Energy and Sustainable Renovation of Building Stock in Europe: The Environmental Benefits of Biobased Insulation Materials.

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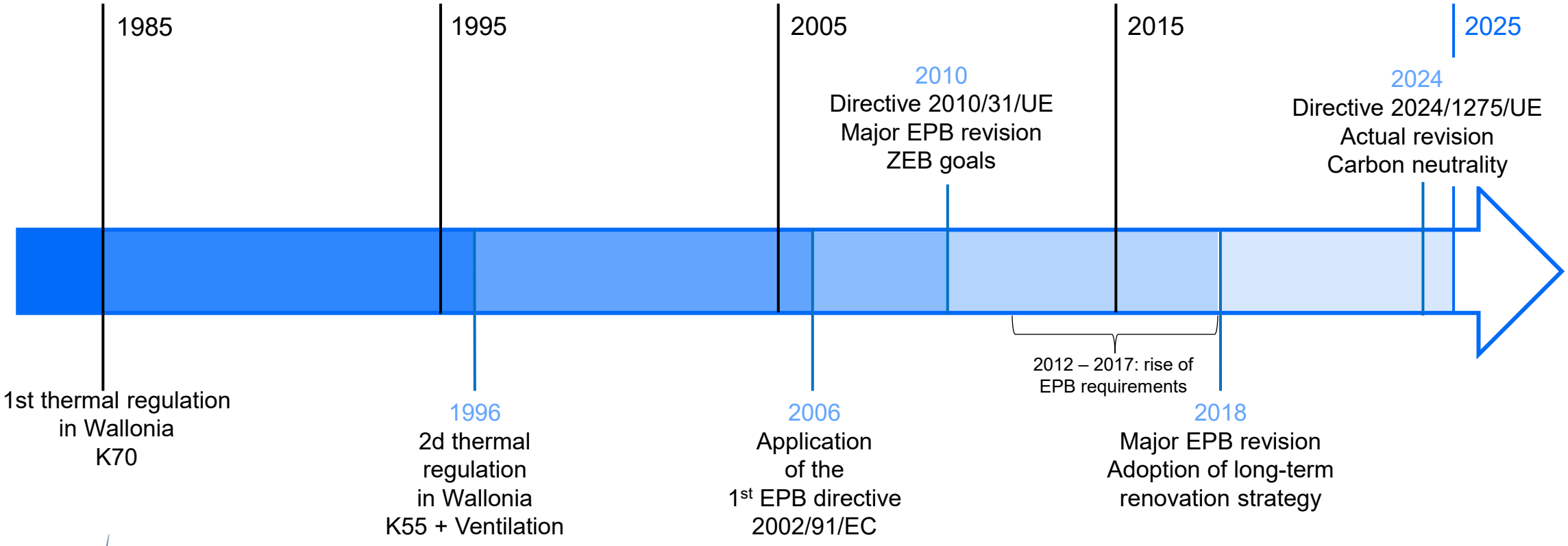
Sophie Trachte[1], Dorothée Stiernon[2]

[1] Research Lab ACTE, Research Unit Art, Archeologie et Patrimoine (AAP), Université de Liège (Uliège), Belgium
Louvain Research Institute for Landscape, Architecture, Built Environment (LAB), Université Catholique de Louvain (UCLouvain), Belgium

Context

For over thirty years, insulation materials have played a vital role in building design, driven by **evolving energy regulations** and stricter **thermal insulation standards**.



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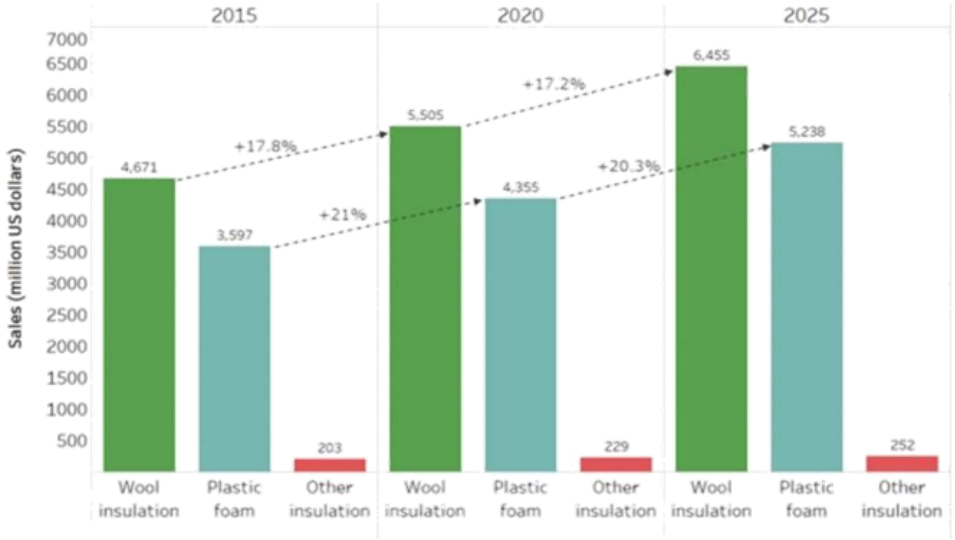
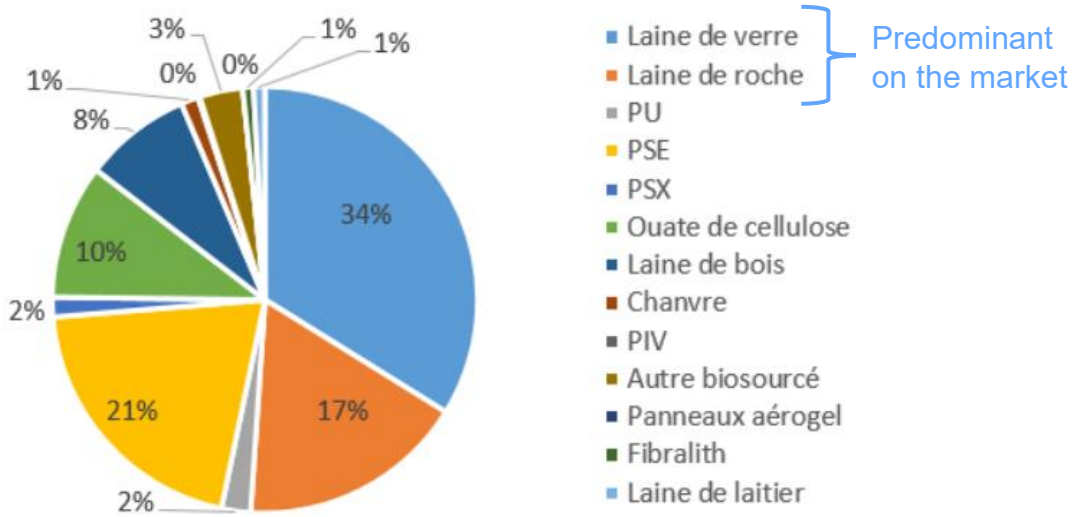
Context

The 2018 update of European EPB regulations urged member states to enhance renovation efforts and to improve energy efficiency of the existing building stock by 2050, by increasing the annual renovation rate from 1 to 3%

Global demand for thermal insulation materials is projected to increase significantly by 2050



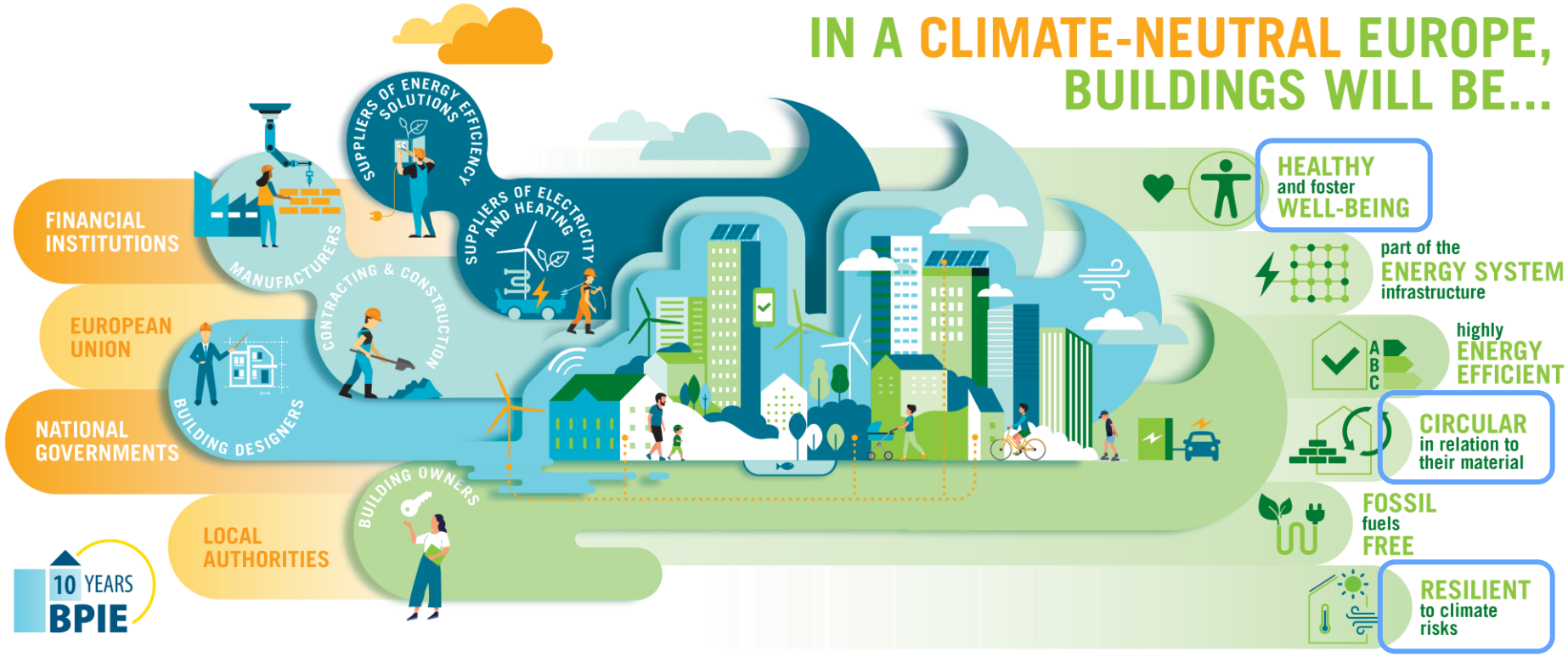
Thermal insulation market in EU in 2015 and forecast for 2020 and 2025, by value
Source: : JRC representation with data from Visiongain, 2017.



Insulation demand for housing low carbon and energy renovation in France
Source: : ADEME. Prospective de consommation de matériaux pour la re novation énergétique BBC des bâtiments résidentiels aux horizons 2035 et 2050. 2019..

Context

Insulation materials are also required to align with European goals for sustainable, healthy, circular and resilient buildings. They can no longer be selected solely for their thermal conductivity!



