Grey Energy of Buildings Materials

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Architecture et Climat

Challenges

«A development which meets the needs for the generations of the present without compromising the capacity of the future generations to answer theirs » Brundtland Report, 1987

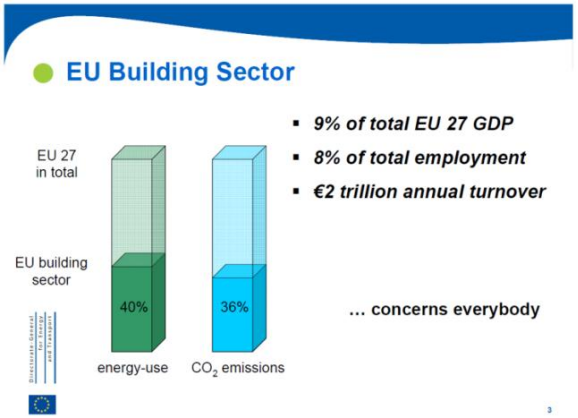
Impacts of the building sector in Europe:

- 50 % of natural resources depletion;
- 45 % of energy consumption;
- 40 % of waste production;
- 30 % of greenhouse gas emissions;
- 16 % of water consumption

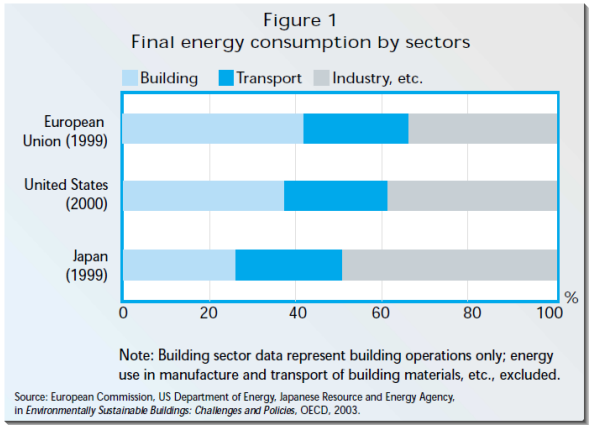
Source: Traité d'architecture et d'urbanisme bioclimatique, Observ'ER, Paris, 2005

Challenges

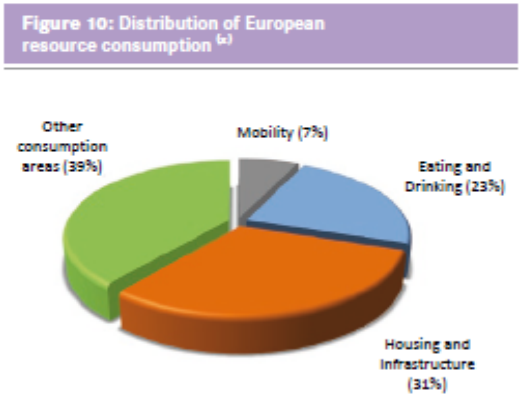
Building sector is a key sector in Europe



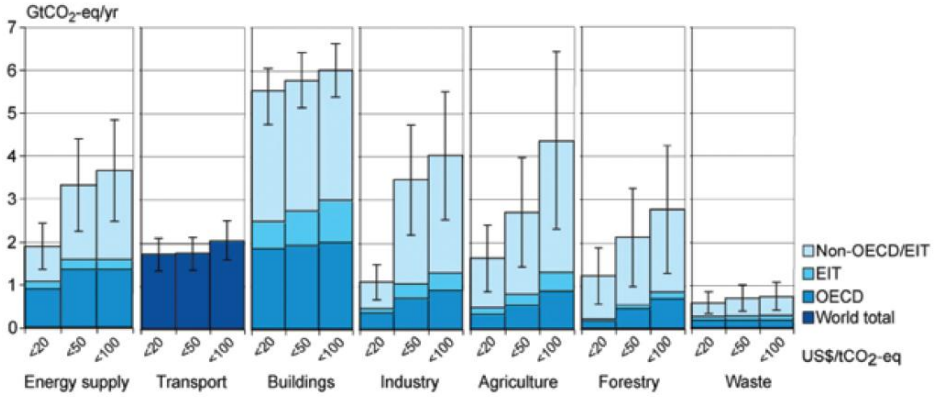
… it is also a major consumer of energy



…it consumes a lot of resources



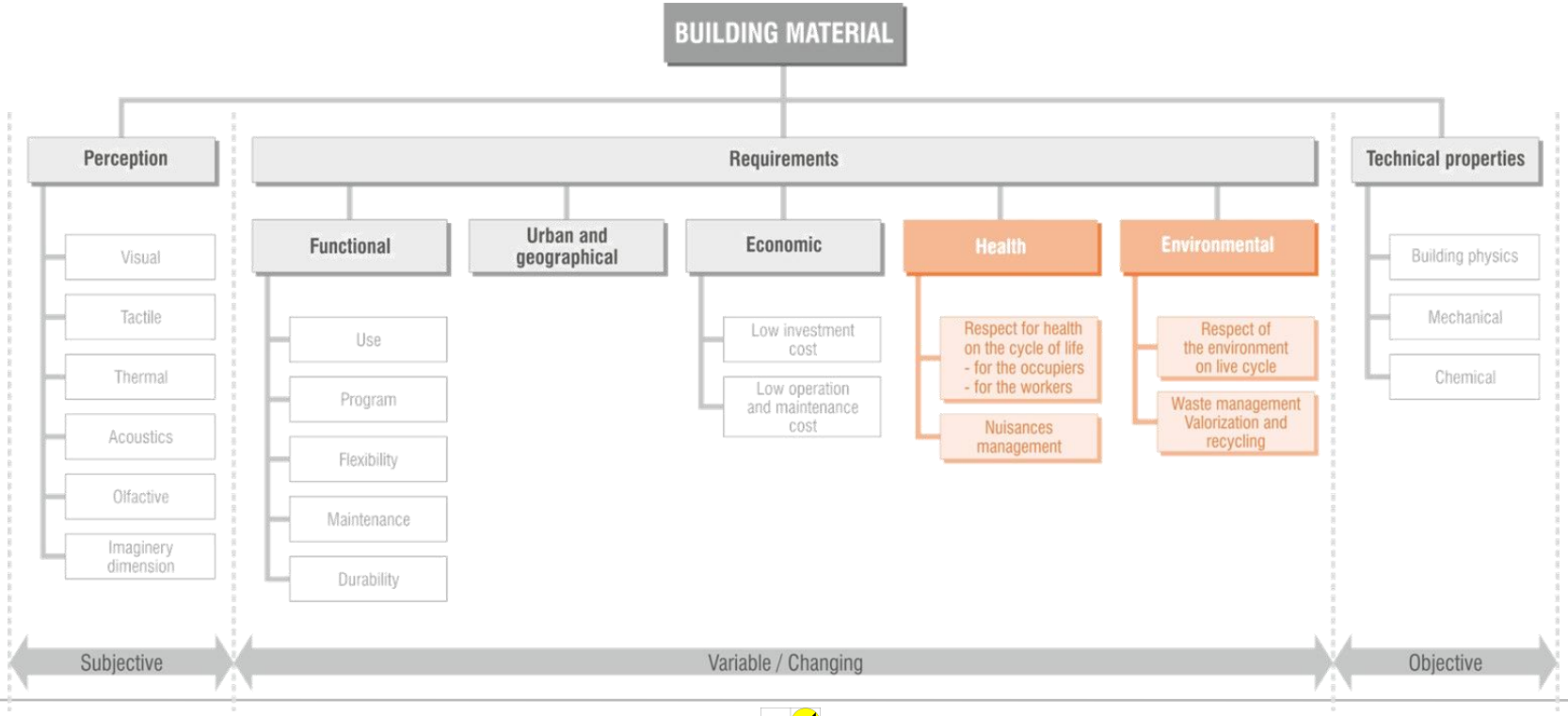
… BUT it offers a great potential for improvement, especially in terms of greenhouse gases emissions and use of resources (recycling potential)



Source: Wim Debacker, presentation "Bouw en renovatie van duurzame gebouwen 2011 – 2012 »

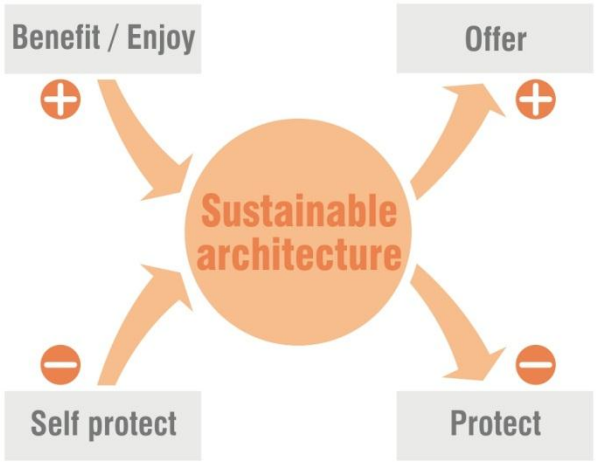
The choice of materials is a fundamental step:

- Buildings material is the base, **the substance which will give shape and form to architecture**;
- Selecting and assembling materials to create a building is a **complex process based on a variety of constraints and knowledge and on different scales of time and space**



