Incseb
LOW CARBON STEEL ENVELOPE SYSTEMS

WORKSHOP PROGRAMME

- INTRODUCTION AND OVERVIEW OF THE INCSEB PROJECT
  L'Enveloppe Métallique du Bâtiment

DESCRIPTION OF THE 5 INNOVATIVE STEEL ENVELOPE SYSTEMS WITH WOOD FIBRE INSULATION

- Two prefabricated systems: cladding and pitch roofing sandwich panels with two steel facings and a wood fibre insulation core
  Monopanel
- Three site-assembled systems using wood fibre insulation: double skin steel system and facade cladding system with cassettes and flat roof sandwich panel
  Joris Ide

PERFORMANCE OF THE 5 INNOVATIVE STEEL ENVELOPE SYSTEMS

- Static and dynamic mechanical performances
  Technical University of Darmstadt and Tecnalia
- Building physic performances: thermal, air, water and vapour permeability, acoustic performances and fire performance
  Tecnalia and University of Coimbra

- DURABILITY OF THE 5 SYSTEMS: LESSONS LEARNED FROM OBSERVING (OVER A PERIOD OF 2 YEARS) THE REAL BEHAVIOUR OF THE SYSTEMS INCORPORATED IN 2 DEMONSTRATORS AND CONSISTENCY WITH LABORATORY RESULTS
  University of Coimbra and Technical University of Darmstadt

- LIFE CYCLE ASSESSMENT (LCA) FOR THE 5 INNOVATIVE STEEL ENVELOPE SYSTEMS
  L'Enveloppe Métallique du Bâtiment

- DETERMINATION OF THE CARBON FOOTPRINT (GWP) BENEFITS OBTAINED AT A BUILDING LEVEL
  University of Coimbra

- ECONOMIC ASSESSMENT FOR THE 5 INNOVATIVE STEEL ENVELOPE SYSTEMS
  L'Enveloppe Métallique du Bâtiment

- TOOLS, GUIDES AND DATA FOR DESIGNING AND IMPLEMENTING THE 5 SYSTEMS
  § Design guides, installation guides and BIM objects for cladding and pitch roofing sandwich panels
  Monopanel
  Design guides, installation guides and BIM objects for double skin steel system, facade cladding system with cassettes and flat roof sandwich panels
  Joris Ide

CONCLUSIONS
L'Enveloppe Métallique du Bâtiment

LOW CARBON STEEL ENVELOPE SYSTEMS

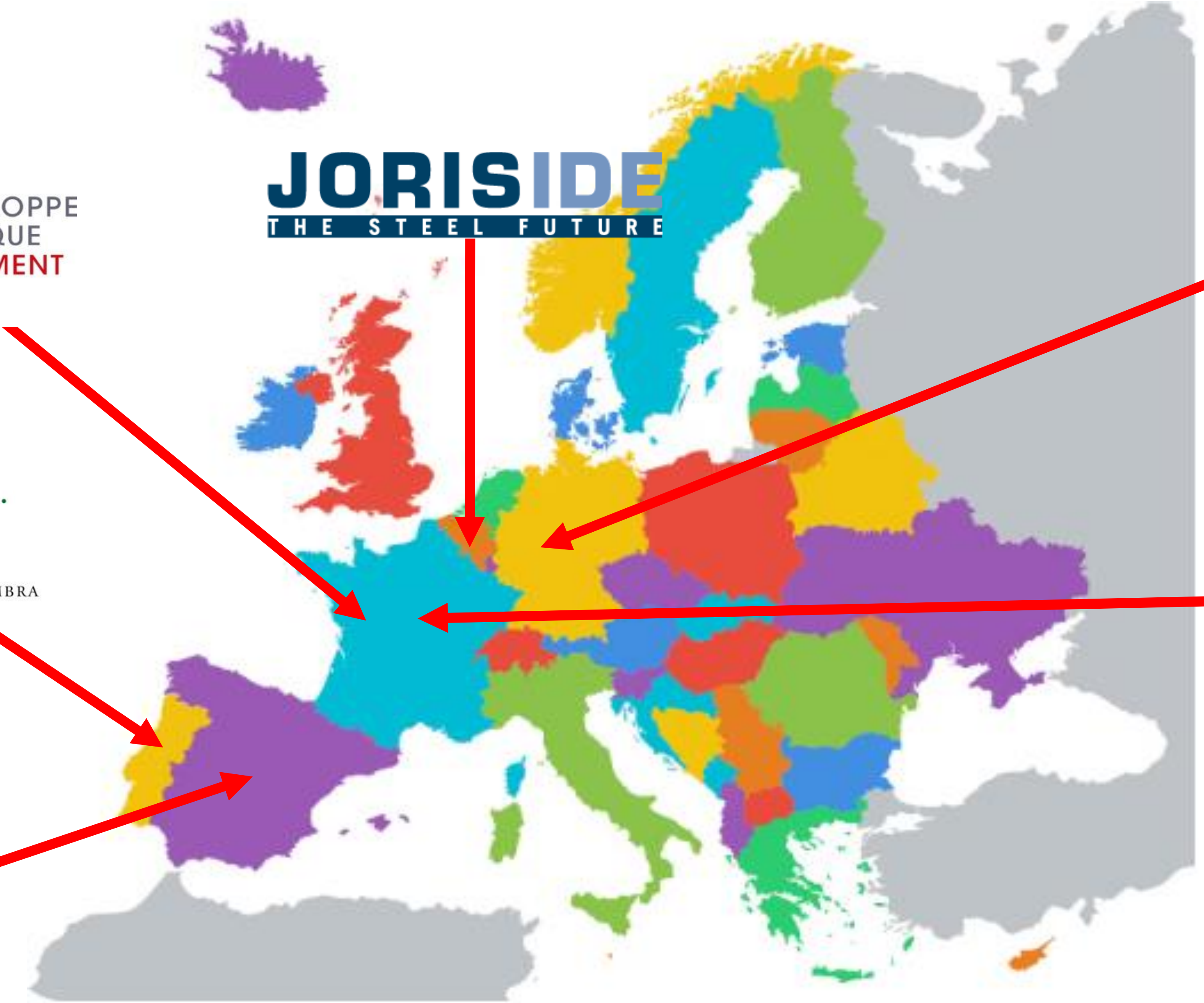
www.incseb.eu

Workshop, 7-9 rue La Pérouse 75116 PARIS

Thursday 12 June 2025, 14.00hrs to 18.00hrs

The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

6 PARTNERS FROM 5 EUROPEAN COUNTRIES



L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

JORISIDE
THE STEEL FUTURE

TECHNISCHE UNIVERSITÄT DARMSTADT

· U C ·
UNIVERSIDADE DE COIMBRA

monopanel BUILDING ENVELOPE
: your vision, our challenge

tecnalia
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

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Problem tackled by the Incseb project

i. Meeting the new low carbon construction requirements for the building envelope

ii. Propose new steel envelope systems that will be both low carbon and meet all other performance requirements (thermal, mechanical, fire , acoustic…)

Development of a *3rd family* of steel envelopes!

NEW! →

1. *steel envelope systems with wood fibre insulation*
2. steel envelope systems with polyurethane insulation
3. steel envelope systems with mineral wool insulation

Main objectives of the Incseb project

1. Manufacture *5 low carbon steel envelope systems* which incorporate the innovative use of wood fiber:
   - ✓ Three sandwich panels (cladding & roofing) ,
   - ✓ One double skin cladding
   - ✓ One façade cladding system with cassette

2. *Evaluate all system performances* in laboratory and real-life conditions (construction of 2 demonstrators in Germany): mechanical, thermal, fire, acoustic performances and air permeability and vapour and water permeability, durability, LCA indicators

The project began on 1 August 2021 and will end on 31 July 2025 (duration of 4 years)

WORKSHOP ORGANISATION

The workshop is divided into 5 main sections:

1. Presentation of the 5 systems developed
2. Systems' performance : description of the tests and studies carried out, in the lab or in real-life conditions, and the results obtained with classification reports

Questions & Answers session

16H-16H30 Coffee Break

3 Specific point on carbon performance at system/product level and building level

4. Economic study

5. Practical design & installation guides

Questions & Answers session

17H55 Conclusion

18H00-19H30 Cocktail reception

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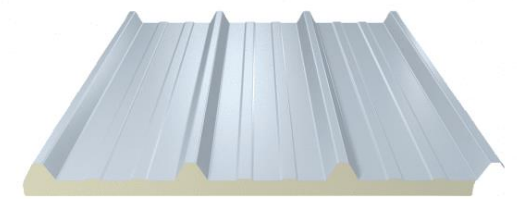
LOW CARBON STEEL ENVELOPE SYSTEMS

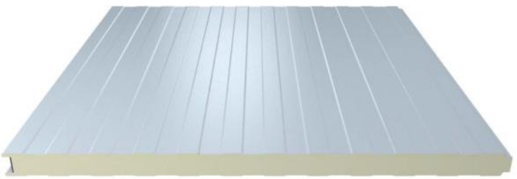
INCSEB Workshop

Innovative low-carbon prefabricated steel envelope solutions

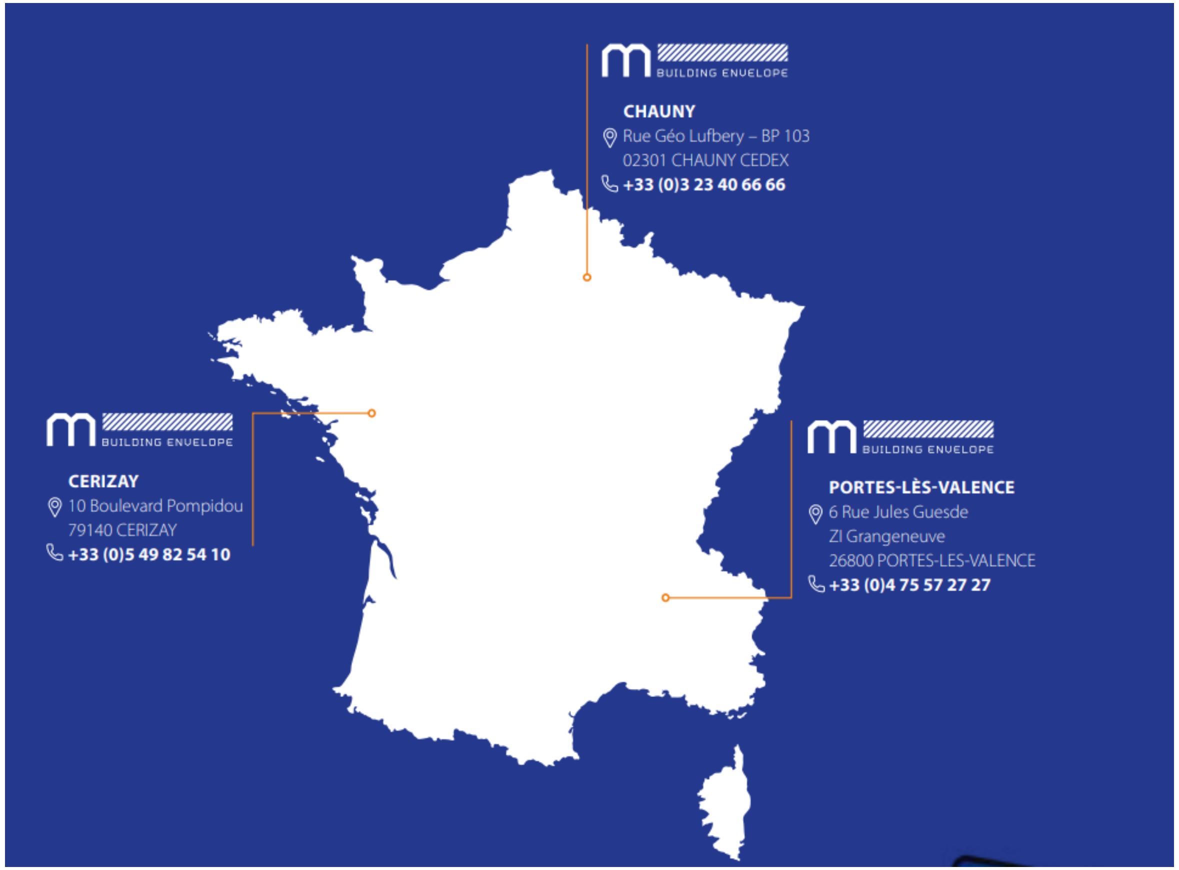
monopanel BUILDING ENVELOPE

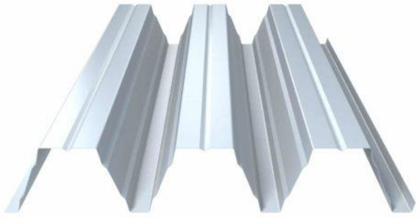
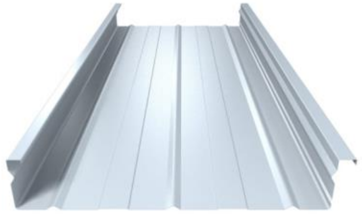
MONOPANEL






- Founded in 1961
- Previously part of the TATA STEEL Group
- **Since 2022 : held by BREMHOVE SA, an industrial holding company managed by Joris & Enzo Ide**

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MONOPANEL

- Some examples with MONOPANEL current solutions

To face new market demand and to meet future environmental requirements

⇒need to develop new innovative low carbon solutions

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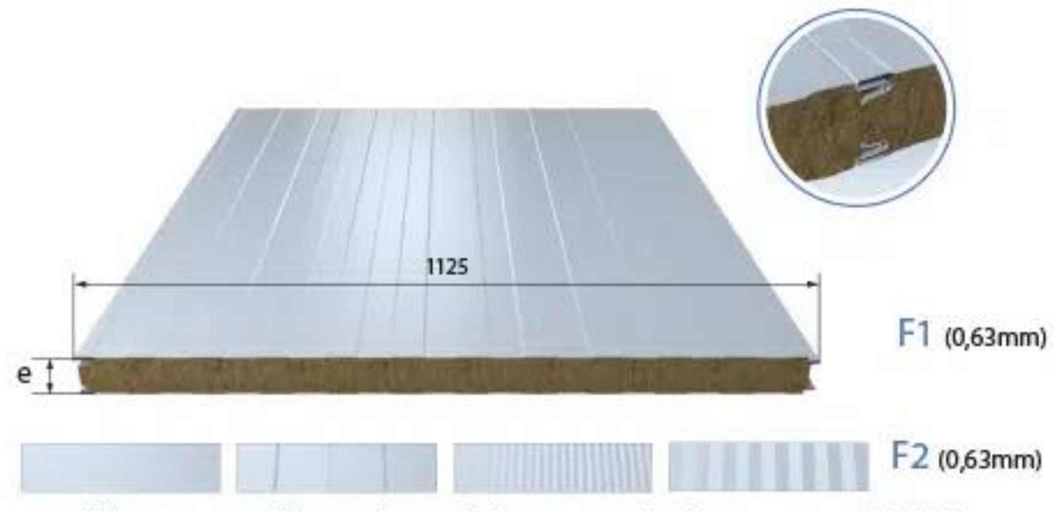
MONOPANEL: INCSEB partner

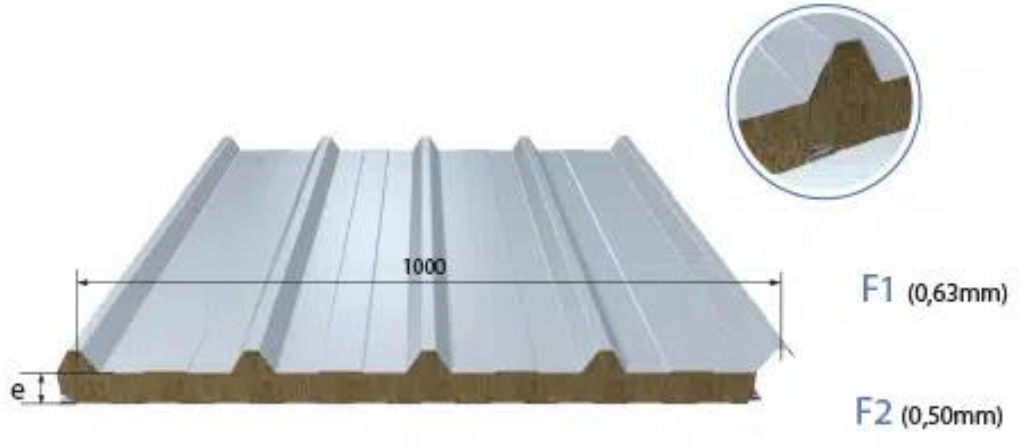
- **In charge of the design, production and delivery of the two prefabricated steel envelopes made of sandwich panels with a wood fibre insulation core**

Monowood B
Cladding sandwich panels with visible fixings



Flat Ribbed Microrib. Macrorib.

Monowood T
Roofing sandwich panels



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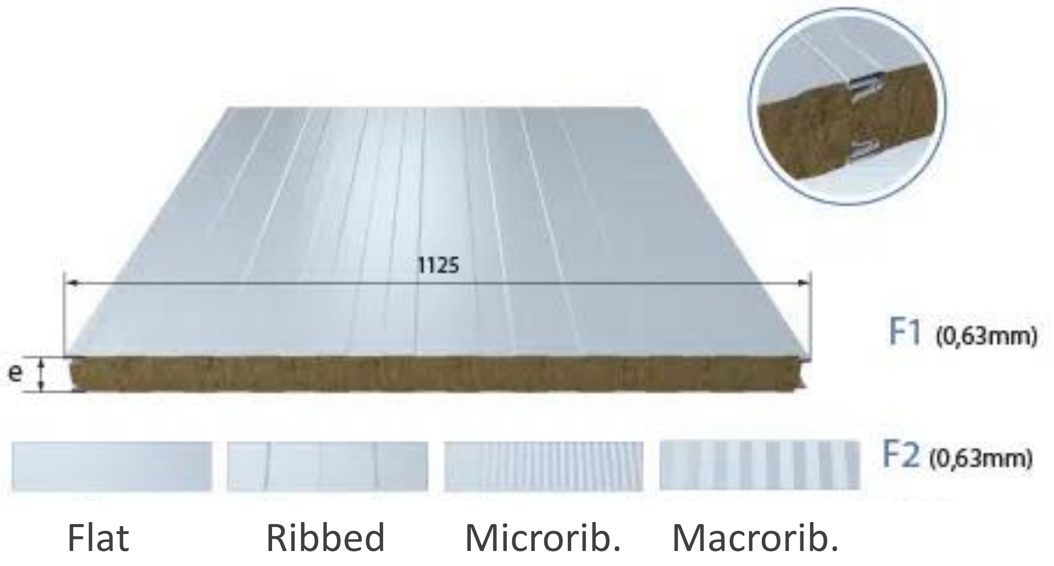
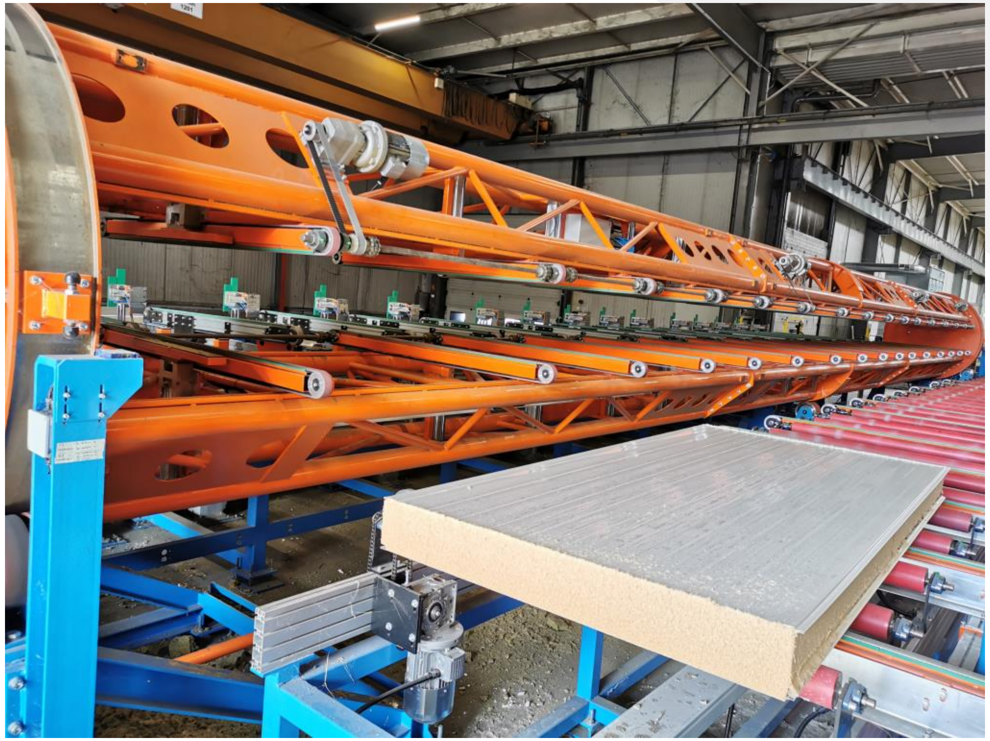
MONOPANEL: INCSEB partner

