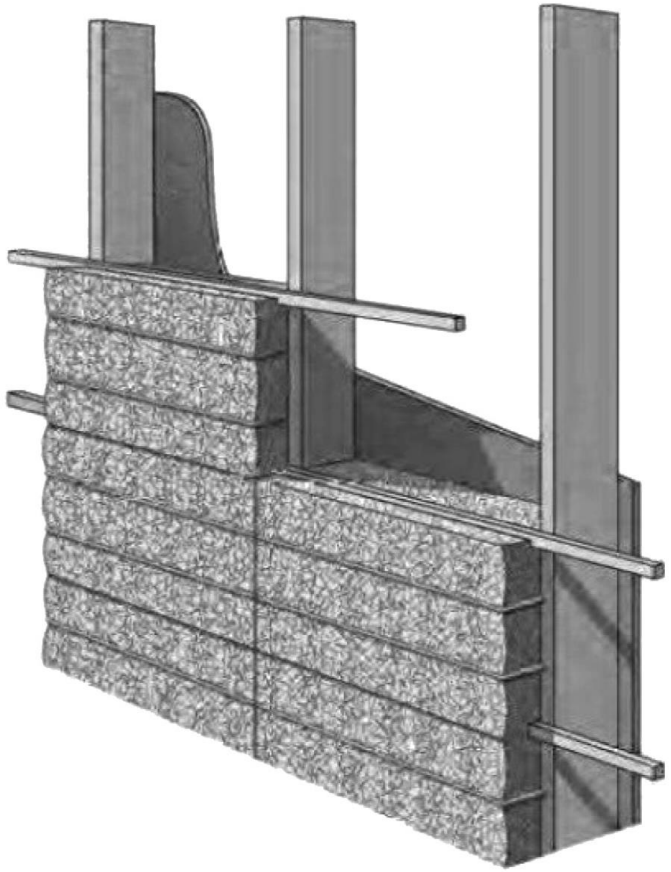


Sequestration



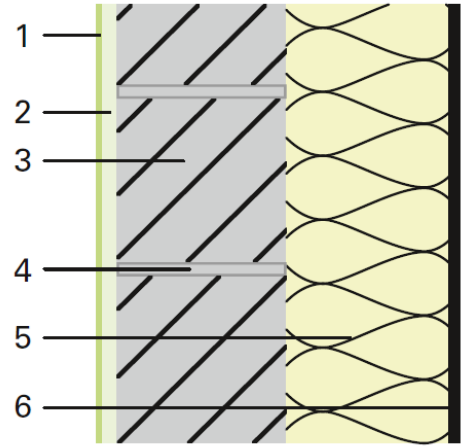
CASE STUDY: BIO-BASED AND NON BIO-BASED WALL

Wheat straw bales and wood frame



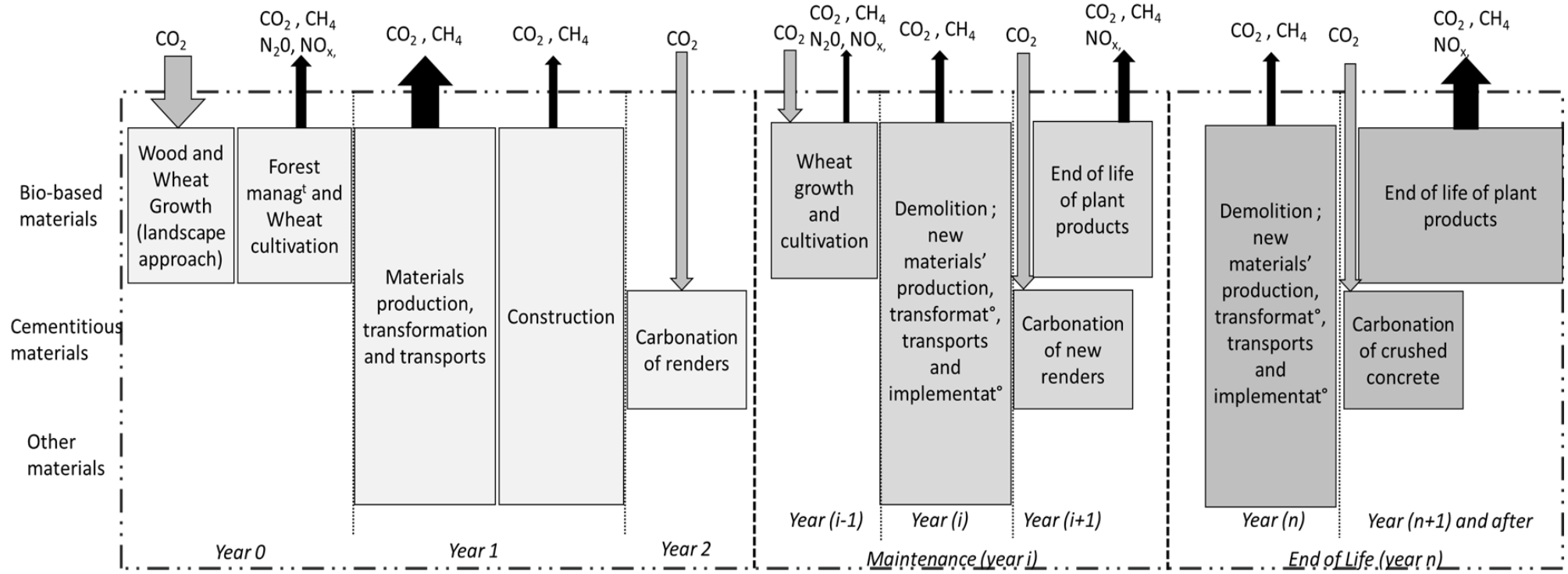
[**Zieger et al.**, Building and Environment, 2021]