Source: of figure : action plan – bpie.eu

Aim and focus of the study

The objective is to highlight their **balanced characteristics and effective solutions** for energy renovation

- Technical performances
- Constructive performances
- Environmental performances
- Circular performances

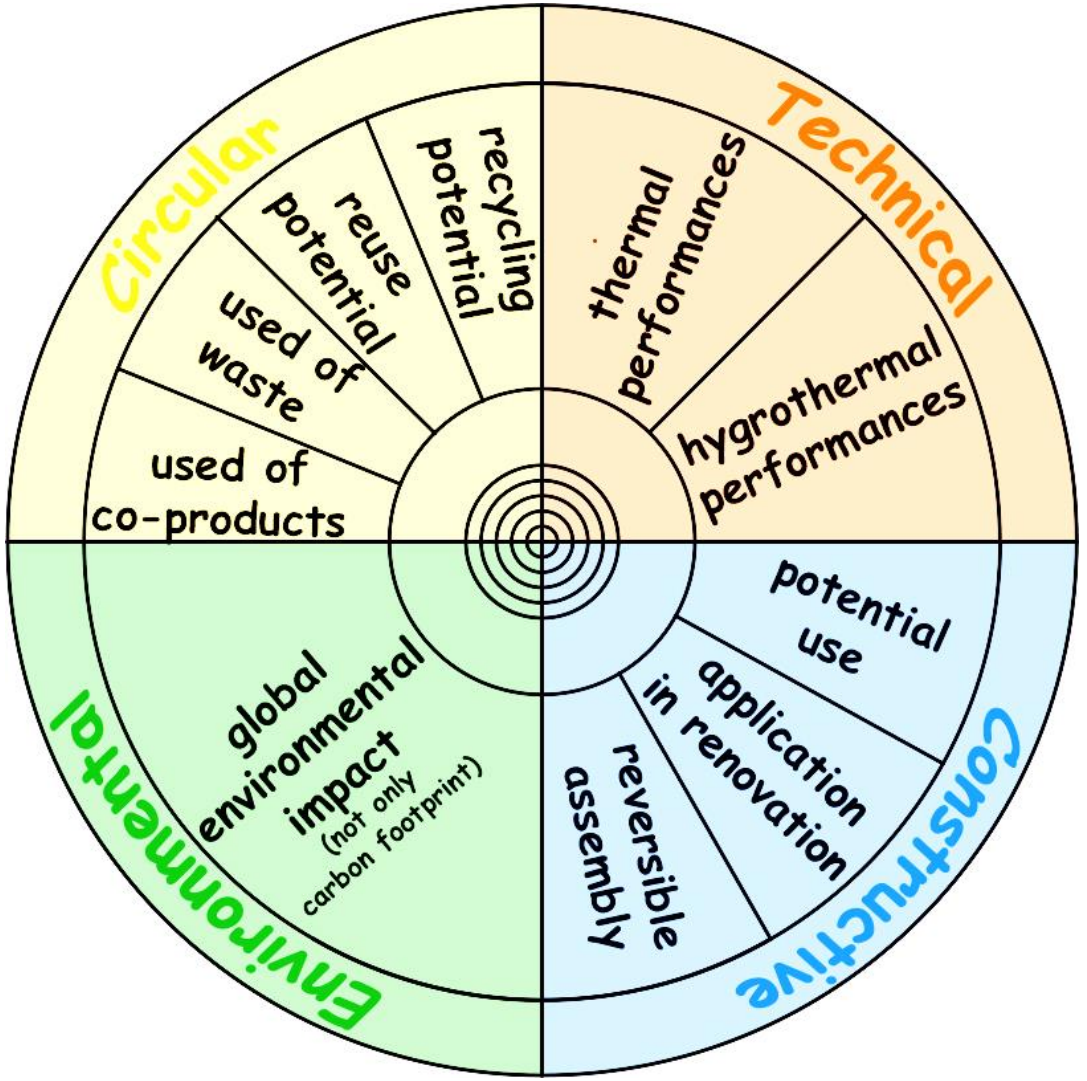


Figure - © Dorothée Stiernon

Aim and focus of the study

Biobased material = material derived from plant or animal origin, produced from renewable biomass resources, and often biodegradable or compostable.

Insulation material = material with a biobased content (new or recycled) > 70%

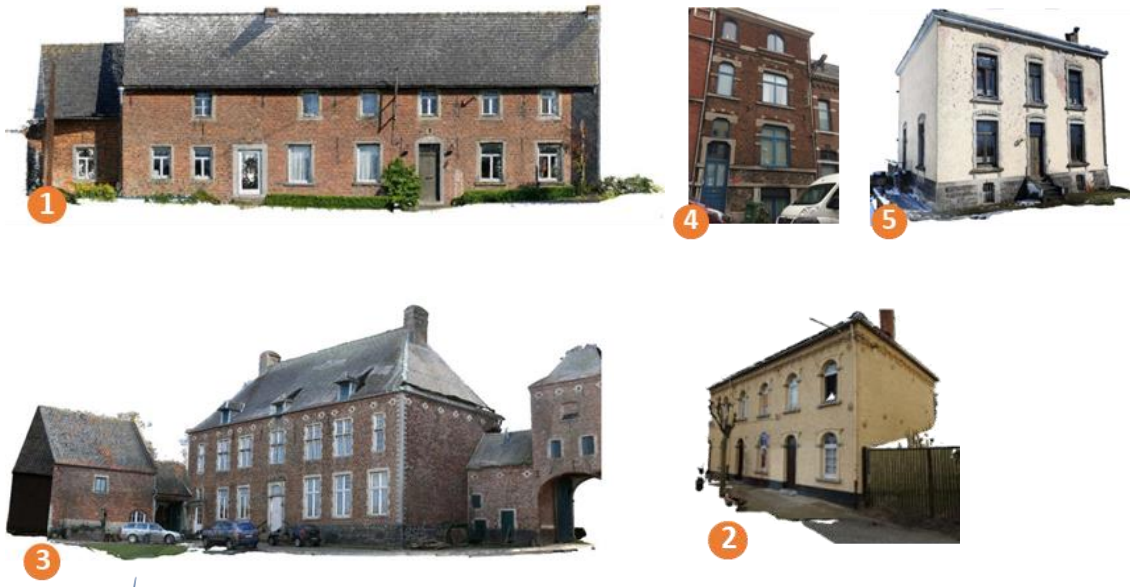
Around 30 biobased insulation with various natures and in several forms have been analyzed

Pictures © S. Trachte

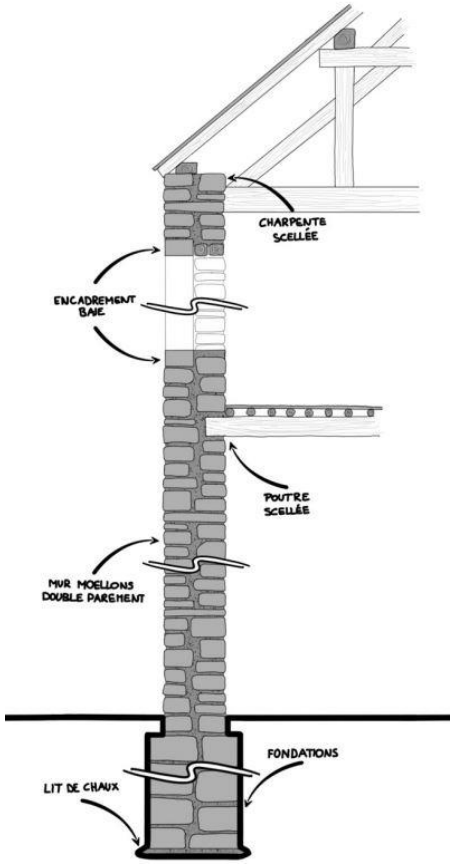
Aim and focus of the study

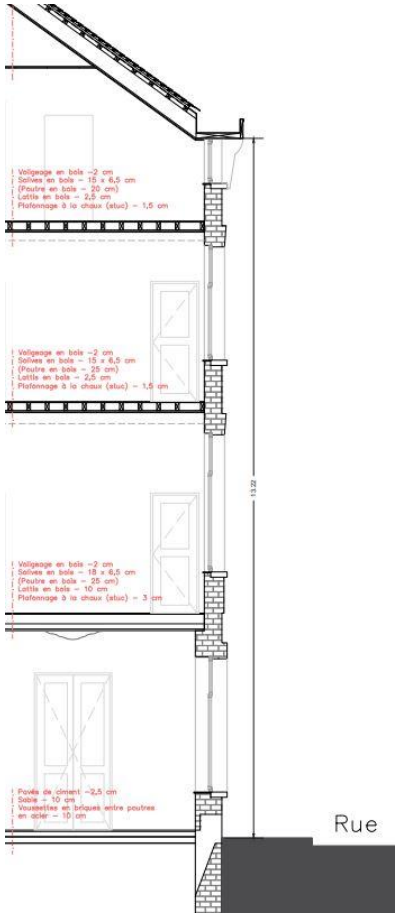
Focus on old traditional buildings (buit before 1919) and internal insulation of the façade thick walls.

- Built with solid brick or natural stone masonry, both with lime mortar.
- With specific thermal and hygrothermal behavior, open to the diffusion of water vapor



Representative case studies of the traditional residential walloon building stock, used in the P-Renewal project.





Section in natural stone masonry (© A. Gusbin, 2024) and brick masonry (© S. Falcone, 2023)

Methodology - Inventories

(1.a) Availability of biobased insulation on European market

Insulation materials	Form of products	Dominant raw materials	Bio-based content byproducts or waste	Additional raw materials	Adjuvants Fongicides / Flame-retardant	Origin of raw materials in Europe	Belgian producers
Natural organic insulation materials, from biobased resources							
Cereal straw	in bulk / loose	cereal stem	100%	NO	NO	Europe	RBFCP
	in bales	cereal stem	100%	binding wires	NO	Belgium, France, Germany	Pailletech, RBFCP
Cereal husks	in bulk / loose	cereal husks	100%	NO	NO	France	/
Cork	in bulk / loose	tree bark or bottle stopper	100%	NO	NO	France, Belgium, Portugal, Spain	Recycork, Isoliège
	rigid panel	tree bark	98 to 100 %	binder	NO	France, Belgium, Portugal, Spain	Isoliège
Flax fibers	flexible panel	plant stem	around 85%	polyester fibers	ammonium phosphate salts	Austria, Germany	/
Hemp fibers	in bulk / loose	plant stem	100%	NO	sometimes fongicides	France, Germany	/
	flexible panel	plant stem	85% to 90%	polyester fibers	fongicides and flame-retardants	France, Germany	Dechanvre
	rigid panel	plant stem	85%	polyester fibers	fongicides and flame-retardants	France, Germany	Dechanvre
Hemp granules	in bulk / loose	plant stem	100%	lime or clay (powder)	sometimes fongicides	France, Germany	Dechanvre
Hemp-lime	blocks	plant stem	70 to 90%	lime binder	NO	France, Germany	Isohemp, Dechanvre
	rigid panel	plant stem	70 to 90%	lime binder	NO	France, Germany	Isohemp, Dechanvre
Hemp and cellulose fibers	flexible panel	plant stem and paper waste	25% hemp and 60% cellulose	polyester fibers	ammonium phosphate salts	France	/
Hemp and cotton fibers	in bulk / loose	plan stem and textile waste	100%		mothproof, fongicides	France, Germany	/
	flexible panel	plan stem and textile waste	92%	polyester fibers	mothproof, fongicides	France, Germany	/
Hemp and flax fibers	flexible panel	plant stem	90%	polyester fibers	fongicides and flame-retardants	France	/
Hemp, flax and cotton fibers	flexible panel	plan stem and textile waste	92%	polyester fibers	fongicides and flame-retardants	France	/
Grass fibers	flexible panel	grass cuttings	70% grass 20% recycled jute fibers	PET and PLA binder fibers	amonium polyphosphate, urea and silica	Belgium, Switzerland	Gramitherm
Mycelium	rigid panel	mushrooms grow	100%	possible biobased fibers	NO	Belgium, England, Netherlands	Permafungi
Miscanthus	blocs (argile et chaux)	plan stem	70 to 90%	NO	NO	Belgium, France	Promisc
	in bulk / loose	plant stem	100%	NO	NO	Belgium, France	Promisc
Reed	rigid panel	plant stem	100%	binding wires	NO	France, Germany	Claytec
Rice straw	semi rigid panel	rice stem	90% minimum	polyester fibers	NO	France	/
Rice husks	in bulk, uncompacted	rice husks	100%	NO	NO	France	/
	compacted, in bales	rice husks	100%	NO	NO	France	/
Wood chips	in bulk / loose	softwood and hardwood fibres from sawmills	75%	lime or clay (powder)	boron salts	Austria, France, Germany,	in development
Wood fibers	in bulk / loose		100%		amonium salts, 'boron salts	Austria, Belgium, France, Germany	Lenoo
	flexible panel		90 to 95%	synthetic or natural binder	amonium polyphosphate, borates	France, Germany,	/
	rigid panel		85 to 90%	parafine and PUR resin	fongicides and flame-retardants	France, Germany,	/
Natural organic insulation materials, from animals resources							
Sheep wool	in bulk / loose	shorn wool	100%	/	mothproof, flame-retardants	Austria, Belgium, France, Germany	Woolconcept
	flexible panel	shorn wool	70 to 100%	polyester fibers	mothproof, flame-retardants	Austria, Belgium, France, Germany	Woolconcept
Recycled organic insulation materials							
Cellulose fibers	in bulk / loose	Used, shredded and shredded paper	90% recycled paper		boric acid, boron salts, ammonium salts, magnesium sulphate	Austria, France, Germany	Isoproc, Isocell
	flexible panel		up to 90% recyceld paper	polyester fibers	fongicides and flame-retardants	France	/
Cellulose granules	in bulk / loose	used paper	100% recycled paper	NO	NO	Europe, Belgium	/
Cotton fibers	in bulk / loose	used cotton or textil	100% recycled cotton	other textil fibers	fongicides and flame retardants	France, Germany	/
	flexible panel	used cotton or textil	75% recyled cotton	polyester fibers	antibacterial agents, fongicides and flame retardant	France, Germany	/
Flax and paper fibers	rigid panel		100%	NO	NO	Belgium	Acoustix