Challenges

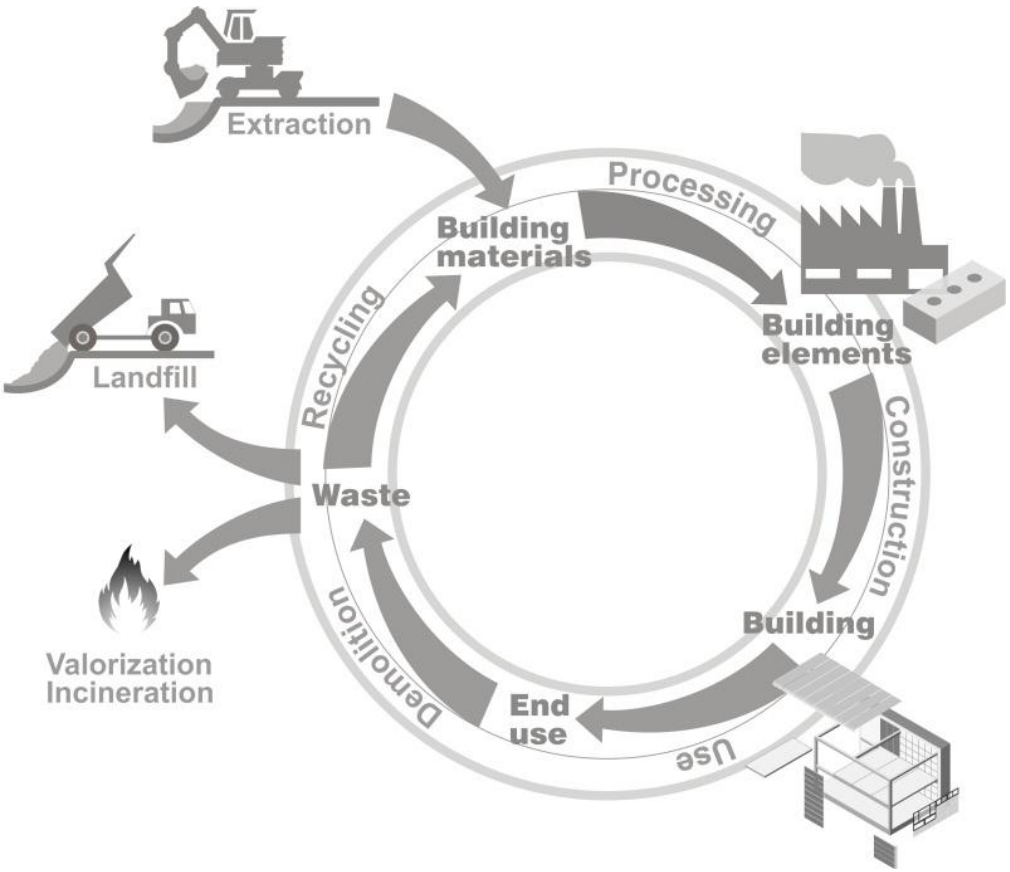
With the objective of designing energy efficient buildings in a sustainable way:



Improve comfort, well-being and quality of life while limiting/reducing environmental impacts

- Scale of time:
  From the design to the demolition, from extraction of raw materials to end of life;
- Scale of space:
  From the interior of a room to the global scale of the planet, through the public space, the city blocks and the city

Building materials and life cycle

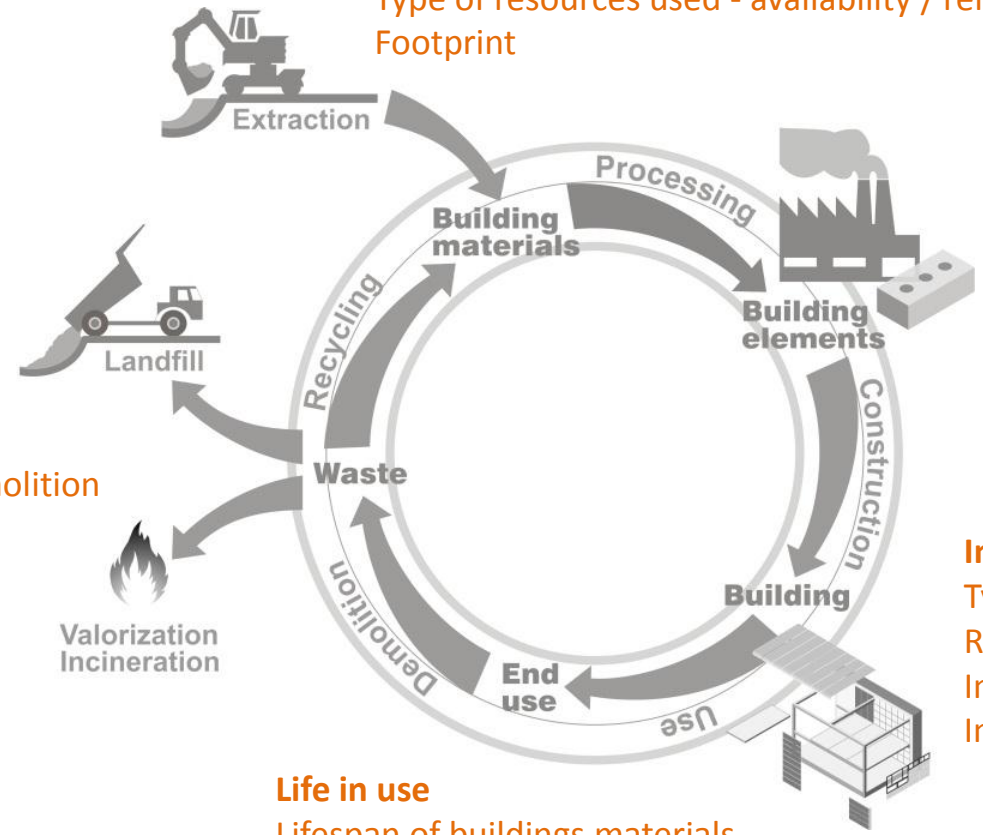


Life cycle

The life cycle of a building material can be considered as **the set of transformations undergone by the material from the extraction of raw materials to the end of life and waste treatment.**

Building materials and life cycle

Extraction of raw materials:
Nature of raw materials
Type of resources used - availability / renewal
Footprint



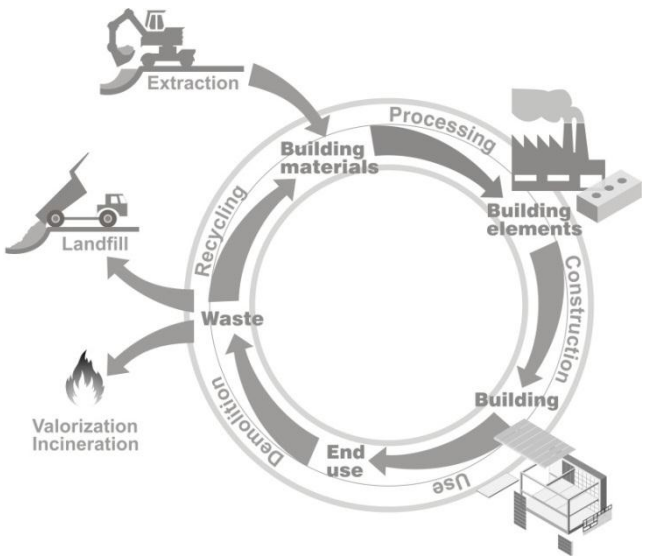
Production / transformation:
Type of raw materials used
Type and amount of energy used
Type of transformations

End of life
Deconstruction >< demolition
Type of treatment
Valorization / recycling

Implementation
Type of assembly
Reversibility / Flexibility
Implementation and additives
Impact on health (workers)

Life in use
Lifespan of buildings materials
Preservation of performances
Impact on health (occupants)

Building materials and environmental impacts



Consumption of non energy resources

Type of resources , availability , renouvellement

Consumption of energy resources

Embodied energy, grey energy, renewable and non renewable energy

Environmental impacts:

Pollution of atmospheric air, waters and soils
Landscape changes, loss of biodiversity

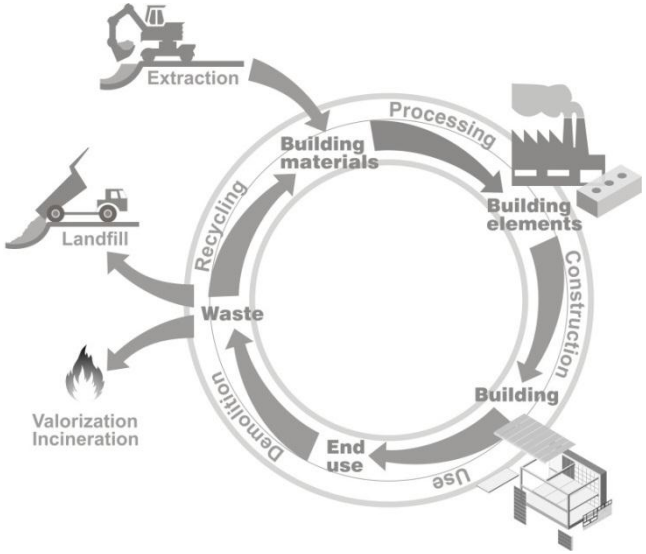
Health impact (workers / occupants):

Use of toxic materials (production, implementation)
Emission of physical and chemical pollutants...