Monowood B
Cladding sandwich panels with visible fixings



Thickness: 150 mm



Production of the wood fibre sandwich panel for cladding at the MONOPANEL factory

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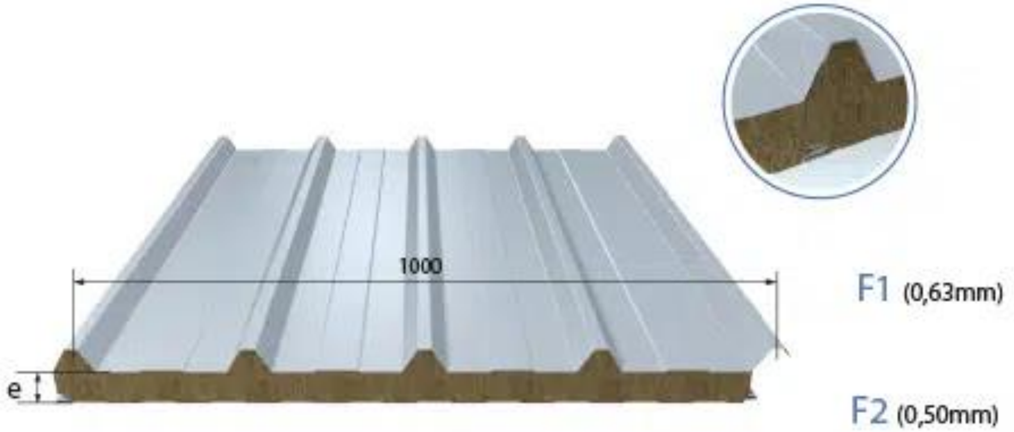
MONOPANEL: INCSEB partner

Monowood T
Roofing sandwich panels



Thickness: 150 mm

Production of the wood fibre sandwich panel for roofing at the MONOPANEL factory

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MONOPANEL
Achievement of the main objective

- New innovative low carbon solutions **manufactured & ready to be delivered** at all the testing labs to be characterized

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Site-assembled systems using WF insulation

Double skin cladding / façade cladding / flat roofing

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Typical range of products for building steel envelope solutions

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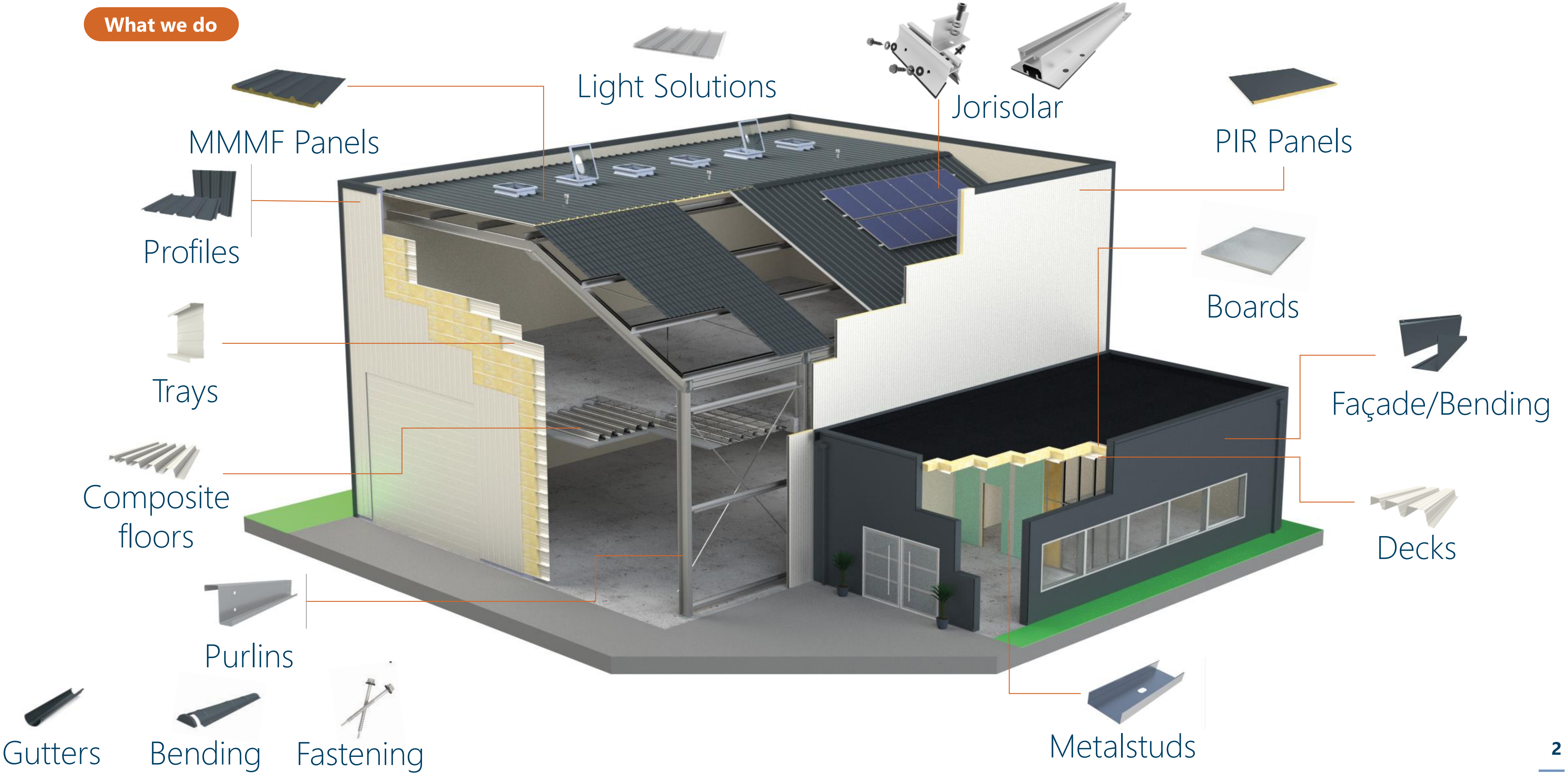
What we do



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3 site-assembled solution to prepare the future of the construction

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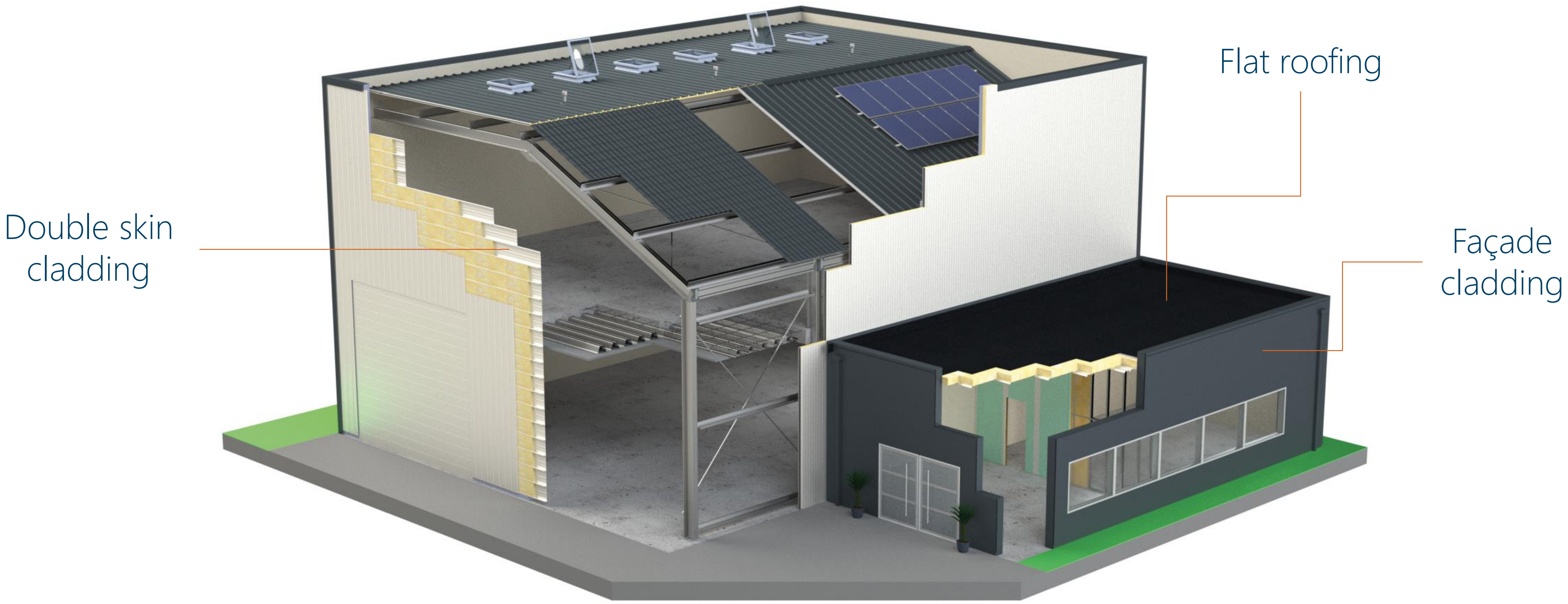
Anticipating new European and national environmental regulations



Create a new generation of steel envelope by incorporating bio-sourced insulation

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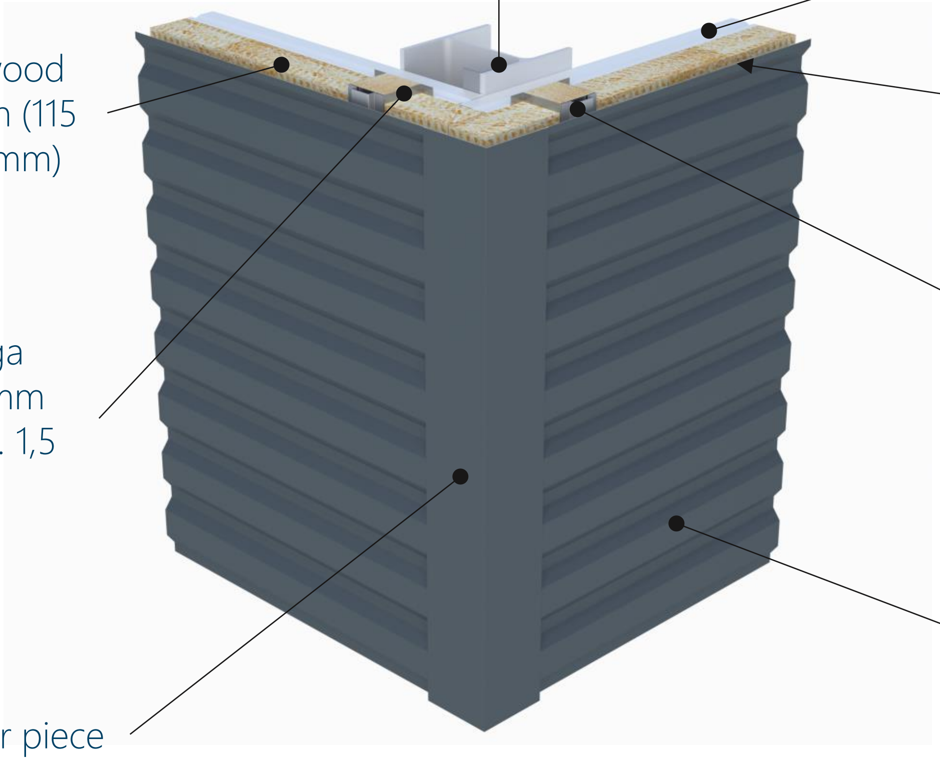
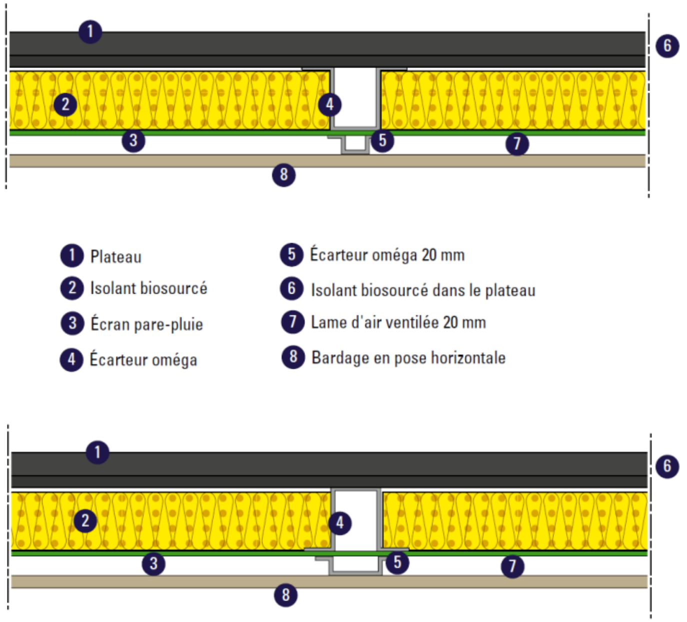
Double skin cladding with wood fibre insulation





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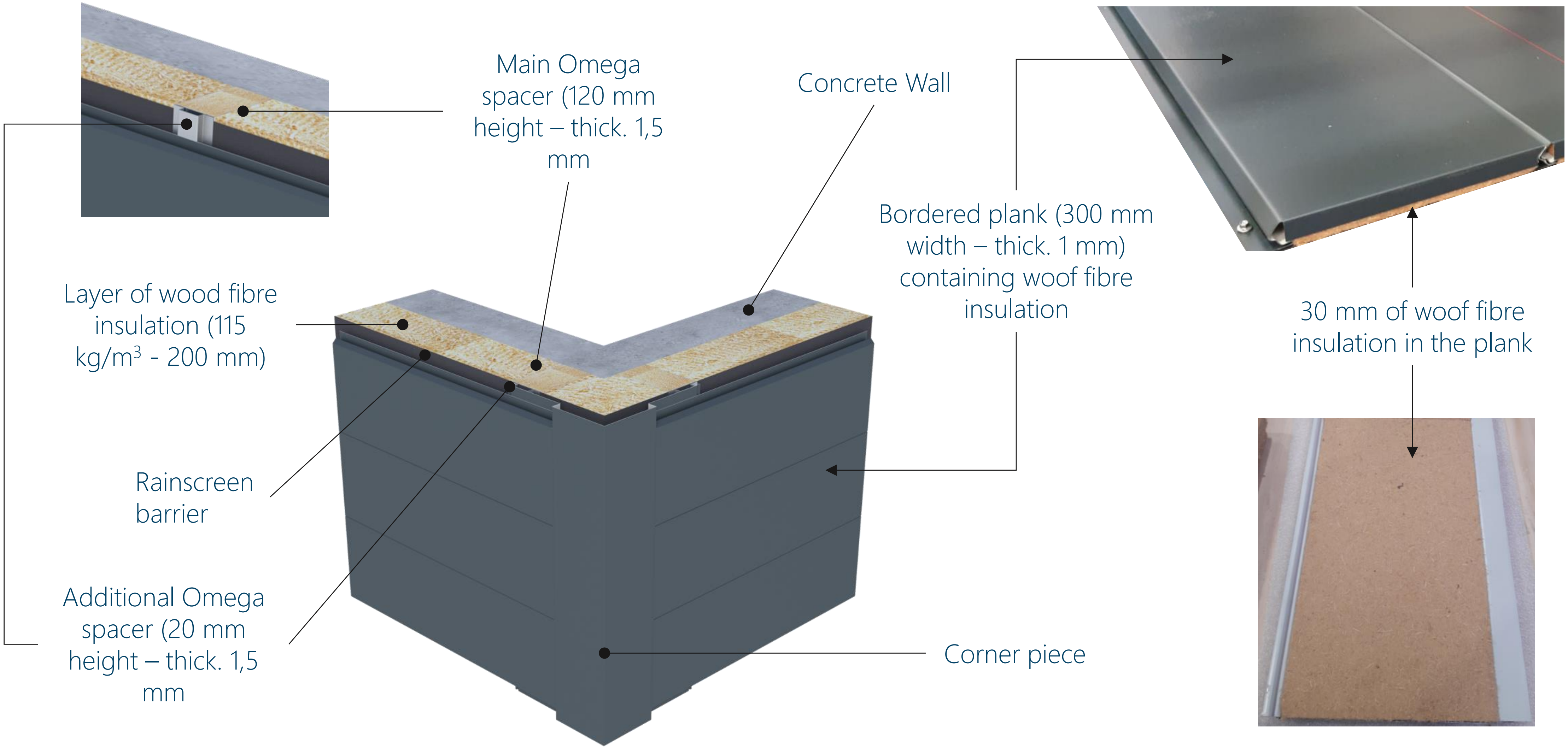
LIVRAISONS
à l'arrière du
BATIMENT


Façade cladding with wood fibre insulation



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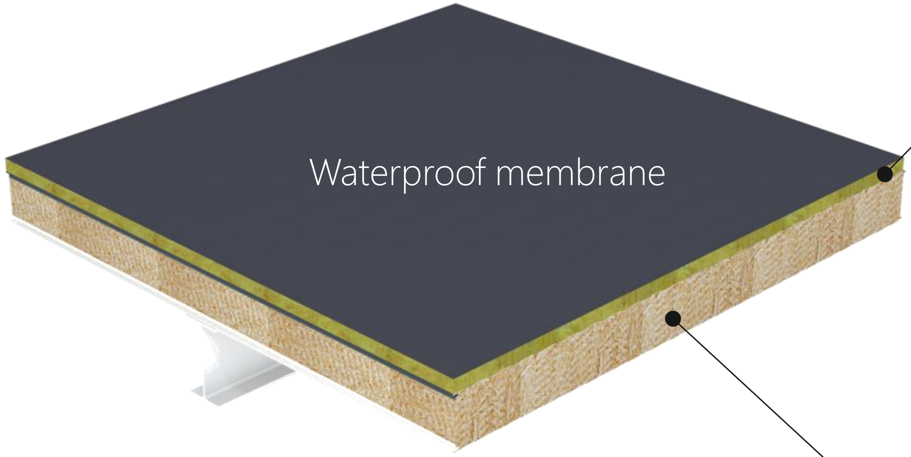
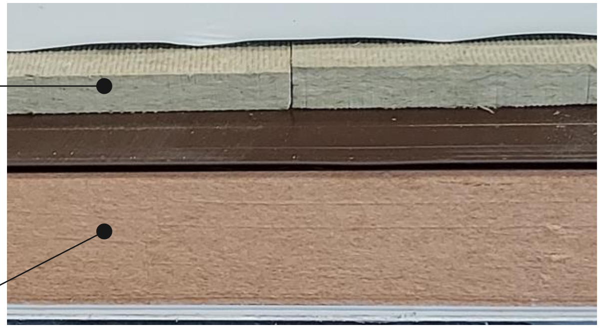
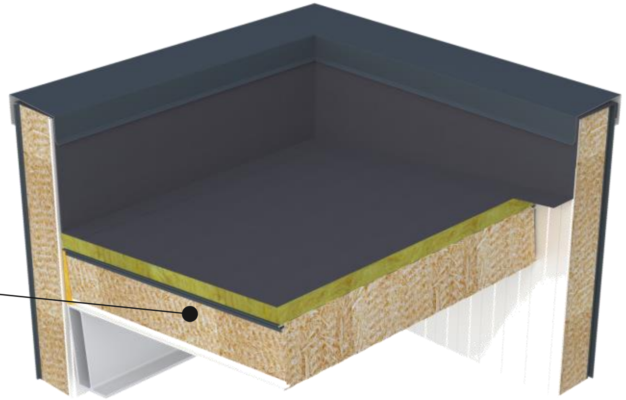
Flat roofing with wood fibre core sandwich panel + addition insulation + waterproof membrane

50 mm rock wool
additional insultation







Sandwich panel with 200 mm wood fibre insultation core
(115 kg/m^3 - 0,55/0,50 mm facings thick.)

