Institut de Recherche Dupuy de Lôme
UMR CNRS 6027

Faculté sciences & sciences de l'ingénieur
Université Bretagne Sud

De la complexité d'une approche globale de la conception des logements, au regard de l'atténuation et de l'adaptation au changement climatique

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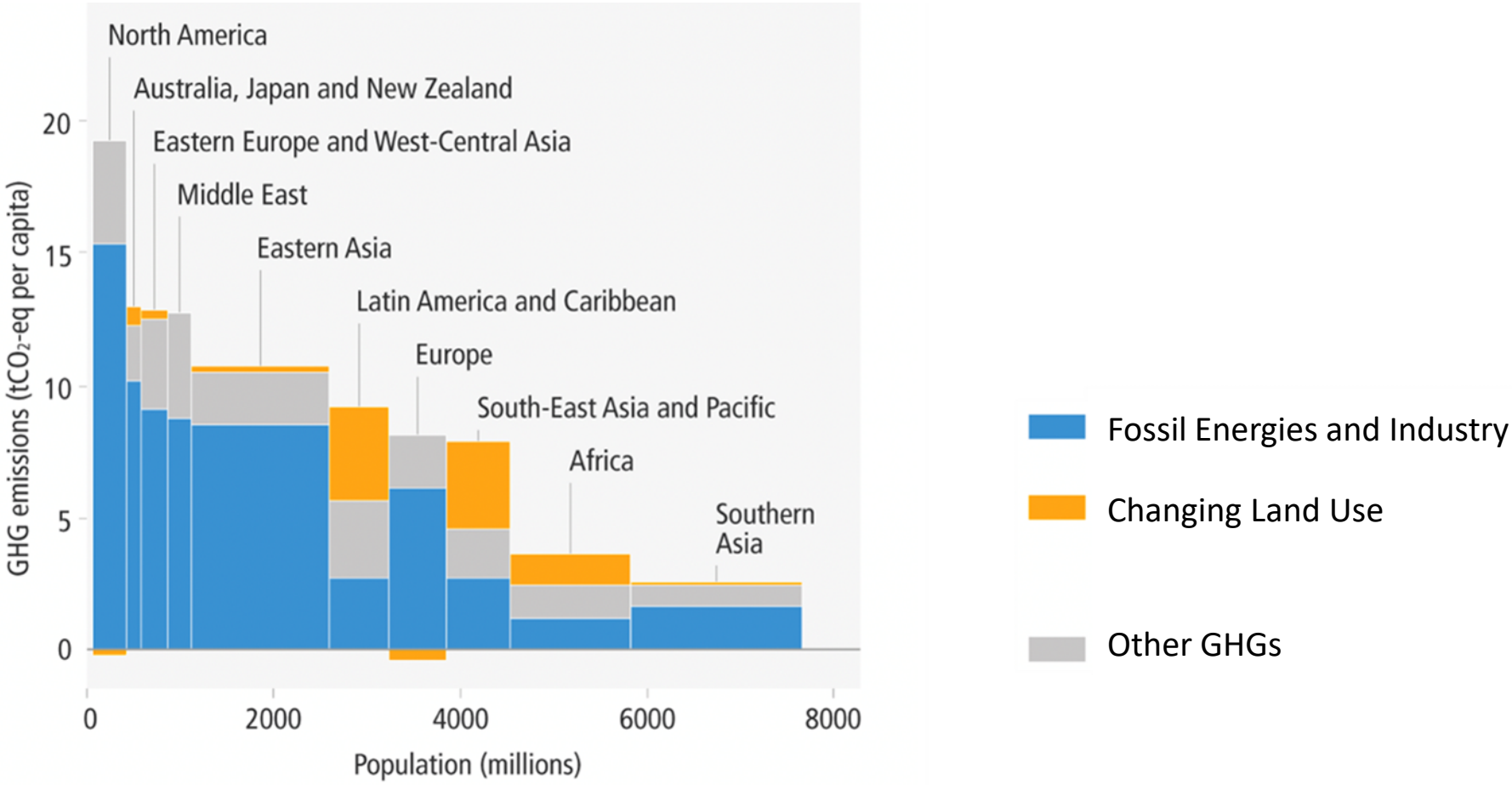
Séminaires généralistes, Institut d'Alembert, 18 septembre 2025

Haut Conseil Breton pour le Climat

Climate change issues: global disparities



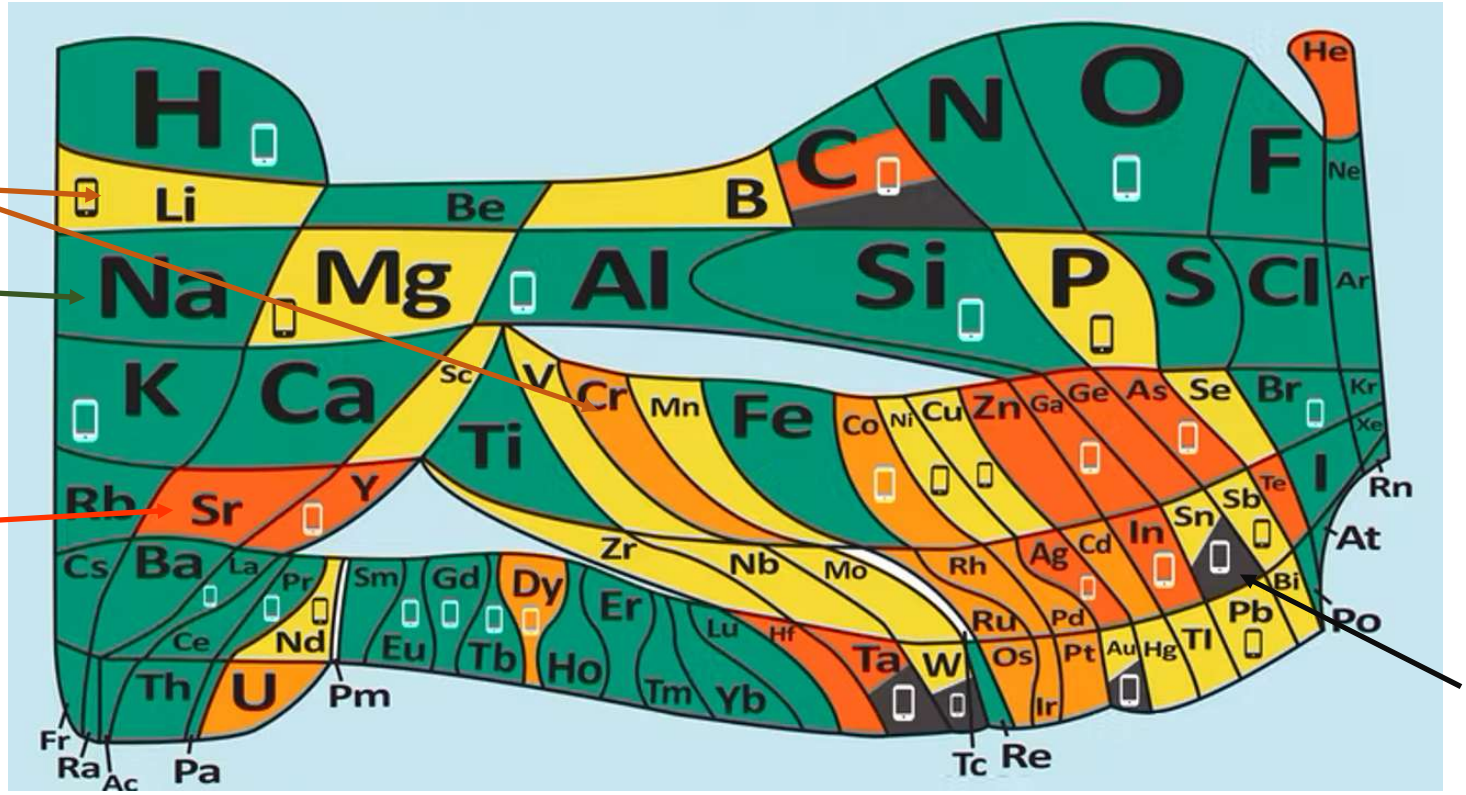
[After Valérie Masson-Delmotte, presentation to French Government Council, 2022]

Climate change: a limits' to growth symptom

Limited disponibility

Abundant

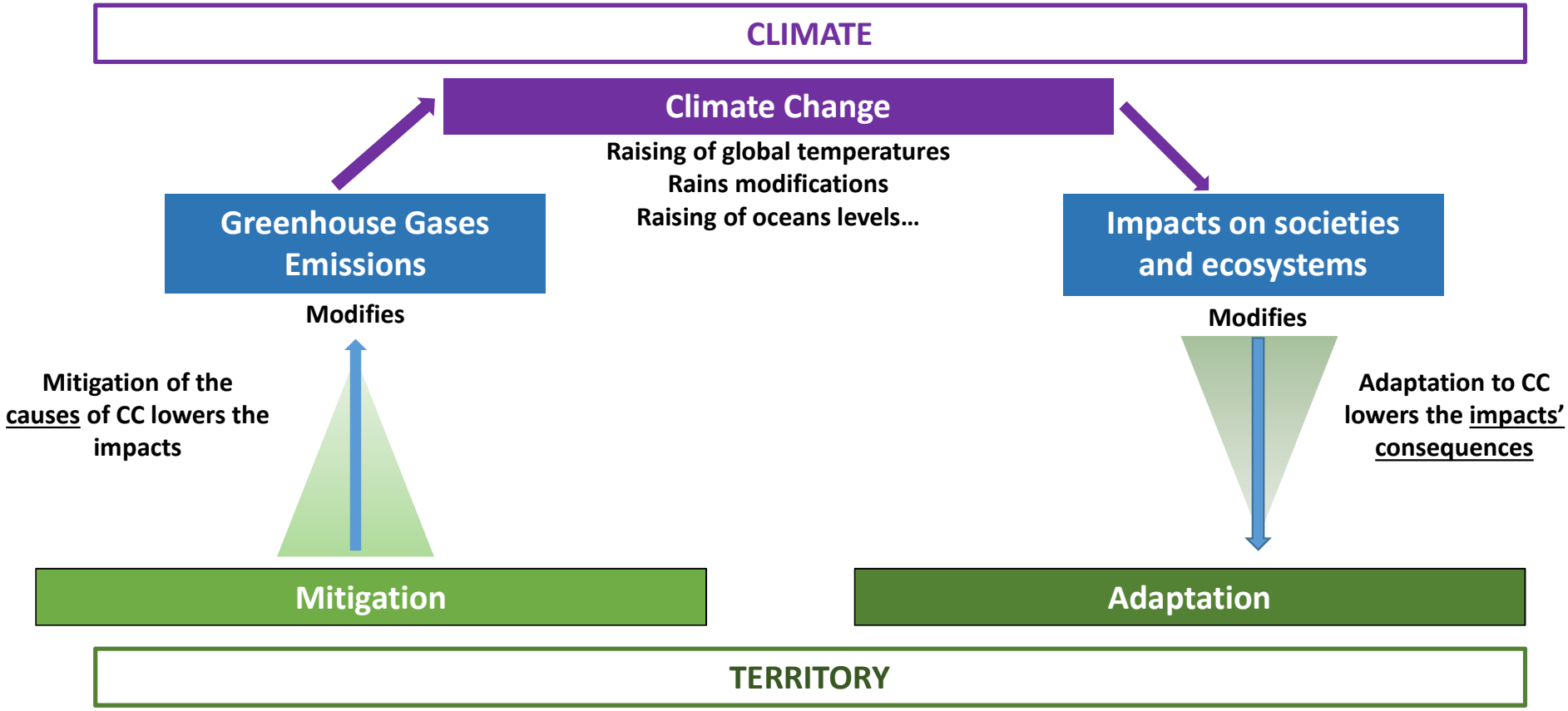
Serious threat in the next 100 years



Ressources in conflict's areas

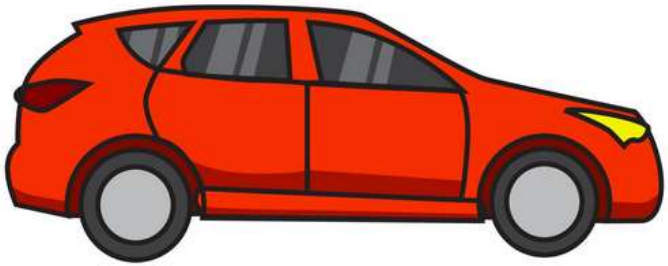
[European Chemical Society, 2021]

Climate change issues: mitigation and adaptation



[After Chantal Fitoussi / Agence française pour la biodiversité: Atténuation et adaptation : deux approches complémentaires]

Climate change issues: mitigation and adaptation



Heavy rains?
Heat waves?

≠

GHG limitation?