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Attention was also given to:

- Ecological and IAQ labels,
- Existence of EPDs
- Environmental data included in Totem tool

Also identified in literature review:

- Jute and hemp fibers
- Flax granules
- Reed granules
- Seewead in bulk
- Seewead mattress

Methodology - Inventories

(1.b) Technical performances of biobased insulation

Insulation materials	Thermal Conductivity W/mK		Density kg/m³		Specific heat capacity J/kgK		Volumetric heat capacity kg.J/m³.K		Thermal diffusivity m²/s		Theorical thickness to achieve R=5 m².K/W	
	min	max	min	max	min	max	min	max	min	max	min	max
Cereal straw - balls	0,045	0,085	80	250	1600	1600	128	400	0,352	0,213	0,23	0,43
Cereal husks - balls	0,049	0,065	70	150	1600	1600	112	240	0,438	0,271	0,25	0,33
Cork- granules	0,041	0,049	60	180	1670	1670	100	301	0,409	0,163	0,21	0,25
Cork - rigid panel	0,035	0,048	70	200	1800	1800	126	360	0,278	0,133	0,18	0,24
Flax fibers - flexible mat	0,037	0,045	25	400	1600	1600	40	640	0,925	0,070	0,19	0,23
Grass fibers - flexible mat	0,041	0,041	35	45	2200	2200	77	99	0,532	0,414	0,21	0,21
Hemp fibers - flexible mat	0,040	0,050	28	110	1800	2300	50	253	0,794	0,198	0,20	0,25
Hemp - granules	0,050	0,060	100	250	2300	2300	230	575	0,217	0,104	0,25	0,30
Hemp lime -rigid block	0,065	0,115	300	650	1700	2100	510	1365	0,127	0,084	0,33	0,58
Hemp and cellulose fibers - flexible mat	0,040	0,040	45	45	1800	1800	81	81	0,494	0,494	0,20	0,20
Hemp and cotton fibers - flexible mat	0,038	0,052	15	40	1800	1800	27	72	1,407	0,722	0,19	0,26
Hemp and flax fibers	0,041	0,041	30	30	1800	1800	54	54	0,759	0,759	0,21	0,21
Hemp, flax and cotton fibers	0,038	0,038	30	40	1800	1800	54	72	0,704	0,528	0,19	0,19
Micelium	0,040	0,180	57	100	NS	NS	NS	NS	NS	NS	0,20	0,90
Miscanthus Block	0,070	0,090	440	440	NS	NS	NS	NS	NS	NS	0,35	0,45
Miscanthus granules	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Reed - rigid panel	0,056	0,065	100	200	1600	1600	160	320	0,350	0,203	0,28	0,33
Rice straw - flexible mat	0,039	0,039	50	50	1790	1790	90	90	0,436	0,436	0,20	0,20
Rice husks	0,043	0,052	117	153	1600	1600	187	245	0,230	0,212	0,22	0,26
Wood fibers - in bulk	0,038	0,038	25	60	2100	2100	53	126	0,724	0,302	0,19	0,19
Wood fibers - flexible mat	0,036	0,040	40	75	1900	2000	76	150	0,474	0,267	0,18	0,20
Wood fibers - rigid panel	0,038	0,050	100	300	2100	2100	210	630	0,181	0,079	0,19	0,25
Wood chips	0,040	0,090	70	350	1600	2300	112	805	0,357	0,112	0,20	0,45
Sheep wool - flexible mat	0,035	0,041	12	30	1720	1800	21	54	1,696	0,759	0,18	0,21
Recycled cellulose fibers in bulk	0,036	0,045	25	60	2100	2100	53	126	0,686	0,357	0,18	0,23
Recycled cellulose granules	0,108	0,112	455	455	NS	NS	NS	NS	0	0	0,54	0,56
Recycled cotton fibers- in bulk	0,042	0,049	10	15	1600	1600	16	24	2,625	2,042	0,21	0,25
Recycled cotton fibers - flexible mat	0,039	0,047	20	25	1600	1600	32	40	1,219	1,175	0,20	0,24
Flax and paper fibers	0,053	0,053	260	260	NS	NS	NS	NS	0	0	0,27	0,27

Those performance were compared to conventional insulation such as wool minerals and plastic foams (PUR, EPS, XPS,…)

Table © S. Trachte

Methodology - Inventories

(1.b) Technical performances of biobased insulation

Insulation materials	Theorical thickness to achieve R=5 m².K/W		Moisture behaviour				Fire Resistance class according EN 13501-1	Acoustic absorption according ISO 11654
			Water vapour diffusion resistance		Water absorption - W (kg/m²)			
	min	max	min	max	min	max		
Cereal straw - balls	0,23	0,43	1	2	14,9	14,9	class E	class C
Cereal husks - balls	0,25	0,33	NS	NS	NS	NS	NS	NS
Cork- granules	0,21	0,25	2,9	30	0,68	0,68	class B2 to E	class C
Cork - rigid panel	0,18	0,24	5	30	0,5	1	class E	class D
Flax fibers - flexible mat	0,19	0,23	5,7	5,7	1,7	1,7	class C-s2	class D
Grass fibers - flexible mat	0,21	0,21	1	2	4,6	4,6	class E	class B
Hemp fibers - flexible mat	0,20	0,25	1	2	4,2	4,2	class E	class C
Hemp - granules	0,25	0,30	2	3	NS	NS	class E	NS
Hemp lime -rigid block	0,33	0,58	1	3	NS	NS	class B-s1,d0	class B
Hemp and cellulose fibers - flexible mat	0,20	0,20	2	2	7,3	10,3	class E	class A
Hemp and cotton fibers - flexible mat	0,19	0,26	1	2	NS	NS	class E	class A
Hemp and flax fibers	0,21	0,21	1	2	NS	NS	class E	class B
Hemp, flax and cotton fibers	0,19	0,19	1	2	0,7	2,2	NS	class A
Micelium	0,20	0,90	4	4	1	1	NS	class D
Miscanthus Block	0,35	0,45	NS	NS	NS	NS	NS	NS
Miscanthus granules	NS	NS	NS	NS	NS	NS	NS	NS
Reed - rigid panel	0,28	0,33	NS	NS	NS	NS	NS	class C
Rice straw - flexible mat	0,20	0,20	2,8	4	NS	NS	class E	class B
Rice husks	0,22	0,26	NS	NS	NS	NS	class C-s2-d0	NS
Wood fibers - in bulk	0,19	0,19	1	2	NS	NS	class E	NS
Wood fibers - flexible mat	0,18	0,20	1	3	1	1	class E	class A
Wood fibers - rigid panel	0,19	0,25	2	5	1	3	class E	class C
Wood chips	0,20	0,45	1	4	NS	NS	class E	NS
Sheep wool - flexible mat	0,18	0,21	2	5	0,27	2,45	class E	class C
Recycled cellulose fibers in bulk	0,18	0,23	1	2	7	15	class B-S1,d0 to E	class A
Recycled cellulose granules	0,54	0,56	2	3	34	34	class E	NS
Recycled cotton fibers- in bulk	0,21	0,25	1	2	NS	NS	class B-s2,d0 to F	NS
Recycled cotton fibers - flexible mat	0,20	0,24	2	3	3	4	class D-s2,d0 to E	class B
Flax and paper fibers	0,27	0,27	NS	NS	NS	NS	class F	class A

Lack of data in scientific literature as well as in technical sheets from producers

Table © S. Trachte

Methodology - Inventories
(1.c) Use and application of biobased insulation in retrofit

Insulation materials	Form of products	Pitched roof				Flat roof		Attic floor		Façade			
		Sarking system above rafters	*Sarking system with wood frame*	*Between purlins and rafters*	*Between and under purlins*	*On slab or structure, by outside*	*Between wood frame*	*On the floor (slab or wood frame)*	*Between wood frame*	*By outside glued or mechanically fixed*	*By outside, between wood frame*	*By inside glued*	*By inside, between wood frame*
Natural organic insulation materials, from biobased resources													
Cereal straw	in bulk / loose		v	v	v		v	v	v		v		v
	in bales		v								v		v
Cereal husks	in bulk / loose		v	v	v		v	v	v		v		v
Cork	in bulk / loose		v	v	v		v	v	v		v		v
	rigid panel	v	v			v		v		v	v	v	v
Flax fibers	flexible panel		v	v	v		v	v	v		v		v
Hemp fibers	in bulk / loose		v	v	v		v	v	v		v		v
	flexible panel		v	v	v		v	v	v		v		v
	rigid panel		v	v	v		v	v	v		v		v
Hemp granules	in bulk / loose		v	v	v		v	v	v		v		v
Hemp-lime	plaster and blocks							v		v	v	v	v
	rigid panel							v		v	v	v	v
Hemp and cellulose fibers	flexible panel		v	v	v		v	v	v		v		v
Hemp and cotton fibers	in bulk / loose		v	v	v		v	v	v		v		v
	flexible panel		v	v	v		v	v	v		v		v
Hemp and flax fibers	flexible panel		v	v	v		v	v	v		v		v
Hemp, flax and cotton fibers	flexible panel		v	v	v		v	v	v		v		v
Grass fibers	flexible panel		v	v	v		v	v	v		v		v
Mycelium	rigid panel	v	v			v		v		v	v	v	v
Miscanthus	blocs (argile et chaux)							v		v	v	v	v
	in bulk / loose		v	v	v		v	v	v		v		v
Reed	rigid panel							v				v	
Rice straw	semi rigid panel		v	v	v		v	v	v		v		v
Rice husks	in bulk, uncompacted		v	v	v		v	v	v		v		v
	compacted, in bales		v	v	v			v	v		v		v
Wood chips	in bulk / loose		v	v	v		v	v	v		v		v
Wood fibers	in bulk / loose		v	v	v		v	v	v		v		v
			v	v	v		v	v	v		v		v
	flexible panel		v	v	v		v	v	v		v		v
	rigid panel	v				v		v		v	v	v	v

Various solutions for different applications in buildings, and especially for roof and walls