Waste production

Recycling potential, existence of recycling options
Type of assembling

Building materials and life cycle analysis



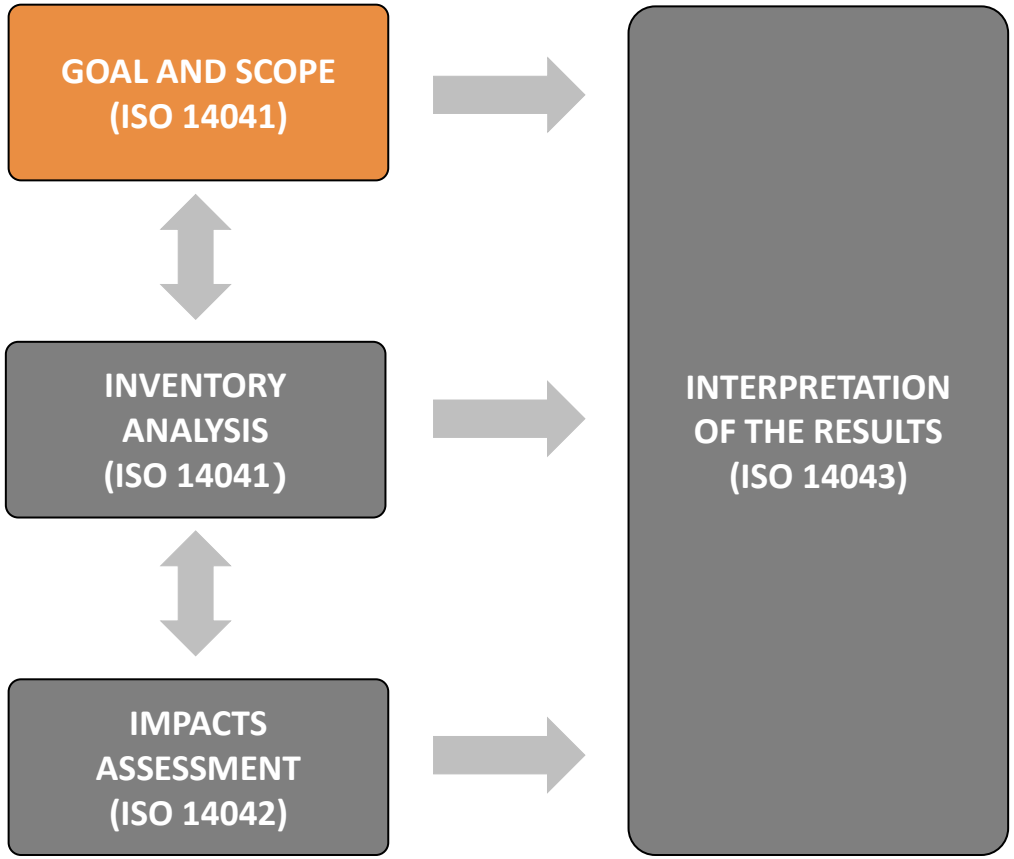
Quantification and evaluation of environmental impacts

« LCA provides a method to quantify and evaluate the potential environmental impacts of a product from the extraction of raw materials to its disposal at end of life, through the phases of production, distribution and use »

EN ISO 14040: Environmental management– Life cycle analysis– Principles and framework, 2006

- Norme **EN ISO 14040**: LCA - principles and framework
- Norme **EN ISO 14044**: LCA - Requirements and guidelines

Building materials and life cycle analysis



Function

The function of a painting is to protect and color a wall

Functional unit

Quantification of the function
Covering 1m ² of wall over 5 years

Reference flow

Quantity of the product analyzed and/or substances used to meet the needs of the functional unit
2 liters, 5 or 10 liters

Limits of the system

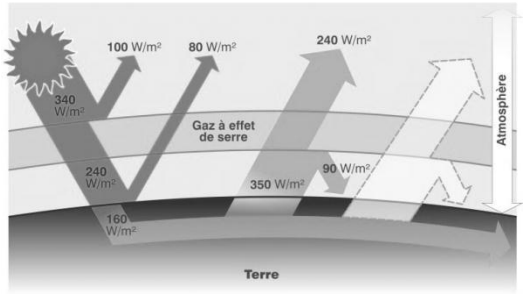
Defining the limits of the study (steps included):

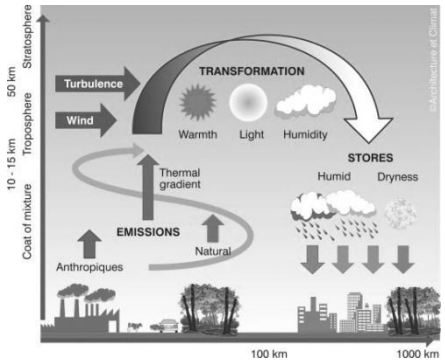
- Cradle to gate
- Cradle to grave

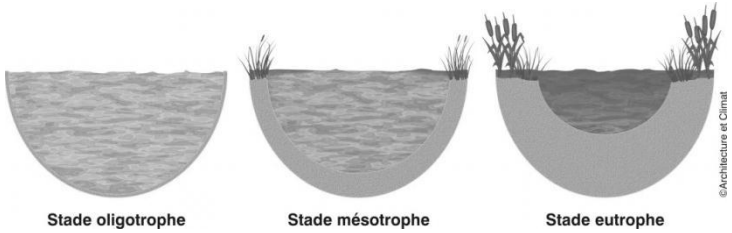
Building materials and life cycle analysis

According to ISO standard 14044, the potential environmental impacts to be mandatory covered are:

- **Natural resources depletion (energy and non energy resources)**
- **Global warming**
- **Acidification**
- **Eutrophication**
- **Stratospheric ozone depletion**
- **Photochemical ozone creation**





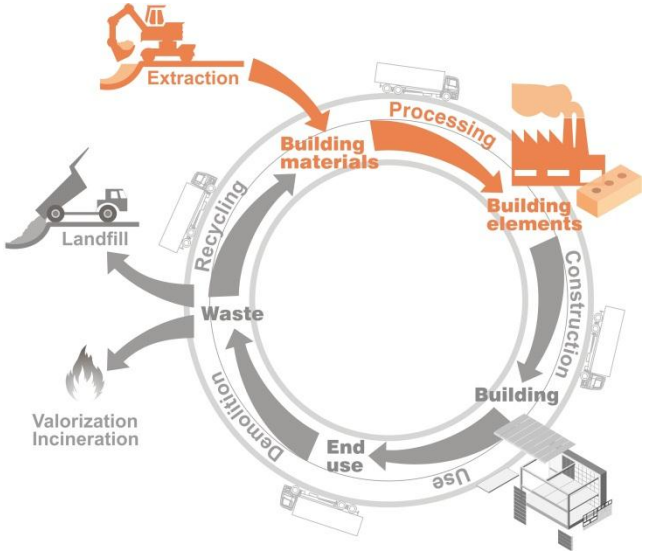


Some potential impacts are not necessarily taken into account:

- Impact of human activities on landscape
- Impact of nuisances caused by human activities: noise, odors
- Impact of the potential toxicity of products emitted or used on environment or on human health

LCA is not intended to cover all environmental issues: only what is quantitative (measurable) and extensive (summable) is taken into account

Embodied energy



Embodied energy [kWh/kg product]

Embodied energy is the energy required by the production process of a product.
Embodied energy = process energy requirement

Embodied energy is the energy consumed by all of the processes associated with the production of a building material, from the mining and processing of natural resources to manufacturing, transport and product delivery.
Embodied energy does not include the operation and disposal of the building material.

Grey energy [MJ/kg product]

Grey energy is the energy required by the all the transformations undergone by a product throughout its life cycle.

Grey energy, calculated in primary energy, can be divided into 4 types of energy:

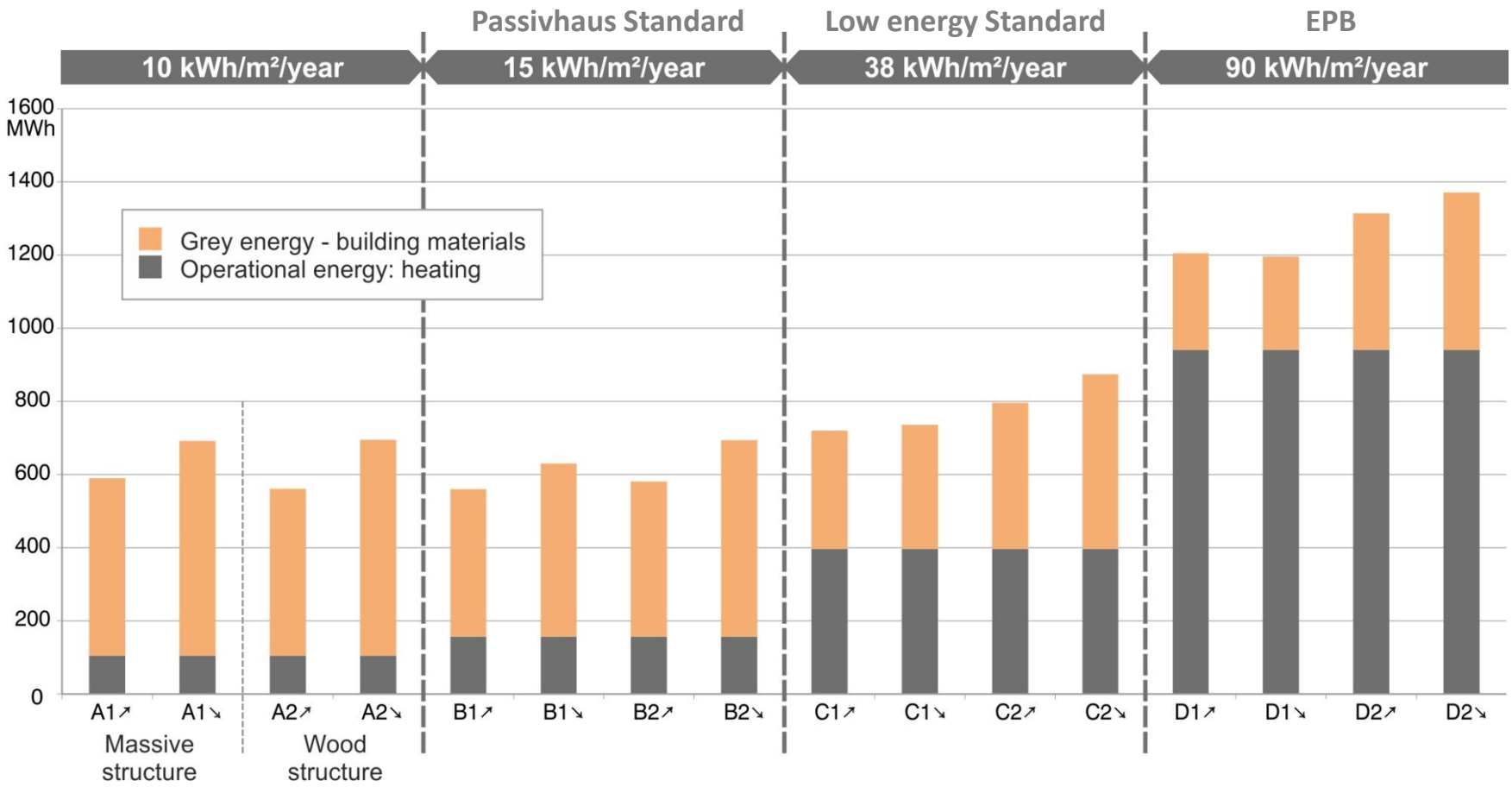
- **Primary renewable energy**
- **Primary non renewable energy (NRE)**
- **Primary energy « material » :** this energy takes into account the energy stored in materials and theoretically recoverable at end of life.
- **Primary energy « process :** this energy takes into account the energy used in operations of processing, operating and transportation over its life cycle.