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From theory to practice

We have succeeded in manufacturing these solutions.

Solutions with a high potential for reducing CO2 impact.

Are these solutions really relevant ? How do they perform ?

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THE STEEL FUTURE

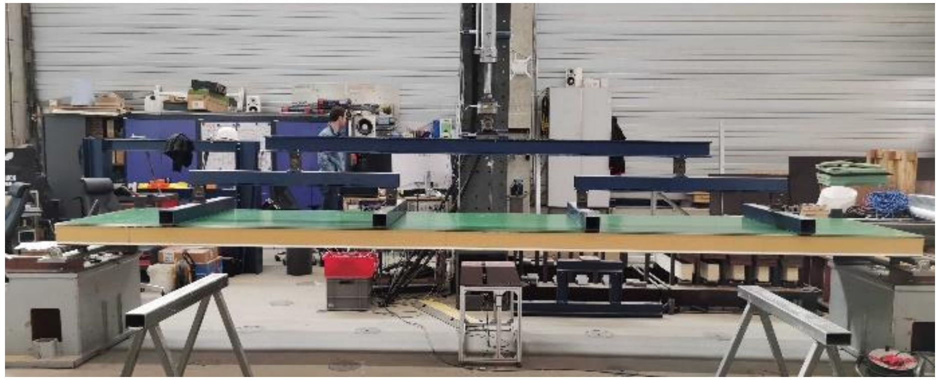
Thank you for your attention

STATIC AND DYNAMIC MECHANICAL PERFORMANCES

Research of Technical University of Darmstadt and Tecnalia

Workshop - June 12th, 2025

Paris, France



Prof. Dr.-Ing. Jörg Lange, Eric Man Pradhan, MSc.
Technical University of Darmstadt

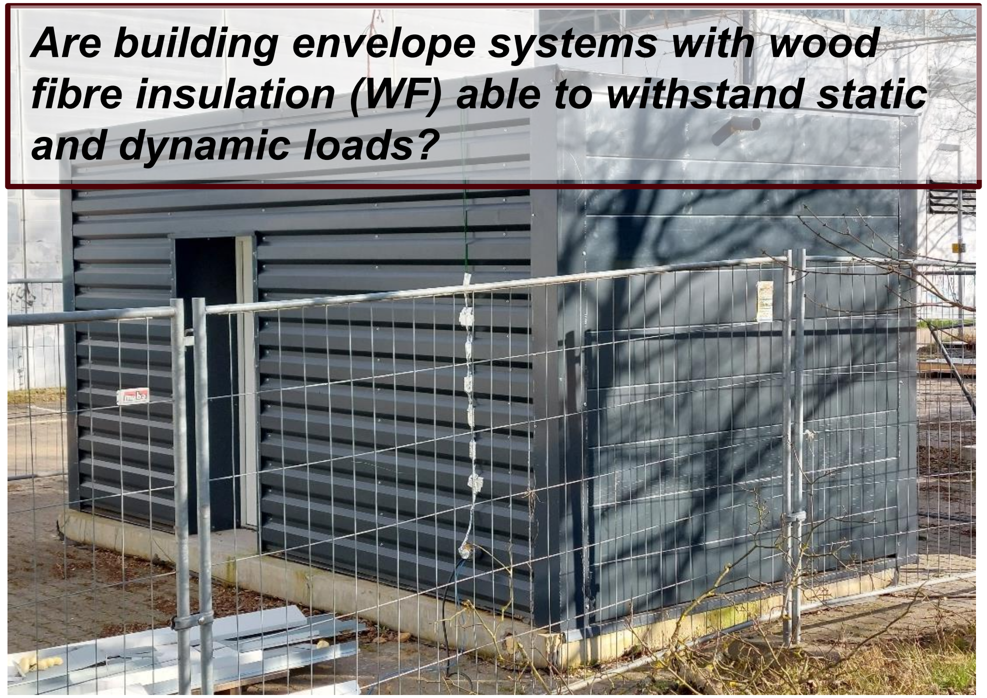
Mechanical Performance of building envelopes

As enclosing unit, building envelopes must transfer the external loads to the primary load-bearing structure without affecting their other functions such as thermal insulation and sealing.

Possible static and dynamic load scenarios

- snow
- wind
- temperature
- maintenance
- earthquake

Are building envelope systems with wood fibre insulation (WF) able to withstand static and dynamic loads?



AGENDA

1 Introduction

2 Out-of-plane static behaviour

3 Vacuum chamber tests in cassette cladding system

4 Seismic tests (static and dynamic)

5 Summary

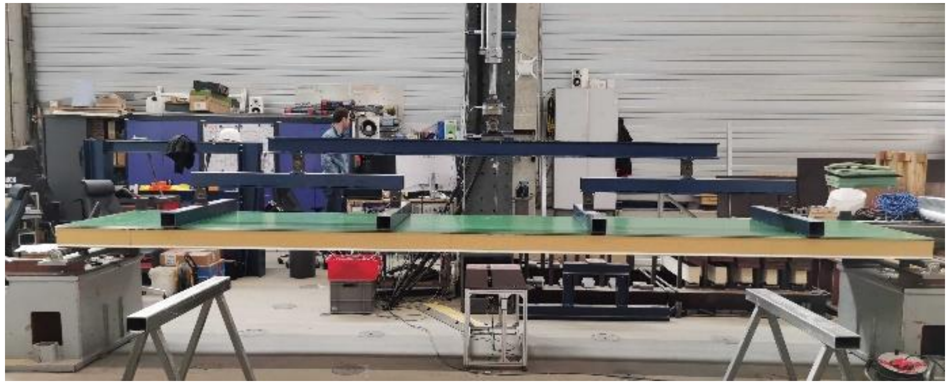
2 OUT-OF-PLANE BEHAVIOUR

Testing roof and cladding WF sandwich panels acc. to EN 14509

Extensive test program similar to the ITT tests for technical approval

- Small-scale tests
  → stiffness and strength of the wood fibre (WF) core material
- Full-scale tests with span length of L = 6 m
  → load bearing capacity of the sandwich panels for single span and multispan applications
- Supplementary tests to check the feasibility in application

Comparison of the performance of the WF sandwich panels with established solutions



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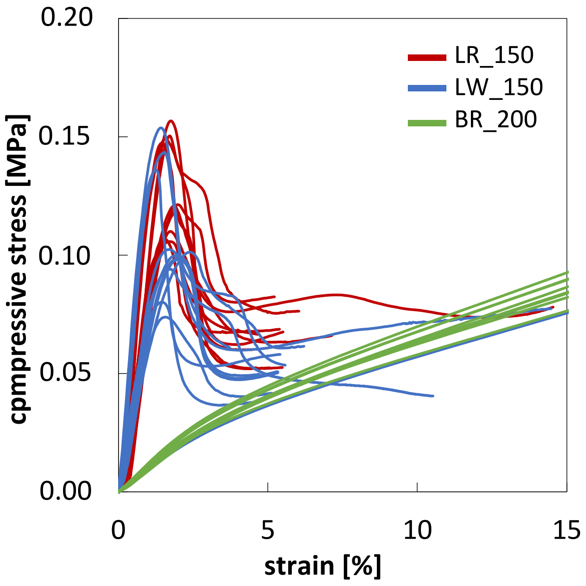
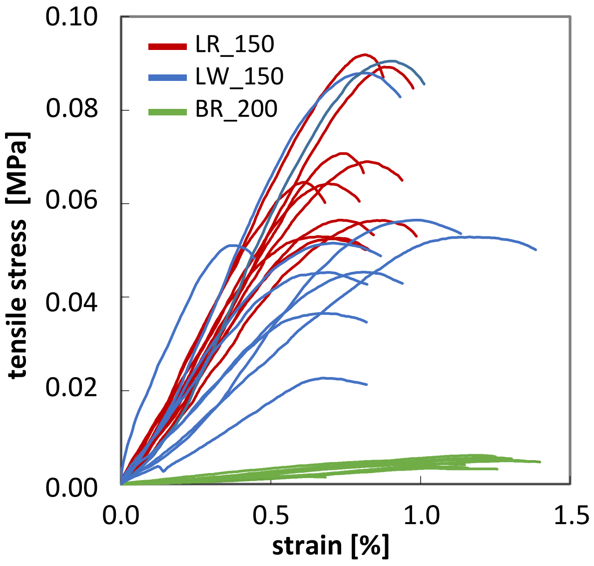
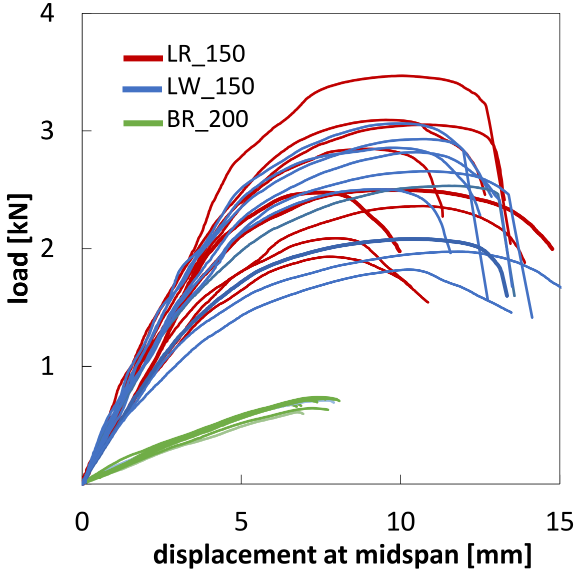
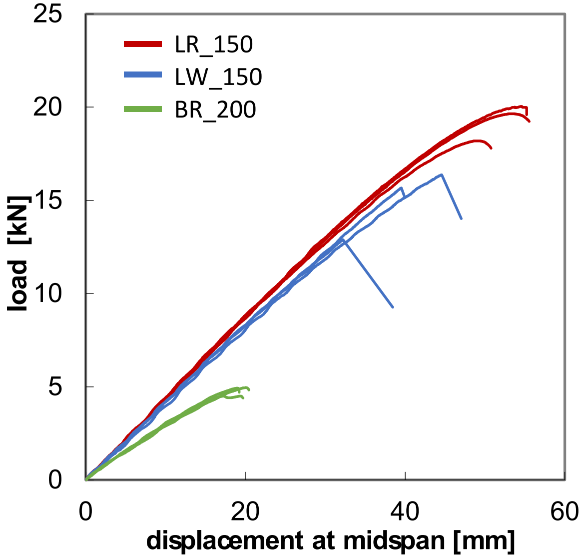
Wood fibre exhibit a strong anisotropic material behaviour





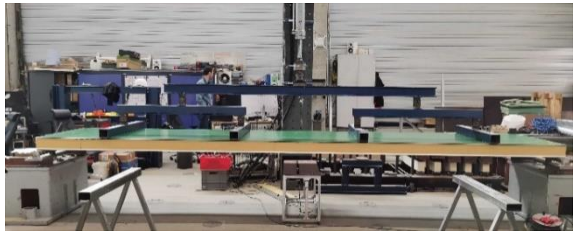




compression

tension

shear



bending

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Wood fiber has fundamentally similar material properties to the established core materials

Mechanical properties	WF pitch roof panel d = 150 mm	WF wall panel D = 150 mm	WF flat roof panel d = 200 mm	PU acc. to [1]	MW acc. to [1]
E_{Cc} in MPa	12.55	10.34	0.92	2 – 8	6 – 20
f_{Cc} in MPa	0.129	0.108	0.064	0.08 – 0.20	0.20 – 0.25
$E_{Ct,20\,°C}/E_{Ct,80\,°C}$ in MPa	11.19/9.14	9.56/8.42	0.51/0.52	2 – 6*	5 – 40*
$f_{Ct,20\,°C}/f_{C,80\,°C}$ in MPa	0.067/0.060	0.054/0.061	0.0048/0.0052	0.08 – 0.25*	0.03 – 0.20*
G_C in MPa	11.87	10.25	1.52	2 – 5	2 – 20
f_{Cv} in MPa	0.081	0.077	0.0086	0.08 – 0.18	0.03 – 0.20
ρ in kg/m³	127.7	118.9	116.5	25 – 45	90 – 150

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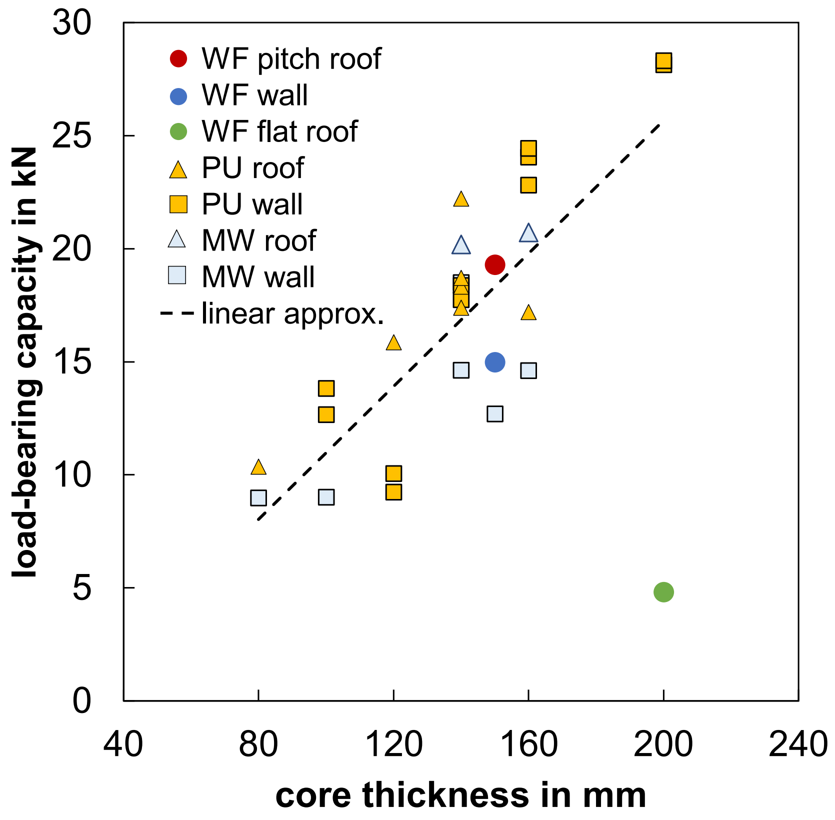
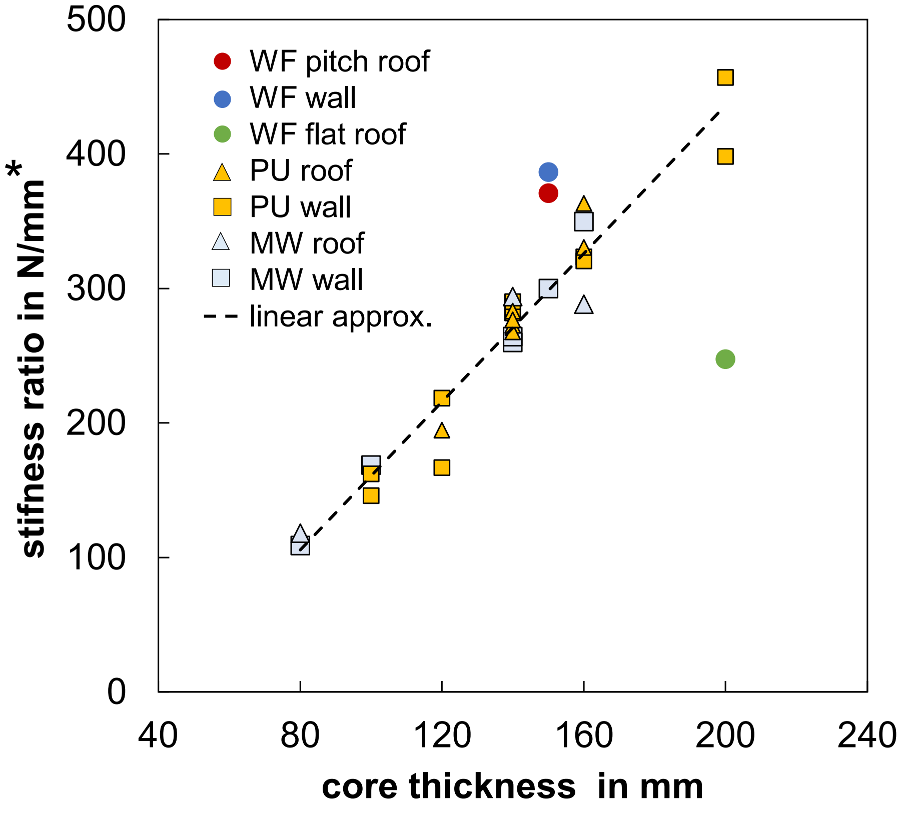
Depending on the production, WF sandwich panels exhibit comparable load bearing capacities as established products





*load capacity by related deformation

WF sandwich panels values for analysis were obtained and pass additional tests for the feasibility in application

Additional tests show applicability

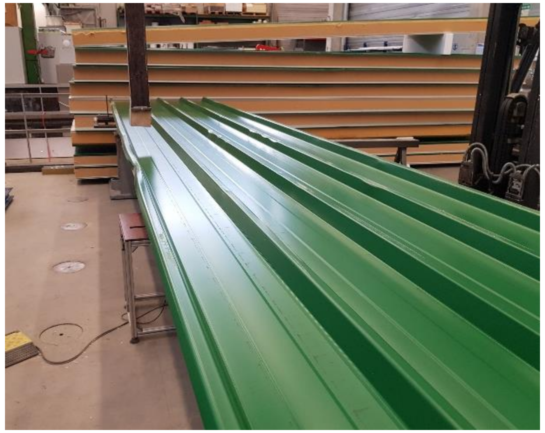
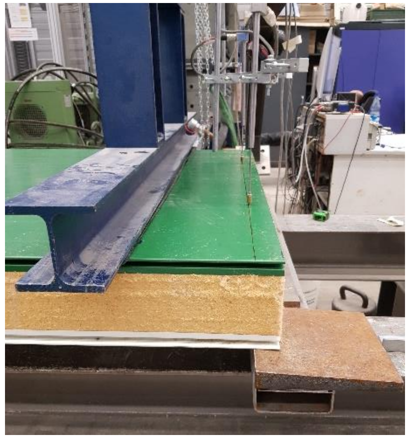
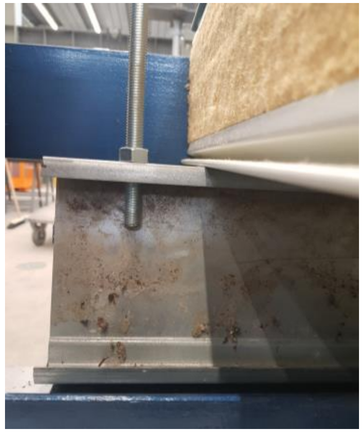
- creep tests