Mitigation

Work on the causes of CC

Adaptation

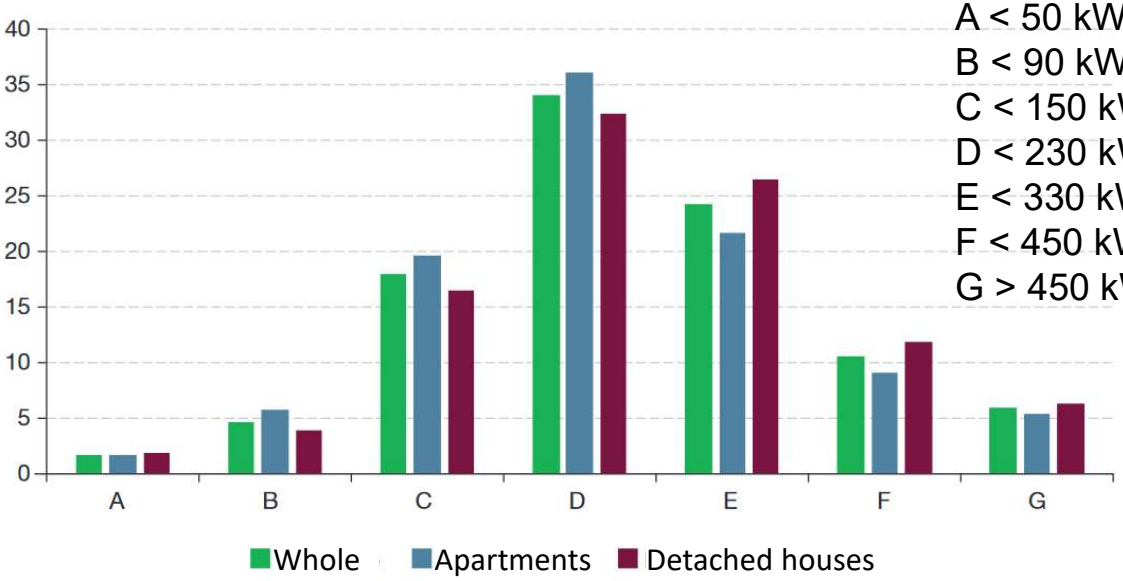
Work on the consequences of CC

Dwelling sector issues: building and operating impacts

Example of France

FRENCH DWELLING PARK BY ENERGY CONSUMPTION CLASS (JANUARY 2018)

% of the primary residences



Final Energy Consumption
A < 50 kWh / m² / yr
B < 90 kWh / m² / yr
C < 150 kWh / m² / yr
D < 230 kWh / m² / yr
E < 330 kWh / m² / yr
F < 450 kWh / m² / yr
G > 450 kWh / m² / yr

YEARLY CARBON FOOTPRINT OF BUILDING SECTOR IN FRANCE (2019)

~ whole: **31%** of anthropogenic GHGs in France

=

~ **5%** : Building phases (new and renovation)

+

~ **26%** : Buildings Energy Consumption

[https://www.statistiques.developpement-durable.gouv.fr/chiffres-cles-de-lenergie-edition-2021 ; J. Daunay, et al., Neutralité & Bâtiment, comment les acteurs du secteur peuvent s'inscrire dans une démarche zéro emission nette, Carbone 4/ ADEME, 2019]

Dwelling sector issues: building and operating impacts

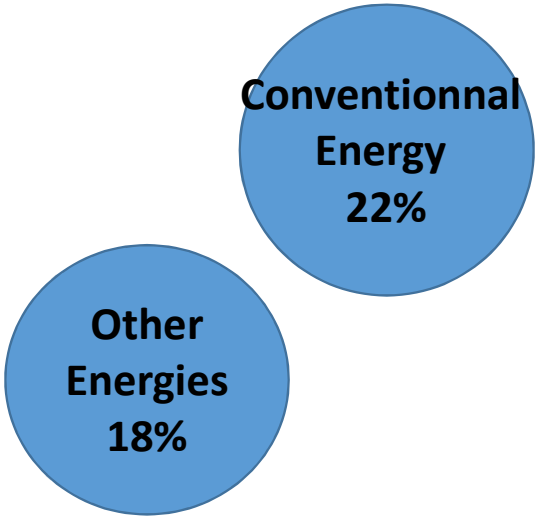
Example of France

⇒ Necessity to intensify renovations

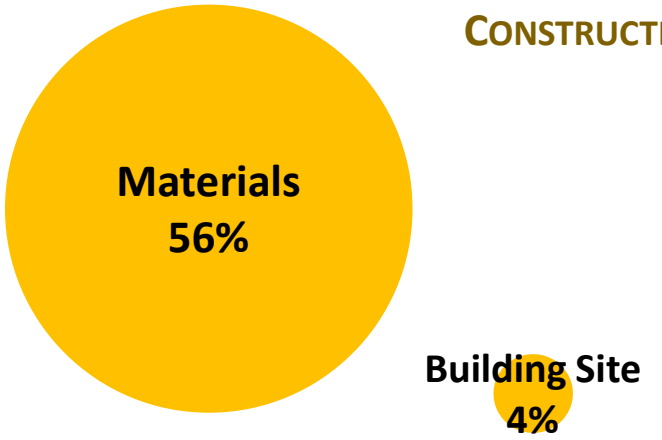
⇒ Necessity to reinforce energy consumption rules

Carbon Footprint of **low-energy buildings** (after french regulation « RT2012 »), **Lifespan of 50 years**, offices and collective housing

OPERATING STAGE: 40%

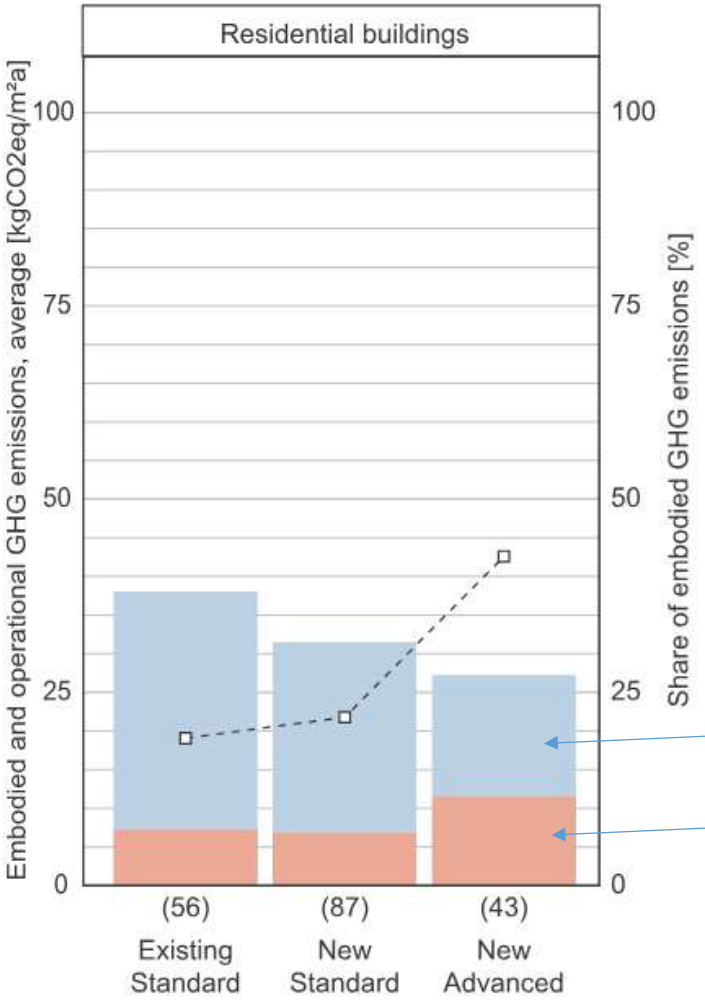


CONSTRUCTION STAGE: 60%

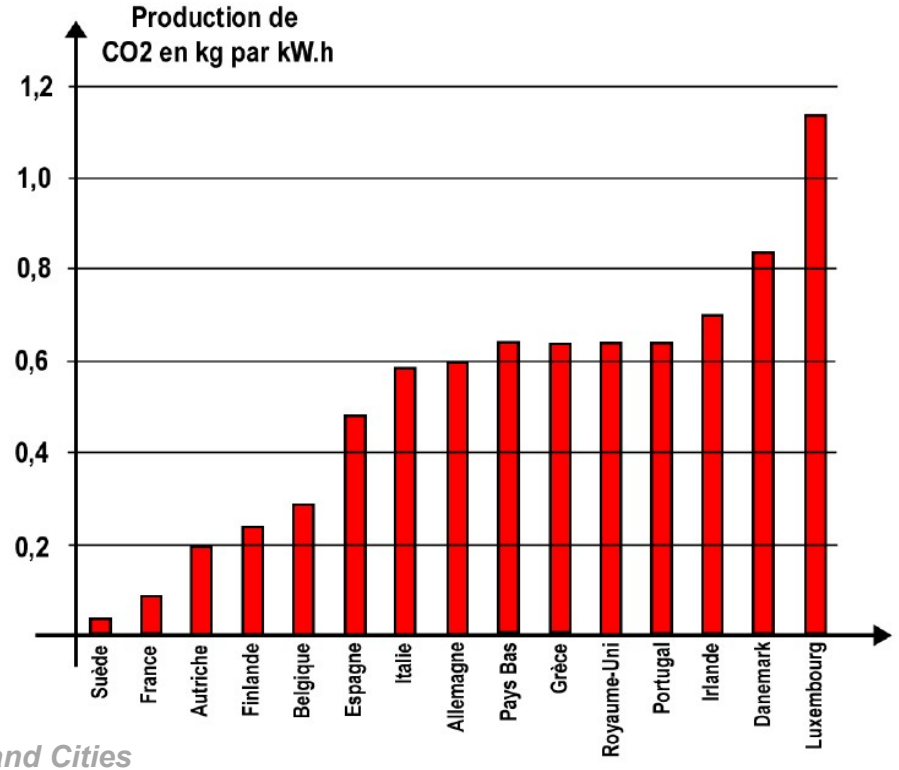


[after BBCA study- offices and collective housings, 2013]

Dwelling sector issues: building and operating impacts



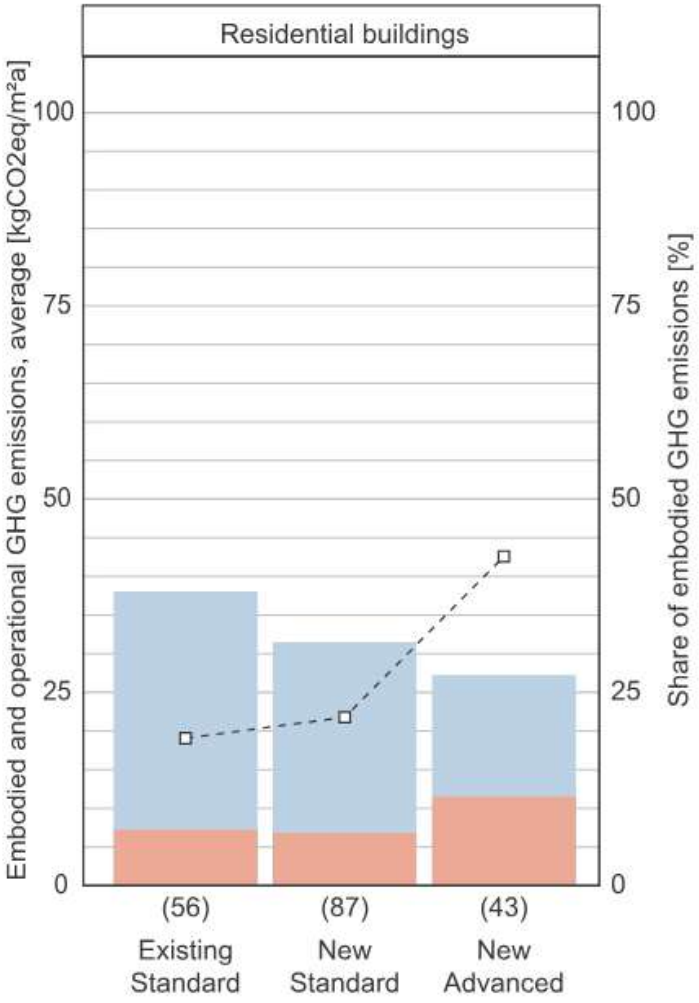
Global Building Sector Assessment



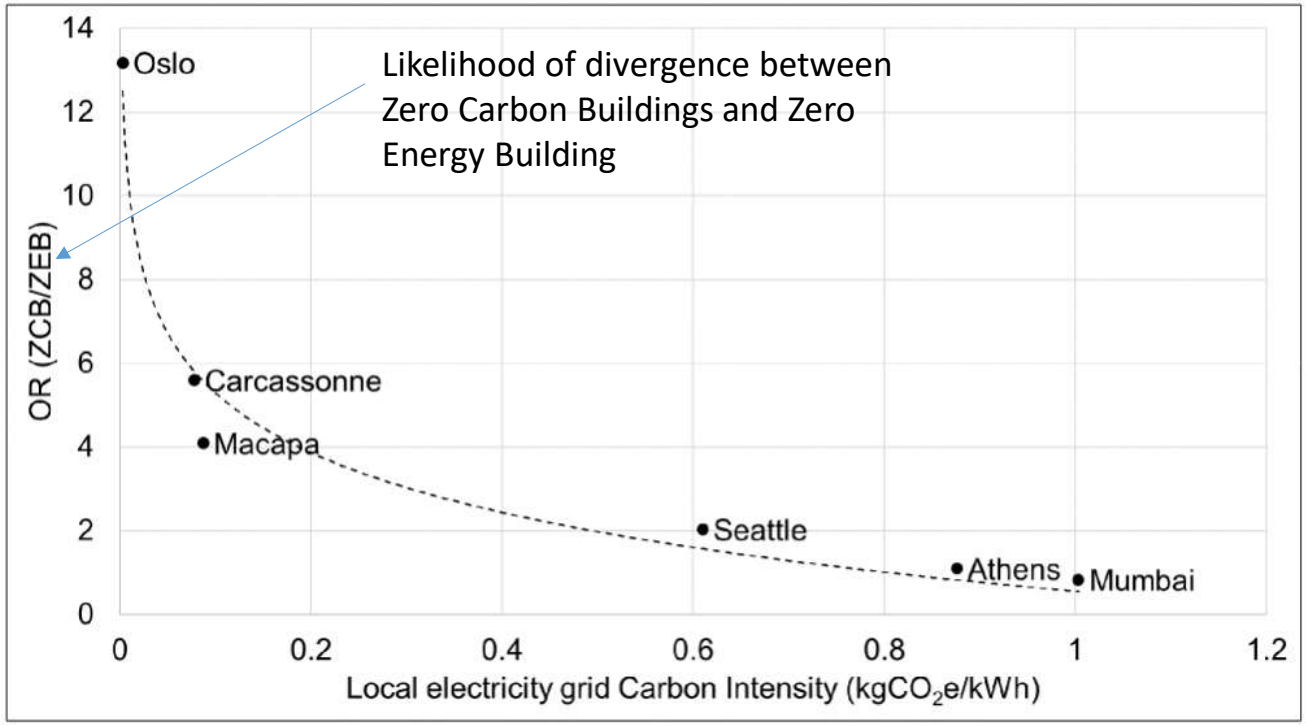
[Parkin et al., Net Zero buildings: when carbon and energy metrics diverge, Buildings and Cities 2020 ; Röck et al., Embodied GHG emissions of buildings – the hidden challenge for effective climate change mitigation, Applied Energy 2020]