Type of primary energy	Renewable	Non renewable	TOTAL
MATERIAL	Primary renewable energy « material »	Primary non renewable energy « material »	**Total of primary energy » material »**
PROCESS	Primary renewable energy « process »	Primary non renewable energy « process »	**Total of primary energy » process»**
TOTAL	**Total of primary renewable energy**	**Total of primary non renewable energy**	**GREY ENERGY**

Grey energy

Matériaux et composants	Densité *ρ* ***kg/m³***	Ressources (DAR) *fabrication* ***kg antim.-Eq/kg***	Energie grise *fabrication* ***MJ/kg***	NRE *fabrication* ***MJ/kg***	Energie grise *élimination* ***MJ/kg***	Effet de serre *fabrication* ***kg CO2 eq/kg***	Effet de serre *élimination* ***kg CO2 eq/kg***	Acidification *fabrication* ***kg SO2 eq/kg***	Ozone troposph. *fabrication* ***kg H2C2 eq/kg***
GRANULATS									
sable de rivière/mer	2000	/	0,0587	0,0541	0,235	0,00239	0,0118	0,00004	0
sable de carrière	2000	0,000016261	0,0587	0,0541	0,235	0,00239	0,0118	0,00004	0
gravier de rivière/mer	2000	/	0,136	0,1	0,177	0,00426	0,00937	0,00004	0
gravier de carrière	2000	0,000018911	0,0587	0,0541	0,177	0,00239	0,00937	0,00004	0
BETON COULE ET CIMENT									
béton maigre	*[2000 à 2200]* **2000**	0,30027	0,374	0,351	0,177	0,05	0,0088	0,00019	0,00001
béton normal armé (dalles)	2400	0,41429	0,61	0,56	0,201	0,11	0,0104	0,00021	0,00001
béton normal armé (charges élévées)	2400	0,56528	0,96	0,89	0,201	0,134	0,0104	0,0003	0,00001
ciment portland CEM I	*[900 à 1900]* **1250**	0,00137	3,78	3,5	/	0,83	/	0,0013	0,00004
chape de compression sur hourdis	1700	0,0013757	1,292	1,088	0,196	0,17	0,00953	0,00306	0,0000085
chape ciment	1700	0,0013757	1,292	1,088	0,196	0,17	0,00953	0,00306	0,0000085
BETON PREFABRIQUE									
hourdis en béton	1800	/	0,8	0,8	/	0,13	/	0,00041	0,00001
BLOCS DE MACONNERIE									
bloc de béton lourd	2400	0,00032165	0,8	0,75	0,201	0,12	0,00935	0,00028	0,00001
bloc de béton semi-lourd	2000		0,8	0,75	0,201	0,12	0,00935	0,00028	0,00001
bloc de béton léger (argile expansé)	1200	0,0028571	5,15	4,94	0,188	0,429	0,00897	0,00262	0,00004
bloc de terre cuite plein	*[1000 à 2200]* **1000**	0,0011781	2,85	2,58	0,188	0,238	0,00867	0,00064	0,00004

Comparison – grey energy and heating energy



Comparison over 50 years
UCL: Sophie Trachte / Catherine Massart

Comparison – grey energy and heating energy

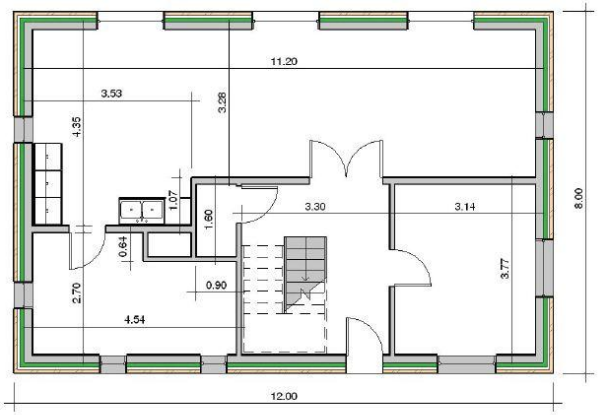


FIGURE 1 : Plan of the ground floor

FIGURE 2 : South, East, West and North façades

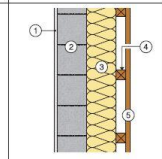
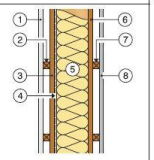
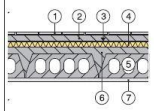
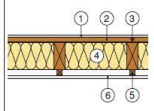
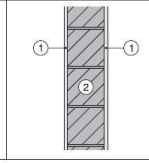
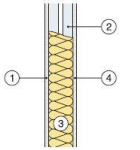
	Massive typology [1]	Wood frame [2]
External wall		
Inner floor		
First floor partition wall		

TABLE 2 : Building differences between typologies The roof, the ground floor slab and inner ground floor walls are the same for the two typologies.

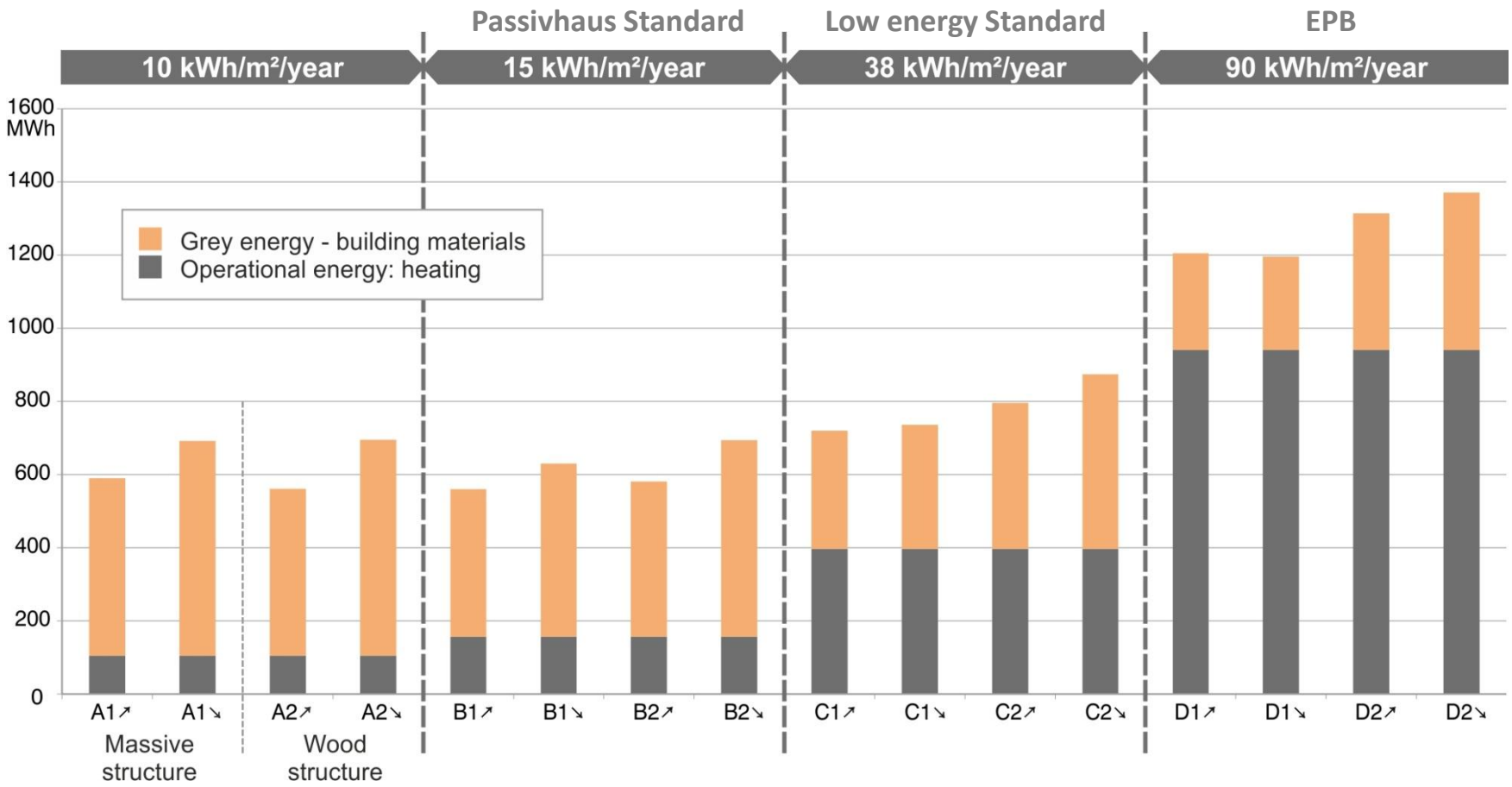
- Two cases of walls composition were selected :

  [↗] with an important GWP

  [↘] with a low GWP

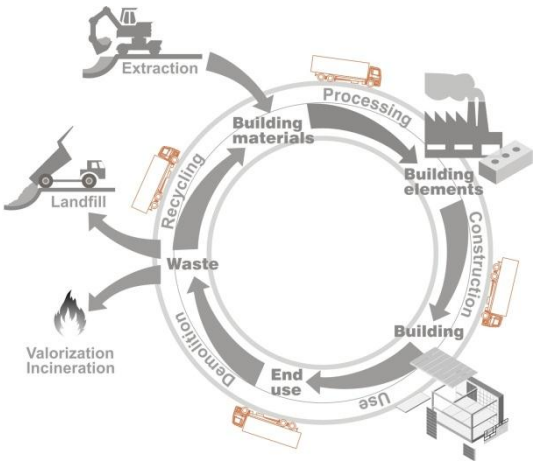
- The wall compositions were analyzed **over 50 years** taking into account **average lifetime of used materials**
- "Cradle to gate" phase, replacement and "end of life" phase were analysed.
- Life cycle inventory values have been selected among 3 databases: ECOSOFT, KBOB/ECO-BAU/IPB and ECOINVENT.