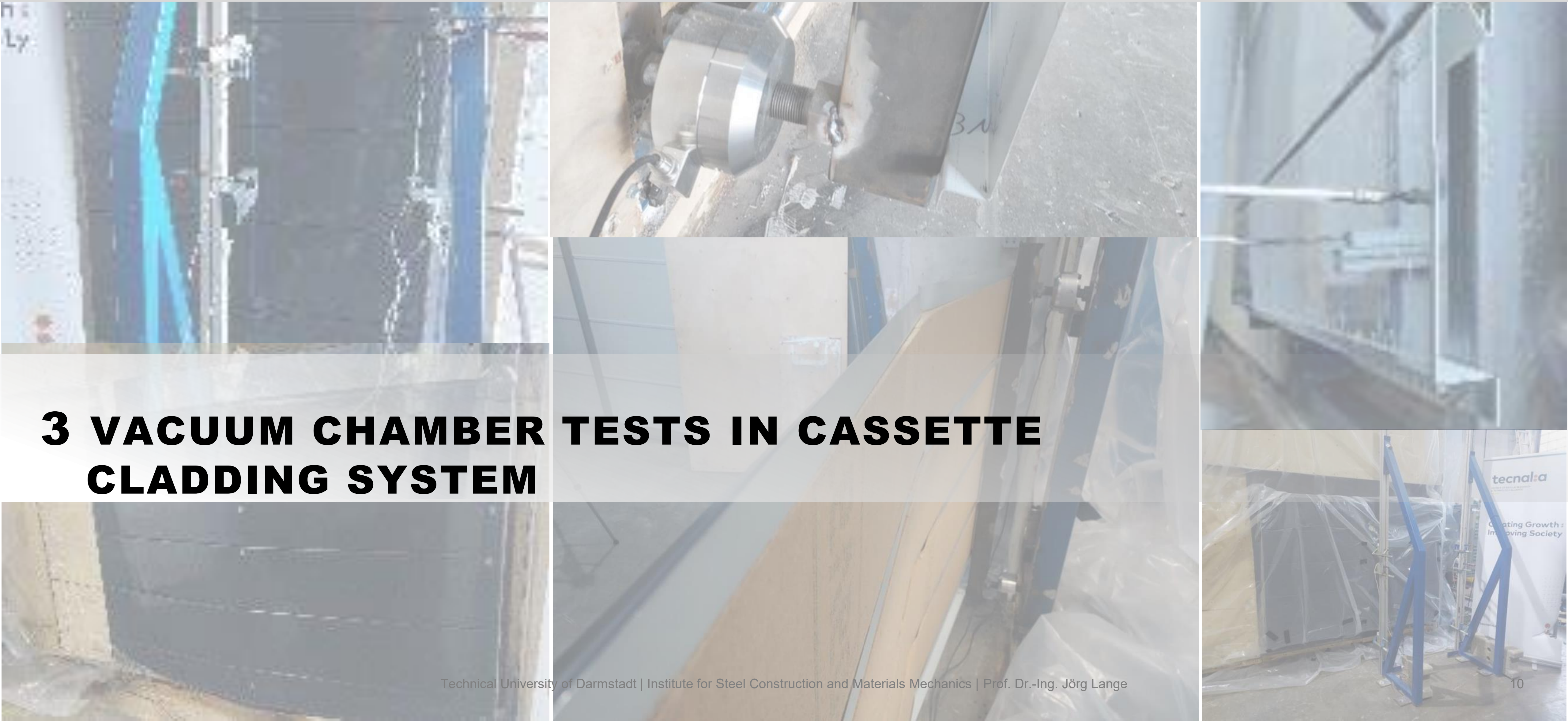
	WP1	WP2
φ_{2000h}	3.5	3.5
$\varphi_{100000h}$	3.8	4,7

- end support capacity test
  0.3 < k < 0.5
- CDA tests provide stiffness values for different load ranges:
  1. slope = 150 - 1970 Nmm/mm/rad

The following tests were passed

- **DUR 2 (durability)**
- **resistance against point loads**
- **walkability**

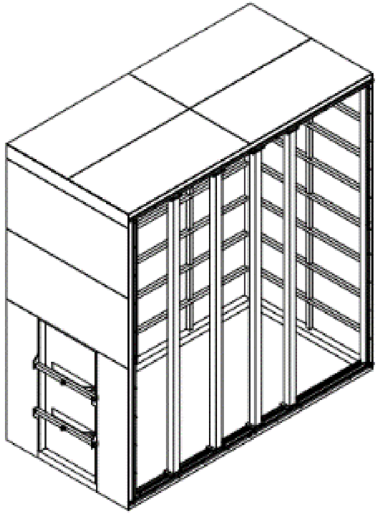




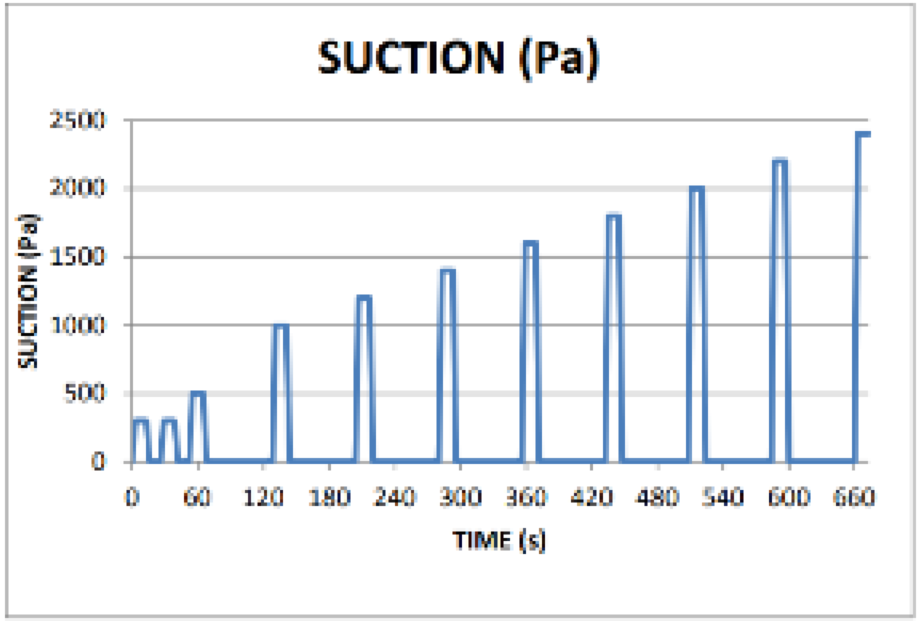



3 VACUUM CHAMBER TESTS IN CASSETTE CLADDING SYSTEM

Test procedure -
Wind suction and compression load tests acc. to EAD 090062-00-0404

- The cladding is assembled to a compression or suction chamber.
- The uniformly distributed loads are exerted on the surface of the assembled cladding system.
- The test is performed in successive steps until significant irreversible deformation or/and failure occurs.
- Parameters measured:
  - Deflection as a function of the load. Results: maximum deflections and failure load Q.
  - Failures (break of elements, permanent deflection of elements, falling of detached components, failure of detachment of the kit subframe). Result: type of failure





Possible suctions or compressions and their duration

Test samples

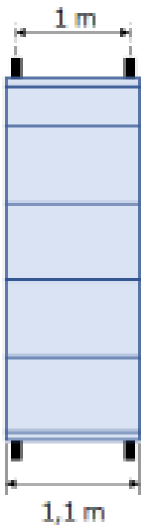
- **Materials used**
- **System tested:**

  Cassette cladding

COMPONENT	USE IN THE CLADDING SYSTEM	COMMERCIAL REFERENCE	MATERIAL DESCRIPTION	PARAMETERS
External steel cladding sheet with insulation	External cladding SKIN	Ref: JI Grégale Bordée 300 Manufacturer: JORIS IDE	Steel grade S 320 GD Z225+PE35. Insulation: wood fibre insulation boards PAVATHERM 30 MM (manufacturer: PAVATEX).	Section: 300 x 30 mm Nominal thickness 1,00 mm
External cladding sheet fixing	External cladding sheet to small omega spacer fixing	Ref: 6325/099 VIS TETINOX P5 6,3x25 TK12 NAT + EPDM Manufacturer: FAYNOT	Crimped screw head in 18/8 stainless steel. Screw body in case-hardened steel with metal coated	Diameter: 6.3 mm Length: 25 mm

8 samples

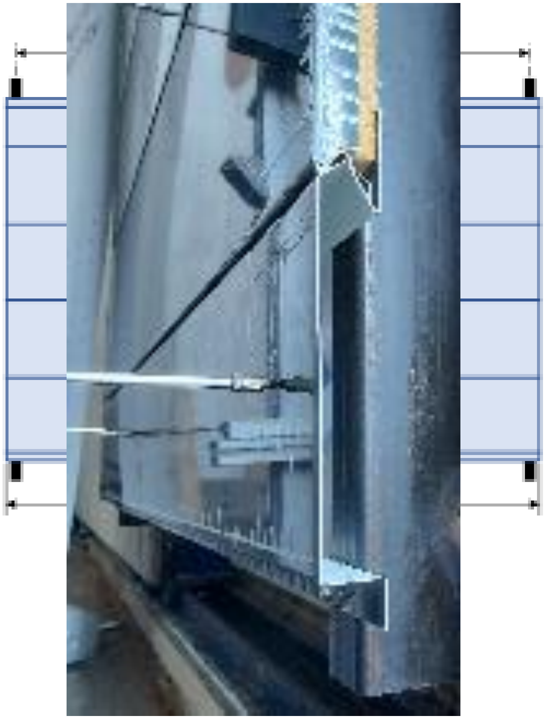
- 4 configurations in suction
- 4 configurations in compression



Configuration 1

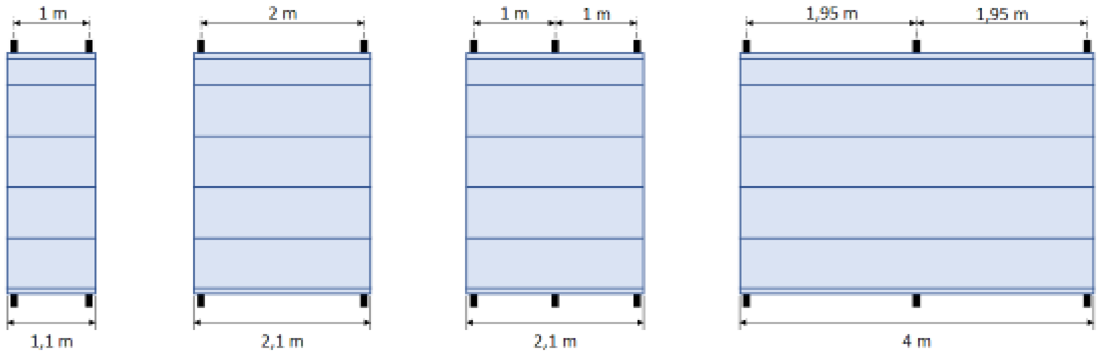
Configuration 2

Configuration 3



Test results

- 1 m span samples in configuration 1 and 3 (suction and compression) tested with a maximum pressure of 7000 Pa without failure
- 2 m span samples in configurations 2 and 4 failed due to deformation in the middle of the span
  - Configuration 2: max. suction of 4600 Pa and a max. compression of 4000 Pa
  - Configuration 4: max. suction of 5000 Pa and a max. compression of 5200 Pa



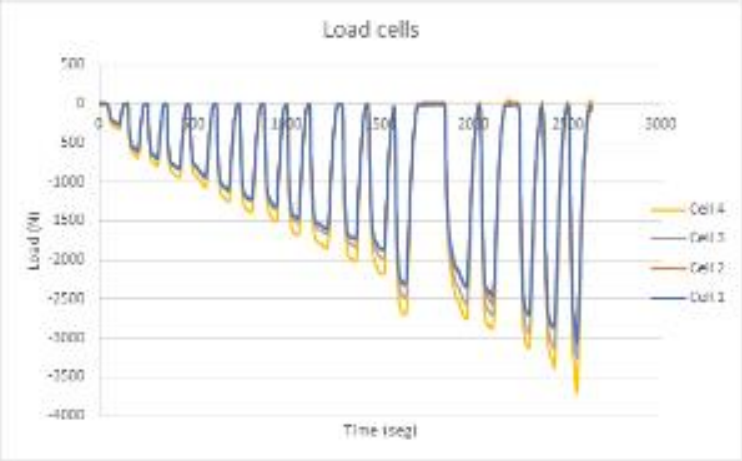
Configuration 1 Configuration 2 Configuration 3 Configuration 4

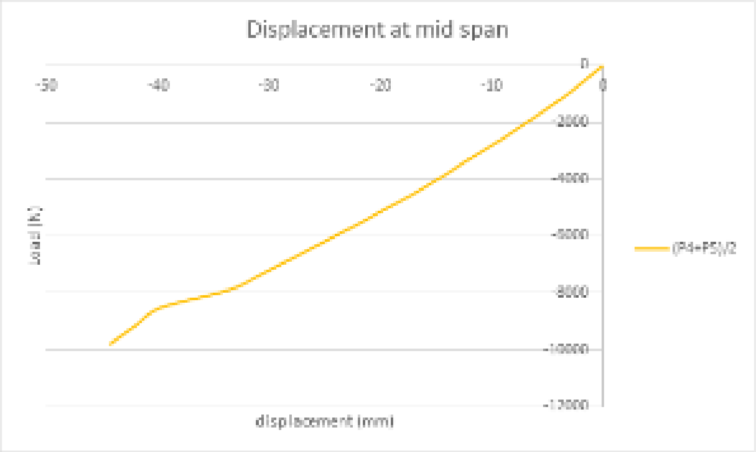
Configuration 1	**suction**	**pression**
Maximum suction applied without failure (Pa)	7000	7000
Failure mode	no failure	no failure
Residual displacement after applying 3600 Pa (mm)	1.8	2.4
Configuration 2	**suction**	**pression**
Maximum suction applied without failure (Pa)	4600	4000
Failure mode	deformation in mid span	deformation in mid span
Residual displacement after applying 3600 Pa (mm)	7	2.6
Configuration 3	**suction**	**pression**
Maximum suction applied without failure (Pa)	7000	7000
Failure mode	no failure	no failure
Residual displacement after applying 3600 Pa (mm)	3	2.6
Configuration 4	**suction**	**pression**
Maximum suction applied without failure (Pa)	5000	5200
Failure mode	deformation in mid span	deformation in mid span
Residual displacement after applying 3600 Pa (mm)	7.5	7.6

Test results: Example

Configuration 2 suction

- Maximum load applied without failure: 4600 Pa
- Type of failure: deformation in mid span
- Residual displacement after applying 3600 Pa: 7 mm





4 SEISMIC TESTS (STATIC AND DYNAMIC)

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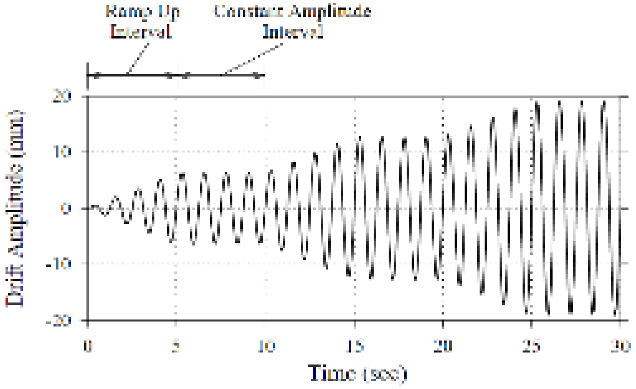
Test procedure

Static test acc. to AAMA 501.4-09

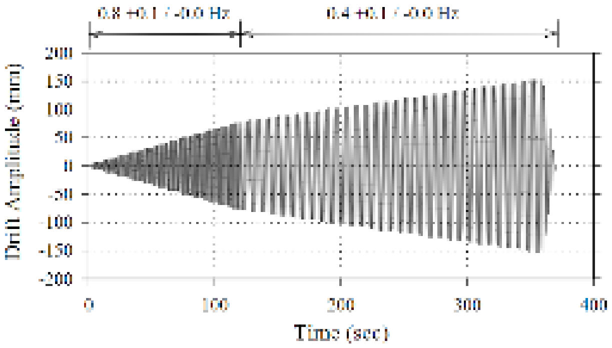
- Evaluating the seismic serviceability limit state
- Three full cycles

Dynamic tests acc. to AAMA 501.6-09

- Evaluating the seismic **ultimate limit** state
  → determining the dynamic fallout of the system panels
- **Crescendo test** as concatenated series of "ramp up" intervals and "constant amplitude" intervals of four sinusoidal cycles each



(a) First 30 Seconds of Crescendo Test



(b) Full Crescendo Test

Test samples

Materials used

SYSTEM TESTED	THICKNESS (mm)	DESCRIPTION OF COMPONENTS	ADDITIONAL MASS
a) Cladding sandwich panel	150	3 sandwich panels of 4000 mm length fixed to two horizontal steel profiles of 80 x 40 x 4 mm (DRILLNOX 12,5DF TH8 5.5x200I19 fasteners and sealing washer diameter 19mm, three per panel and profile)	58.24 kg/panel included to simulate a 6 m high sample
b) Pitch roofing sandwich panel	150 + rib	3 sandwich panels of 4000 mm length fixed to two horizontal steel profiles of 80 x 40 x 4 mm (DRILLNOX DF TH8 6.5x240I19 fasteners and saddle washers) and stitching elements between panels	53 kg/panel included to simulate a 6 m high sample
c) Flat roofing sandwich panel	200	3 sandwich panels of 4000 mm length fixed to three horizontal steel profiles of 80 x 40 x 4 mm (fasteners Faynot Tetinox P13 6,3x230DF+V19, five per panel and profile)	80 kg/panel included to simulate a 6 m high sample
d) Double skin cladding system	90 + 120	4000 x 4000 mm envelope system composed of several layers of metal sheets, insulations and profiles. Back trays fixed to two vertical steel profiles of 80 x 40 x 4 mm (VIS AUTOPERCEUSE 6,3x25 TH ZINGUEE fasteners). First insulation layer inserted in the back trays and second layer between 120 mm omega profiles. External trapezoidal sheeting fixed to 20 mm spacers.	No additional mass

Test results

Sandwich panels

- No collapse for sandwich panels (a, b and c) → satisfactory.
- Internal face sheets were damaged around fixings; insulations were affected in the fixation areas and some of the fixations were broken.
- Maximum accelerations between 1,85 and 2,5 m/s².
- Principal modes are located at around 10,5Hz for the test bench and between 7,25 Hz (with 1.7% damping) and 9,5 Hz (with 3% damping) respectively for the envelopes installed with stitching or without stitching elements.

Double skin systems

- test bench not able to apply the necessary force to perform the seismic test due to the high rigidity of the system
  → tests were not completed.

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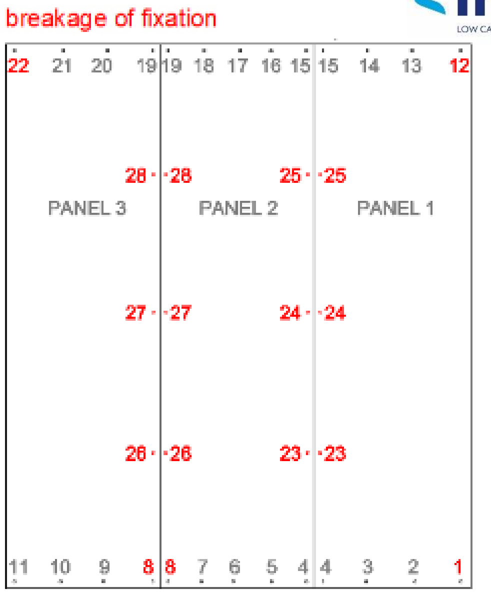
Test results (example)



Pitch roofing sandwich panel (b)

- No collapse of panels
- Fixation: some of them are broken

Internal cladding

Ovalisation of holes

PANEL 1		PANEL 2		PANEL 3	
Nº	Dimension (mm)	Nº	Dimension (mm)	Nº	Dimension (mm)
1	58	4	51	8	51
2	36	5	11	9	11
3	18	6	30	10	32
4	41	7	63	11	63
12	60	8	65	19	45
13	33	15	46	20	31
14	21	16	23	21	64
15	48	17	35	22	52
23	7	18	73	26	10
24	6	19	35	27	9
25	16	23	10	28	9

4 SUMMARY

Summary

- Sandwich panels
  - material behaviour of wood fibre is suited as core material
  - Load bearing capacity of WF sandwich panels can show comparable values like established products
  - Pass tests on durability (DUR 2), walkability and point load
  - No collapse for the seismic tests
- Cassette cladding
  - 1 m span samples in configuration 1 and 3 (suction and compression) tested with a maximum pressure of 7000 Pa without failure
  - 2 m span samples in configurations 2 and 4 failed due to deformation in the middle of the span at ca. 4000 – 5000 Pa (suction or compression)
- Double skin system
  - Due to high rigidity not able to conduct complete seismic test

Conclusion
Envelope systems with wood fibre show in general behaviour to withstand static and dynamic loads

MERCI BEAUCOUP POUR VOTRE ATTENTION

Funding and Acknowledgement

The InCSEB project has received financial support from the European Community 's Research Fund for Coal and Steel (RCFS) under grant agreement No. 101033984.

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Building physic performances:

Thermal, air, water and vapour permeability, acoustic performances and fire performance

- Paris
- 12/06/2025

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The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N°101033984

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01

Water and air permeability

Test procedures

Test samples

Test results

Test procedures

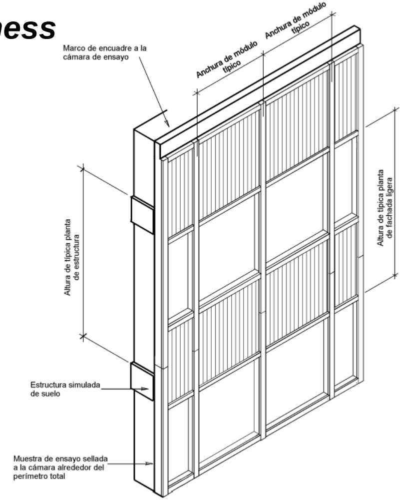
EN 12114 *Air permeability* / EN 12865 *Watertightness*

The cladding is assembled in the test chamber and is sealed. In this case, 80 x 80 mm wooden profiles are used as substructure.