Table © S. Trachte

Methodology - Inventories

(1.d) Circular character of biobased insulation

Insulation materials	Form of products	Use of byproducts	Recycled content	Percentage of drop in implementation *according EPD*	Producer take-back system	Potential of waste valorisation						
						Reuse	Pretreatment before recycling	Upcycling potential	Downcycling	Organic recovery	Heat recovery	Landfill
Natural organic insulation materials, from biobased resources												
Cereal straw	in bulk / loose	100%	/	5%	NO	Possible	/	/	Animal litter	Possible	Actual treatment	Actual treatment
	in bales	100%	/	NS	NO	Possible	/	/	Animal litter	Possible	Actual treatment	Actual treatment
Cereal husks	in bulk / loose	100%	/	5%	NO	Possible	/	/	/	Possible	Actual treatment	Actual treatment
Cork	in bulk / loose	100%	100% cork stoppers	NS	YES Recycork	Possible	/	Cork concrete	/	Possible	Actual treatment	Actual treatment
	rigid panel	98%	/	5%	YES Recycork	Depends on the assembly	Crushing	Cork concrete	Cork granules	Not possible if expanded	Actual treatment	Actual treatment
Flax fibers	flexible panel	80%	/	2%	NO	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Flax fibers in bulk	Not possible	Actual treatment	Actual treatment
Hemp fibers	in bulk / loose	100%	/	0%	NO	Possible	/	/	/	Possible if no fongicide	Actual treatment	Actual treatment
	flexible panel	85% to 90%	/	2%	NO	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Hemp fibers in bulk	Not possible	Actual treatment	Actual treatment
	rigid panel	85%	/	2 to 5%	NO	Depends on the assembly	Crushing or pulping	Depends on the % of synthetic fibres	Hemp fibers in bulk	Not possible	Actual treatment	Actual treatment
Hemp granules	in bulk / loose	100%	/	0%	NO	Possible	/	Production of hemp lime	/	Possible	Actual treatment	Actual treatment
Hemp-lime	plaster and blocks	70 to 90%	/	3%	NO	Not possible	Crushing	Reintroduction in the manufacturing process	Hemp granules	Possible	/	Actual treatment
	rigid panel	70 to 90%	/	3%	NO	Not possible	/	Reintroduction in the manufacturing process	Hemp granules	Possible	/	Actual treatment
Hemp and cellulose fibers	flexible panel	30%	60 % recycled paper	2%	YES Biofib	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Hemp / cellulose fibers in bulk	Not possible	Actual treatment	Actual treatment
Hemp and cotton fibers	in bulk / loose	50%	50% recycled cotton	NS	NO	Possible	/	/	/	Not possible	Actual treatment	Actual treatment
	flexible panel	40%	50% recycled cotton	2%	NO	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Hemp / cotton fibers in bulk	Not possible	Actual treatment	Actual treatment
Hemp and flax fibers	flexible panel	90%	/	NS	NO	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Hemp / flax fibers in bulk	Not possible	Actual treatment	Actual treatment
Hemp, flax and cotton fibers	flexible panel	/	/	2%	YES Biofib	Possible	Crushing or pulping	Depends on the % of synthetic fibres	Hemp / flax / cotton fibers in bulk	Not possible	Actual treatment	Actual treatment
Grass fibers	flexible panel	/	70% grass 20% recycled jute fibers	2%	NO	Possible	Crushing or pulping	Reintroduction in the manufacturing process	/	Not possible	Actual treatment	Actual treatment
Mycelium	rigid panel	100%	/	NS	NO	Depends on the assembly	NS	NS	NS	Possible	NS	NS
Miscanthus	blocks (lime and clay)	100%	/	NS	NO	Not possible	Crushing	Reintroduction in the manufacturing process	Miscanthus granules	Possible	NS	NS
	in bulk / loose	100%	/	NS	NO	Possible	/	Reintroduction in the manufacturing process	/	Possible	NS	NS
Reed	rigid panel	100%	/	NS	NO	Possible if not glued	Panel disassemby or crushing	Reintroduction in the manufacturing process	Reed granules in bulk	Possible, without metallic bonds	Actual treatment	Actual treatment

Table © S. Trachte

Potential currently underexploited

Actual treatment = CO_2 emissions

Methodology - Analysis
(2) Reversibility potential of biobased insulation assemblies

Type of assembly	Type of insulation material	Reversibility of connection	Simplicity of disassembly	Speed of disassembly	Ease of handling
Insulation by inside					
Bonded connection	Rigid panels or blocks	no reversible	/	/	/
By friction between frames	Flexible mats	reversible	very simple	very speedy	very easy to handle manually
Mechanical connection with staples between frames	Flexible mats	reversible	simple	speedy but time required for staples removal	very easy to handle manually
By insufflation between frames	In bulk	reversible	complex, requires specific tools and/or several workers	rather slow disassembly	can be handled manually, but requires two or more workers
Insulation by outside					
Fixing by screw and glue	Rigid panels	no reversible	/	/	/
Mechanical connection with screw	Rigid panel	reversible with small damages		rather slow disassembly	
By friction between frames	Flexible mats	reversible	very simple	very speedy	very easy to handle manually
Mechanical connection with staples between frames	Flexible mats	reversible	simple	speedy but time required for staples removal	very easy to handle manually
By insufflation between frames	In bulk	reversible	complex, requires specific tools and/or several workers	rather slow disassembly	can be handled manually, but requires two or more workers

Table © S. Trachte and E. Gobbo

Methodology – Analysis

(3) Environmental assessment of biobased insulation

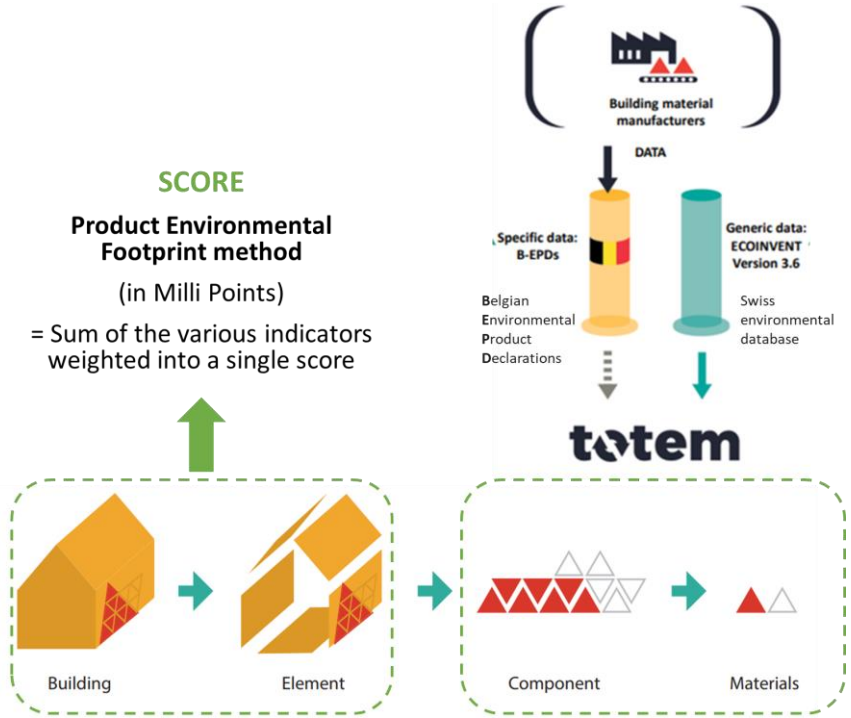


Figure 1: Illustration of the hierarchical structure of TOTEM and its four levels of analysis.

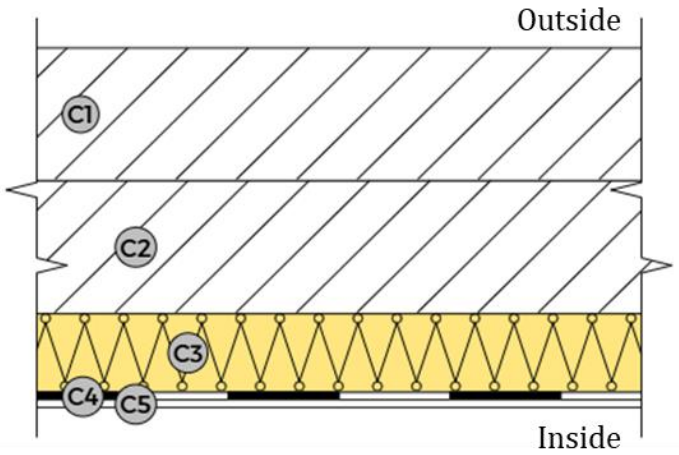
- Based on 18 indicators defined by the EN 15804-A2 standard and over 60 years (including maintenance and replacement)
- Unique environmental score (PEF weighting method) + a detailed breakdown by indicator and life cycle stage
- Materials database : generic data + EPD's data
- Various materials status : existing, new, reused, demolished