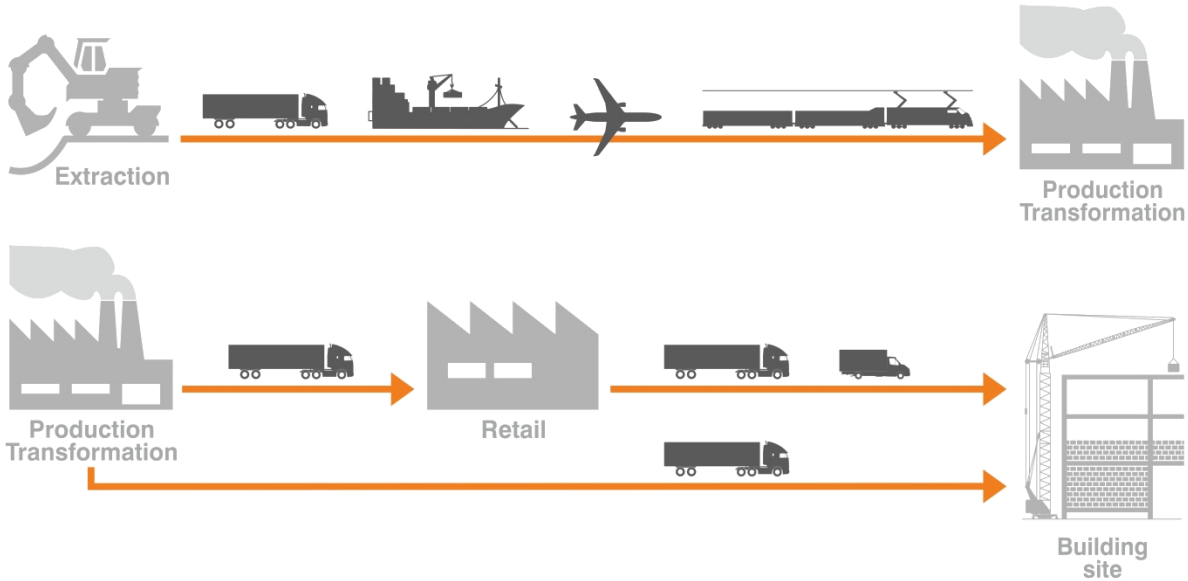
Comparison – grey energy and heating energy

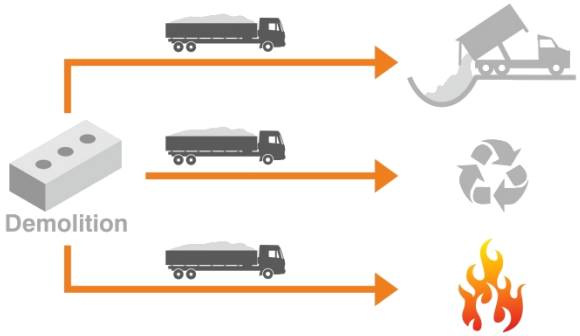


Comparison over 50 years
UCL: Sophie Trachte / Catherine Massart

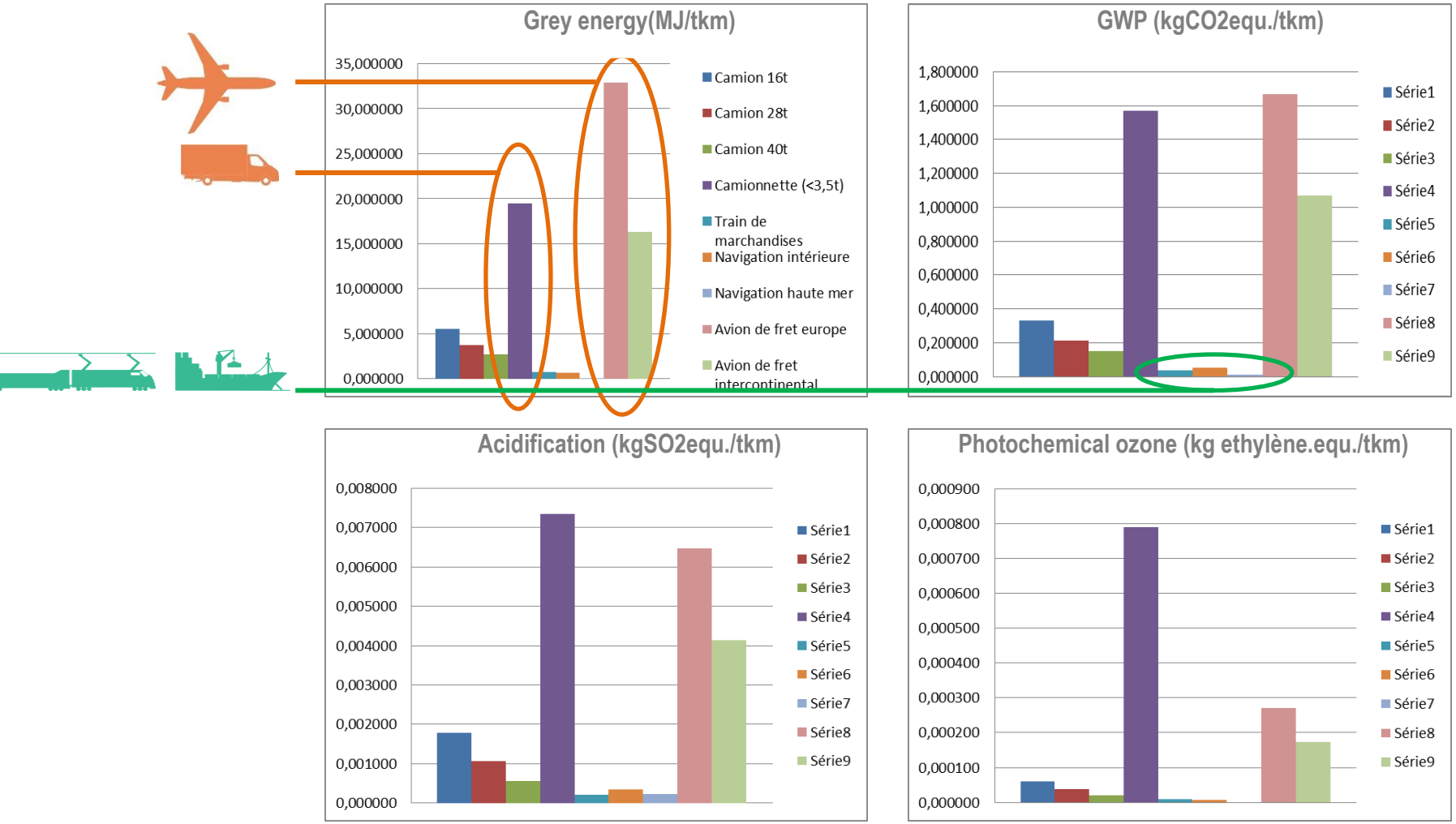
Grey energy and transport





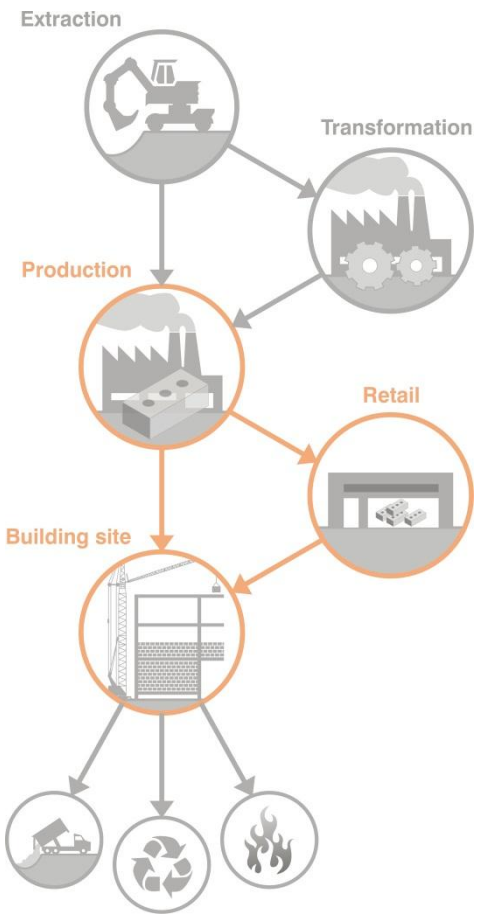


Grey energy and transport



Grey energy and transport

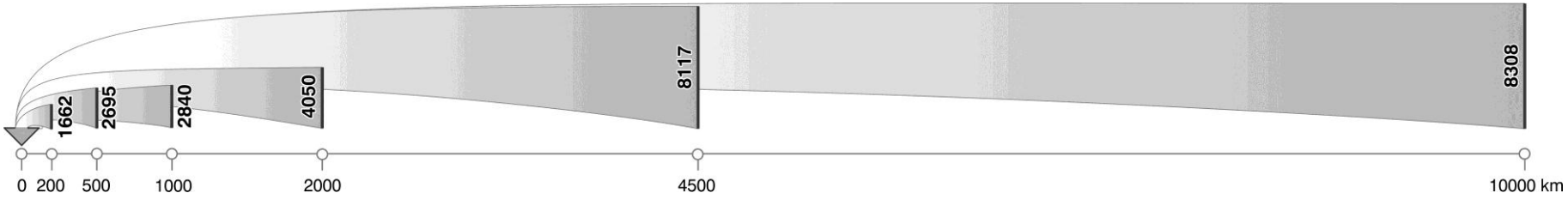
Does « local » building material really limit the impact of transport?