For the same sample two tests are performed: air permeability first and water permeability then.

Different pressions and cycles are used according to the standards.

Parameters registered or measured:
- Air flux for each test pressure.
- Water leakages (location, duration and applied water pression).



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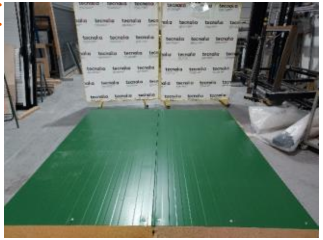
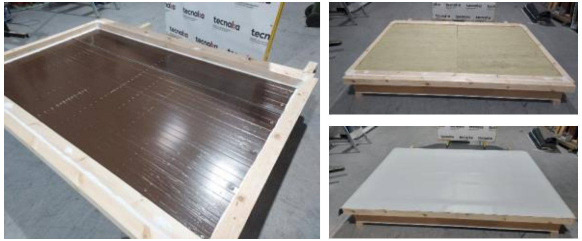


b


c


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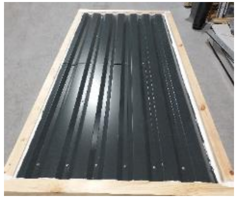

e


Test samples

SYSTEM TESTED	a) Cladding sandwich panel	b) Pitch roofing sandwich panel	c) Flat roofing sandwich panel	d) Double skin cladding system	e) Facade cladding system
N. of samples	2	1	2	1	1
Description	150 mm sandwich panel with circular or plain gasket at joints	150 mm + rib sandwich panel with plain gasket at joints	200 mm sandwich panel without gaskets at joints (+ mineral wool insulation and membrane)	Envelope system composed of several layers of metal sheets, insulations and profiles. External trapezoidal sheeting.	Envelope system composed of several layers of metal sheets, insulations and profiles. External cladding with insulation

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Test results

The **watertightness** limit is ≥ 1200 Pa in all cases so classification for resistance to rainwater is **≥ 1200** $_A$

Air permeability varies depending on envelope system (double skin vs sandwich panels), but acceptable results are obtained in all cases.

a

b

d

e

SYSTEM TESTED		a) Cladding sandwich panel	b) Pitch roofing sandwich panel	c) Flat roofing sandwich panel	d) Double skin cladding system	e) Facade cladding system (double skin)
Water permeability	1200 Pa	Class A 1200 Pa	Class A 1200 Pa	Class A 1200 Pa	Class A 1200 Pa	Class A 1200 Pa
Air permeability	(+200Pa)	VA+= 1.4 m3/h.m2 1.1≤ n ≤1.5 / c= 0	VA+= 1.33 m3/h.m2 n = 1.4 / c= 0	VA+= 4.1 m3/h.m2 n = 0.8 / c= 0.2 VA+= 0.68 m3/h.m2 n = 2.1 / c= 0	VA+= 6.02 m3/h.m2 n = 0.8 / c= 0.3	VA+= 9.82 m3/h.m2 n = 0.6 / c= 1
	(-200Pa)	VA+= 1.3 m3/h.m2 1.3≤ n ≤1.7 / c= 0	VA+= 1.22 m3/h.m2 n = 1.2 / c= 0	VA+= 3,6 m3/h.m2 n = 0.9 / c= 0.1 VA+= 0.55 m3/h.m2 n = 2.0 / c= 0	VA+= 5.43 m3/h.m2 n = 0.8 / c= 0.3	VA+= 9.44 m3/h.m2 n = 0.7 / c= 0.6

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02

Hygrothermal cycles / Thermal shock evaluation

Test procedure

Test samples

Test results

Test procedure

Internal procedure *hygrothermal cycles* based on EAD 040083-00-0404

The cladding is assembled in the test chamber and is sealed.

TYPE	NO. OF CYCLES	OPERATION	ENVIRONMENTAL CONDITIONS
HEAT/RAIN	80	Heat	Temperature rise to 70 ºC in 1 hour and maintained for 2 hours at (70±5) ºC and at 10-30% relative humidity.
		Rain	Water spraying at a temperature of (15 ± 5) ºC and flow of 1 l/m2 for a period of 1 hour.
		Drainage	2 hours in standard laboratory conditions
CONDITIONING			48 hours in standard laboratory conditions
HEAT/COLD	5	Heat	Temperature rise to 50 ºC in 1 hour and maintained for 7 hours at (50±5) ºC and at ≤30% relative humidity.
		Cold	Temperature drop to -20 ºC in 2 hours and maintained for 14 hours at (-20±5) ºC.

Assessment criteria: visual observations during and after the test (blistering, peeling detachment, crazing, loss of adhesion, formation of cracks, etc.)

Test samples

Samples: 150 mm **(a)** and 200 mm sandwich panels **(c)**

A joint between panels and one strip of fasteners are exposed to the hygrothermal cycles.

a) Vertical joint / horizontal fixings

c) Horizontal joint / vertical fixings

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Test results

During or after test, no visual defects were detected.

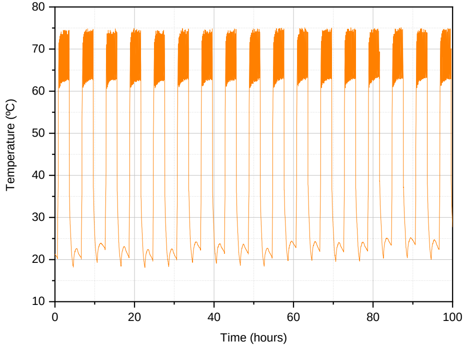
After test, water had run only on the external side of the panels.

Once the sandwich panels were removed, no faults or water were found except dry water marks in the outer face of the panels.

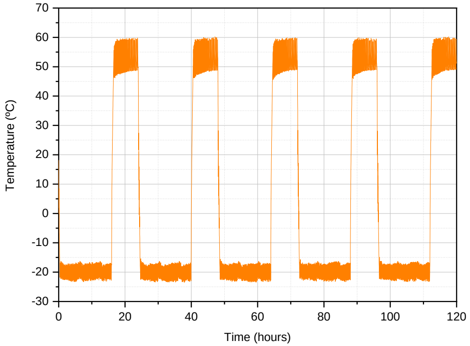
It was observed that water had not penetrated at the joints between the sandwich panels.

The wall sandwich panels tested can support 80 heat-rain cycles and 5 heat-cold cycles according to Clause 2.2.15.1 of document EAD 090062-00-0404 (July 2018 issue) without failures.

Heat-rain cycle values



Heat-cold cycle values



a) Vertical joint / horizontal fixings

c) Horizontal joint / vertical fixings

03

Thermal and hygrothermal calculations

Calculation procedure

Considerations

Evaluated samples

Results

Calculation procedure

EN ISO 6946:2017 Building components and building elements. Thermal resistance and thermal transmittance. Calculation method

The objective is to determine the thermal resistance and transmittance for building elements

The detailed calculation method is carried out with a numerical simulation of a representative part of the building element. The modelling rules must comply with those of EN ISO 10211.

The THERM software is used to perform the two-dimensional heat transfer calculations.

Linear thermal transmittance, Ψ

$$\Psi = L_{2D} - \sum_{j=1}^{N_j} U_j \cdot l_j$$

Thermal transmittance of the panel, U

$$U_W = \frac{\sum A_g U_g + \sum A_f U_f + \sum A_p U_p + \sum l_g \Psi_g + \sum l_p \Psi_p + \sum l_{gb} \Psi_{gb}}{A_f + A_g + A_p}$$

Considerations:

The boundary conditions to be applied: indoor temperature: 20ºC; outside temperature: 0ºC

Surface resistances used: table 7 of EN ISO 6946:

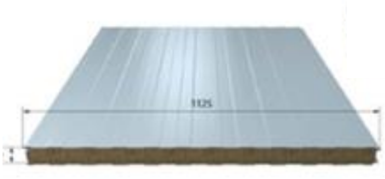
Surface resistance m²·K/W	Direction of heat flow		
	Upwards	Horizontal	Downwards
R_{si}	0,10	0,13	0,17
R_{se}	0,04	0,04	0,04

Main material data:

- Steel: λ = 50 W/mK s/ (EN 10456)
- PAVATHERM insulation: λ = 0,038 - 0,044 - 0,06 W/mK (depending on DoP or client data and orientation of fibres)
- Mineral wool insulation:λ = 0,04 W/mK (supplier data)

Evaluated samples

SYSTEM TESTED	a) Cladding sandwich panel	b) Pitch roofing sandwich panel	c) Flat roofing sandwich panel	d) Double skin cladding system	e) Facade cladding system
Description	Prefabricated sandwich panel	Prefabricated sandwich panel	200 mm sandwich panel with 50 mm mineral wool insulation and water membrane	Envelope system composed of several layers of metal sheets, insulations and profiles. External trapezoidal sheeting.	Insulated external cladding and non-combustible insulation fixed to a concrete wall.
U Thermal transmittance [Nº of envelope configurations]	**[2]** - 150 mm thick panel - 200 mm thick panel	**[2]** - 150 mm thick panel - 200 mm thick panel	**[3]** - 1 plain - 2 inclinations	**[3]** - Depending on distances between profiles (1120-2120mm)	**[3]** - Depending on distances between profiles (620-1620mm)
Ψ Linear thermal transmittance [Nº of junctions]	**[6]** - Internal angle - External angle - Lower cladding horizontal layer - Horizontal junction - Opening upper horizontal installation - Opening lower horizontal installation	**[3]** - Roof junction ridge - Roof to wall junction - Acrotere vertical installation	**[0]**	**[2]** - Lower cladding horizontal layer - Acrotere vertical installation	**[2]** - Lower cladding horizontal layer - Acrotere vertical installation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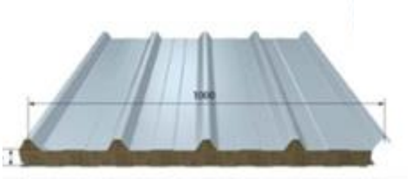
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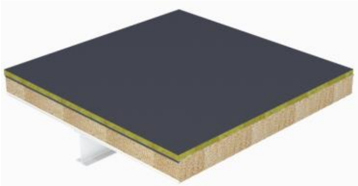
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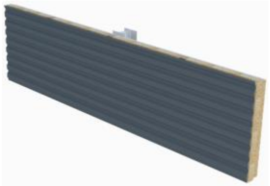
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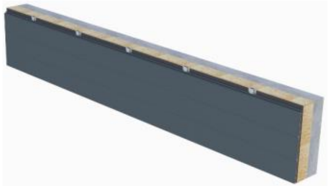
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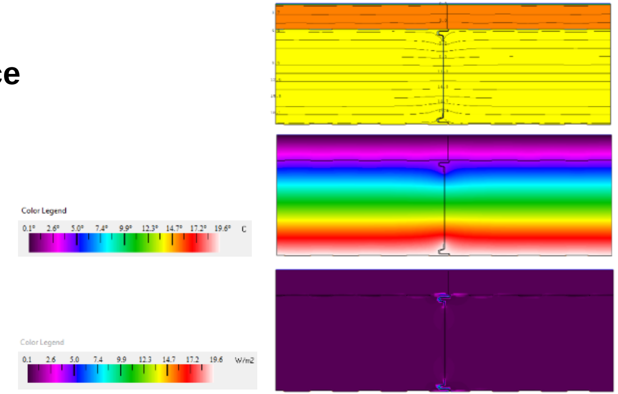
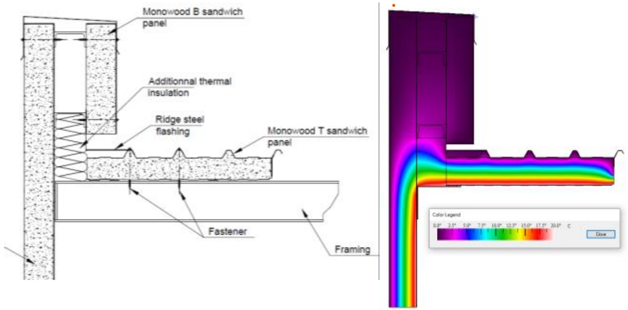
Results

Thermal performance



SYSTEM TESTED	variable	U Thermal transmittance [W/m2K] λ: data from DoP	U Thermal transmittance [W/m2K] λ: measured data
a) Cladding sandwich panel	150 mm		0,38
	200 mm		0,29
b) Pitch roofing sandwich panel	150 mm		0,35
	200 mm		0,28
c) Flat roofing sandwich panel	200 mm (installation angle)	0.15 – 0.16	0.16 – 0.17
d) Double skin cladding system	profile distance (1120-2120 mm)	0,22 – 0,26	0,26 – 0,31
e) Facade cladding system	profile distance (620-1620 mm)	0,30 – 0,54	0,32 – 0,57



SYSTEM TESTED	variable	Ψ Linear thermal transmittance [W/mK]
a) Cladding sandwich panel	Internal angle	0.03 (h)
	External angle	0.03 (h)
	Lower cladding horizontal layer	0.13 (h)
	Horizontal junction	0.20 (h)
	Opening upper horizontal installation	0.11 (h)
	Opening lower horizontal installation	0.18 (h)
b) Pitch roofing sandwich panel	Roof junction ridge	0.06 (h)
	Roof to wall junction	0.02 (h)
		0.21 (v)
	Acrotere vertical installation	0.16 (h)
		0.07 (v)
d) Double skin cladding system	Lower cladding horizontal layer	0.12 (h)
	Acrotere vertical installation	0.09 (h)
		0.11 (v)
e) Facade cladding system	Lower cladding horizontal layer	0.42 (h)
	Acrotere vertical installation	0.27 (h)
		0.10 (v)

Calculation procedure

EN ISO 13788 Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation method.

To carry out the determination of the condensation risk of the different systems, the **inner surface temperature factors**, **fRsi,** and the **useful inner surface temperature factors, fRsi, min**, shall be calculated, which is the minimum acceptable surface temperature factor to avoid condensation.

$$f_{Rsi} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e} \qquad f_{Rsi,mín.} = \frac{\theta_{si,mín.} - \theta_e}{\theta_i - \theta_e}$$

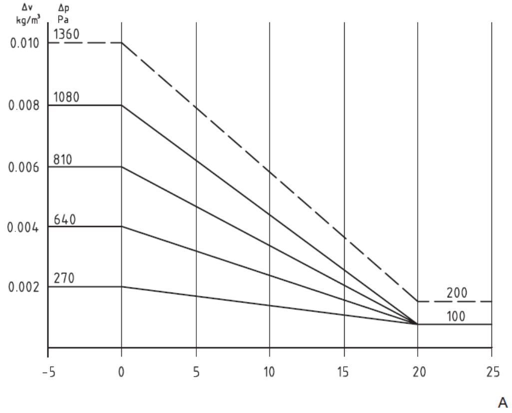
where θe and θi are the outdoor and indoor ambient temperatures, respectively. And θsi, the indoor surface temperature in ºC.

The criteria used to assess the risk of condensation is as follows:

- The month with the value of fRsi, max. higher required, it will be the most critical month.
- The temperature factor for this month is fRsi, max it will be compared with the fRsi;
    - If fRsi > fRsi, max. there will be no condensation.
    - if fRsi < fRsi, max. there will be at least superficial condensation.

Considerations:

Humidity class	Building
1	Unoccupied buildings, storage of dry goods
2	Offices, dwellings with normal occupancy and ventilation
3	Buildings with unknown occupancy
4	Sports halls, kitchens, canteens
5	Special buildings, e.g. laundry, brewery, swimming pool



Key

A monthly mean outdoor temperature, expressed in °C

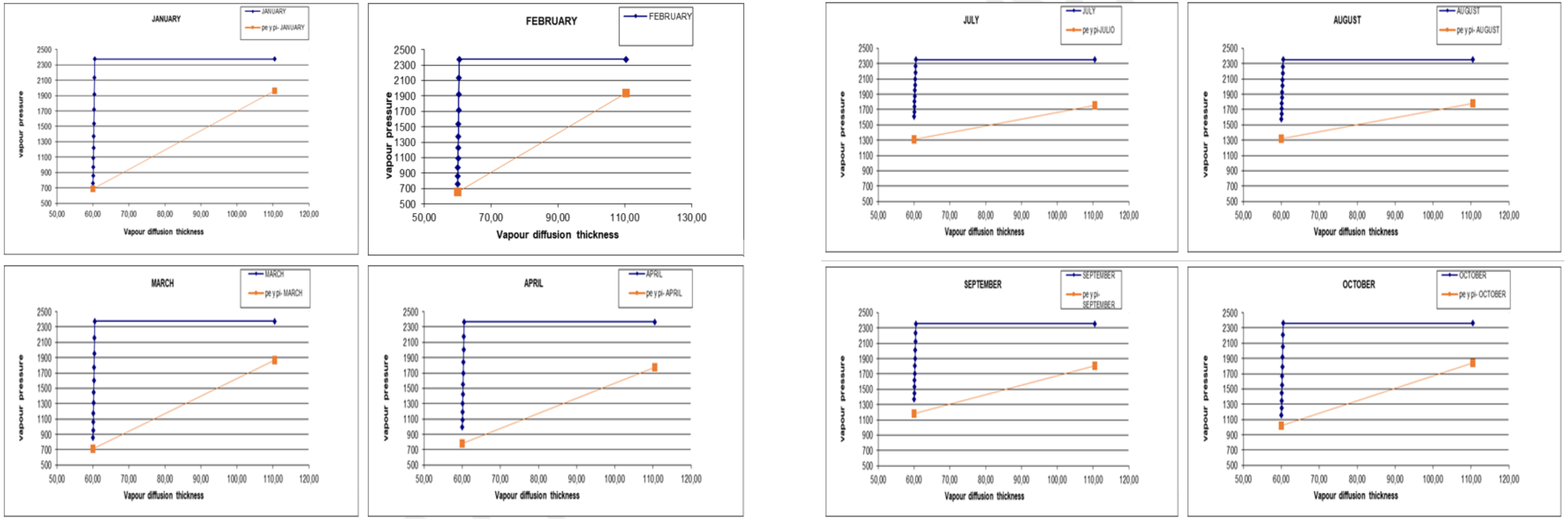
Results (Hygrothermal performance)

a) **Cladding sandwich panel**
b) **Pitch roofing sandwich panel**

There is risk of superficial condensation (only in hygrometry 5), but not interstitial condensation.

		HYGROMETRY 5		HYGROMETRY 4		HYGROMETRY 3	
	fRsi	fRsi max.		fRsi max.		fRsi max.	
« WALL SANDWICH PANEL (WW)»	0,952	1,05	Risk condensation exist	0,92	No risk to condensation	0,77	No risk to condensation
« ROOF SANDWICH PANEL (WW)»	0,953	1,05	Risk condensation exist	0,92	No risk to condensation	0,77	No risk to condensation

Wall sandwich panel and roof sandwich panel

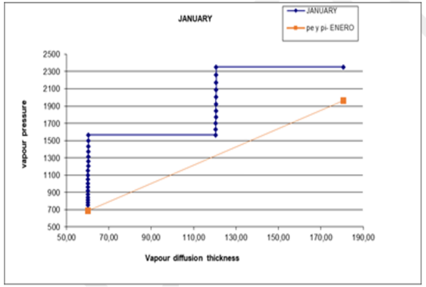


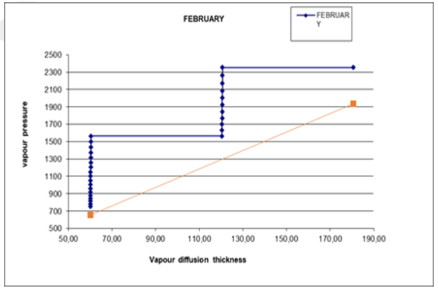
Results (Hygrothermal performance)

There is risk of superficial and insterstitial condensation (only in hygrometry 5) depending on the system:

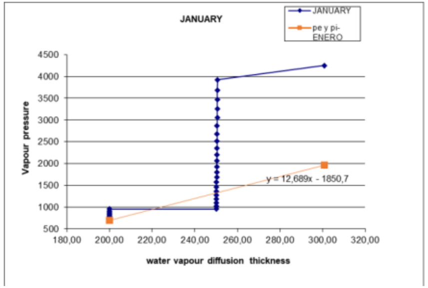
c) **Flat roofing sandwich panel:** interstitial condensation from October to April.
d) **Double skin cladding system:** no interstitial condensation.
e) **Facade cladding system:** interstitial condensation from September to May.