Methodology - Analysis

(3) Environmental assessment of biobased insulation

Three scenarios were investigated by varying the nature of the insulation

Scen. 01 – U=0,24W/m²K

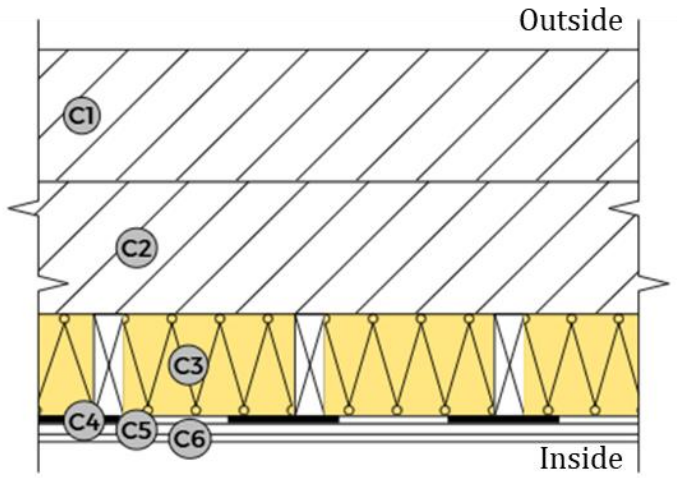


Glued rigid panel

Biobased insulation : hemp-lime, cork and wood

Conventional insulation : EPS, PUR, rockwool and silicate calcium

Scen. 02 – U=0,24W/m²K

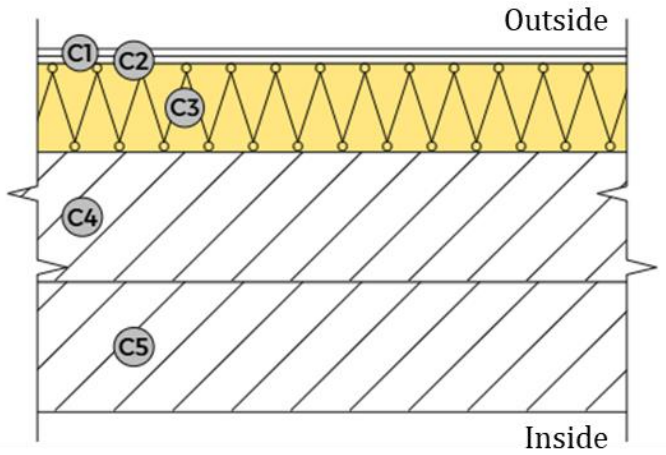


Flexible mat or in bulk

Biobased insulation : cellulose, cork, cotton, grass, flax, hemp, straw and wood

Conventional insulation : EPS, glass wool, PUR, rockwool

Scen. 03 – U= 0,24W/m²K



Glued and mechanically fixed rigid panel

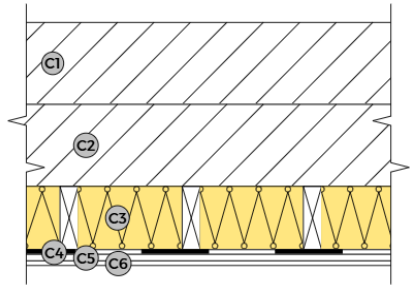
Biobased insulation : cork and wood

Conventional insulation : EPS, PUR, rockwool and silicate calcium

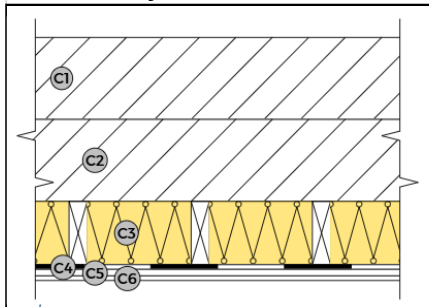
Methodology - Analysis

(3) Environmental assessment of biobased insulation

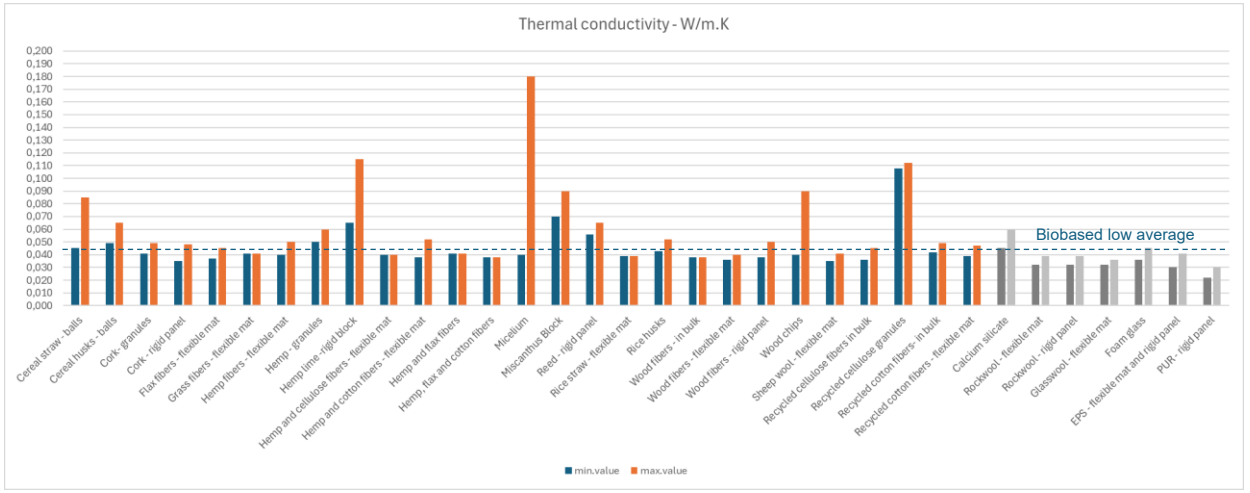
The evaluation was conducted on a one-square-meter wall using a three-step modelling approach. Except existing brick wall, all materials were considered as “new”

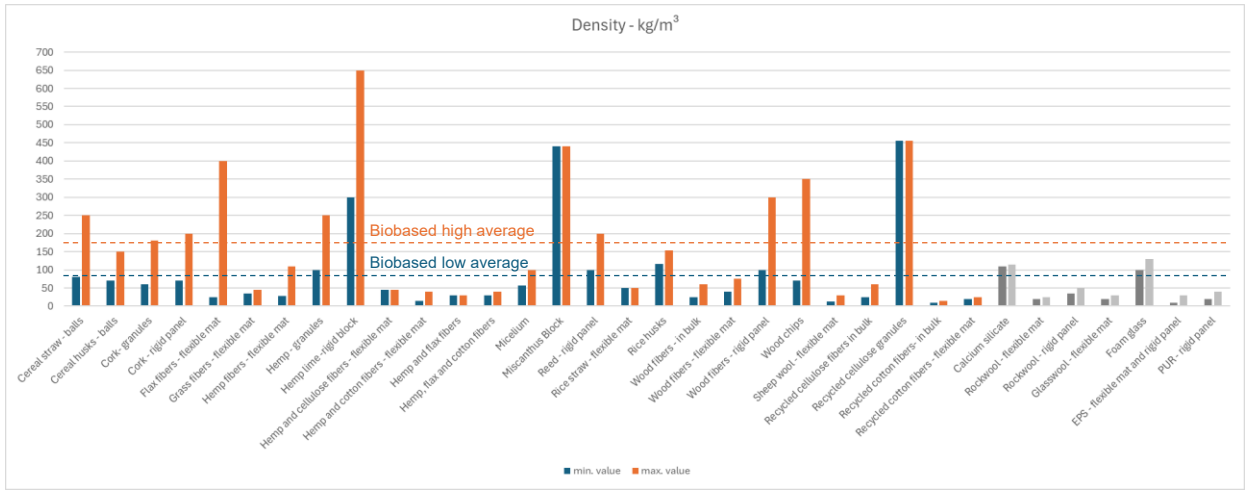
Insulation system	Wall composition composition (external to internal)					
	**Layers**	**Thickness**	**Percentage**	**Materials**	**Status**	**Modelisation**
	C1	22	100%	Solid brick - fired clay - laid in lime mortar	Existing	Step 01
	C2	22	100%	Solid brick - fired clay - laid in lime mortar	Existing	
	C3	varying	15%	Woodframe - nailed	New	Step 02
			85%	Insulation - flexible mat or in bulk blown on site	New	Step 3
	C4	0,025	100%	Proofing sheet - stapled	New	Step 02
	C5	1,8	100%	OSB board - nailed	New	
	C6	1,25	100%	Gypsum plaster board - screwed	New	

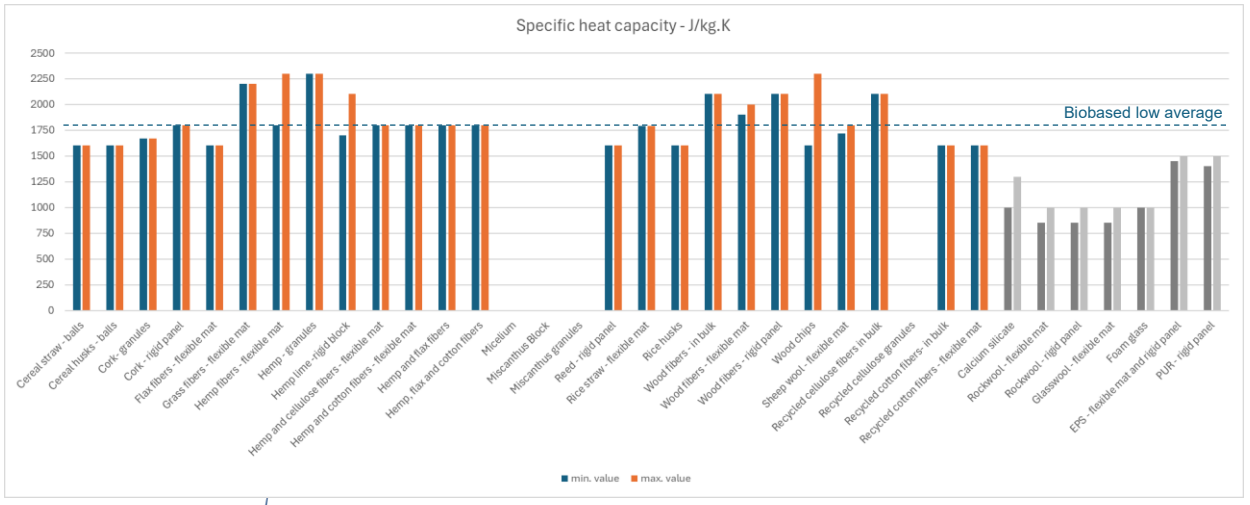
A last evaluation has considered reused insulation materials – modelling with status « ex-situ reused »

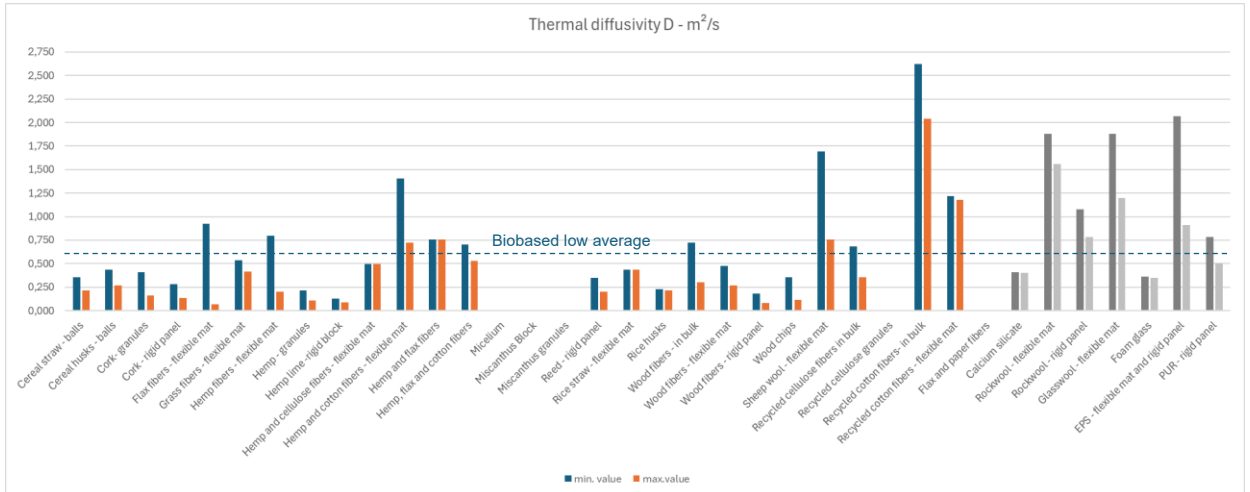
Insulation system	Wall composition composition (external to internal)				
	Layers	Thickness	Percentage	Materials	Status
	C1	22	100%	Solid brick - fired clay - laid in lime mortar	existing
	C2	22	100%	Solid brick - fired clay - laid in lime mortar	existing
	C3	varying	15%	Woodframe - nailed	new
			85%	Insulation - flexible mat or in bulk blown on site	reused (ex-situ)
	C4	0,025	100%	Proofing sheet - stapled	new
	C5	1,8	100%	OSB board - nailed	new
	C6	1,25	100%	Gypsum plaster board - screwed	new

Results - technical qualities of biobased insulation

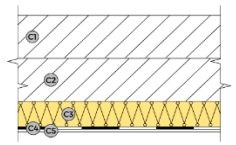


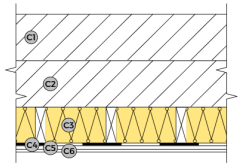


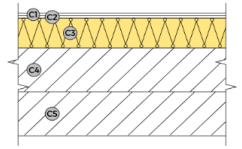




Results - reversibility

Scen. 01 (insulation by inside)	Materials	Reversibility of connection	Simplicity of disassembly	Speed of disassembly	Ease of handling
	Solid brick - laid in lime mortar				
	Solid brick - laid in lime mortar				
	Insulation - bonded panel				
	Proofing layer - glued				
	Gypsum plaster board - glued				

Scen. 02 (insulation by inside)	Materials	Reversibility of connection	Simplicity of disassembly	Speed of disassembly	Ease of handling
	Solid brick - laid in lime mortar				
	Solid brick - laid in lime mortar				
	Woodframe - nailed				
	Insulation - flexible mat				
	Insulation - in bulk				
	Proofing sheet - stapled				
	OSB board - nailed				
	Gypsum plaster board - screwed				