[Données AIE, 2013]

Dwelling sector issues: building and operating impacts



Global Building Sector Assessment



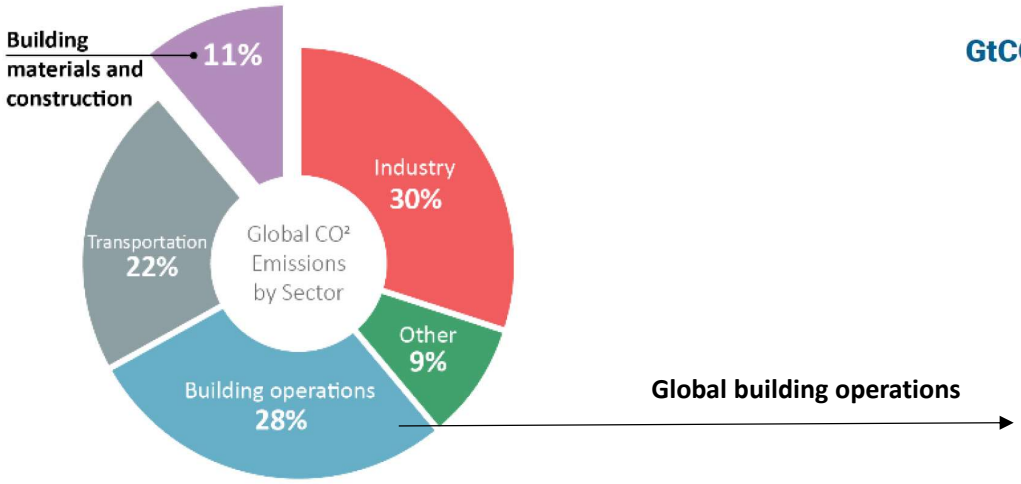
[Parkin et al., Net Zero buildings: when carbon and energy metrics diverge, Buildings and Cities 2020 ; Röck et al., Embodied GHG emissions of buildings – the hidden challenge for effective climate change mitigation, Applied Energy 2020]

Dwelling sector issues: building and operating impacts

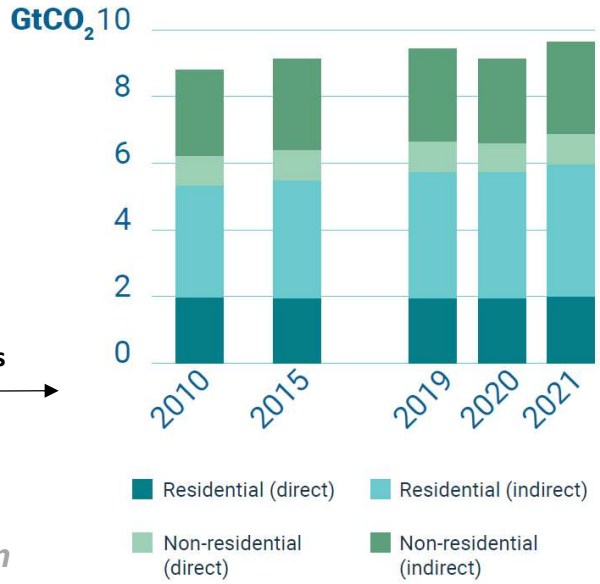
Global Building Sector Assessment

2022 UN environment programme:

- In 2021, emerging economies increased **their use of fossil fuel gases** in buildings.
- In 2021, GHG emissions **from buildings operations** have reached an all-time high of around 10 $GtCO_{2eq}$



Global building operations



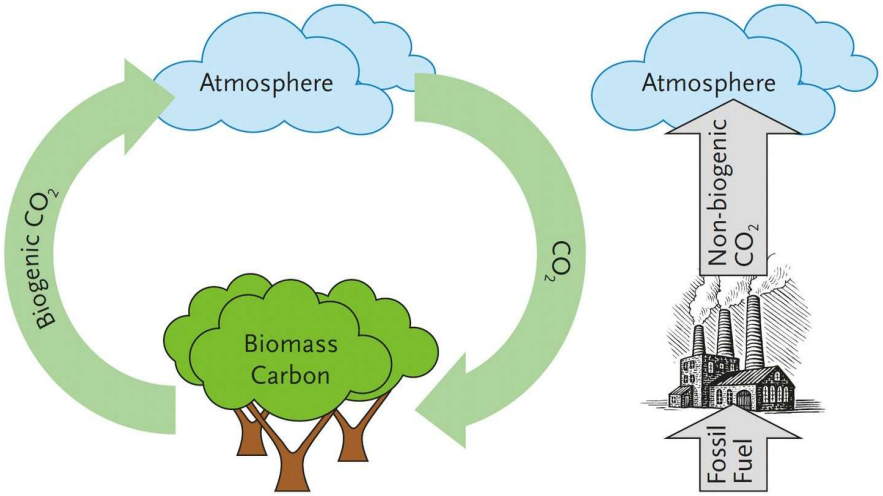
•[UN environment program, 2022 global status report for building and construction towards a zero-Emissions, efficient and resilient building and construction sector ;
•Rondinel-Oviedo & Keena, 2022 IOP Conf. Ser.: Earth Environ.Sci.]

Dwelling sector issues: building and operating impacts

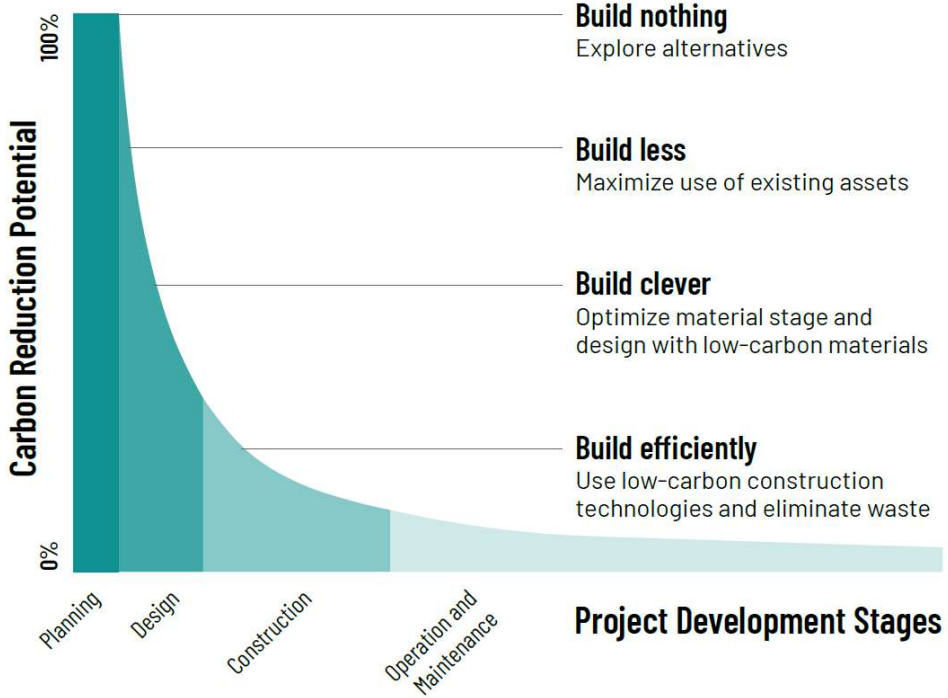
Intermediate Outcomes

Operating Carbon Footprint

- Necessity to estimate and measure the real performance of building envelopes
- Necessity to select low GHG emitters energy systems



Embodied GHGs

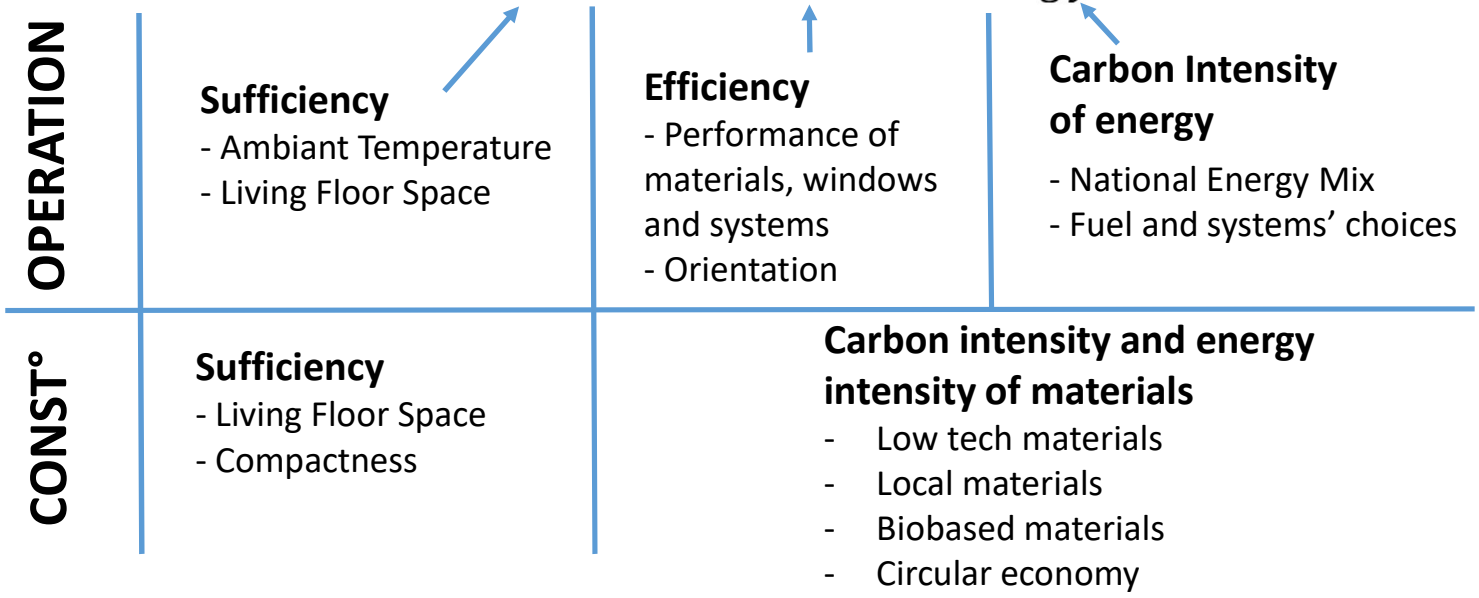


•[UN Environment Programme (2023). Building Materials and the Climate: Constructing a New Future ; Berndes, et al. (2023), Forest biomass, carbon neutrality and climate change mitigation, From Science to Policy 3, European Forest Institute]

Dwelling sector issues: building and operating impacts

Adaptation of the « Kaya » formula

$$CC\ (housing) = Nb\ of\ Inhabitants \times \frac{Service}{Inhabitant} \times \frac{Energy}{Service} \times \frac{CC}{Energy}$$



[Adapted from Kaya & Yokobori, Tokyo conference on Global Environment, Energy and Economic Development (1993)]