French « conventional » wall



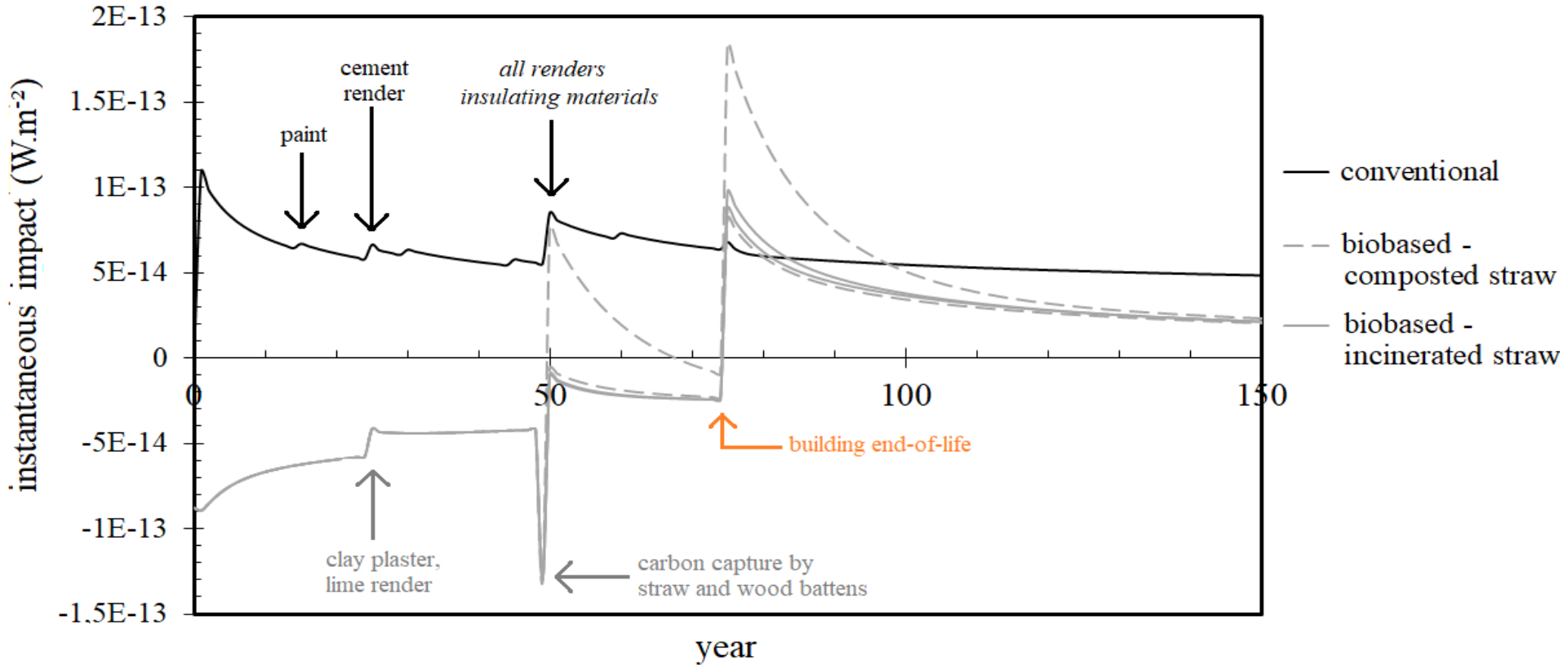
1-Peinture extérieure ; 2-enduit extérieur à base de mortier de ciment ; 3-blocs de béton creux ; 4-joints de mortier ; 5-isolant de laine minérale ; 6-plaques de plâtre + peinture intérieure