Scen. 03 (insulation by outside)	Materials	Reversibility of connection	Simplicity of disassembly	Speed of disassembly	Ease of handling
	External plaster				
	Insulation panel - glued and mechanically fixed				
	Solid brick - laid in lime mortar				
	Solid brick - laid in lime mortar				

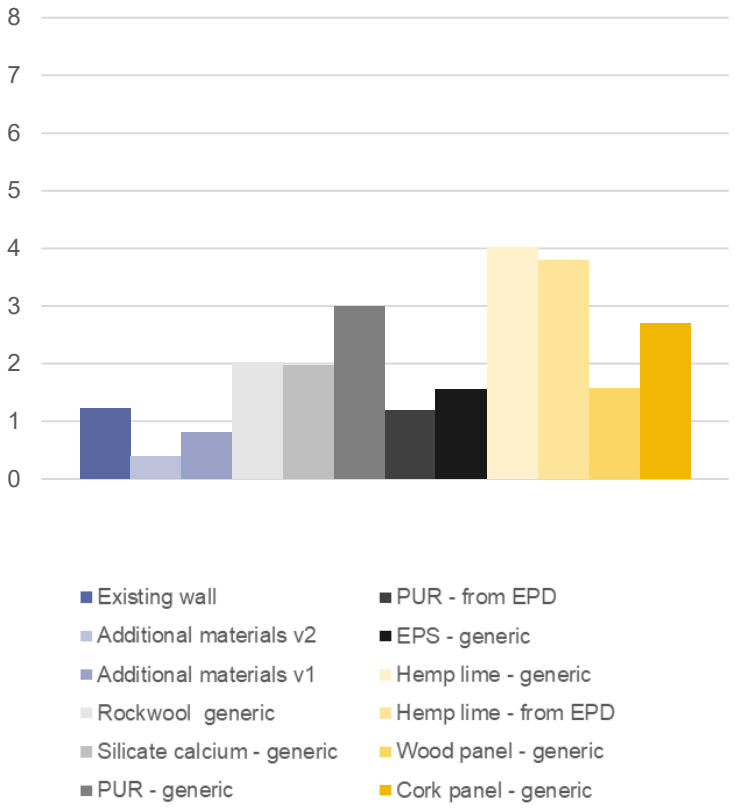
All materials used in this solution offer good reversibility

Most rigid panels solution - whether biobased or conventional - are not-reversible, limiting their reuse potential.

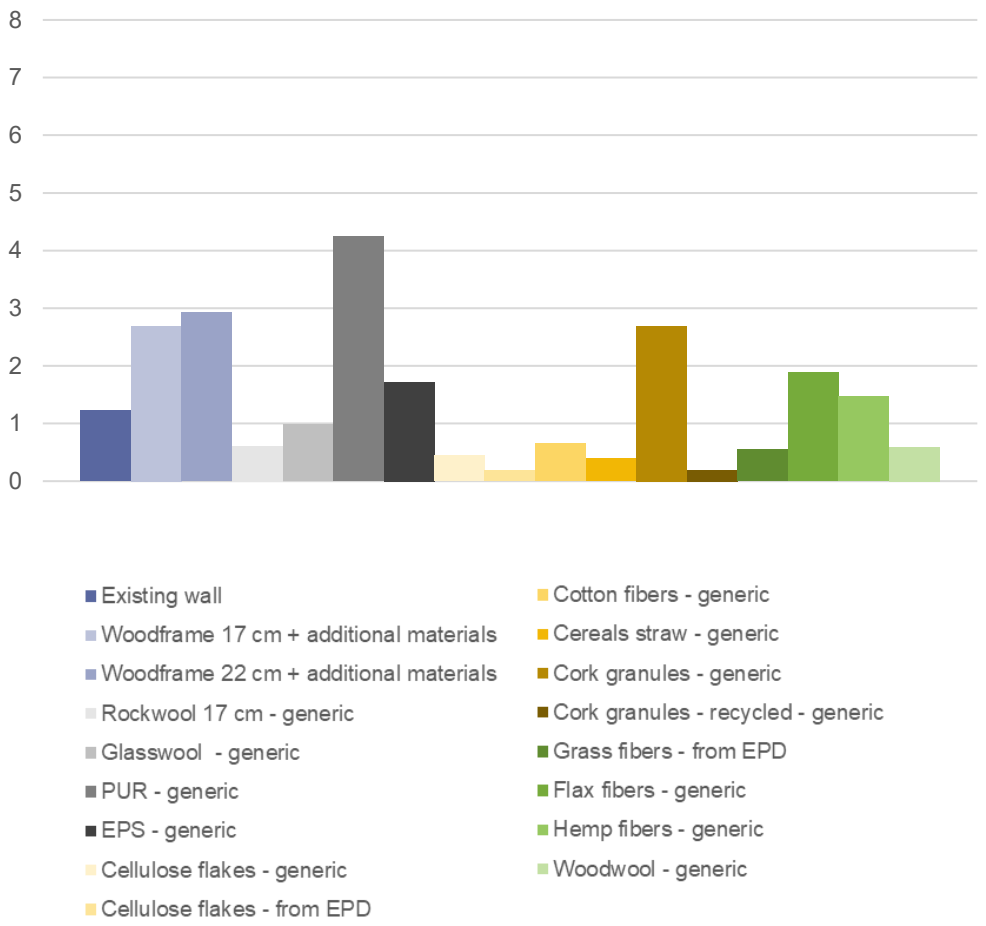
Currently, only mechanical connection and assemblies by friction or blowing within a frame enable reversibility and quite easy disassembly and handling

Results – environmental impact for 1m² of wall
Global score (mPt)

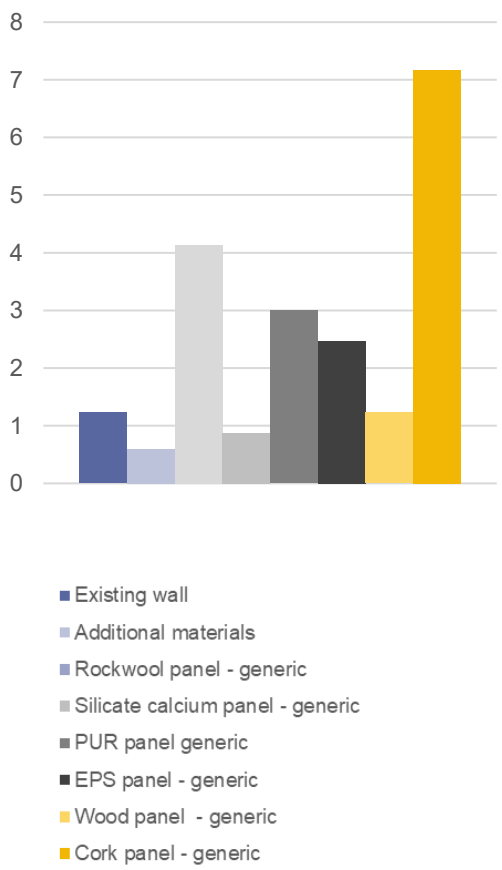
Scenario 01



Scenario 02



Scenario 03



Results – environmental impact for 1m² of wall

Carbon sequestration ($kgCO_2$ equ.) – modules A1- A3

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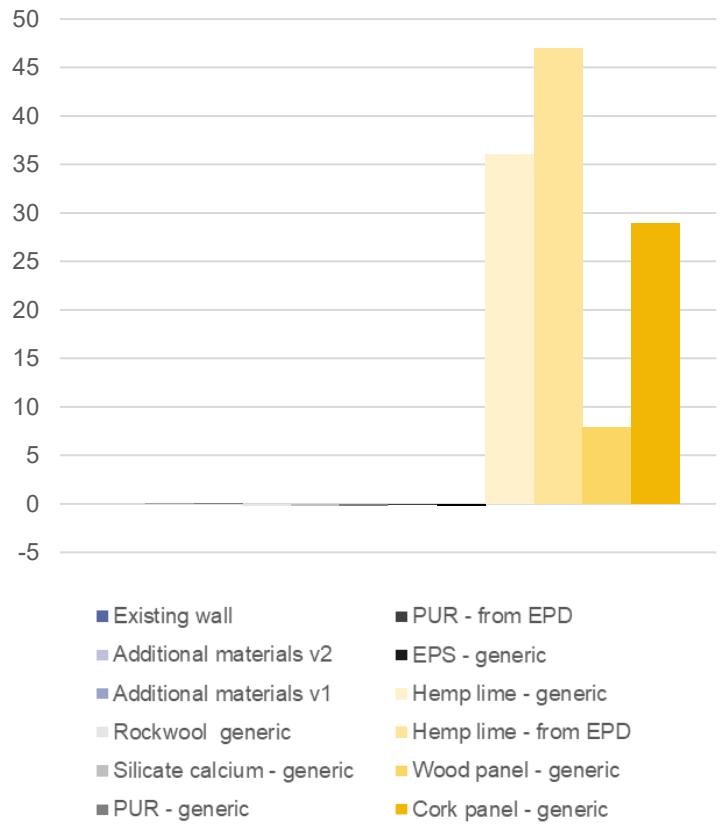
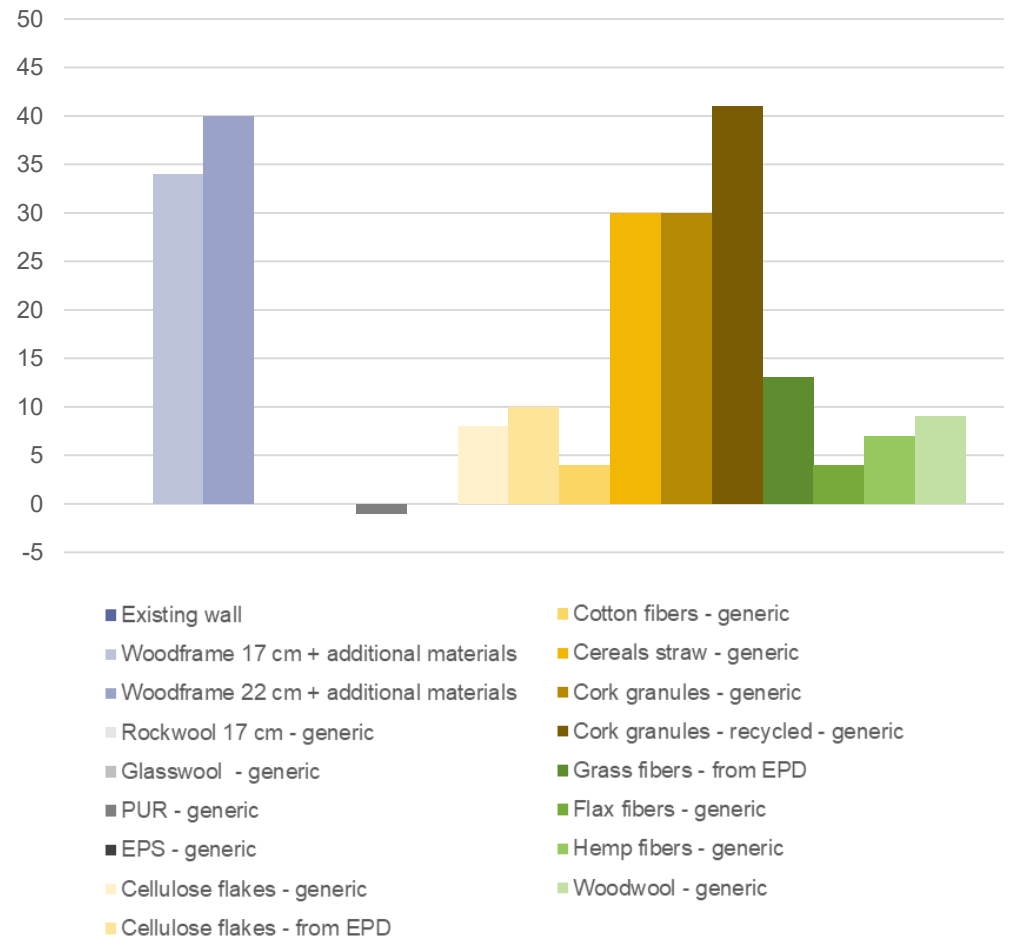
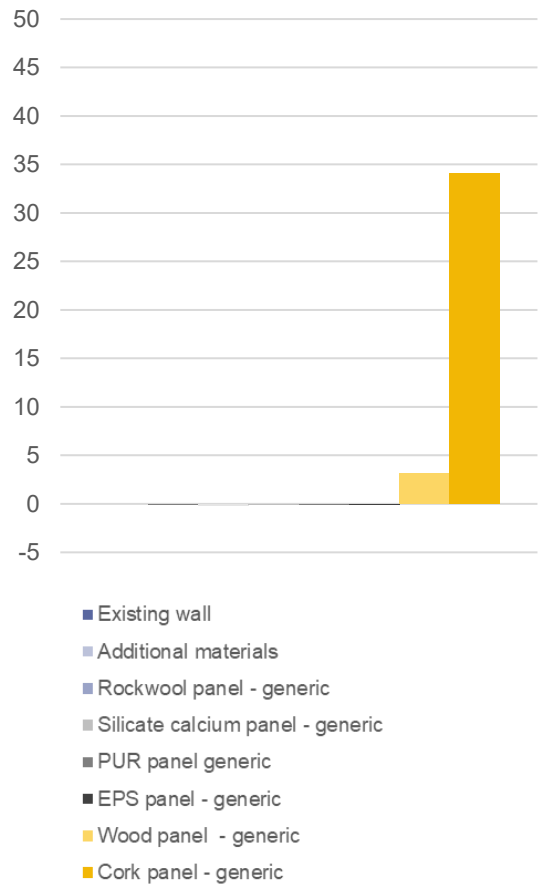
Scenario 01