Dwelling sector issues: building and operating impacts

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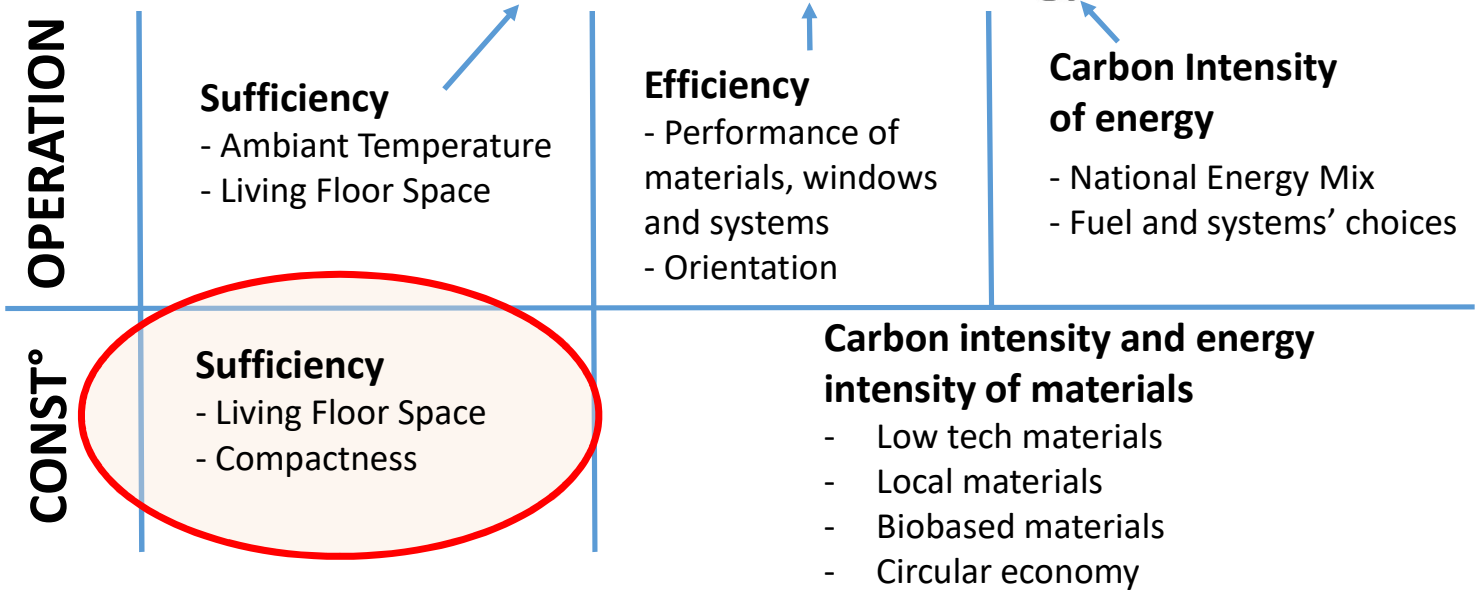


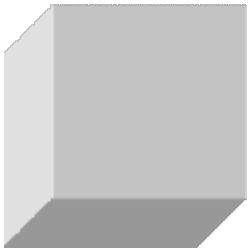
[Adapted from Kaya & Yokobori, Tokyo conference on Global Environment, Energy and Economic Development (1993)]

Dwelling sector issues: building and operating impacts

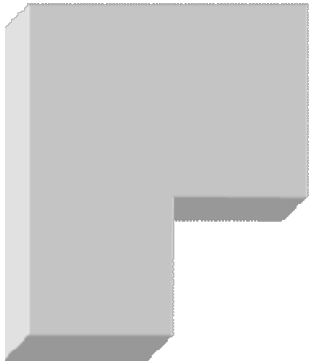
Sufficiency : living floor surface and compactness

Living Floor Surface: 100 m² (French Climate)

« cubic », 2-floors house
compactness = 0.97 m^{-1}



Angular one-floor house
compactness = 1,27 m^{-1}



+ 40% materials
+ 30% heating energy

[T Lecompte, JACV, Matériaux biosourcés pour le bâtiment : notions d'équilibres et indicateurs de réchauffement climatique. AJCE, vol.38 (2022)]

Dwelling sector issues: building and operating impacts

Adaptation of the « Kaya » formula

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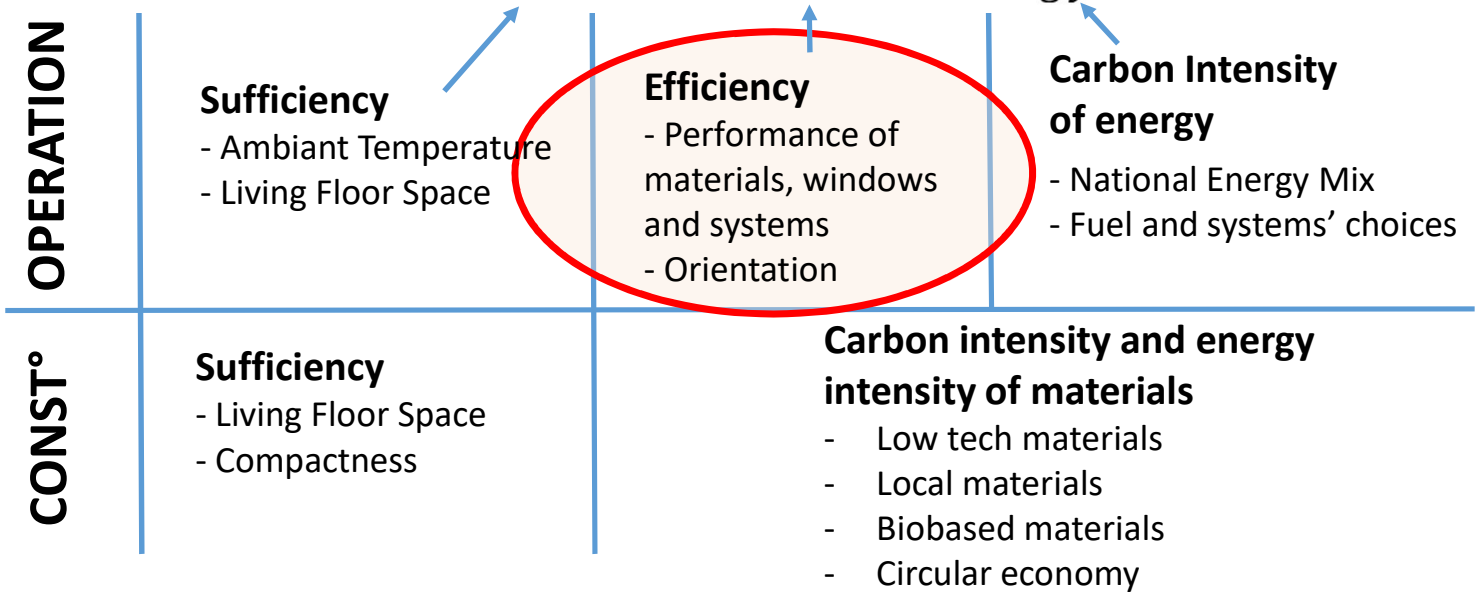
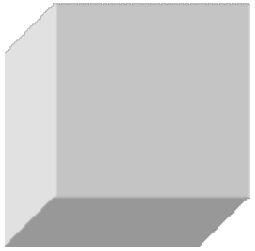


[Adapted from Kaya & Yokobori, Tokyo conference on Global Environment, Energy and Economic Development (1993)]

Dwelling sector issues: building and operating impacts

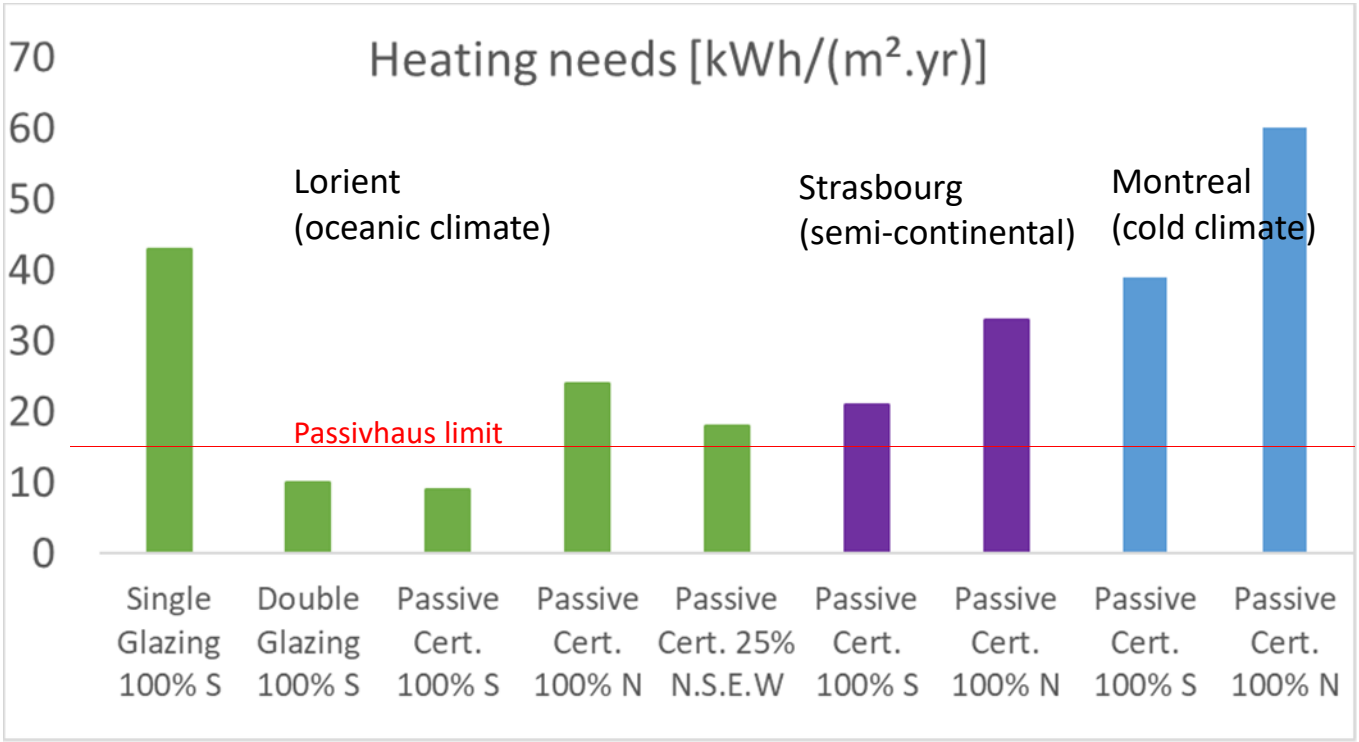
Efficiency : Windows performance and orientation

« cubic », 2 floors house



Living Floor Surface: **100 m²**
Windows area : 20 m²
U (walls) = 0,14 W/(m²K)

(Data from PHPP Sofware)



[T Lecompte, JACV, Matériaux biosourcés pour le bâtiment : notions d'équilibres et indicateurs de réchauffement climatique. AJCE, vol.38 (2022)]

Dwelling sector issues: building and operating impacts

Efficiency : Windows performance and orientation

Sun Right Manifesto!!

Dwelling sector issues: building and operating impacts

Adaptation of the « Kaya » formula

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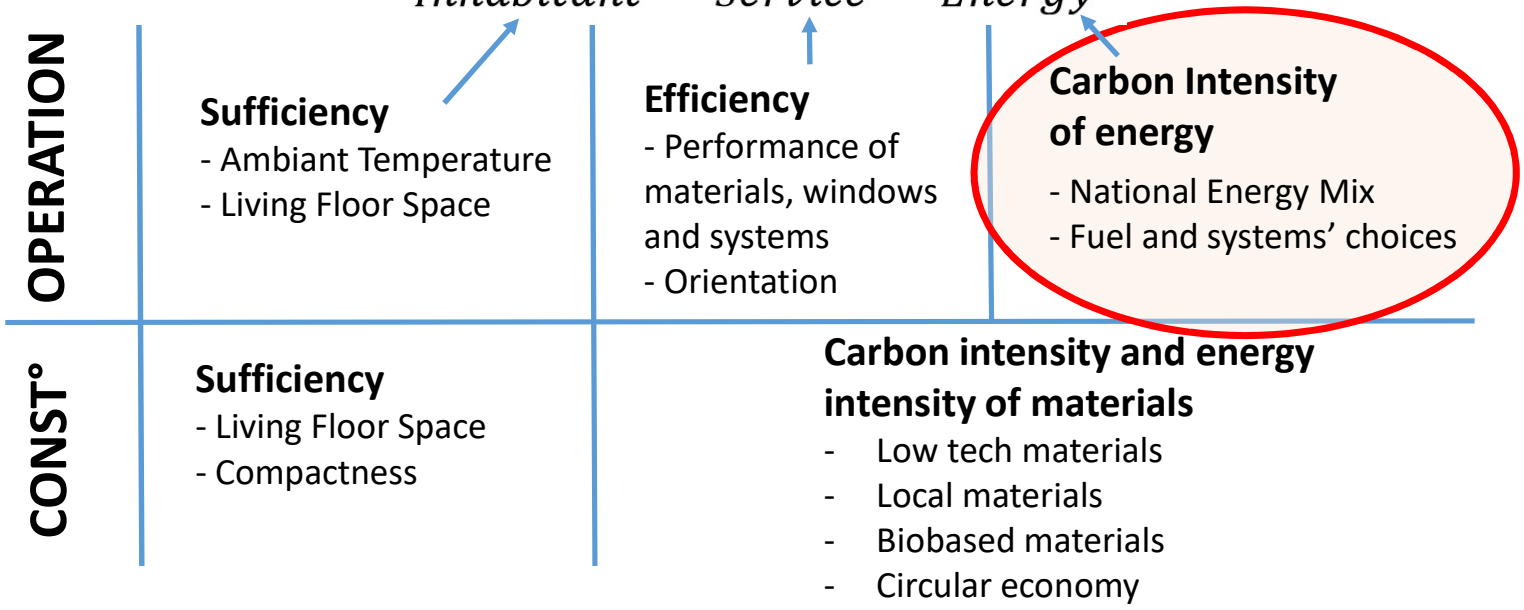


[Adapted from Kaya & Yokobori, Tokyo conference on Global Environment, Energy and Economic Development (1993)]

Dwelling sector issues: building and operating impacts

Carbon Intensity of Energy

GHG Emissions for 1 kWh of electric energy (gCO_2eq)
(French context)