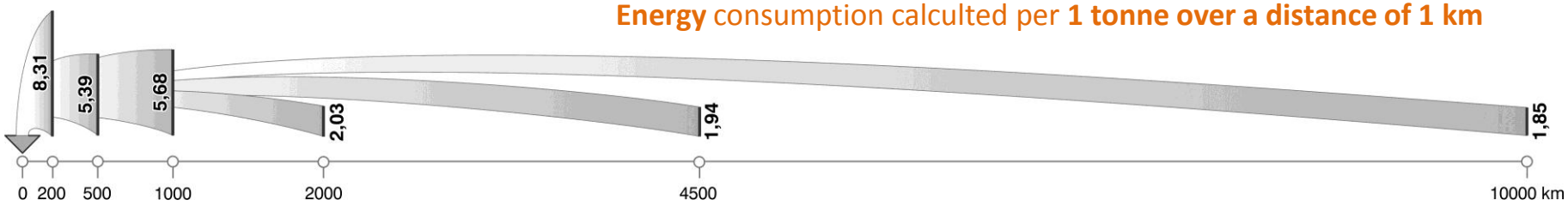
1: Belgium – 90 km
2: Benelux – 200 km
3. Neighboring regions– 500 km
4. Neighboring countries– 1000 km
5. Close Europe– 2000 km
6. Wider Europe– 4500 km
7. World – 10 000km

Grey energy and transport

Energy consumption calculated per ton multiplied by the **number of km covere**d

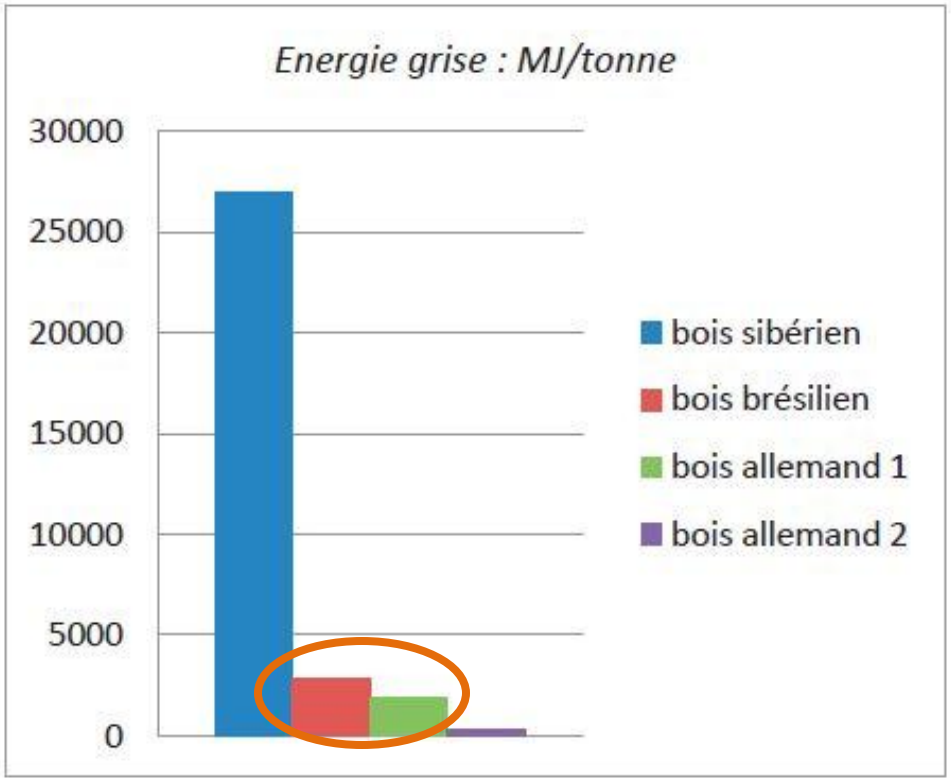


Energy consumption calculted per **1 tonne over a distance of 1 km**



The mode of transport influences more the environmental impact that the distance

Grey energy and transport



- Siberian wood : 10 000 km by road (truck)
- Bresilian wood : 10 000 km by sea (90 %) and road (10 %)
- German wood : 500 km by road (truck)
- German wood : 500km by train

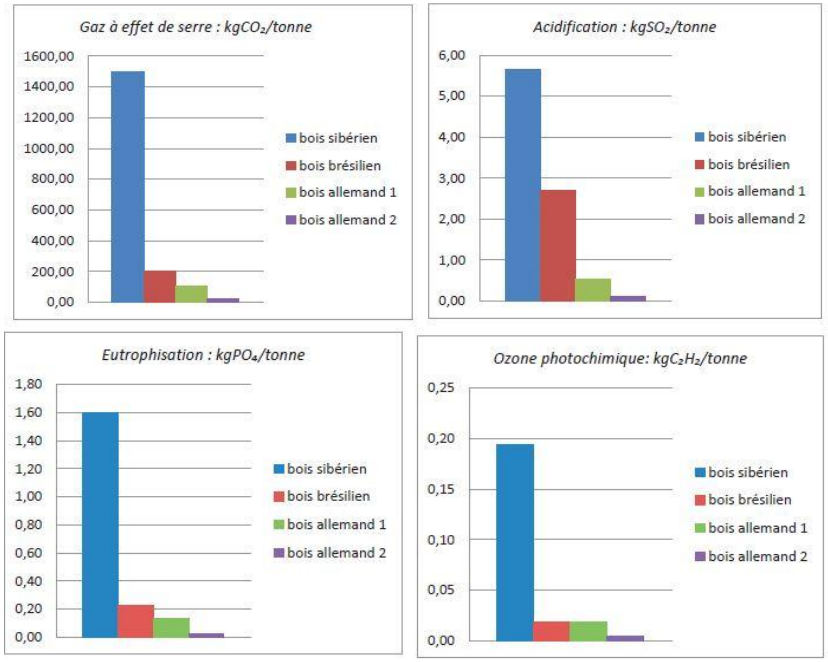


Illustration B4.25 : Impact du transport selon l'origine - cas du bois

Grey energy – assessment tools

Environmental product declaration (EPD)

Environmental product declarations are statements prepared under the responsibility of buildings materials/ products manufacturers according to the standard ISO 14025

Information sheets - verified by an independent third party - in which the manufacturer provides, based on a life cycle analysis, quantitative data on the environmental impact of the product

- cradle to gate
- cradle to grave

OBJECTIVE:

To compare two products with the same functional unit

Example:

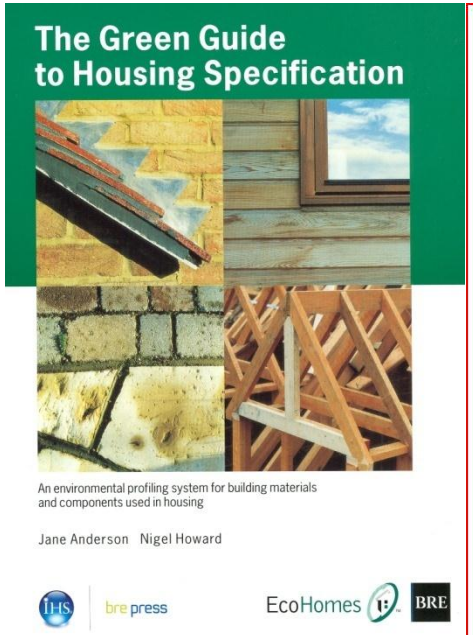
1m ² of concrete or terracotta roofing tile

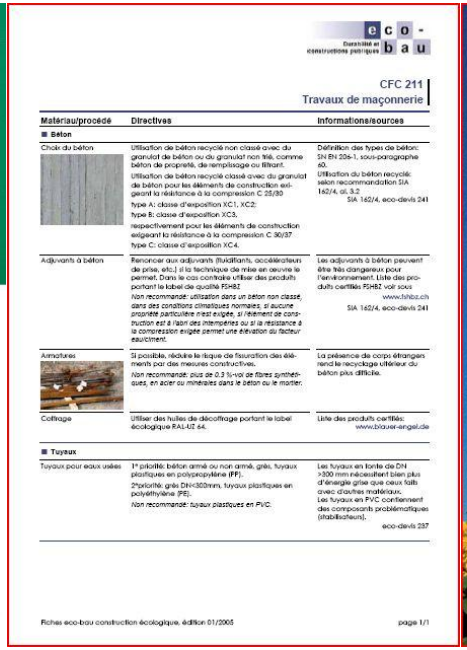
Grey energy – assessment tools

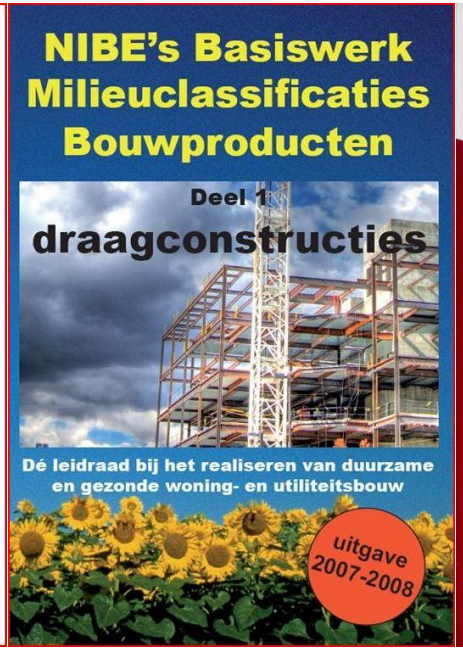
N°	Impact environnemental		Unité par UF
1	Consommation de ressources énergétiques	Energie primaire totale	MJ
		Energie renouvelable	MJ
		Energie non renouvelable	MJ
2	Epuisement des ressources		Kg équivalent Antimoine
3	Consommation d'eau totale		L
4	Déchets solides valorisés total		kg
	Déchets solides éliminés	Déchets dangereux	kg
		Déchets non dangereux	kg
		Déchets inertes	kg
		Déchets radioactifs	kg
5	Changement climatique		Kg équivalent CO2
6	Acidification atmosphérique		Kg équivalent SO2
7	Pollution de l'air		m^3
8	Pollution de l'eau		m^3
9	Destruction de la couche d'ozone stratosphérique		kg équivalent CFC
10	Formation d'ozone photochimique		kg équivalent éthylène