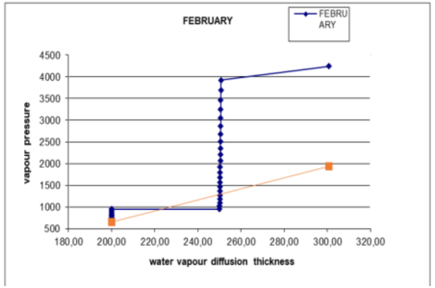
Double skin cladding system



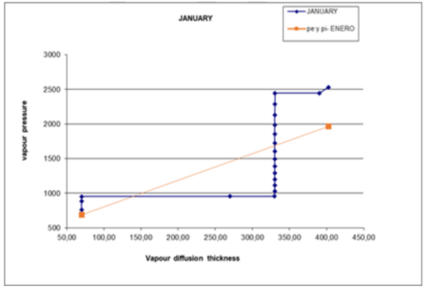


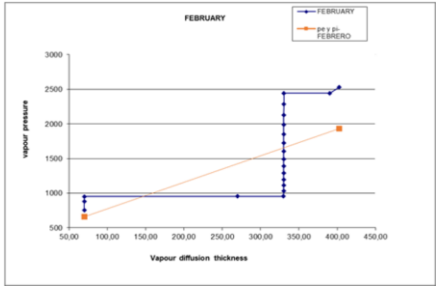
Flat roofing sandwich panel





Facade cladding system





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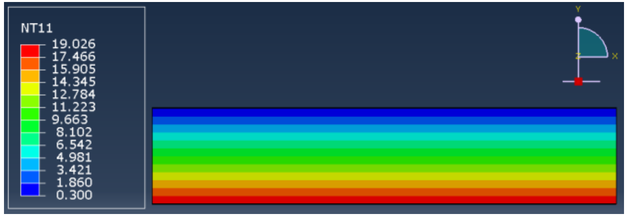
Validation

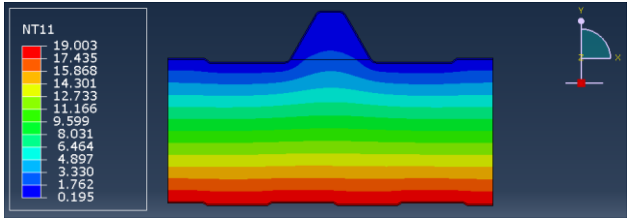
of 2D calculations by 3D modelling

A commercial finite element software package Abaqus CAE was used to create the 3D models and obtain the inner surface temperature.

a) Cladding sandwich panel



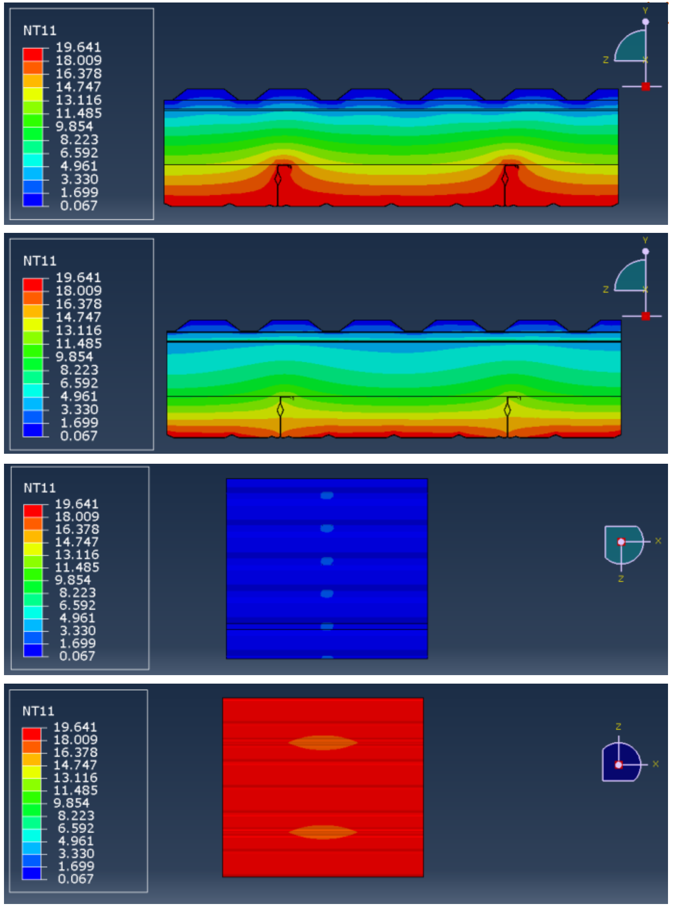
b) Pitch roofing sandwich panel



Obtained temperatures are quite similar and **risk of condensation** is again identified **for hygrometry 5**.

In **double skin cladding system**, risk of condensation exits also in **hygrometry 4** in specific points (at the vertical alignment between the steel profile and the joint between two adjacent cassettes).

d) Double skin cladding system



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04

Fire safety performance

Test procedures

Test samples

Test results

Conclusions

Test procedures

REACTION TO FIRE (class. EN 13501-1)

EN 13823 single burning item (SBI)

Potential contribution of a product to the development of a fire, under a fire situation simulating a single burning item in a room corner near to that product. Flammability test to confirm the classification obtained from the SBI test.

Parameters or observations registered:

- FIGRA, Fire Growth Rate Index.
- THR, Total Heat Release.
- SMOGRA, Smoke Growth Rate Index.
- TSP, Total Smoke Production.
- Lateral spread of flames
- Fall of flaming particles and droplets.

	A2 / B	C	D
THR	≤ 7,5MJ	≤ 15 MJ	
FIGRA	≤ 120 W/s	≤ 250 W/s	≤ 750 W/s
	s1	**S2**	**s3**
SMOGRA	≤ 30 m^2/s^2	≤ 180 m^2/s^2	not s1 or s2
TSP	≤ 50 m^2	≤ 200 m^2	not s1 or s2
	d0	**d1**	**d2**
Flaming droplets / particles within 600s	no	no persisting longer than 10 s	not d0 or d1

Limits for classification accord. to EN 13501-1

EXTERNAL FIRE EXPOSURE (class. EN 13501-5)

CEN/TS 1187 external fire exposure to roofs (B_{ROOF} t1)

This test evaluates fire spread across the external surface of the roof, the fire spread within the roof, the fire penetration and the production of flaming droplets or debris falling from the underside of the roof or from the exposed surface.

Parameters or observations registered :

- External fire spread
- Fire penetration and openings
- Damage of tests specimen

Class	Classification criteria
B_{ROOF} (t1)	External and internal flame spread upwards < 0,700 m External and internal flame spread downwards < 0,600 m Maximum burnt length, external and internal < 0,800 m No burning material (droplets or debris) falling from the exposed side No burning/glowing particles penetrating the roof construction No single through opening > 25 mm² Sum of all through openings < 4500 mm² Lateral flame spread does not reach the edges of the measuring zone Maximum radius of the fire spread on 'horizontal roofs', external and internal < 0,200 m
F_{ROOF} (t1)	No performance determined

Criteria to determine the classification of roofs according to EN 13501-5

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Test procedures

FIRE PROPAGATION (internal procedure)

ISO 13785-1:2002 fire propagation intermediate-scale test

Fire performance of façades when exposed to heat from a simulated external fire with flames impinging directly upon the façade.

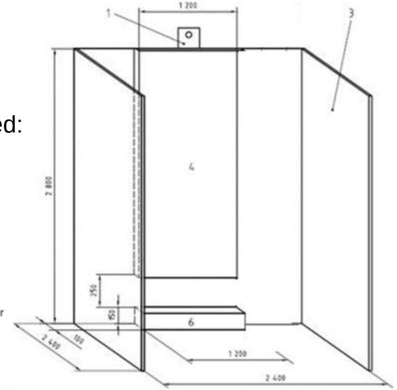
Heat release: 300 kW for 30 minutes.

Parameters or observations registered :

- Heat flux.
- Temperatures.
- Ignition of the test specimen.
- Flame spread.
- Any unusual behaviour.
- Falling and/or burning parts.

ISO 13785-1 does not determine any pass/fail criteria, so tests results refer to the data obtained:

- Heat flux as a function of time.
- Temperatures as a function of time
- Maximum value of heat flux.
- Fire development (photographs).
- Observations.



Key
1 Position of heat flux meter
2 Back wall
3 Draught screen
4 Test specimen back wall
6 Ignition burner

FIRE RESISTANCE (class. EN 13501-2)

EN 1364-1 Walls and EN 1365-2 Floors

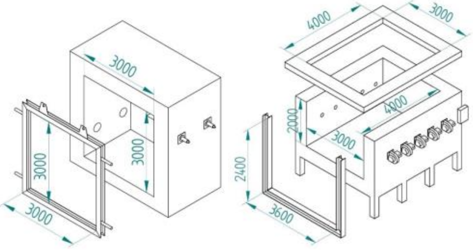
The ability of a wall or a floor to withstand a fully developed fire. This determines how long it can resist the spread of fire from one side to the other.

Criteria to be maintained:

- Loadbearing capacity (R): the maximum deflection and the rate of deflection of the test sample are evaluated using extensometers.
- Integrity (E): the passage of flame and hot gases or the appearance of openings…
- Insulation (I): the temperature of the sample (average and maximum)…

Classification according to EN 13501-2

(R)EI	15	20	30	45	60	90	120	180	240



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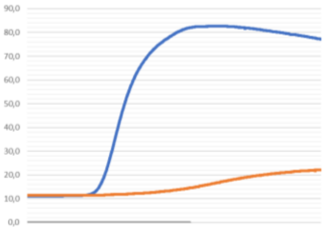
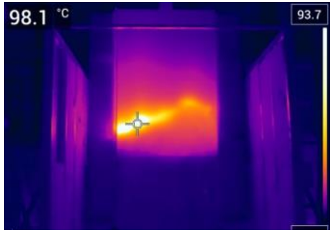
Test procedures

SMOULDERING

Smouldering assessment of bio-based insulations at the system level based on 4 type of fire tests.

EVALUATION	Testing/Classification Procedure	Smoldering or Heat Transfer Evaluation	Design Strategies
REACTION TO FIRE	EN 13823 EN ISO 11925-2 EN 13501-1	• Internal thermocouples • Thermographic camera • Visual observations	-
EXTERNAL FIRE EXPOSURE	CEN/TS 1187 EN 13501-5	• Visual observations	✓
FIRE PROPAGATION	Internal procedure based on ISO 13785-1	• Internal thermocouples • Thermographic camera • Visual observations	✓
FIRE RESISTANCE	EN 1364-1/EN 1365-2 EN 13501-2	• Internal thermocouples • Thermographic camera	-





Evaluation techniques:

- Temperature measurement within the wood fibre insulation → internal thermocouples.
  - During fire test: maximum temperature reached to identify any possible combustion process of insulation.
  - After fire test: smouldering phenomenon curve until total combustion of the insulation to identify temperature peaks related to the combustion process.
- Visual evaluation of temperature distribution → thermographic camera.
  - Thermographic images after the SBI and fire propagation tests to identify a possible self-sustained smoulder propagation process, evaluate its spread along the system, and conclude its limitation or extinction.
  - Thermographic images during fire resistance tests to evaluate the horizontal heat transfer between system elements.
- Visual evaluation of the smouldering process → disassembly of envelope system after each test.
  - Check the damage produced by the smouldering and to examine any possible re-ignition or to identify the effectiveness of the adopted fire safety design strategies.

Process:

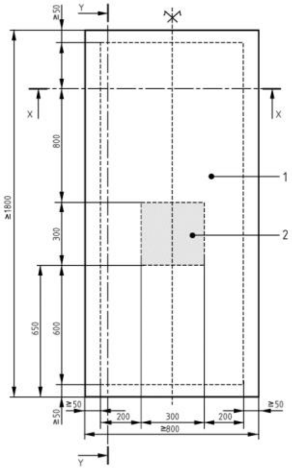
1. Definition of variables affecting the smouldering process and evaluation at system level.
2. Proposal of strategies that address these concerns within the system design.
3. Retesting at system level after implementation of defined strategies.

Test samples

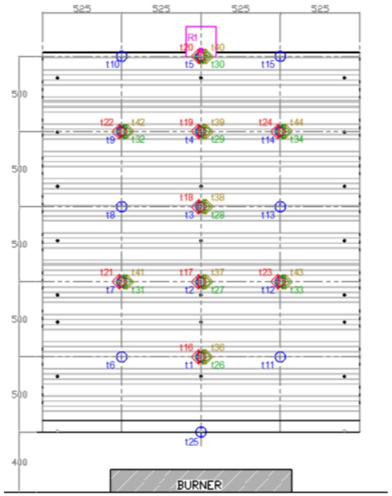
Evaluation	Tested Systems	
REACTION TO FIRE	Facades and roofs	a) b) c) d) e)
EXTERNAL FIRE EXPOSURE	Roofs	b) c)
FIRE PROPAGATION	Facades	a) d) e)
FIRE RESISTANCE	Facades and roofs	a) b) c) d) e)

- a) Cladding sandwich panel
- b) Pitch roofing sandwich panel
- c) Flat roofing sandwich panel
- d) Double skin cladding system
- e) Facade cladding system

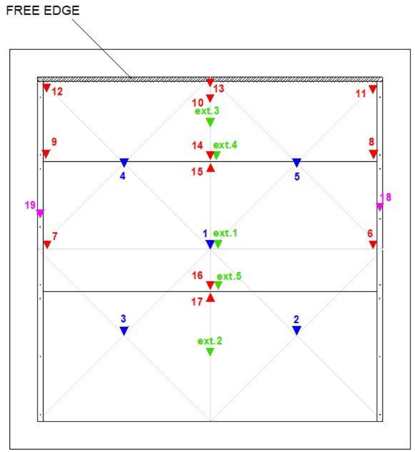
EXTERNAL FIRE EXPOSURE OF ROOFS



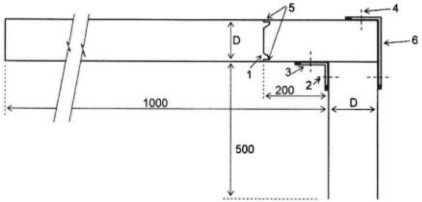
FIRE PROPAGATION OF FACADES



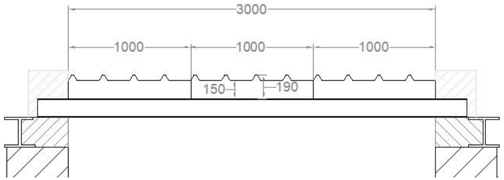
FIRE RESISTANCE OF FACADES



REACTION TO FIRE



FIRE RESISTANCE OF ROOFS



Test results

REACTION TO FIRE

Parameter	a)	b)	c)	d)
THR 600 s (MJ)	0.87	0.52	1.02	0.51
FIGRA 0.2 (W/s)	2.34	1.19	6.69	6.24
FIGRA 0.4 (W/s)	2.34	1.19	6.69	6.11
TSP 600 s (m^2)	11.56	17.42	41.02	62.78
SMOGRA (m^2/s^2)	0.00	0.00	1.62	4.56
Flaming particles	no	no	no	no
Lateral flame spread	no	no	no	no
Classification	B-s1,d0	B-s1,d0	B-s1,d0	B-s2,d0

Sandwich panels a) b) c) B-s1,d0

Same inner steel sheet thickness used → results differ depending on the shape/dimension of the joint material (a and b) or the insulation thickness and lack of joint material (c).

Metal sheet systems d) e) B-s2,d0

Even if thicker metal sheet used and the mounting system not directly represent the reality (cavities and internal profiles not represented in the test).

b) Pitch roofing sandwich panel

d) Double skin cladding system

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Test results

REACTION TO FIRE (smouldering)

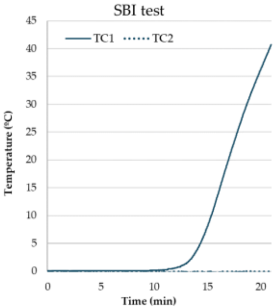
Smouldering phenomenon: heat stored within the system and insulation material burning internally and releasing smoke for hours or even days.

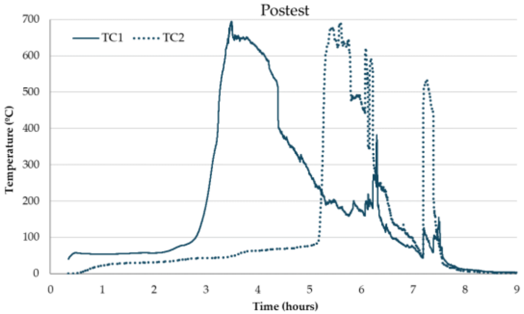
Internal thermocouples:

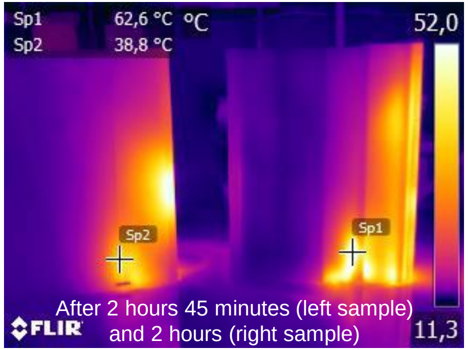
- During fire test: increase in temperature only registered by TC1.
- After fire test: TC2 continued increasing its temperature proving the existence of the smouldering phenomenon.

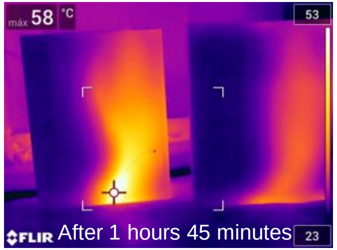
Thermographic camera:

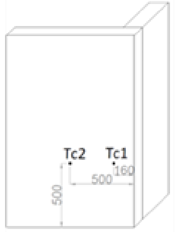
- Sandwich panels: still smouldering and almost all the insulation was consumed after one day of monitorization.

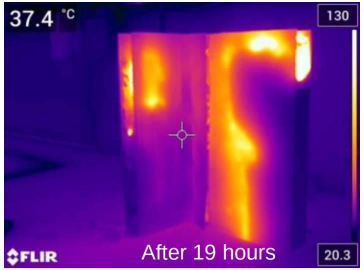












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Test results

EXTERNAL FIRE EXPOSURE

In general, the fire is inserted through the joint between the two panels and the wood insulation catches fire, causing the test to fail.

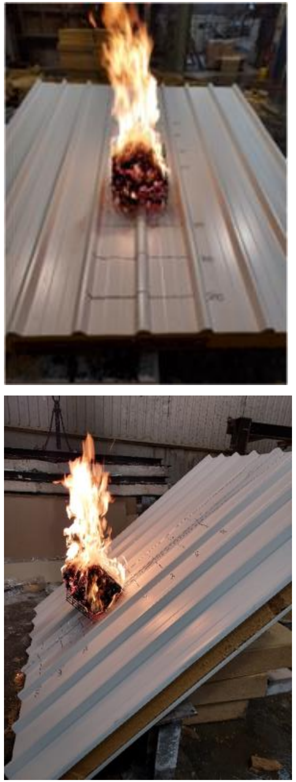
(fire penetration)
internal incandescent combustion

SYSTEM TESTED	Tested product	Result	Classification
b) Pitch roofing sandwich panel	Roof sandwich panel at 15º	Not pass/ Pass	Tent to B_{ROOF} (t1)
	Roof sandwich panel at 45º.	Not pass	F_{ROOF} (t1)
c) Flat roofing sandwich panel	Roof sandwich panel at 15º	Not pass	F_{ROOF} (t1)
	Roof sandwich panel at 15º with insulation + waterproof membrane	Pass	B_{ROOF} (t1)

Several parameters could affect a roof system's behaviour when exposed to external fire:

- Sample fastened or not fastened and distance between fixings;
- Use stitching elements and distance between them;
- Type of joint used (dimensions and combustible materials);
- Sensibility of the mounting.

b) Pitch roofing sandwich panel



c) Flat roofing sandwich panel

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Test results

EXTERNAL FIRE EXPOSURE (smouldering)

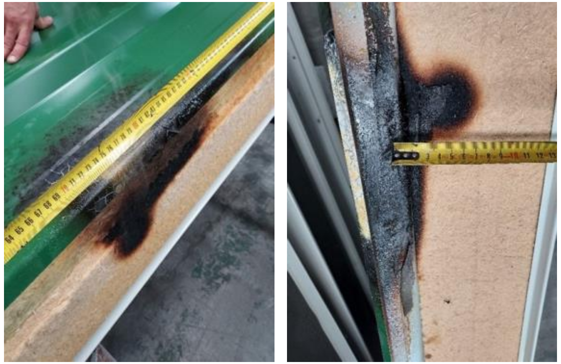
Internal incandescent combustion was not detected at the end of the test when the panels were fixed to a substructure and stitching screws were used to simulate a much more real mounting condition.