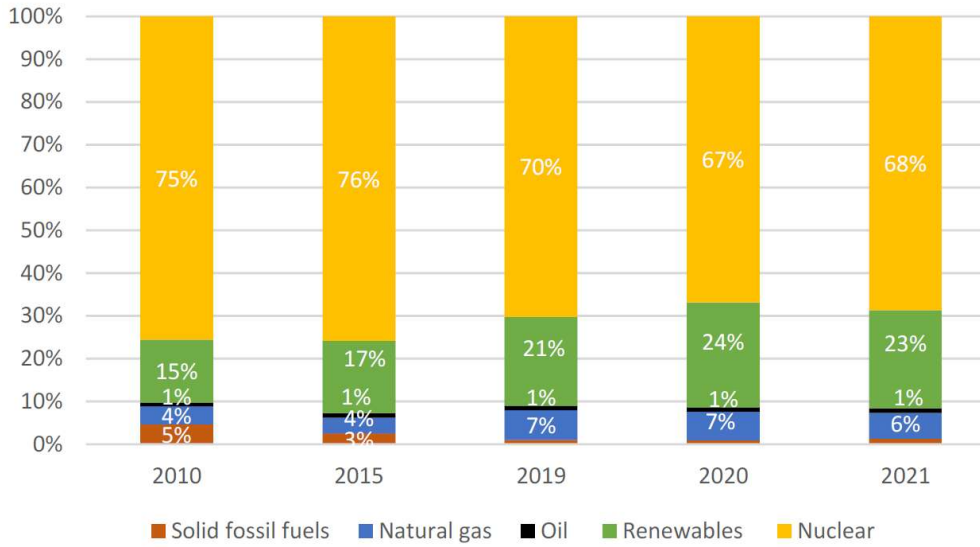
	gCO_2eq/kWh electric
Nuclear	~6
Wind	~15
Solar	~44
Natural Gas	~420
Fuel Oil	~730
Coal	~1000

X 7

X 10

X 170

Electricity Mix (France)



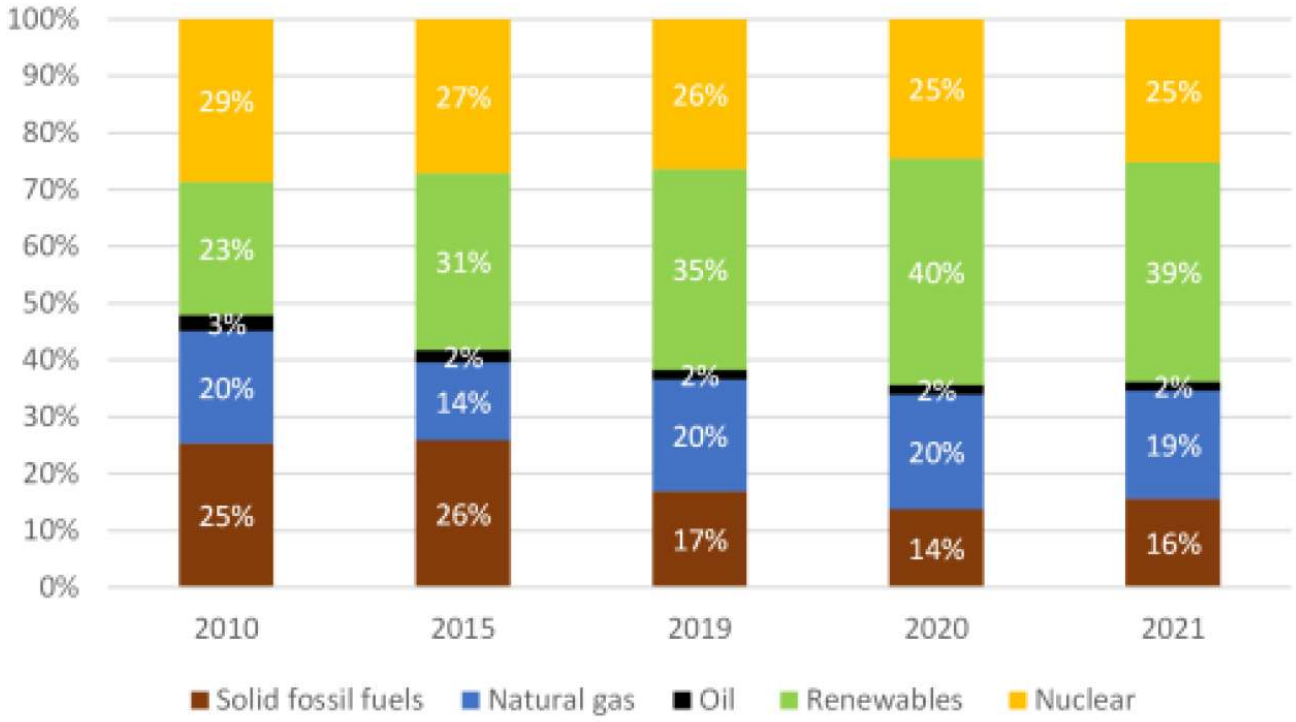
[ADEME, Base Carbone, https://bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter ; European commission, State of the Energy Union, 2023]

Dwelling sector issues: building and operating impacts

Carbon Intensity of Energy

Electricity Mix

(European Union)



[European commission, State of the Energy Union, 2023]

Dwelling sector issues: building and operating impacts

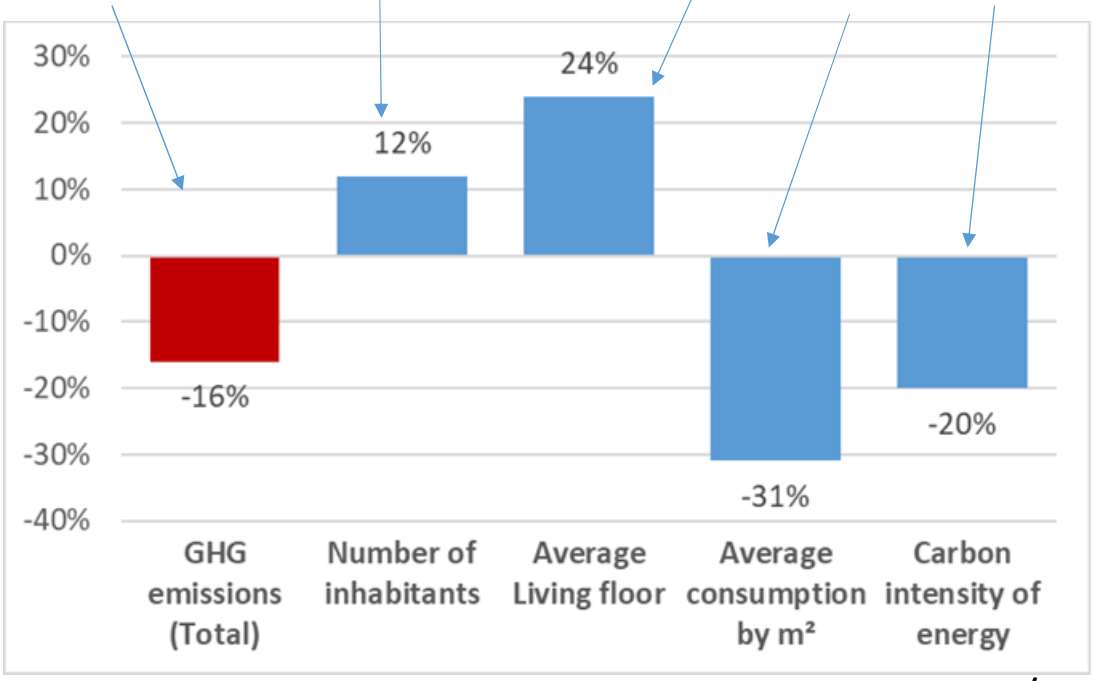
Assessment in the French Context, 1990 => 2016

French Government objectives:

- Carbon neutrality= to divide GHG emissions **by a factor 6** between 1990 and 2050

- To divide **by 2** energy consumption between 1990 et 2030

$$CC\ (housing) = Nb\ of\ Inhabitants \times \frac{Service}{Inhabitant} \times \frac{Energy}{Service} \times \frac{CC}{Energy}$$



[French Government, les Emissions des gaz à effet de serre du secteur résidentiel, mise à jour du 17 juin 2019]

Dwelling sector issues: building and operating impacts

Assessment in GLOBAL Context

Figure 7. Global buildings energy demand and floor area growth under the IEA Net Zero Emissions by 2050 Scenario

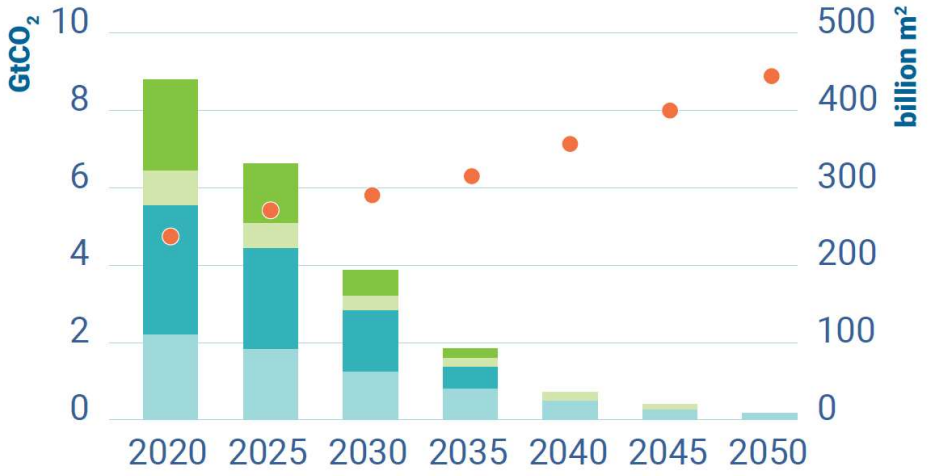
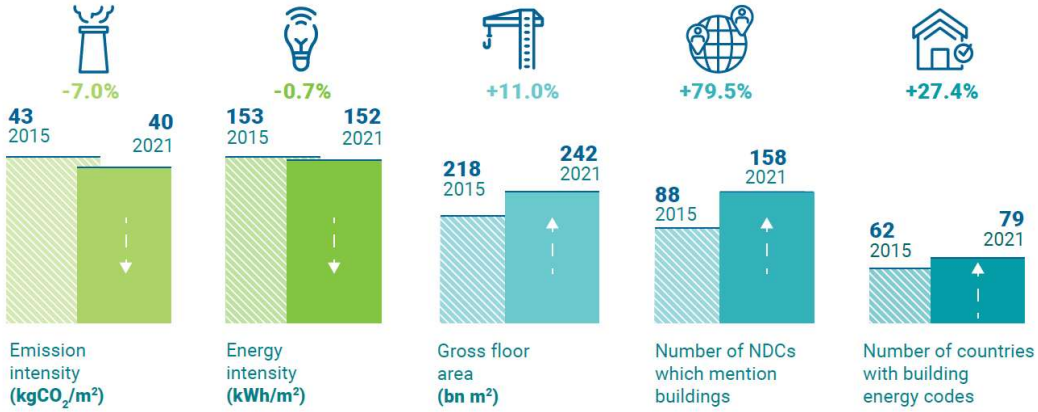


Figure 1. Global buildings and construction key trends 2015 and 2021[1]

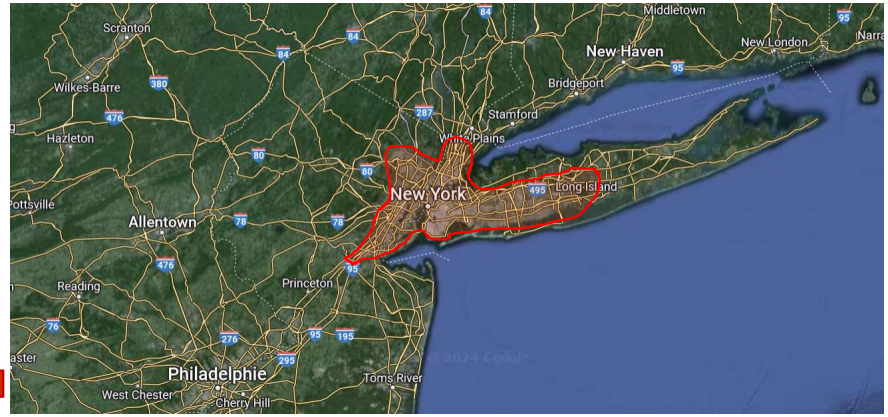


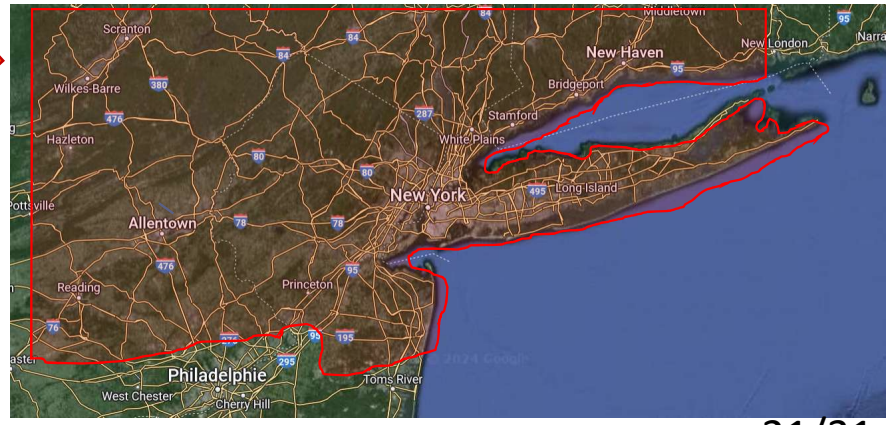
[UN Environment Programme (2022). 2022 Global Status Report for Buildings and Construction]

Dwelling sector issues: building and operating impacts

Assessment in GLOBAL Context

NOT THE SOLUTION!!