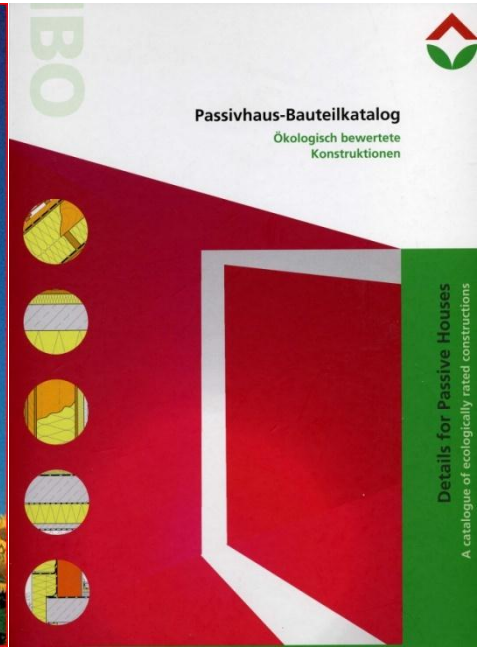
Grey energy – assessment tools

Checklists









www.bre.co.uk

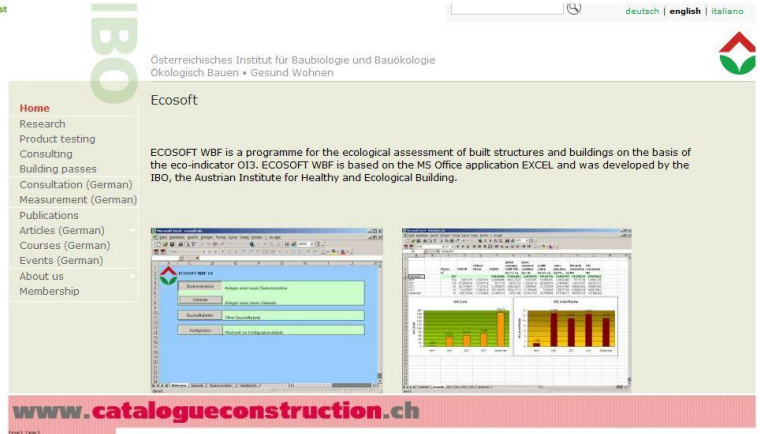
www.nibe.org

www.ecobau.ch

www.baubook.info

Grey energy – assessment tools

LCA Softwares



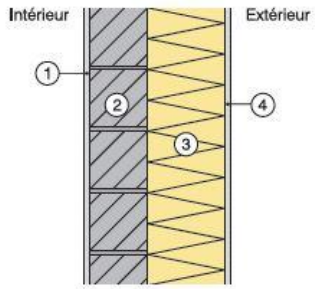
www.envestv2.bre.co.uk

www.ecobat.ch

www.ibo.at

www.cataloguecontruction.ch

Case study – comparison between blocks

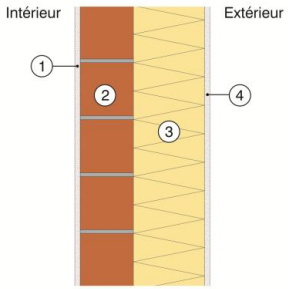


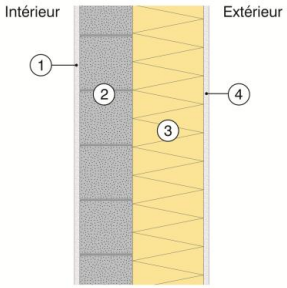
> **Performances physiques**

		A	B	C
Epaisseur totale	[m]	0.335	0.34	0.46
Coeff. de transmission thermique U	[W/m²K]	0.193	0.194	0.192
Inertie thermique	[kJ/m²K]	306	308	308
Affaiblissement acoustique	dB	> 55 dB	> 65 dB	> 65 dB

> **Composants**

A	[m]	Composants	durée de vie	remplacement	élimination	description technique
1	0.02	enduit au plâtre	30	1	2	Le bloc de béton choisi a une densité de 2000kg/m³
2	0.14	bloc béton (90%)	> 50	0	1	
2		mortier ciment (10%)	> 50	0	1	
3	0.17	isolant EPS (polystyrène expansé)	30	1	2	
4	0.005	enduit à résines synthétiques	30	1	2	

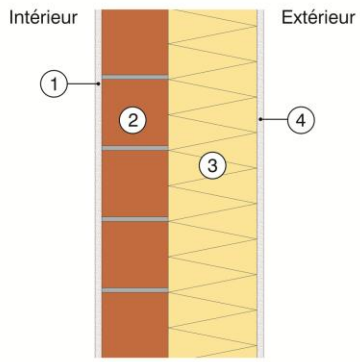




Density

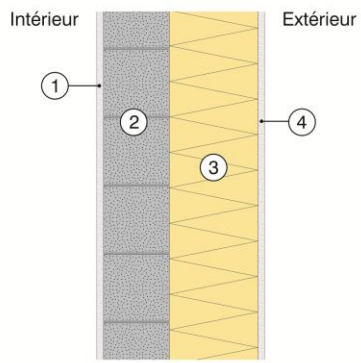
- **Concrete : 2000kg/m³**
- **Terra cotta : 1000kg/m³**
- **Cellular concrete: 650kg/m³**

Case study – comparison between blocks



> **Performances physiques**

		A	B	C
Epaisseur totale	[m]	0.335	0.34	0.46
Coeff. de transmission thermique U	[W/m²K]	0.192	0.192	0.195
Inertie thermique	[kJ/m²K]	166	166	168
Affaiblissement acoustique	dB	48 dB	62 dB	62 dB

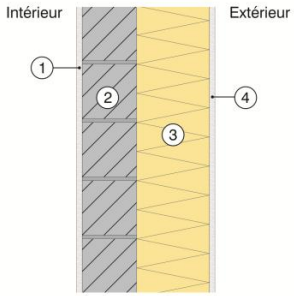


> **Performances physiques**

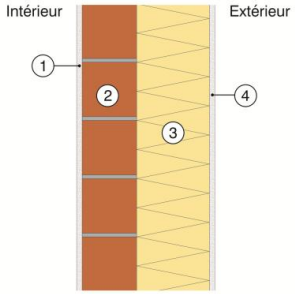
		A	B	C
Epaisseur totale	[m]	0.335	0.34	0.37
Coeff. de transmission thermique U	[W/m²K]	0.191	0.191	0.192
Inertie thermique	[kJ/m²K]	123.5	125.5	125.5
Affaiblissement acoustique	dB	41 dB	57 dB	57 dB

Case study – comparison between blocks

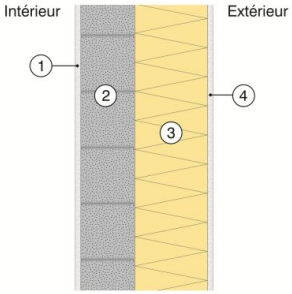
Environmental performances (over 50 years: *production/ replacement/ elimination)*



Grey energy:	**288,76 MJ/m²**
GWP:	**37,38 kgCO_2/m²**
AP:	**0,0792 kgSO_2/m²**
POCP:	**0,0027 kgC_2H_2/m²**



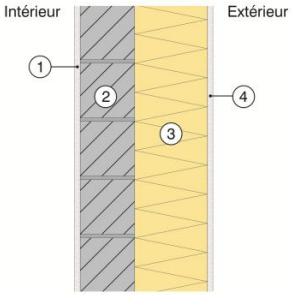
Grey energy:	**446,26 MJ/m²**
GWP:	**37,12 kgCO_2/m²**
AP:	**0,0892 kgSO_2/m²**
POCP:	**0,0052 kgC_2H_2/m²**



Grey energy:	**554,19 MJ/m²**
GWP:	**47,64 kgCO_2/m²**
AP:	**0,0735 kgSO_2/m²**
POCP:	**0,0029 kgC_2H_2/m²**

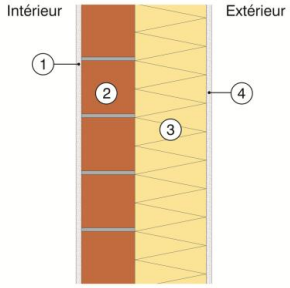
Case study – comparison between blocks

Resources depletion

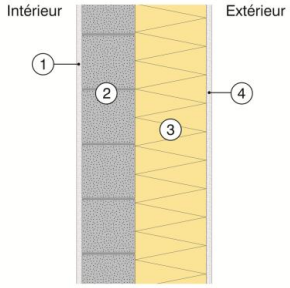


A	[m]	Composants	Quantité (kg)	Nature	Caractéristique	Origine
1	0.02	enduit au plâtre	52			
2	0.14	bloc béton (90%)	252			
2		mortier ciment (10%)	23.80			
3	0.17	isolant EPS (polystyrène expansé)	10.2			
4	0.005	enduit à résines synthétiques	12	pas de données	pas de données	pas de données

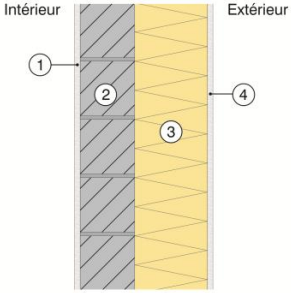
A	[m]	Composants	Quantité (kg)	Nature	Caractéristique	Origine
1	0.02	enduit au plâtre	52			
2	0.14	bloc terre cuite plein (90%)	126			
2		mortier ciment (10%)	23.80			
3	0.17	isolant EPS (polystyrène expansé)	9.90			
4	0.005	enduit à résines synthétiques	12	pas de données	pas de données	pas de données