CASE STUDY: EMISSIONS & UPTAKES



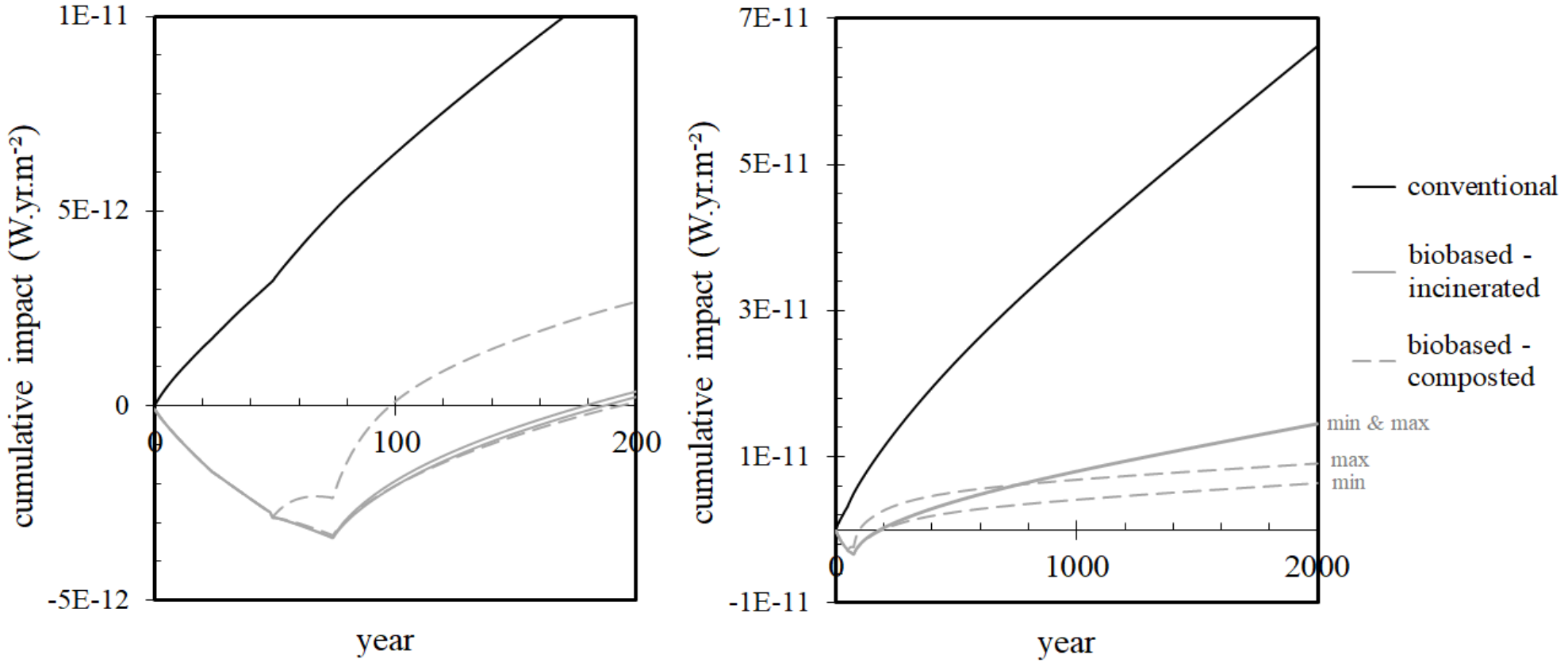
[**Zieger et al**., Building and Environment, 2021]

CASE STUDY: MAIN RESULTS



[**Zieger et al**., Building and Environment, 2021]