Dwelling sector issues: building and operating impacts

Adaptation of the « Kaya » formula

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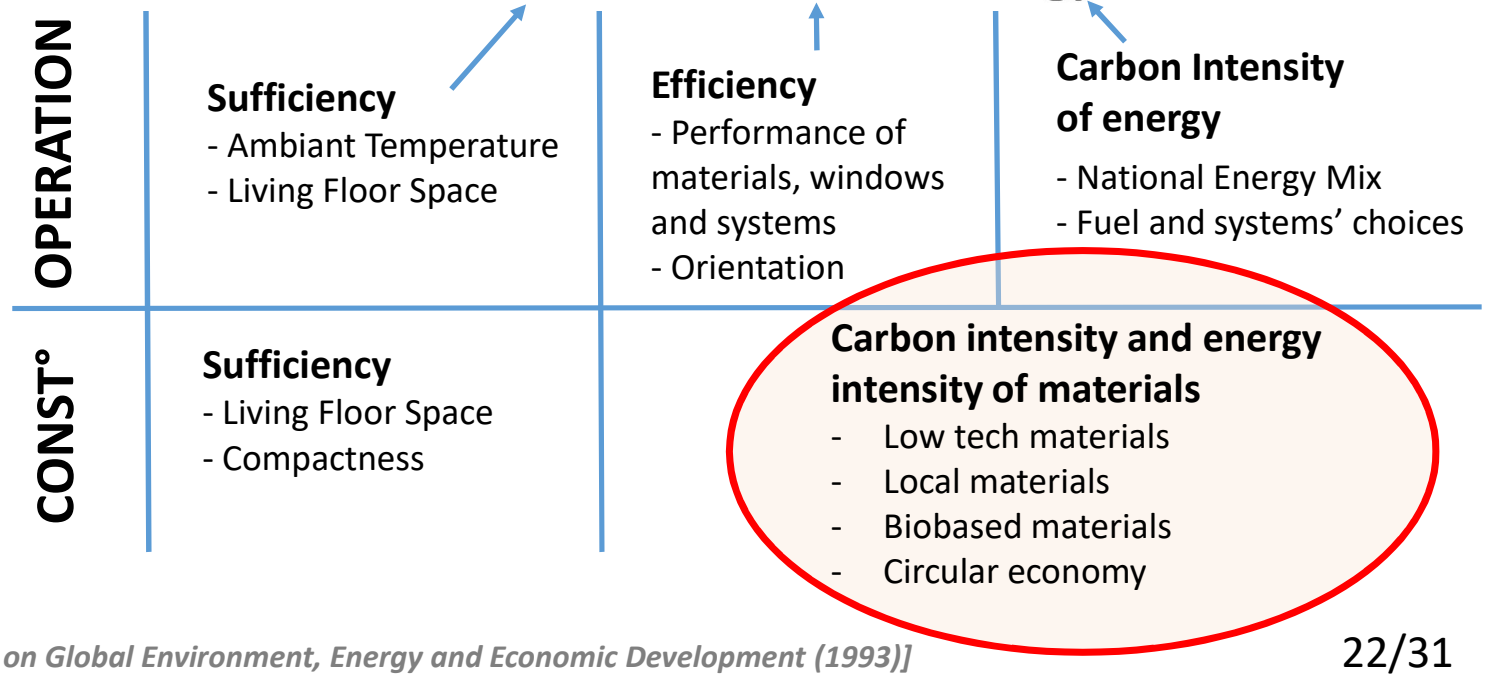
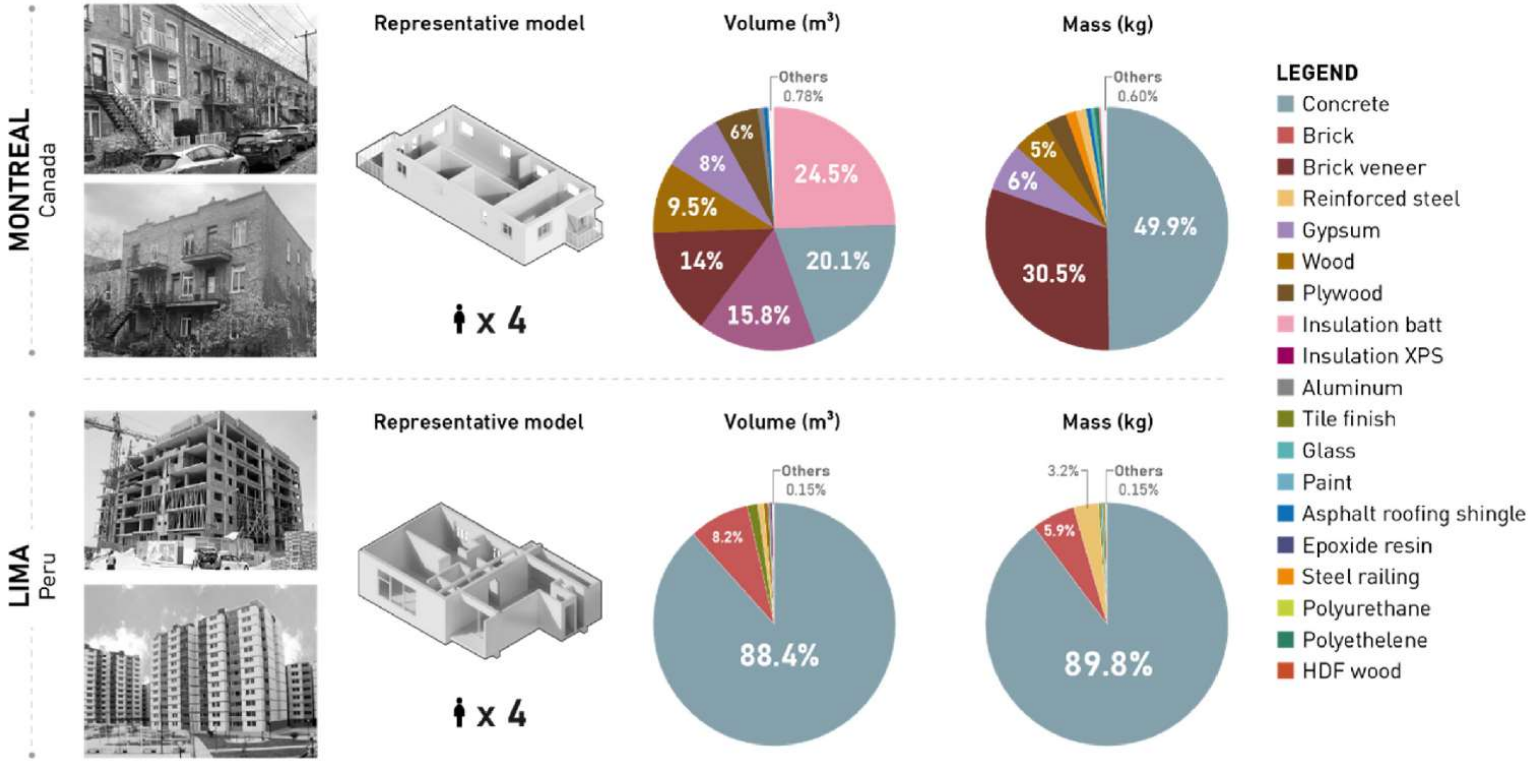


[Adapted from Kaya & Yokobori, Tokyo conference on Global Environment, Energy and Economic Development (1993)]

Dwelling sector issues: building and operating impacts

Carbon Intensity and Energy Intensity of building materials



[Keena et al., Implications of circular strategies on energy, water, and GHG emissions in housing of the Global North and Global South, Cleaner Ingineering and Technology, 2023]

Assessing the Carbon and Energy Intensities of Building Materials

Compare with an appropriate Functional Unit

Typical Concrete (30 MPa grade):	0.14 $kgCO_{2eq}$/ **kg**	(ref)
LC^3 (Calcined Clay Limestone Cement) Concrete :	0.11 $kgCO_{2eq}$ /**kg**	(~-25%)
Timber (Douglas, French context):	0.1 $kgCO_{2eq}$ /**kg**	(~-28%)
Steel (Arcelor Mittal, French context)	0.49 $kgCO_{2eq}$ /**kg**	(~+250%)

Compare by MASS is NOT VALID

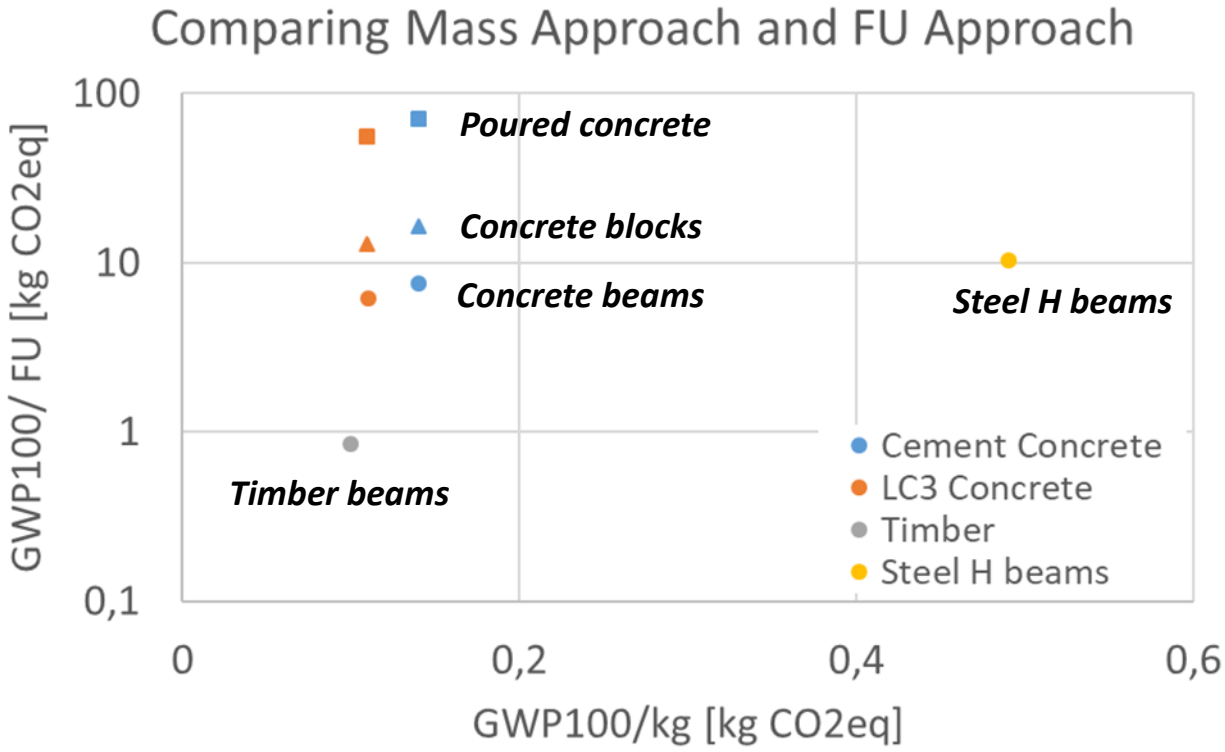
[Scrivener et al., Calcined clay limestone cements (LC 3), Cement and Concrete Research, 2018 ; https://www.base-inies.fr/iniesV4/dist/consultation.html?id=33661; https://www.base-inies.fr/iniesV4/dist/consultation.html?id=29482]

Assessing the Carbon and Energy Intensities of Building Materials

Compare with an appropriate Functional Unit

Function: Vertical structure
Lifespan: 100 years
Performance: load bearing of multistorey building
Quantity: 1m² of wall

⇒ Concretes: solid walls, or blocks, or reinforced beams
⇒ Timber: 45*200mm² beams, every 60 cm
⇒ Steel: H beams HEA 180, every 2 m