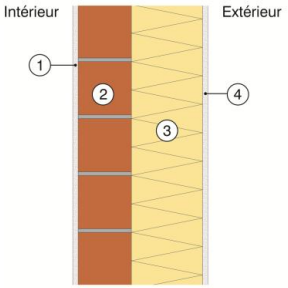
A	[m]	Composants	Quantité (kg)	Nature	Caractéristique	Origine
1	0.02	enduit au plâtre	52			
2	0.15	bloc béton cellulaire (97%)	94.58			
2		mortier colle (10%)	7.20			
3	0.17	isolant EPS (polystyrène expansé)	9.60			
4	0.005	enduit à résines synthétiques	12	pas de données	pas de données	pas de données



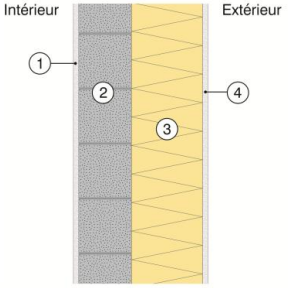
Recycling potential



A	[m]	Composants	Recycled content	Recyclabilité	Moyen d'assemblage	Situation filière
1	0.02	enduit au plâtre		pas de données		pas de données
2	0.14	bloc béton (90%)				
2		mortier ciment (10%)				
3	0.17	isolant EPS (polystyrène expansé)				pas de données
4	0.005	enduit à résines synthétiques	pas de données	pas de données		pas de données

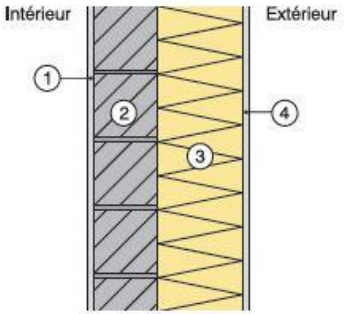


A	[m]	Composants	Recycled content	Recyclabilité	Moyen d'assemblage	Situation filière
1	0.02	enduit au plâtre		pas de données		pas de données
2	0.14	bloc terre cuite plein (90%)				
2		mortier ciment (10%)				
3	0.17	isolant EPS (polystyrène expansé)				pas de données
4	0.005	enduit à résines synthétiques	pas de données	pas de données	pas de données	pas de données



A	[m]	Composants	Recycled content	Recyclabilité	Moyen d'assemblage	Situation filière
1	0.02	enduit au plâtre		pas de données		pas de données
2	0.15	bloc béton cellulaire (97%)				
2		mortier colle (3%)	pas de données	pas de données	pas de données	pas de données
3	0.17	isolant EPS (polystyrène expansé)				pas de données
4	0.005	enduit à résines synthétiques	pas de données	pas de données		pas de données

Case study – comparison between walls



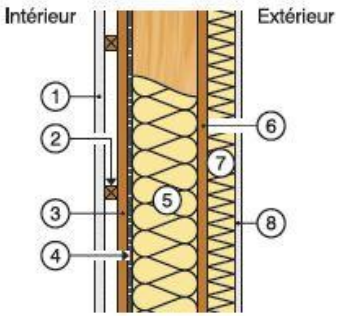
> **Performances physiques**

		A	B	C
Epaisseur totale	[m]	0.335	0.34	0.46
Coeff. de transmission thermique U	[W/m²K]	0.193	0.194	0.192
Inertie thermique	[kJ/m²K]	306	308	308
Affaiblissement acoustique	dB	> 55 dB	> 65 dB	> 65 dB

> **Composants**

B	[m]	Composants	durée de vie	remplacement	élimination	description technique
1	0.02	enduit à la chaux	30	1	2	Le bloc de béton choisi a une densité de 2000kg/m³
2	0.14	bloc béton (90%)	> 50	0	1	
2		mortier ciment (10%)	> 50	0	1	
3	0.17	laine de roche (panneau rigide)	30	1	2	
4	0.01	enduit minéral ciment	30	1	2	

Case study– comparison between walls



> **Performances physiques**

		A	B	C
Epaisseur totale	[m]	0.345	0.345	0.335
Coeff. de transmission thermique U	[W/m²K]	0.190	0.192	0.191
Inertie thermique	[kJ/m²K]	76.44	98.22	72.81
Affaiblissement acoustique	dB	> 45 dB	> 45 dB	> 45 dB

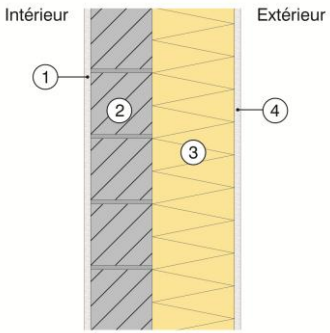
Remarque:
La composition serait davantage efficace d'un point de vue acoustique en rajoutant une couche isolante dans la cloison technique (intérieure).

> **Composants**

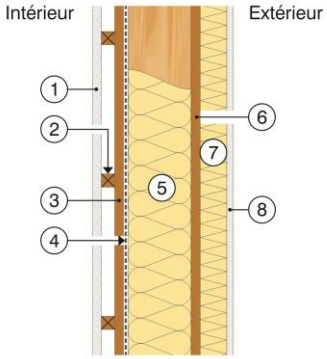
A	[m]	Composants	durée de vie	remplacement	élimination	description technique
1	0.015	plaque de carton plâtre	30	1	2	Excepté la structure portante, l'ensemble des composants est remplacé au bout de 30 ans.
2	0.06	lattage bois 30 x 60 (traité)	30	1	2	
3	0.02	panneau OSB	30	1	2	
4	0.002	pare-vapeur PE	30	1	2	
5	0.18	chevronnage 70 x 180 (traité)	> 50	0	1	
6	0.16	laine de roche (matelas)	30	1	2	
7	0.02	panneau MDF	30	1	2	
8	0.04	laine de roche (panneau rigide)	30	1	2	
9	0.01	enduit minéral ciment	30	1	2	

Case study– comparison between walls

Environmental performances (over 50 years: *production/ renovation / élimination)*



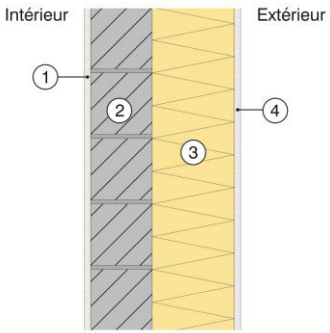
Grey energy:	**288,76 MJ/m²**
GWP:	**37,38 kgCO_2/m²**
Acidification:	**0,0792 kgSO_2/m²**
Photochem. Ozone:	**0,0027 kgC_2H_2/m²**



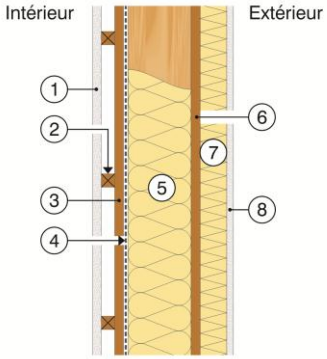
Grey energy:	**2451,27 MJ/m²**
GWP:	**-87,37 kgCO_2/m²**
Acidification:	**0,0889 kgSO_2/m²**
Photochem. Ozone:	**0,0016 kgC_2H_2/m²**

Case study – comparison between walls

Resources depletion

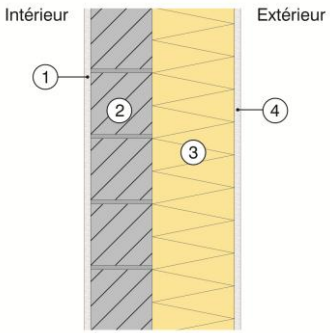


B	[m]	Composants	Quantité (kg)	Nature	Caractéristique	Origine
1	0.02	enduit à la chaux	56			
2	0.14	bloc béton (90%)	252			
2		mortier ciment (10%)	23.80			
3	0.17	laine de roche (panneau rigide)	34			
4	0.01	enduit minéral ciment	30			

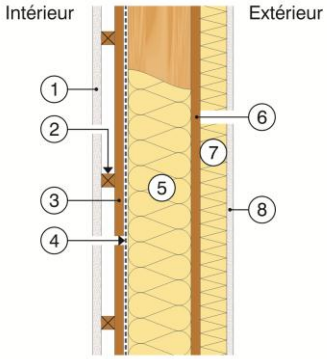


A	[m]	Composants	Quantité (kg)	Nature	Caractéristique	Origine
1	0.015	plaque de carton plâtre	22.50			
2	0.06	lattage bois 30 x 60 (traité)	3.60			
3	0.02	panneau OSB	20			
4	0.002	pare-vapeur PE	1.70			
5	0.18	chevronnage 70 x 180 (traité)	18			
5 7	0.16 0.03	laine de roche (matelas) laine de roche (panneau rigide)	32 6			
6	0.02	panneau MDF	30			
8	0.01	enduit minéral ciment	30			

Recycling potential



B	[m]	Composants	Recycled content	Recyclabilité	Moyen d'assemblage	Situation filière
1	0.02	enduit à la chaux		pas de données		pas de données
2	0.14	bloc béton (90%)				
2		mortier ciment (10%)				
3	0.17	laine de roche (panneau rigide)				
4	0.01	enduit minéral ciment	pas de données	pas de données		pas de données



A	[m]	Composants	Recycled content	Recyclabilité	Moyen d'assemblage	Situation filière
1	0.015	plaque de carton-plâtre		pas de données		pas de données
2	0.06	lattage bois 30 x 60 (traité)				pas de données
3		panneau OSB	pas de données	pas de données		pas de données
4	0.002	pare-vapeur PE	pas de données	pas de données		pas de données
5	0.18	chevronnage bois 70 x 180 (traité)				pas de données
5 7	0.16 0.03	laine de roche (matelas) laine de roche (panneau rigide)				
6	0.02	panneau MDF		pas de données		pas de données
8	0.01	enduit minéral ciment	pas de données	pas de données		pas de données

Thank you for your attention
Questions?

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