CASE STUDY: MAIN RESULTS

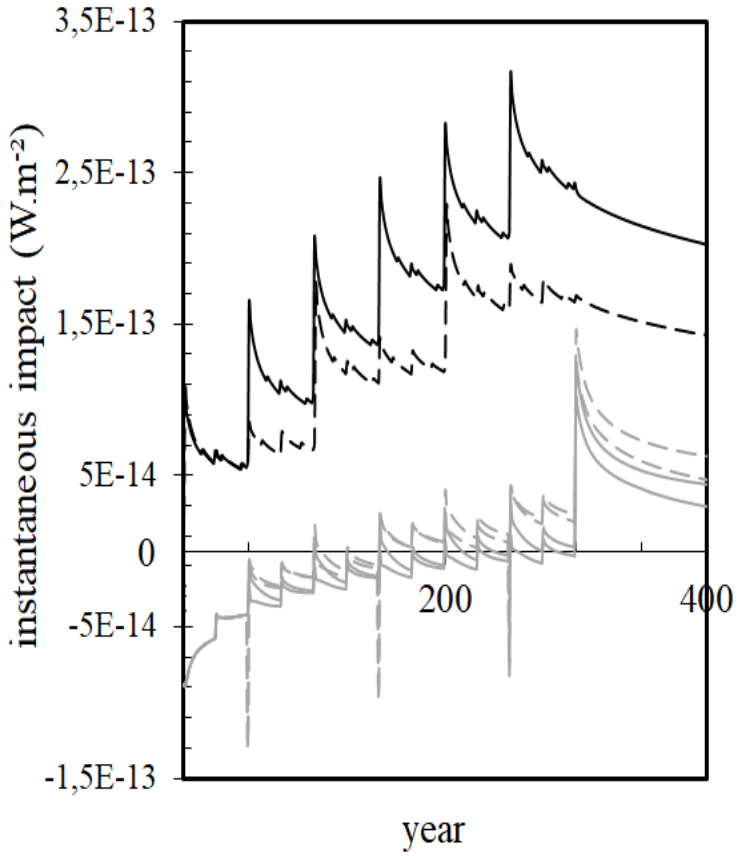


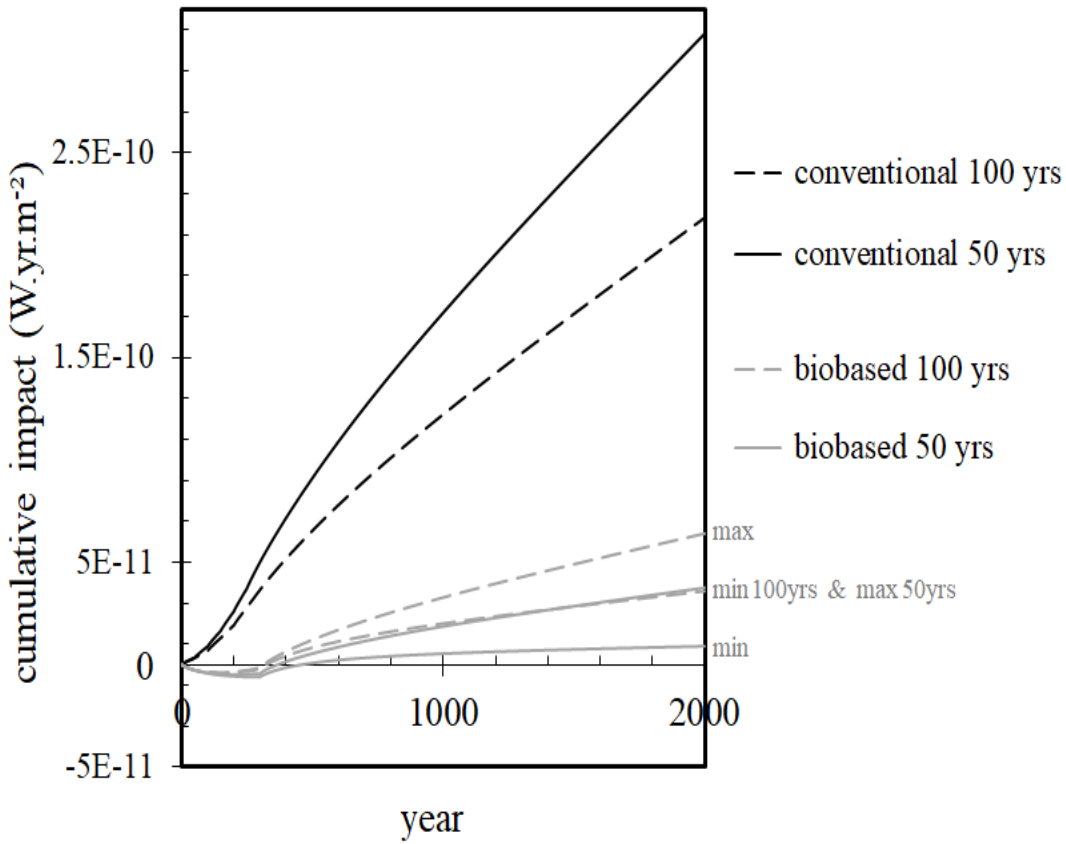
[**Zieger et al**., Building and Environment, 2021]