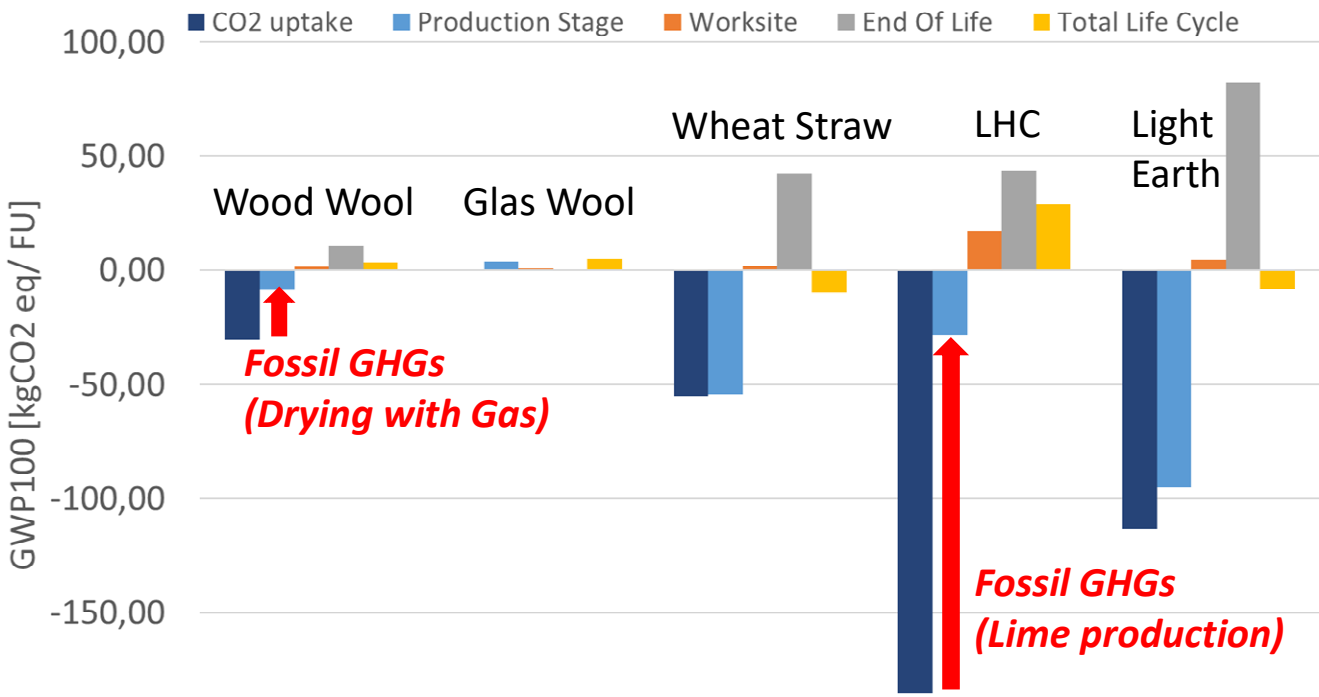


[Scrivener et al., Calcined clay limestone cements (LC 3), Cement and Concrete Research, 2018 ; https://www.base-inies.fr/iniesV4/dist/consultation.html?id=33661; https://www.base-inies.fr/iniesV4/dist/consultation.html?id=29482]

Assessing the Carbon and Energy Intensities of Building Materials

Consider biogenic AND fossil GHGs

Function: Insulation
Lifespan: 50 years
Performance: R=7m²K/W
Quantity: 1m² of wall



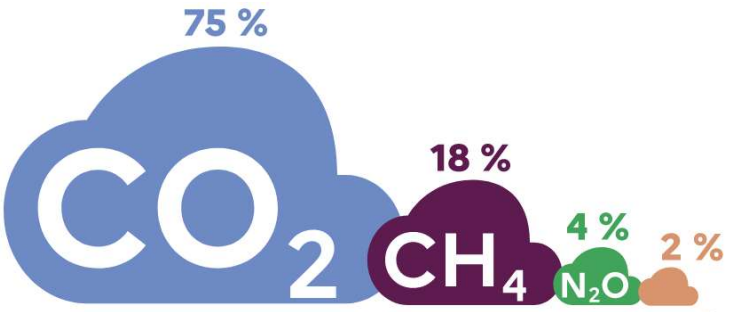
=> Even 100% Biobased materials can contain (hidden) embodied Fossil GHGs

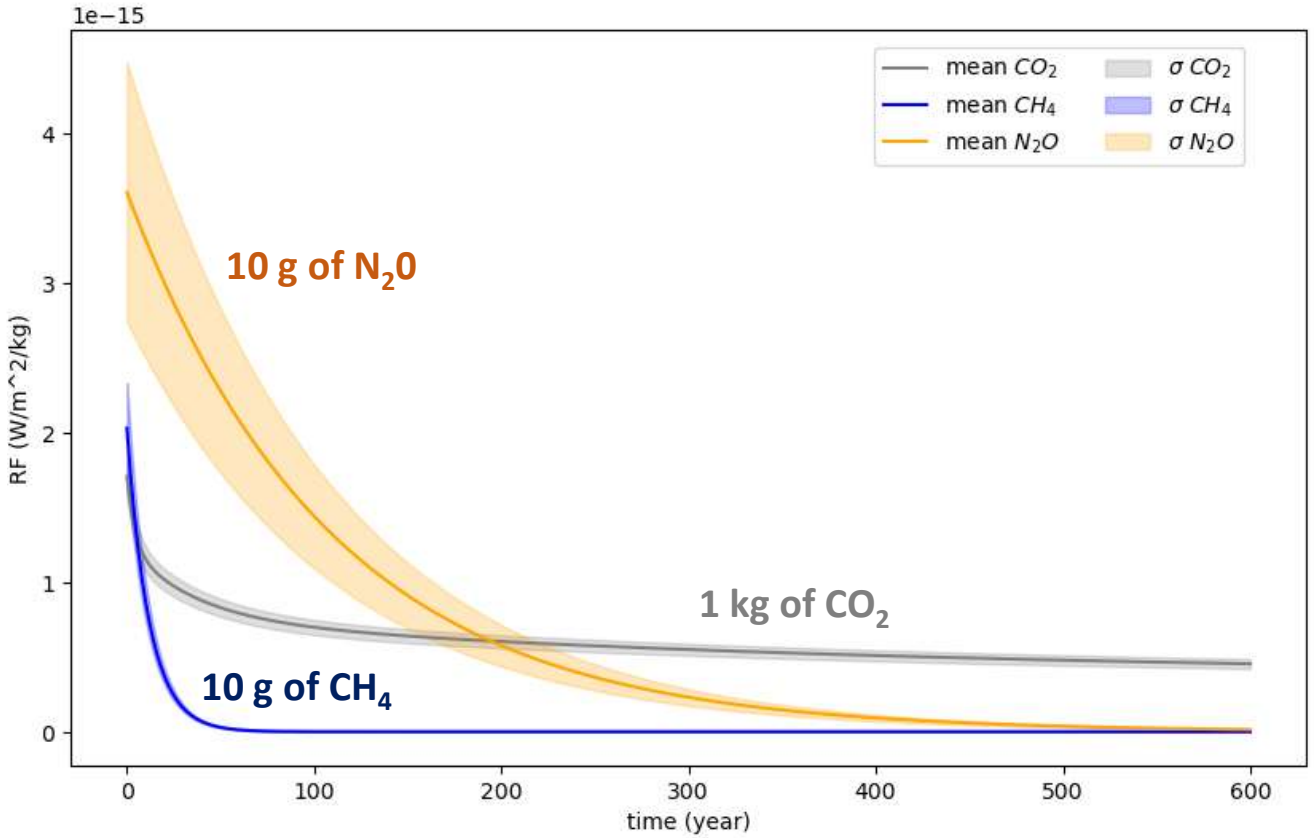
[Lecompte, Matériaux biosourcés pour le bâtiment et stockage temporaire de carbone, Techniques de l'ingénieur, 2019, https://www.base-inies.fr]

Assessing the Carbon and Energy Intensities of Building Materials

Compare with appropriate Metrics

Global GWP100 of human activity:



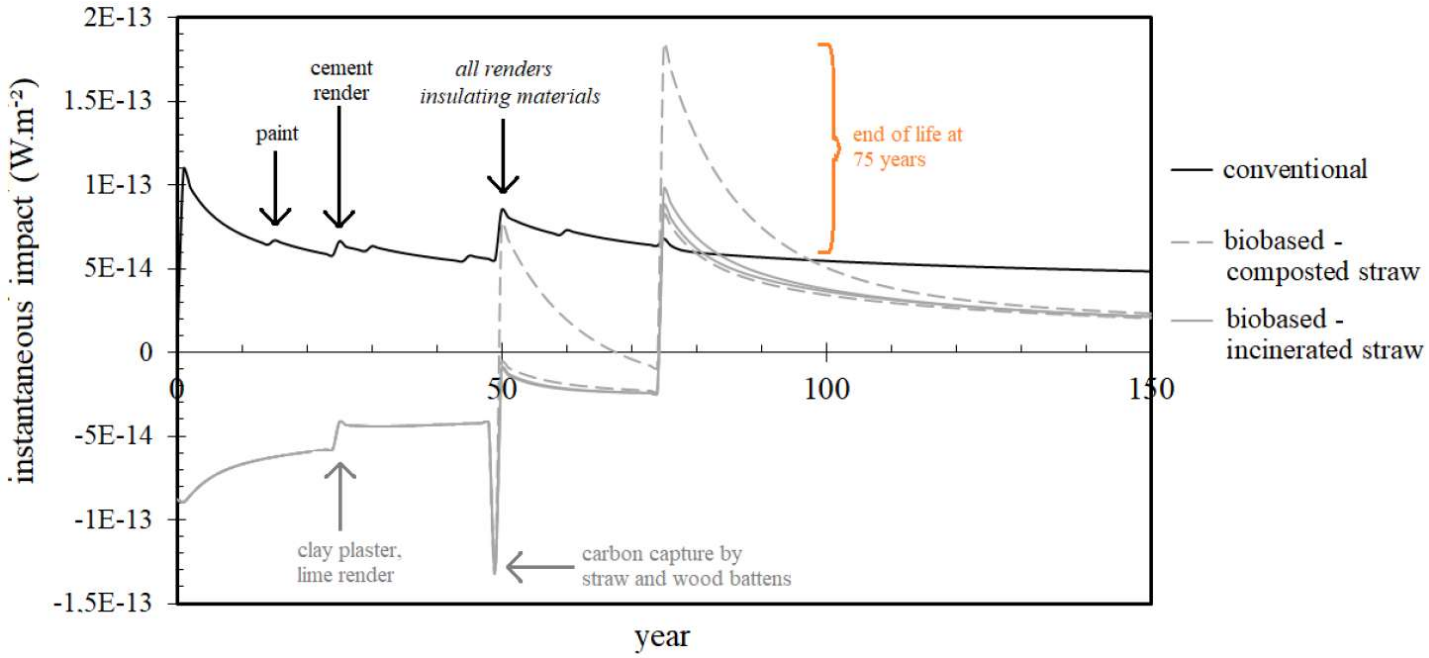


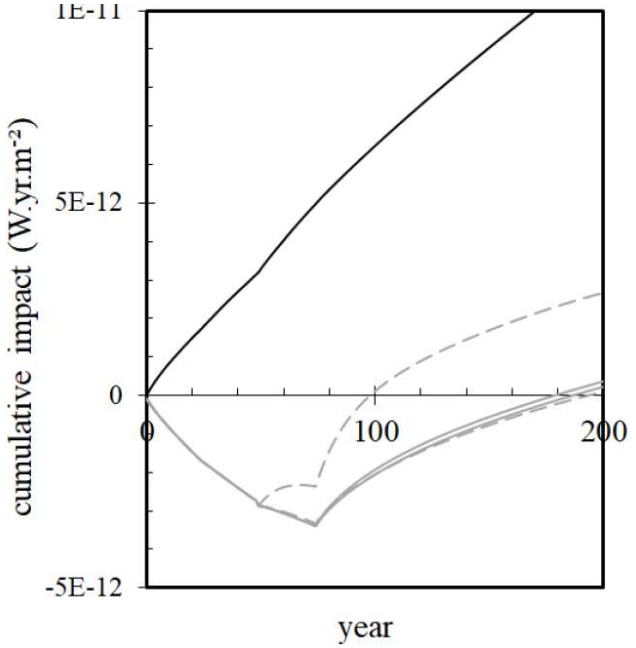
[IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. https://doi.org/10.59327/IPCC/AR6-9789291691647]

Assessing the Carbon and Energy Intensities of Building Materials

Compare with appropriate Metrics

Timber+Straw Bales vs Concrete blocks+Glass Wool



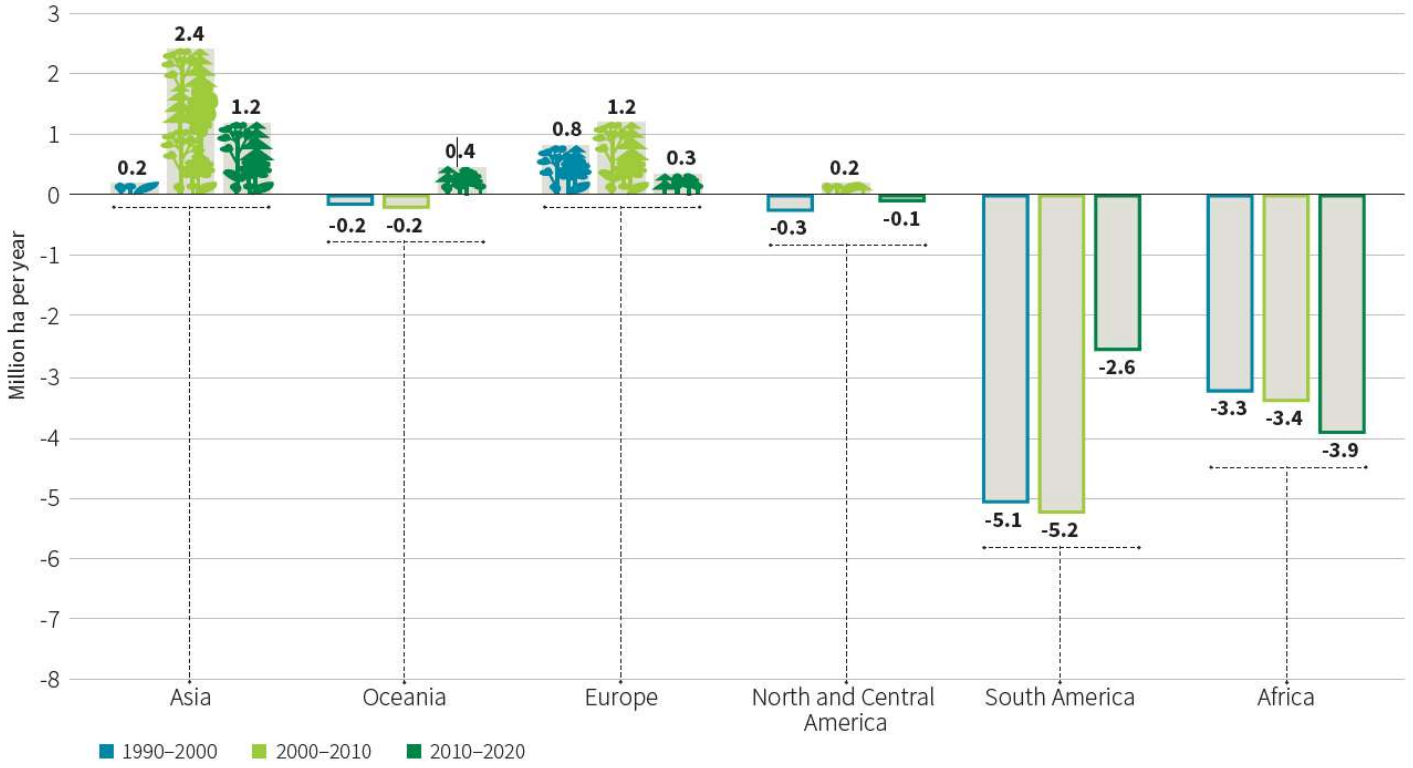


[Zieger et al., Impact of GHGs temporal dynamics on the GWP assessment of building materials: A case study on bio-based and non-bio-based walls, BAE 2020]