Scenario 02



Scenario 03



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Results – environmental impact for 1m² of wall
Global warming potential ($kgCO_2$ equ.)

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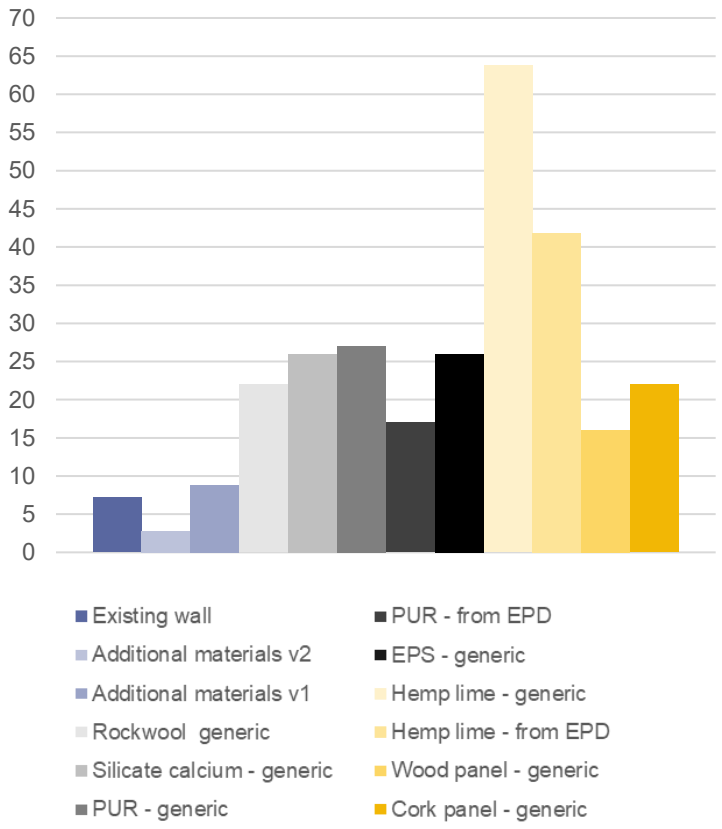
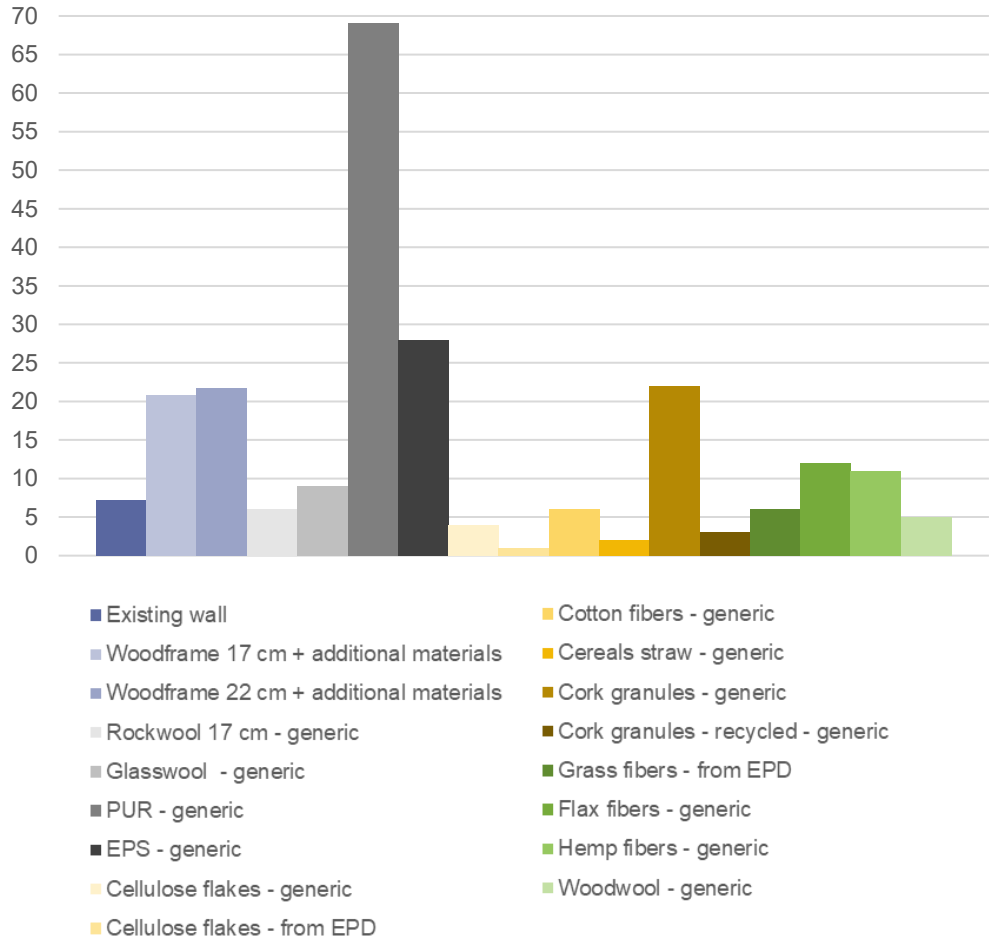
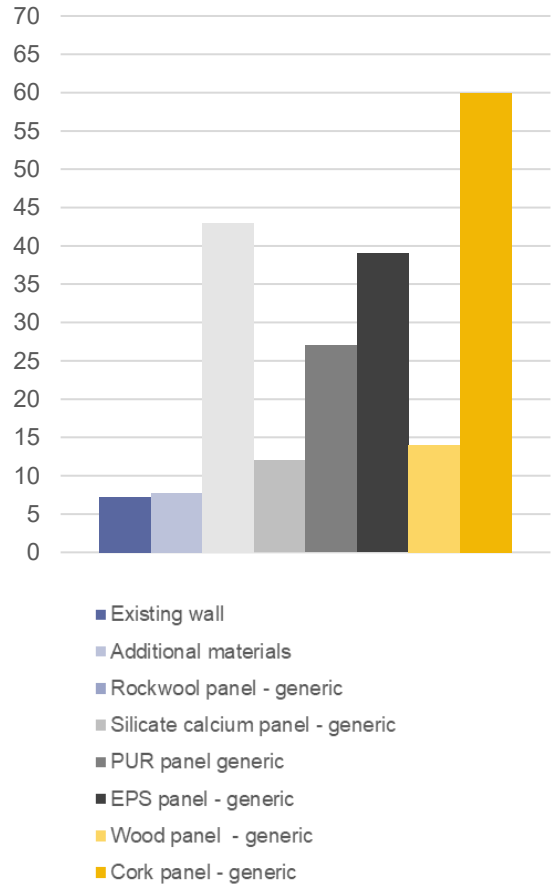
Scenario 01



Scenario 02



Scenario 03



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Results – environmental impact for 1m² of wall
Depletion of abiotic resources (fossils fuels, MJ)