Pass/fail condition could depend on the system configuration and the mounting conditions

Generally, considering that the fire can penetrate the system and reached the wood fiber insulation, it is important to understand how or why it spreads and how to stop it.

DS1_ Use of non-combustible materials as mitigation layer or element: mineral wool insulation and waterproofing membrane.

b) Pitch roofing sandwich panel (not fixed)



b) Pitch roofing sandwich panel (fixed)

c) Flat roofing sandwich panel

c) Flat roofing sandwich panel with insulation and waterproof membrane

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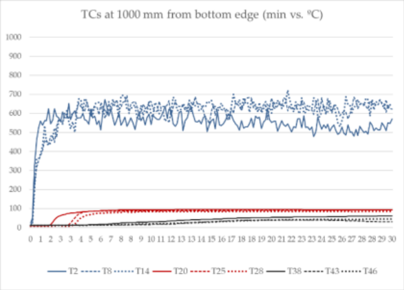
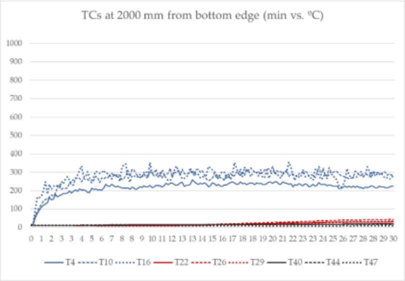
Test results

FIRE PROPAGATION

SYSTEM TESTED	Description	Result
a) Cladding sandwich panel	• No vertical flame propagation beyond the specimen limits • No burning fragments falling from the façade • Temperature limits not reached	Favourable behaviour
d) Double skin cladding system	Flame propagation occurred vertically beyond the upper limit of the test specimen through the combustible components and/or air cavities within the test specimen	Not favourable behaviour
e) Facade cladding system		

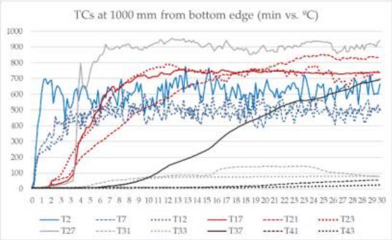
a) Cladding sandwich panel

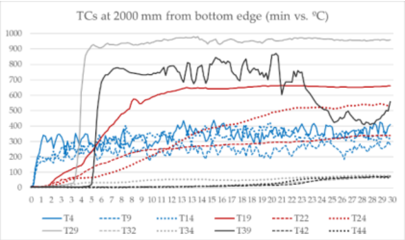




Internal temperatures represent the fire spread occurred within the sample. While external cladding temperatures are similar for both profile façade systems and sandwich panels, internal temperatures differ from one system to other.

d) Double skin cladding system





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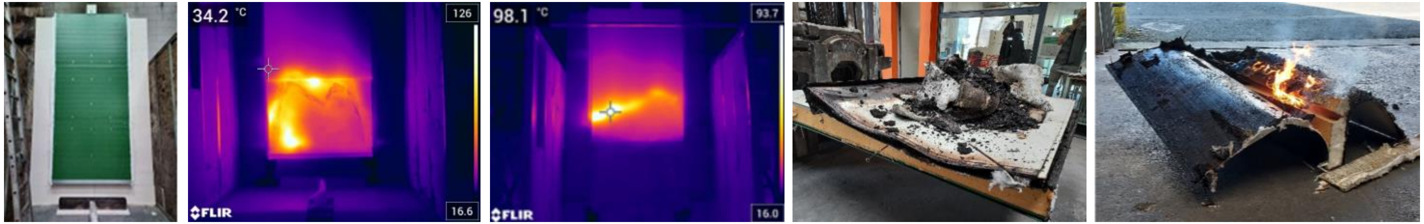
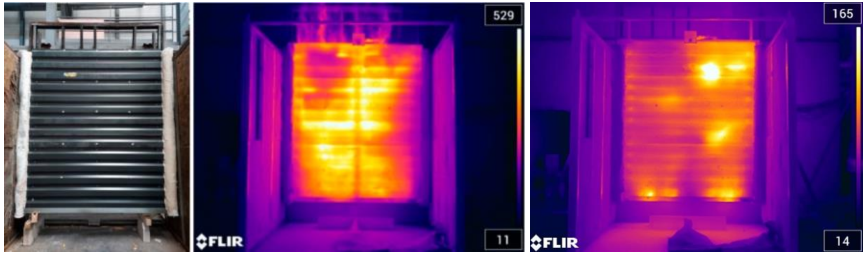
Test results

FIRE PROPAGATION (smouldering and design strategies)

a) Cladding sandwich panel

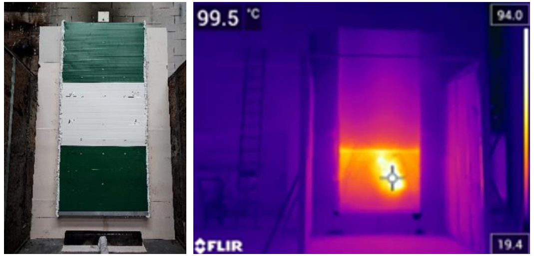


d) Double skin cladding system



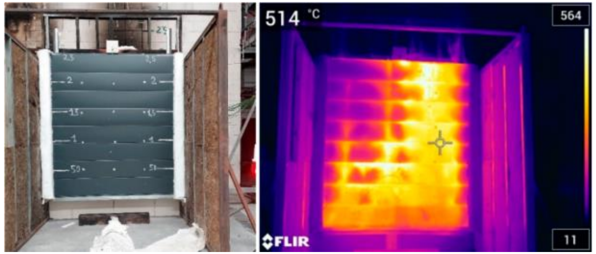
a') Cladding sandwich panel

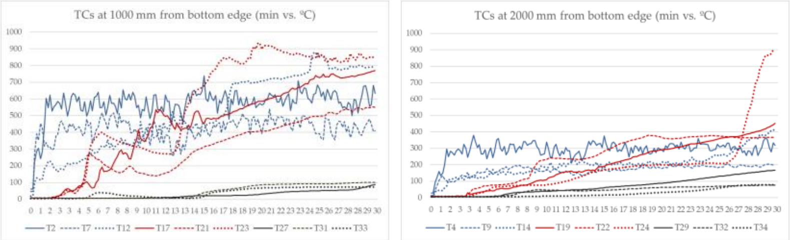
DS1_ Use of non-combustible materials as mitigation layer or element: intercalated mineral wool insulation sandwich panel.



d) Façade cladding system

DS2_Closure, sealing or limiting of air cavities and gaps: mineral wool insulation installed within the omega profiles.





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Test results

FIRE RESISTANCE

SYSTEM TESTED	Fire Resistance EN 1364-1 (walls)	Fire Resistance EN 1365-2 (roofs)
a) Cladding sandwich panel	EI45 as partition EI30 (i→o) as external wall	n.a
b) Pitch roofing sandwich panel	n.a	REI 30
c) Flat roofing sandwich panel	EI60 as partition EI60 (i→o) as external wall	-
d) Double skin cladding system	E90 EI45 as partition E90 EI30 (i→o) as external wall	n.a
e) Facade cladding system	E60 EI45 as partition E60 EI30 (i→o) as external wall	n.a

a) Cladding sandwich panel

c) Flat roofing sandwich panel

b) Pitch roofing sandwich panel

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Test results

FIRE RESISTANCE (heat transfer)

In double skin system, temperature failure was reached before the fire reached the external face of the envelope system.

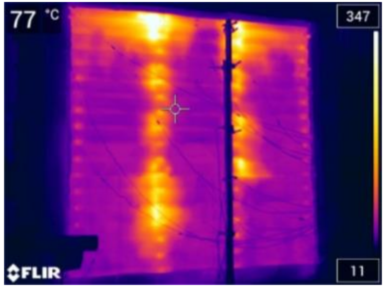
Internal thermocouples:

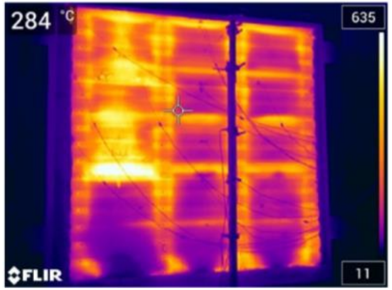
- Showed a quick heat transfer between the metallic elements (elevated temperatures were detected earlier in the omegas and spacers than in the second insulation layer)

Thermographic camera:

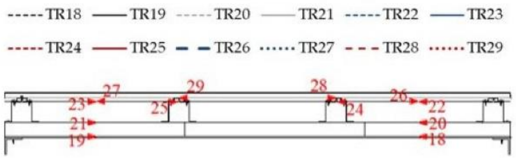
- Also showed the mentioned heat transfer through the different layers

DS3_ Elements that break the contact between metallic elements should be considered for limiting the rapid heat transfer between the internal and external sides of facades.

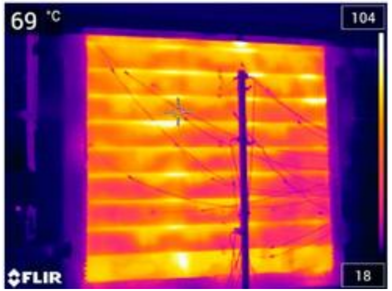


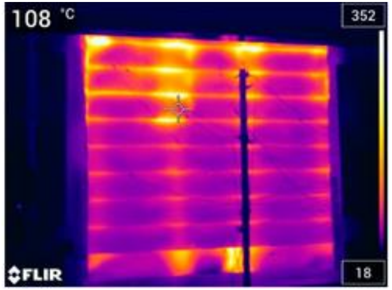


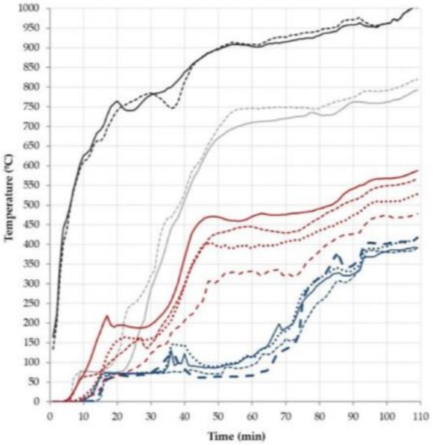
d) Double skin cladding system

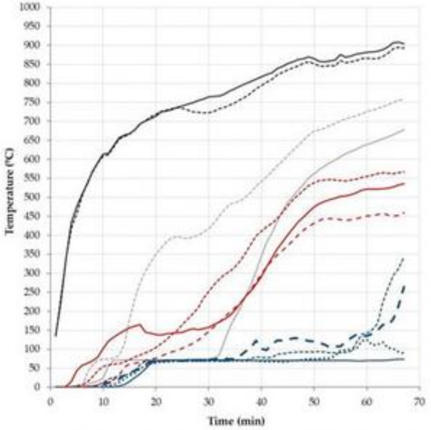


e) Facade cladding system (double skin)









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Conclusions

Fire performance of the bio-based materials in the sandwich panels considering the reaction to fire **(EN 13501-1)**, external fire exposure **(EN 13501-5)**, propagation of fire **(internal procedure)** and fire resistance **(EN 13501-2)** of the envelope systems.

SYSTEM TESTED	Reaction to fire	External Fire Exposure	[1] Fire propagation (Internal protocol)	Fire Resistance of walls	FR of roofs
a) Cladding sandwich panel	B-s1,d0	Not applicable	Pass	EI45 [partition] EI30 (i→o) [ext. wall]	n.a
b) Pitch roofing sandwich panel	B-s1,d0	Not classified [2]	Not applicable	n.a	REI 30
c) Flat roofing sandwich panel	B-s1,d0	B_{ROOF} (t1) [4]	Not applicable	EI60 [partition] EI60 (i→o) [ext. wall]	-
d) Double skin cladding system	B-s2,d0	Not applicable	Not pass [3]	E90 EI45 [partition] E90 EI30 (i→o) [ext.wall]	n.a
e) Facade cladding system	B-s2,d0 [5]	Not applicable	Not pass [3]	[5] E60 EI45 [partition] E60 EI30 (i→o) [ext. wall]	n.a

[1] Evaluation according to Tecnalia's internal procedure in the absence of a harmonized European test standard for fire spread in facades. [2] Performance dependent on design strategy: positive results depending on mounting condition (panels tested at 15°, fixed to a substructure and with stitching screws every 1 m). Not classified as one test was only carried out. [3] Performance dependent on design strategy: implementation and evaluation needed. [4] Performance dependent on design strategy: sandwich panel protected with mineral wool and waterproof membrane tested at 15°. [5] Double skin system tested instead of with concrete base wall.

Comparison of the fire performance of the prefabricated sandwich panels considering different core insulation materials.

- Reaction to fire and fire resistance
- External fire exposure: Broof classification without further testing (CWFT) possible for mineral wool and polyurethane core sandwich panels

	Core Insulation Material			Thickness (mm)
	MW	PIR	WF	
Reaction to Fire	A2-s1,d0	B-s1,d0 B-s2,d0	B-s1,d0	-
Fire Resistance	EI60/EI90	EI30	Not assessed	80
	EI120/EI180	EI30	Not assessed	100
	EI180/EI240	EI45	EI45	150
	EI180/EI240	EI60	EI60	200

- Similar results for wood fibre (WF) and PIR sandwich panels.
- Bio-based insulation panels include benefits regarding sustainability, reducing carbon emission contributions and hence promoting the decarbonization of the construction sector.
- Propensity for continuous smouldering should be considered on WF insulation sandwich panels.

Fire performance assessment of bio-based materials in sandwich panels at the system level including smouldering aspects:

fire Fire Safety of Steel Envelope Systems with Bio-Based Insulation: Evaluation of Smoldering Phenomenon

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05

Acoustic tests

Test procedures

Test results

Discussions on results

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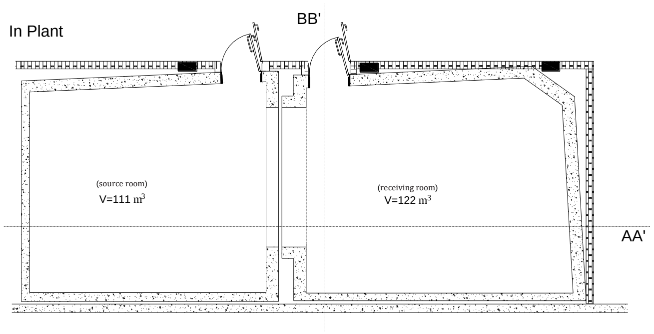
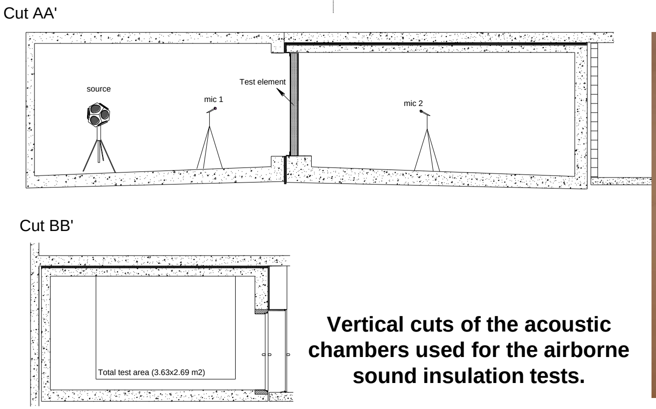
Test procedures

Airborne sound insulation tests (on the laboratory)

- Airborne sound insulation tests were carried out in the Department of Civil Engineering at the University of Coimbra, according to EN ISO 10140:2021 and EN ISO 717-1:2020.
- The acoustic laboratorial facility consists of two horizontally adjacent rooms; in one side, the room is designated as the 'source room' and the other side as the 'receiving room'. The two reverberant rooms have internal volumes of 111 m3 and 122 m3, respectively, for the source and receiving chambers.
- The test element is mounted in the opening between those rooms. The test procedure is based on measuring for every one-third octave frequency band within the range of study, usually in laboratory from 100 Hz to 5000 Hz, the **average sound pressure level** in the 'receiving room' when exciting the source room with an omnidirectional sound source (dodecahedral loudspeaker source) placed in at least two different positions. The **equivalent sound absorption area** in the receiving room is calculated from the reverberation time measurements.



Plants views of the reverberant chambers



Vertical cuts of the acoustic chambers used for the airborne sound insulation tests.

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Test results

a) **Cladding sandwich panel**
b) **Pitch roofing sandwich panel**
c) **Flat roofing sandwich panel**

Two tests were performed:

- no insulation bands in the joints of two adjacent panels
- self-adhesive bands along the joints.

Generally, no sensible airborne sound insulation improvement was registered.

d) Double skin cladding system

Two configurations were tested:

- 25 mm height cladding profile
- 40 mm height cladding profile

Same global weighted sound reduction index obtained, but the use of larger rib is slightly more detrimental since it has a negative impact on high frequencies.

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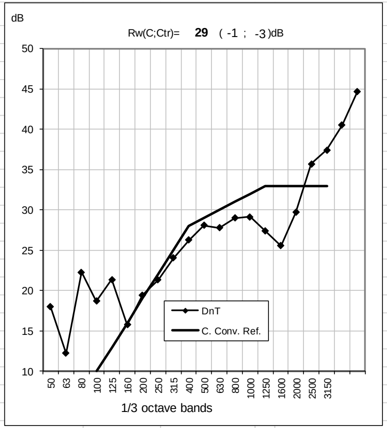
a)

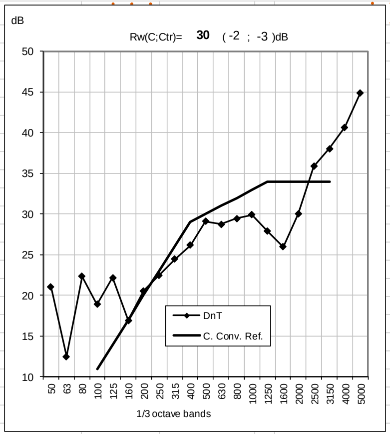
Freq. [Hz]	R (dB)
50	18,0
63	12,2
80	22,3
100	18,7
125	21,4
160	15,8
200	19,5
250	21,3
315	24,1
400	26,3
500	28,1
630	27,8
800	29,0
1000	29,2
1250	27,4
1600	25,6
2000	29,7
2500	35,7
3150	37,4
4000	40,5
5000	44,7

Rw(C;Ctr)=29(-1;-3)



Freq. [Hz]	R (dB)
50	21,1
63	12,5
80	22,3
100	18,9
125	22,2
160	16,9
200	20,6
250	22,5
315	24,4
400	26,2
500	29,1
630	28,8
800	29,4
1000	29,9
1250	27,9
1600	26,0
2000	30,0
2500	35,9
3150	38,0
4000	40,7
5000	44,9

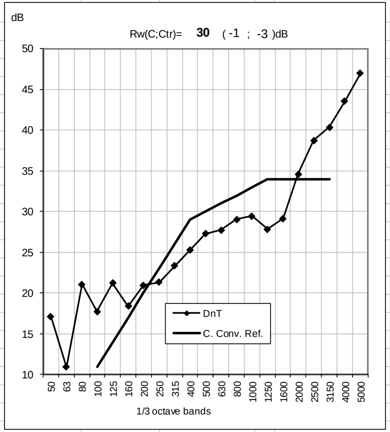
Rw(C;Ctr)=30(-2;-3)



b)

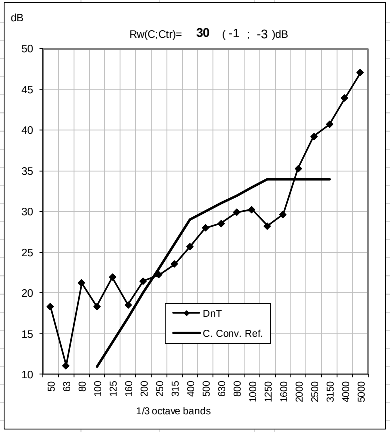
Freq. [Hz]	R (dB)
50	17,1
63	10,9
80	21,1
100	17,8
125	21,2
160	18,4
200	21,0
250	21,3
315	23,4
400	25,3
500	27,3
630	27,7
800	29,1
1000	29,4
1250	27,8
1600	29,1
2000	34,6
2500	38,7
3150	40,3
4000	43,5
5000	47,0

Rw(C;Ctr)=30(-1;-3)



Freq. [Hz]	R (dB)
50	18,3
63	11,1
80	21,2
100	18,3
125	22,0
160	18,6
200	21,5
250	22,2
315	23,5
400	25,7
500	28,0
630	28,6
800	29,9
1000	30,3
1250	28,2
1600	29,6
2000	35,3
2500	39,2
3150	40,7
4000	43,9
5000	47,1

Rw(C;Ctr)=30(-1;-3)



Test results

a) Cladding sandwich panel
b) Pitch roofing sandwich panel
c) Flat roofing sandwich panel

Two tests were performed:

- no insulation bands in the joints of two adjacent panels
- self-adhesive bands along the joints.