Assessing the Carbon and Energy Intensities of Building Materials

The issue of biobased (wood) ressources

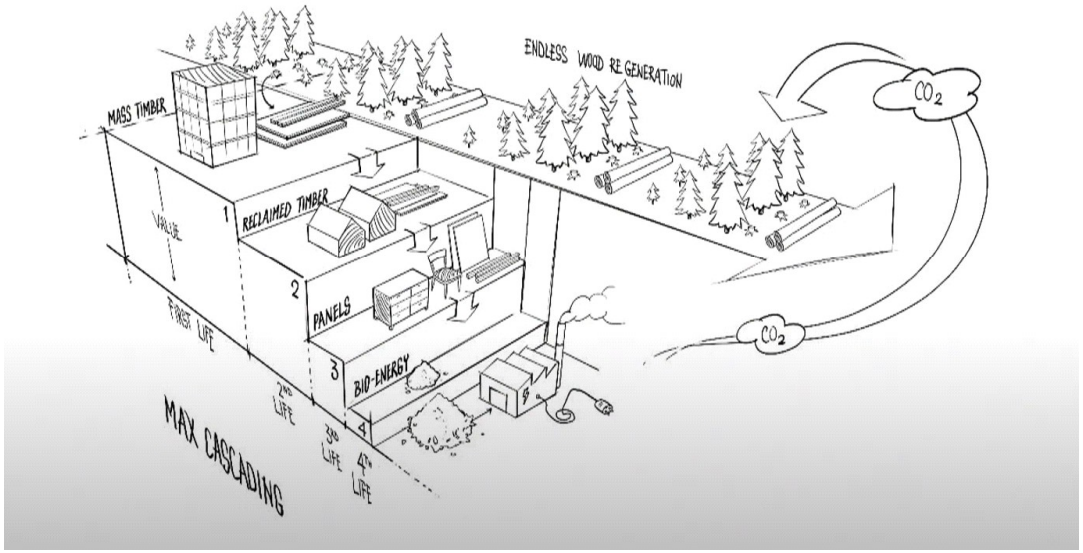
Annual forest area net change, by decades and region, 1990-2020

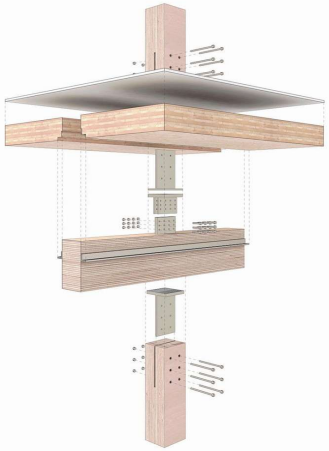


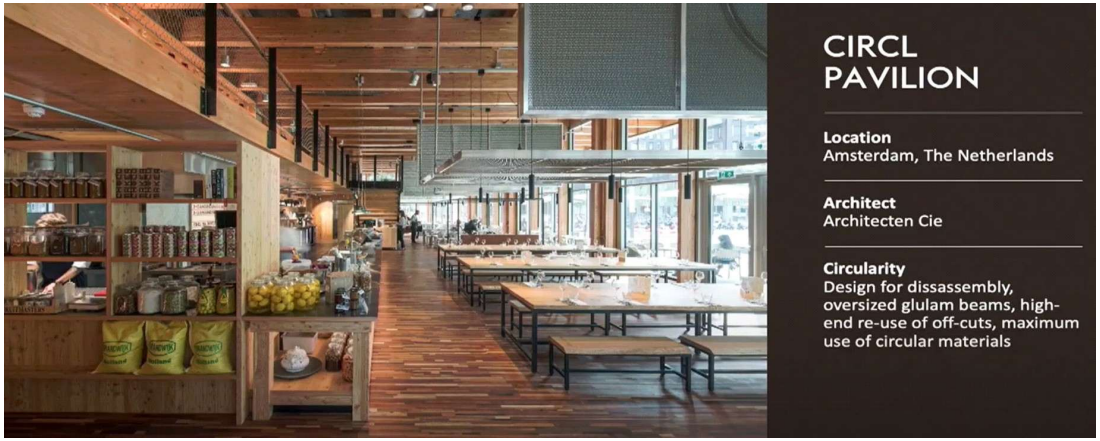
[FAO. 2020. Global Forest Resources Assessment 2020 – Key findings.]

Assessing the Carbon and Energy Intensities of Building Materials

The issue of biobased (wood) ressources

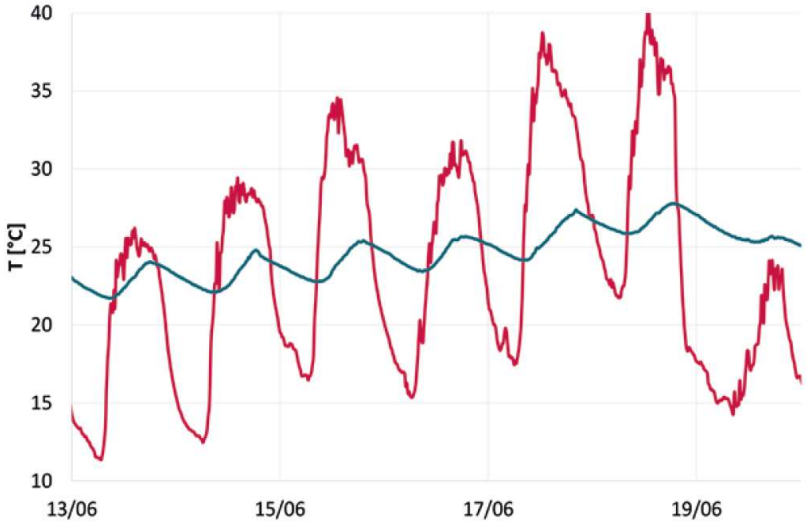






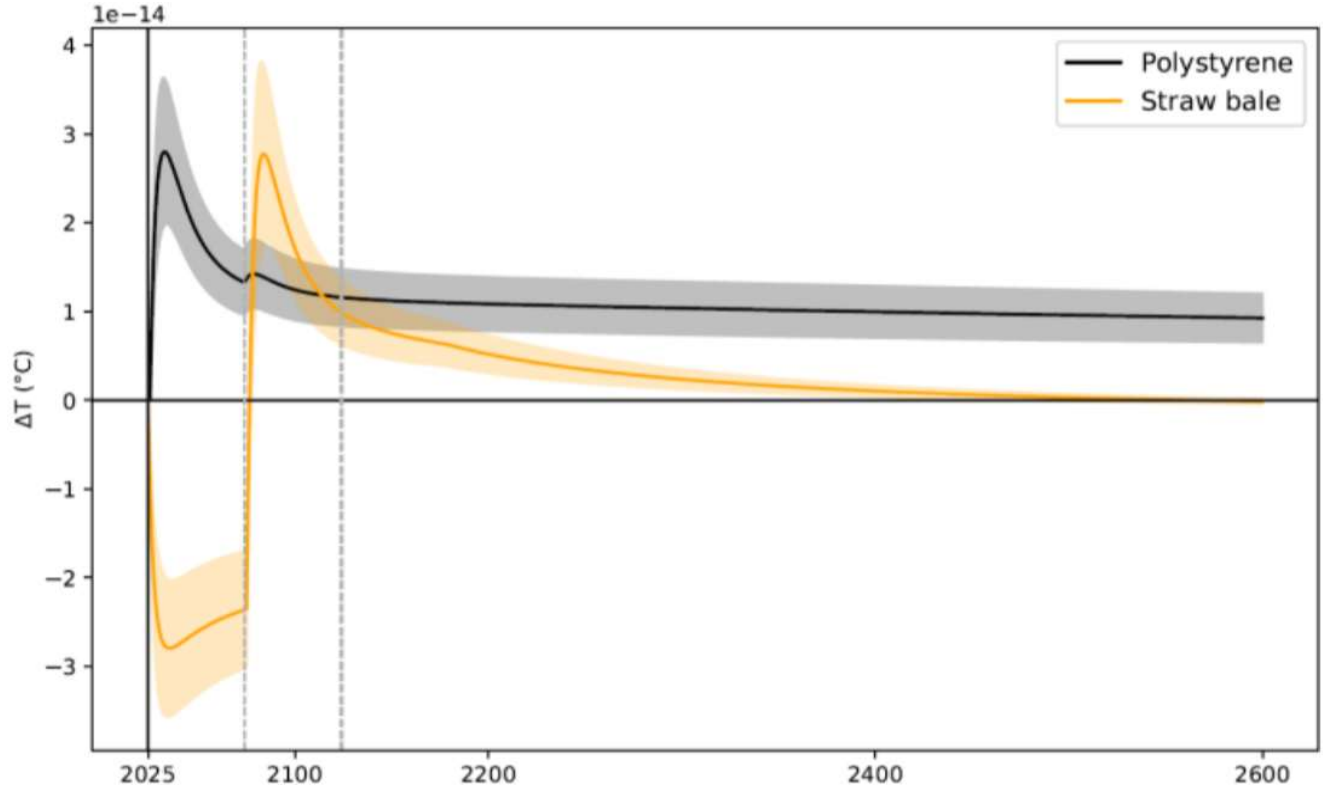
Assessing the Carbon and Energy Intensities of Building Materials

The issue of real performance assessment



Action!

- Proper CC indicators/ metrics needs => PhD Thesis of Vladimir Zieger (2023-2026)



Institut de Recherche Dupuy de Lôme
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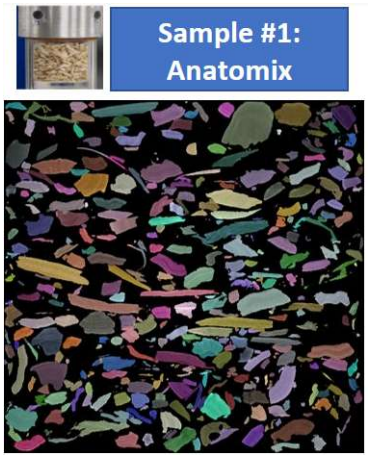
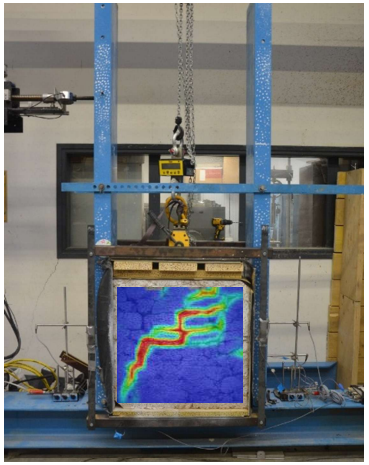
Action!

Faculté sciences & sciences de l'ingénieur
Université Bretagne Sud

- Design and assessment of low carbon materials for building
  - ⇒ « Bauges Porteuses » (AAP SIC ADEME, 2023-2027) : design and mechanics of Cob
  - ⇒ « LOCABATI » (AAP Bât. Resp. ADEME, 2022-2026) : characterisation and performance of agro-ressources for building
  - ⇒ « PROJETERRE » (Région Bretagne, 2024-2027) : light earth for building: process, rendering and exterior insulation





Material Scale

Lab Scale

Building Scale

GdR MBS
MATÉRIAUX de CONSTRUCTION BIOSOURCÉS

Région Bretagne

PNTERRE

Action!

- Dwelling monitoring needs => Rescather project (Région Bretagne, 2024-2026)

Raspberry Pi

⇒ Thermal flux, T°, %rh

⇒ Pollutants, CO_2…

Conclusion

1- Bruce Lee: “Don't pray for an easy life, pray for the strength to endure difficult one”

⇒ Don’t **search** for an easy life, **search to explain** and endure difficult one!

2- Friedrich Nietzsche: “Woe is me, I am nuance!”

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Séminaires généralistes, Institut d’Alembert, 18 septembre 2025