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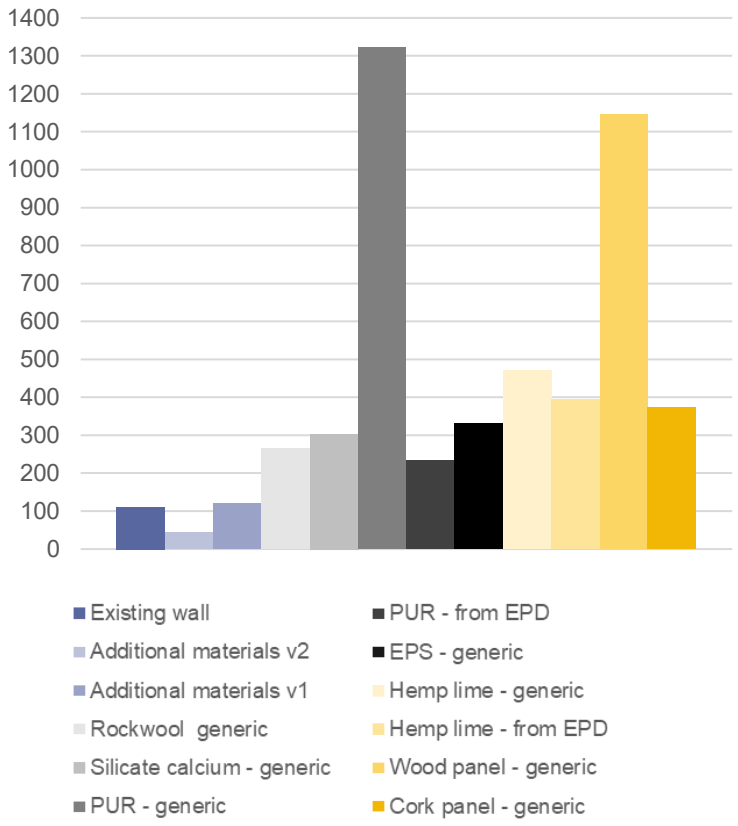
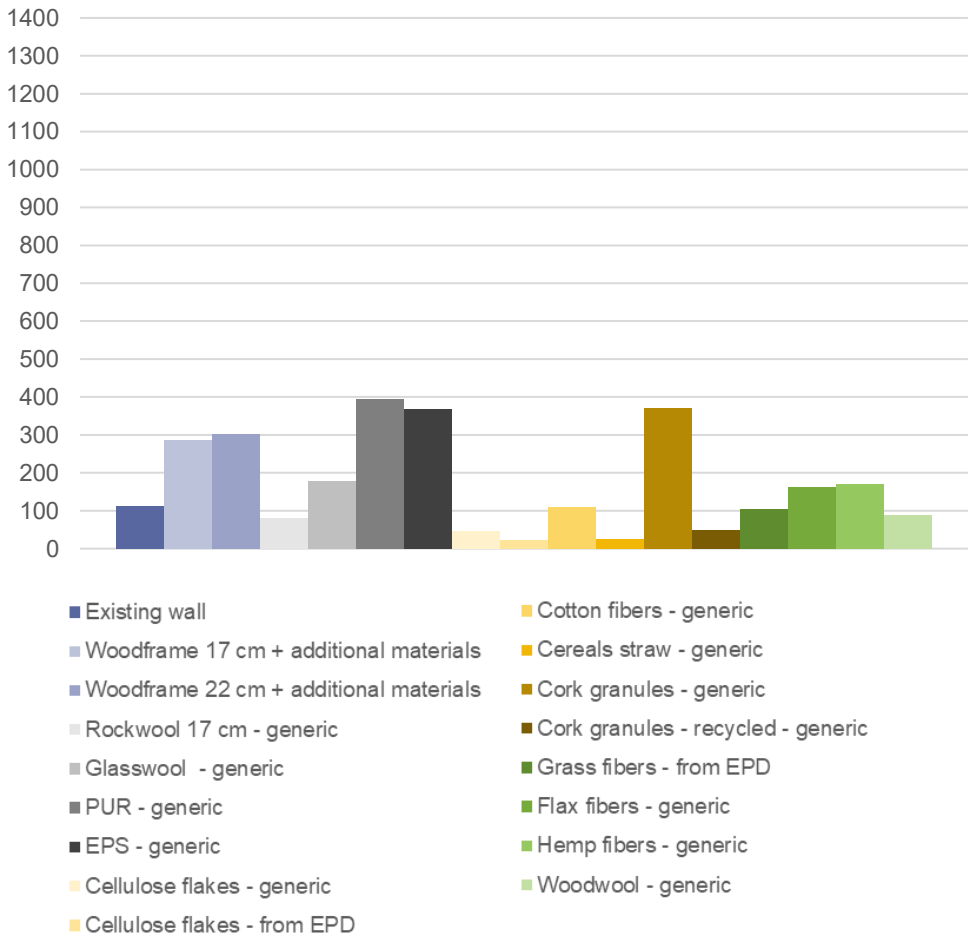
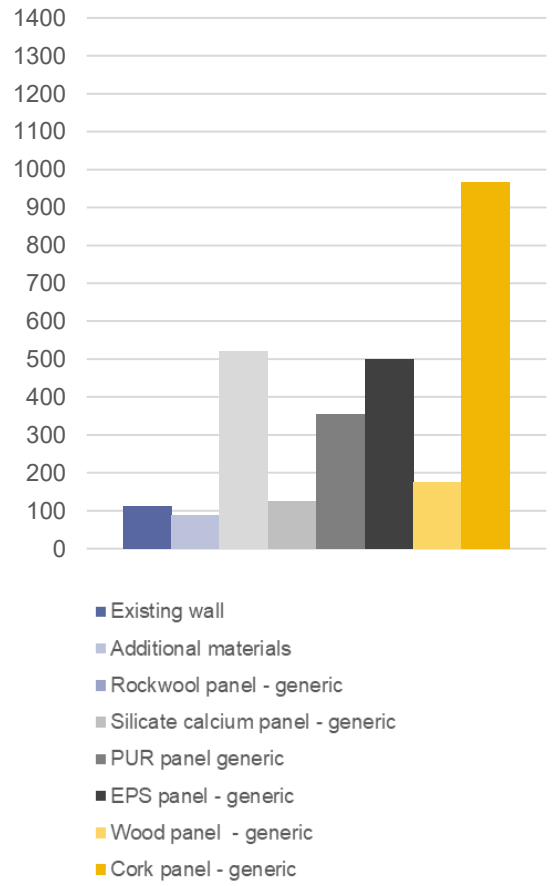
Scenario 01



Scenario 02



Scenario 03



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Results – environmental impact for 1m² of wall
Depletion of abiotic resources (minerals, kg Sb equ.)

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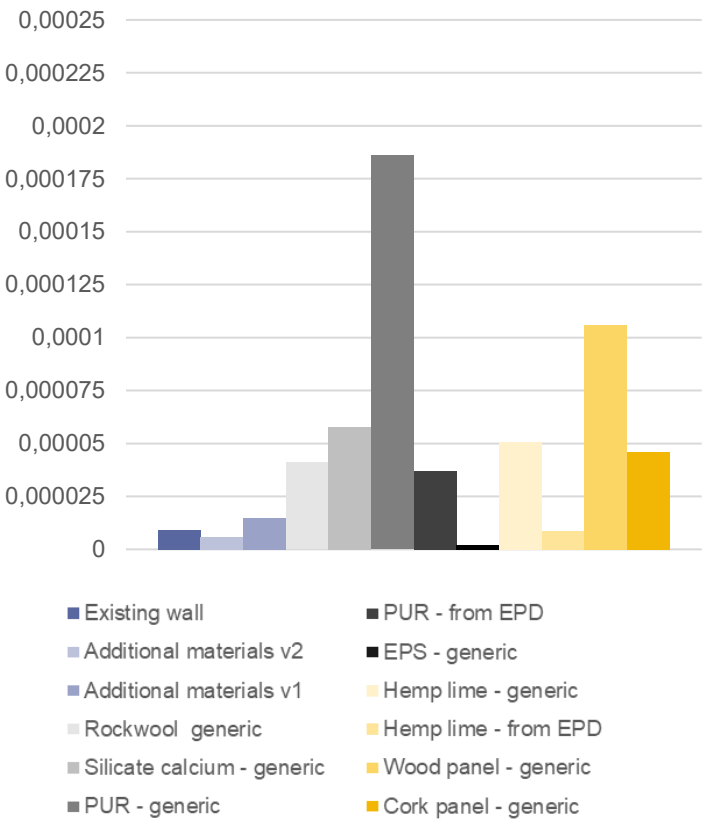
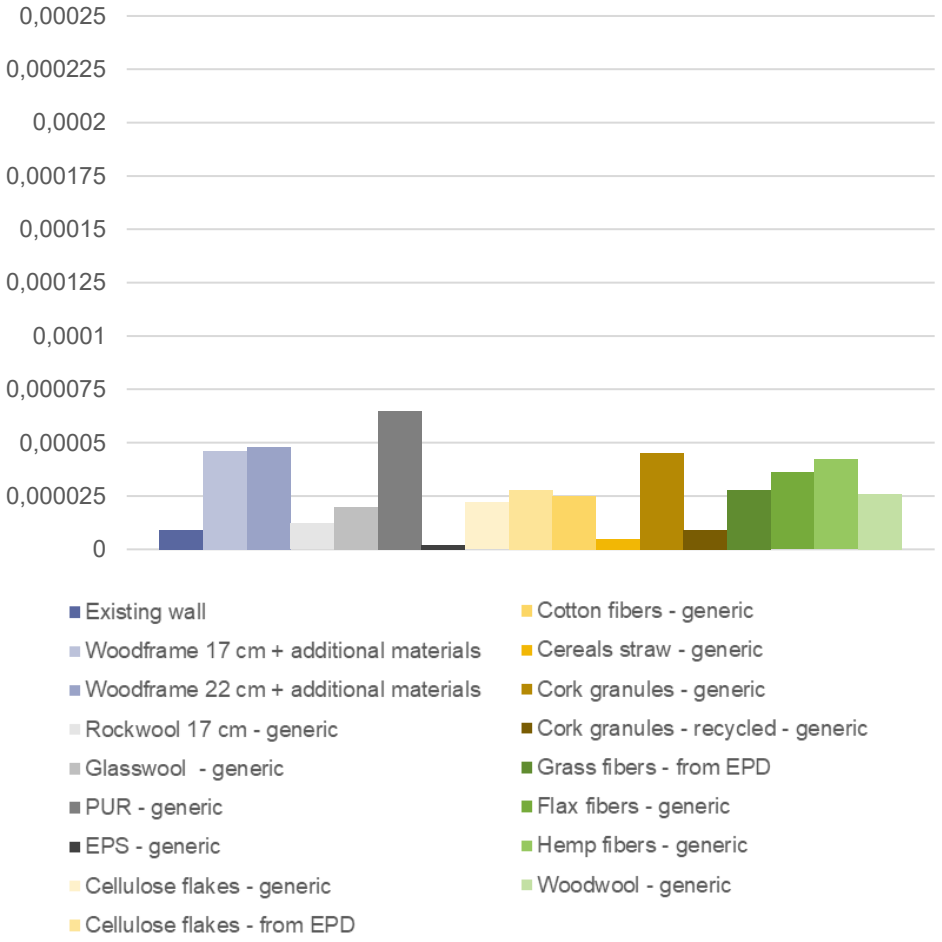
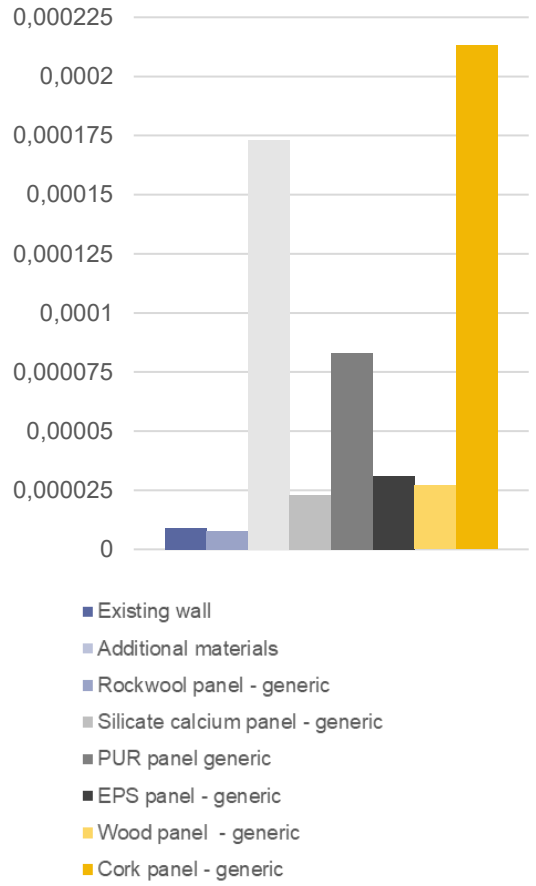
Scenario 01



Scenario 02



Scenario 03



SBE25 ZÜRICH

Conclusion
Materials with balanced character, beyond the carbon footprint

- Through a multicriteria approach, the study demonstrated that biobased materials could compete with conventional materials, as they offer
  - Technical and normative maturity
  - Various natures and forms ➡ solutions adapted to the specificities of each existing wall
- They enhance comfort (both in winter and summer) and energy efficiency in traditional buildings
  - Good thermal conductivity
  - High specific heat capacity
  - Very low thermal diffusivity
  - Considered as open to water vapor and hygroscopic
- They could be considered as drivers for local and circular economic development by using byproducts or waste, undergoing minimal processing and providing reversible assembly solutions
- They could help achieve carbon neutrality and sustainable resource management goals, **BUT** their global environmental performances must be assessed by considering the entire life cycle

Conclusion
Materials with balanced character, beyond the carbon footprint

Despite their technical, constructive and environmental benefits in energy renovation, bio-based insulation are still too often unknown by a large public and underused by professionals.

Develop **knowledge and expertise** in bio-based materials

- Research projects, including industrial development
- Specific academic curricula, for architects and engineers
- Living labs to co-share expertise
- Dissemination and training programs

Thank you for your attention

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Sophie Trachte[1] & Dorothée Stiernon[2]

Research Lab ACTE, Research Unit Art, Archeologie et Patrimoine (AAP), ULiège, Belgium
Louvain Research Institute for Landscape, Architecture, Built Environment (LAB), UCLouvain, Belgium

sophie.trachte@uliege.be, dorothee.stiernon@uclouvain.be

S. Trachte's publications

D. Stiernon's publications