CASE STUDY: MAIN RESULTS

EXTENSION OF THE FU

« The use of a land to continue providing housing for present and future citizens »



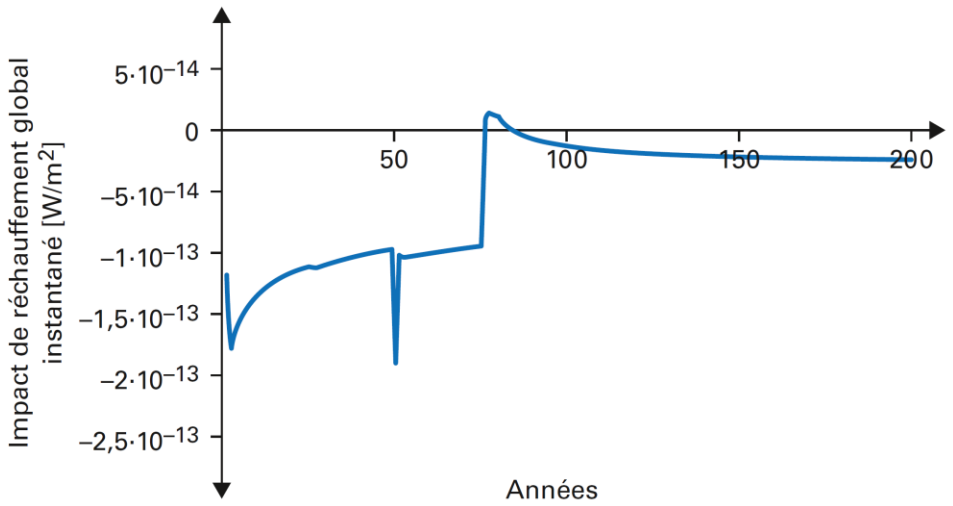


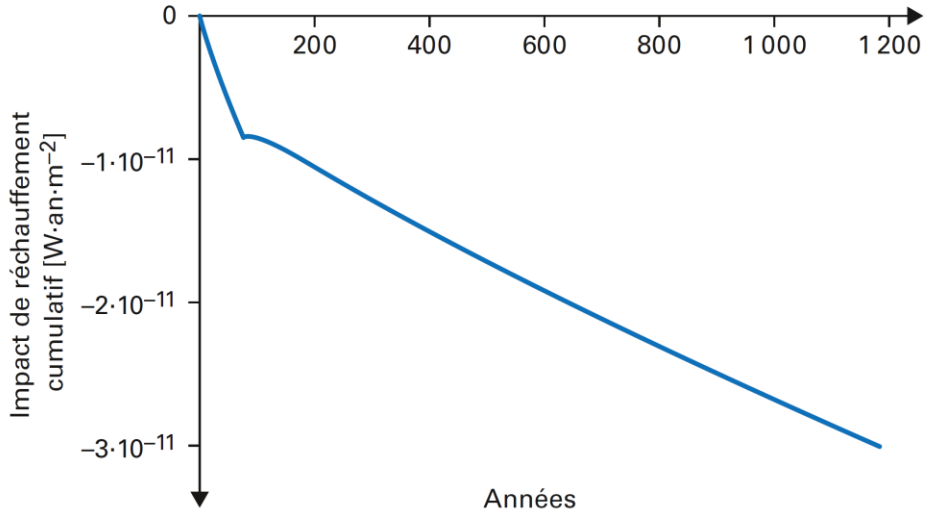
[**Zieger et al**., Building and Environment, 2021]

CASE STUDY: MAIN RESULTS

SUBSTITUTION: TO REPLACE CARBON EMITTERS MATERIALS BY CARBON SEQUESTERS (BIOBASED MATERIALS)

⇒ BENEFITS ESTIMATION





[**Zieger et al**., Building and Environment, 2021]

QUESTIONS?

THANK YOU

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