Generally, no sensible airborne sound insulation improvement was registered.

d) Double skin cladding system

Two configurations were tested:

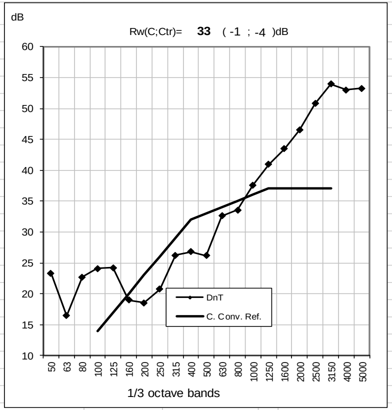
- 25 mm height cladding profile
- 40 mm height cladding profile

Same global weighted sound reduction index obtained, but the use of larger rib is slightly more detrimental since it has a negative impact on high frequencies.

c)

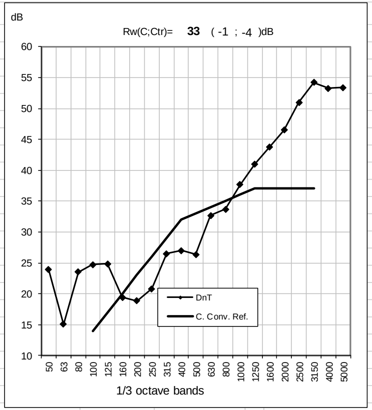
Freq. [Hz]	R (dB)
50	23,3
63	16,5
80	22,7
100	24,1
125	24,2
160	19,0
200	18,5
250	20,8
315	26,2
400	26,8
500	26,2
630	32,6
800	33,6
1000	37,6
1250	41,0
1600	43,5
2000	46,5
2500	50,8
3150	53,9
4000	53,0
5000	53,3

Rw(C;Ctr)=33(-1;-4)



Freq. [Hz]	R (dB)
50	23,9
63	15,1
80	23,5
100	24,7
125	24,8
160	19,4
200	18,9
250	20,8
315	26,5
400	27,0
500	26,4
630	32,7
800	33,7
1000	37,6
1250	41,0
1600	43,8
2000	46,5
2500	51,0
3150	54,2
4000	53,2
5000	53,4

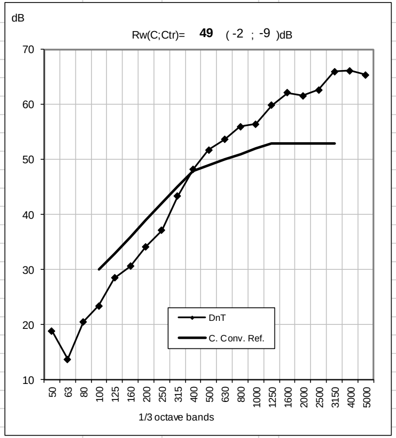
Rw(C;Ctr)=33(-1;-4)



d)

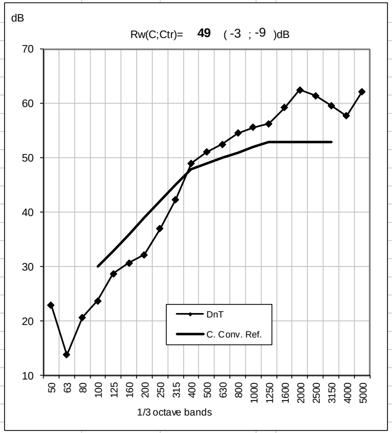
Freq. [Hz]	R (dB)
50	18,9
63	13,7
80	20,6
100	23,4
125	28,5
160	30,6
200	34,2
250	37,1
315	43,4
400	48,3
500	51,8
630	53,7
800	56,0
1000	56,5
1250	59,9
1600	62,1
2000	61,6
2500	62,7
3150	66,0
4000	66,1
5000	65,4

Rw(C;Ctr)=49(-2;-9)



Freq. [Hz]	R (dB)
50	23,0
63	13,8
80	20,7
100	23,8
125	28,8
160	30,7
200	32,2
250	37,0
315	42,4
400	49,0
500	51,1
630	52,5
800	54,6
1000	55,6
1250	56,3
1600	59,3
2000	62,5
2500	61,5
3150	59,6
4000	57,7
5000	62,2

Rw(C;Ctr)=49(-3;-9)



Test procedures

Airborne sound insulation tests (on the Demostrators)

- The airborne sound insulation of the different façades was evaluated by measuring the **Sound Pressure Level** (SPL, in dB, for each 1/3rd octave frequency band between 100 Hz and 3150 Hz) inside and outside each demonstrator module (ISO 16283-3).
- A directional sound source was positioned outside the module, centred with the façade to be measured, and at a distance of 5 m from the façade; in cases where this was not possible due to insufficient space, the source was positioned at around 3.5 m from the façade.
- Background noise was also measured inside the module (with the acoustic source turned off) to ensure that no contamination from other external noise sources occurred, or to account for the adequate SPL correction.

Impact sound insulation tests (on the Demonstrators)

- Standardized impact sound level was evaluated for the roofs of the two modules following the standard ISO 16283-2 and by making use of a standard tapping machine.
- The tapping machine was placed on the roof of each module, at 2 specific positions determined based on the distribution of the materials used in each part of the roofs.
- For each tapping machine position, the SPL, in dB, for each 1/3rd octave frequency band between 100 Hz and 3150 Hz, inside the module was evaluated at 3 different microphone positions.


Demonstrator 1

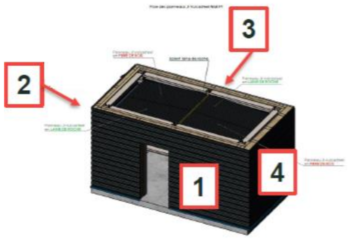

Demonstrator 2

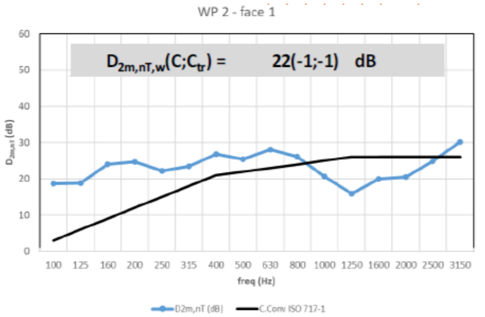
Standard tapping machine

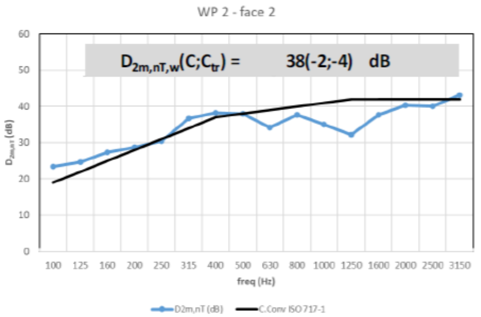
Test results

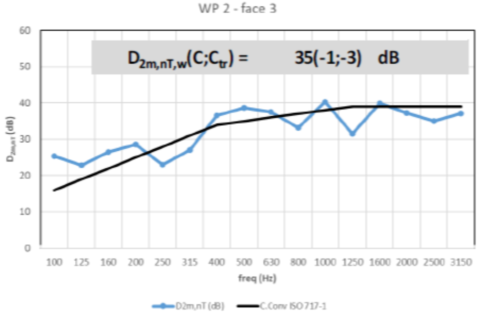
Airborne sound insulation of the façades

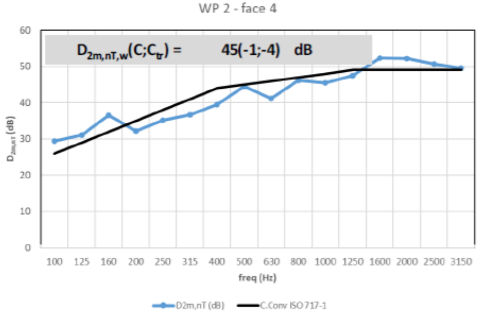
Demonstrator 2
Systems c), d) and e)



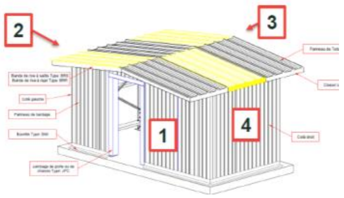


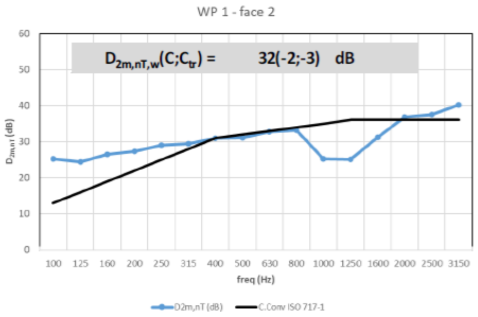


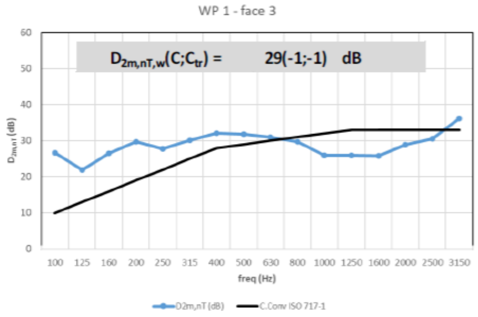


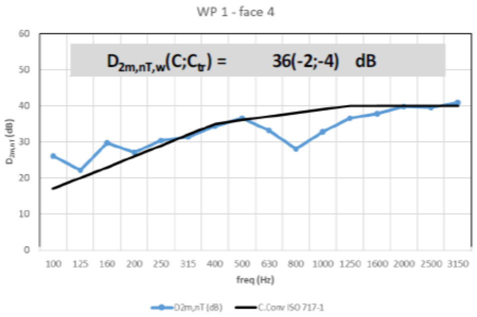


Demonstrator 1
Systems a) and b)



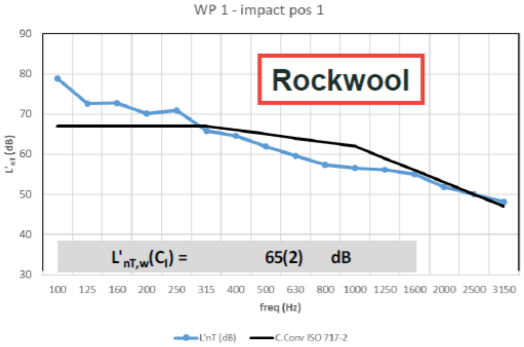


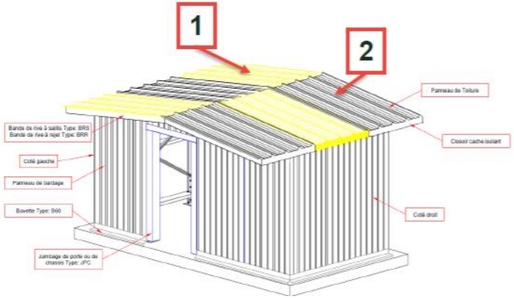




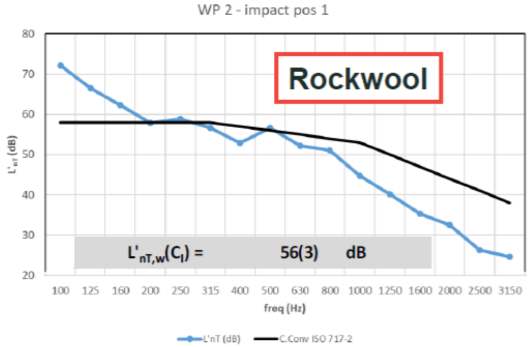
Test results

Impact sound insulation of the roof

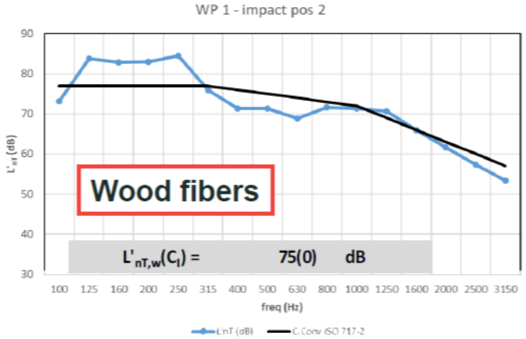


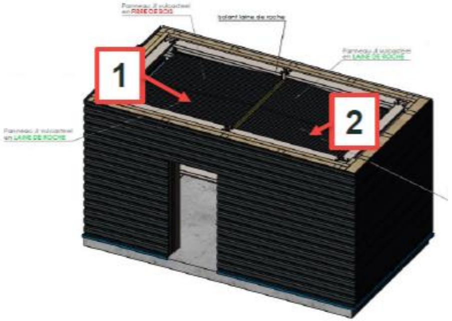


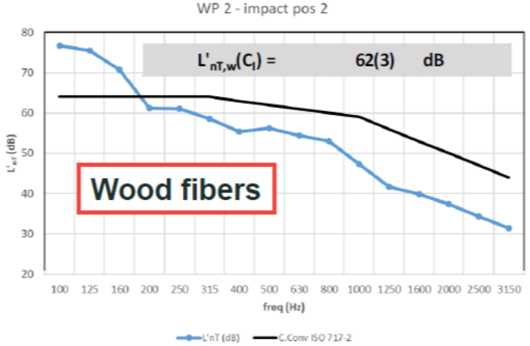
Demonstrator 1
Systems a) and b)



Demonstrator 2
Systems c), d) and e)







Discussion on results

Airborne sound insulation tests (on the Demostrators)

- Higher values of airborne sound insultation index were achieved in Demonstrator WP2, which was expected taking into account that it is composed by a double constructive solution, which already had shown better acoustic behaviour in the laboratory tests (Rw=49 dB vs. Rw=30 dB).
- The in-situ airborne sound results revealed lower values of D_(2m,nT,w) when compared to the laboratory tests (tested solutions may be influenced from deficiencies in the on-site assemblage process of the solutions, since even small openings or weak spots can have a strong influence in the final airborne insulation of the façades);
- The results for façade 1 in demonstrator WP2 clearly show this effect, in that case due to the presence of a weak door with a significant opening in the bottom and weak sealing in the contour strongly influencing the final value of D_(2m,nT,w);
- A weaker part of the on-site construction was also noticed in the bottom of the walls, which may have influence in the airborne sound insulation results for all façades.

Façade [$D_{2m,nT,w}$ (dB)]	Demonstrator WP1 Systems a) and b)	Demonstrator WP2 Systems c), d) and e)
1	--	22(-1;1)
2	32(-2;-3)	38(-2;-4)
3	29(-1;-1)	35(-1;-3)
4	36(-2;-4)	45(-1;-4)
Lab results (R_w)	**30 (-1,-3)**	**49(-3,-9)**

Impact sound insulation tests (on the Demonstrators)

- A much-improved behaviour is seen in Demonstrator WP2, for both roof zones tested.
- The presence of mineral wool and of a flexible (impermeable) membrane above the test solution is certainly responsible for this much improved behaviour, providing an additional protection to impacts.
- In this case, it is possible to better differentiate the performance of each zone, since the impacts are generated at specific positions (corresponding to distinct constructive solutions).
- Comparing the results for mineral wool and wood fibres panels, a better performance was observed for the mineral wool solution in both demonstrators. The more flexible nature and the higher capacity of mineral wool to dissipate impact energy can be seen as relevant factors for this behaviour.

Façade [$L'_{nT,w}$ (dB)]	Demonstrator WP1	Demonstrator WP2
Wood Fibers	75(0)	62(3)
Mineral Wool	65(2)	56(3)

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LOW CARBON STEEL ENVELOPE SYSTEMS

DURABILITY OF THE 5 SYSTEMS: LESSONS LEARNED FROM OBSERVING (OVER A PERIOD OF 2 YEARS) THE REAL BEHAVIOUR OF THE SYSTEMS INCORPORATED IN 2 DEMONSTRATORS AND CONSISTENCY WITH LABORATORY RESULTS

Helena Gervasio & Jorg Lange

12th June 2025

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Durability tests in the laboratory

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Durability tests on samples (small-scale tests)

The durability of wood fibre insulation was compared to mineral wood insulation in terms of the resistance of wood fibre material to attacks by fungi (Tecnalia):

Test fungi	Strain	Results	
		Tested Materials (%)	Mean corrected mass loss (%)
Coniophora puteana	BAM Ebw. 15	WOOD FIBRE	30.92
Gloeophyllum trabeum	BAM Ebw. 109		21.41
Coniophora puteana	BAM Ebw. 15	SPANROCK M (rock wool)	0.69
Gloeophyllum trabeum	BAM Ebw. 109		0.41

✓ Rockwool withstood the attack of the basidiomycete fungi perfectly, while wood fibers were very affected by fungi, the order of magnitude of mass loss was between 21-30%.

Durability tests on panels

Durability tests on the sandwich panels were carried out for the determination of the "Durability test DUR2", according to UNE-EN 14509:2014 - Annex B.3, in a temperature and humidity chamber and traction equipment (Tecnalia):

Results for wall sandwich panels (Monopanel)

Requirements	Results	Observation
(f_{Ct7} - f_{Ct28}) must be equal to or less than 3 (f_{Ct0} - f_{Ct7})	Complies	DUR2 56-day test does not need to be carried out
f_{Ct28} should not be less than 40% of the f_{Ct0}.	Complies	
$Al_{max} \leq 5\%$ - No corrosion	Complies	

Results for roof sandwich panels (Monopanel)

Requirements	Results	Observation
(f_{Ct7} - f_{Ct28}) must be equal to or less than 3 (f_{Ct0} - f_{Ct7})	Complies	DUR2 56-day test does not need to be carried out
f_{Ct28} should not be less than 40% of the f_{Ct0}.	Complies	
$Al_{max} \leq 5\%$ - No corrosion	Complies	

Results for wall sandwich panels (Joris Ide)

Results	f_{Ct0} (N/mm²)	f_{Ct7} (N/mm²)	f_{Ct28} (N/mm²)
tensile strength	0.0051	0.0043	0.0037

- ✓ **All criteria were met for the wall and roof sandwich panels**

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Hygrothermal cycle resistance on panels

Wall sandwich panels were tested for the determination of the hygrothermal cycling resistance according to Clause 2.2.15.1 of document EAD 090062-00-0404 (Tecnalia):

Test sequence

Type	No. of cycles	Operation	Environmental conditions
Heat-Rain	80	Heat	Temperature rise to 70 ºC in 1 hour and maintained for 2 hours at (70±5) ºC and at 10-30% relative humidity.
		Rain	Water spraying at a temperature of (15 ± 5) ºC and a flow of 1 l/m2 for 1 hour
		Drainage	2 hours in standard laboratory conditions
Conditioning			48 hours in standard laboratory conditions
Heat-Cold	5	Heat	Temperature rise to 50 ºC in 1 hour and maintained for 7 hours at (50±5) ºC and at ≤30% relative humidity
		Cold	Temperature drops to -20 ºC in 2 hours and is maintained for 14 hours at (-20±5) ºC.

✓ **All panels (for Monopanel and Joris Ide) were able to support 80 heat-rain cycles and 5 heat cold cycles without failures.**

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Installation of sensors and monitoring of the demonstrators

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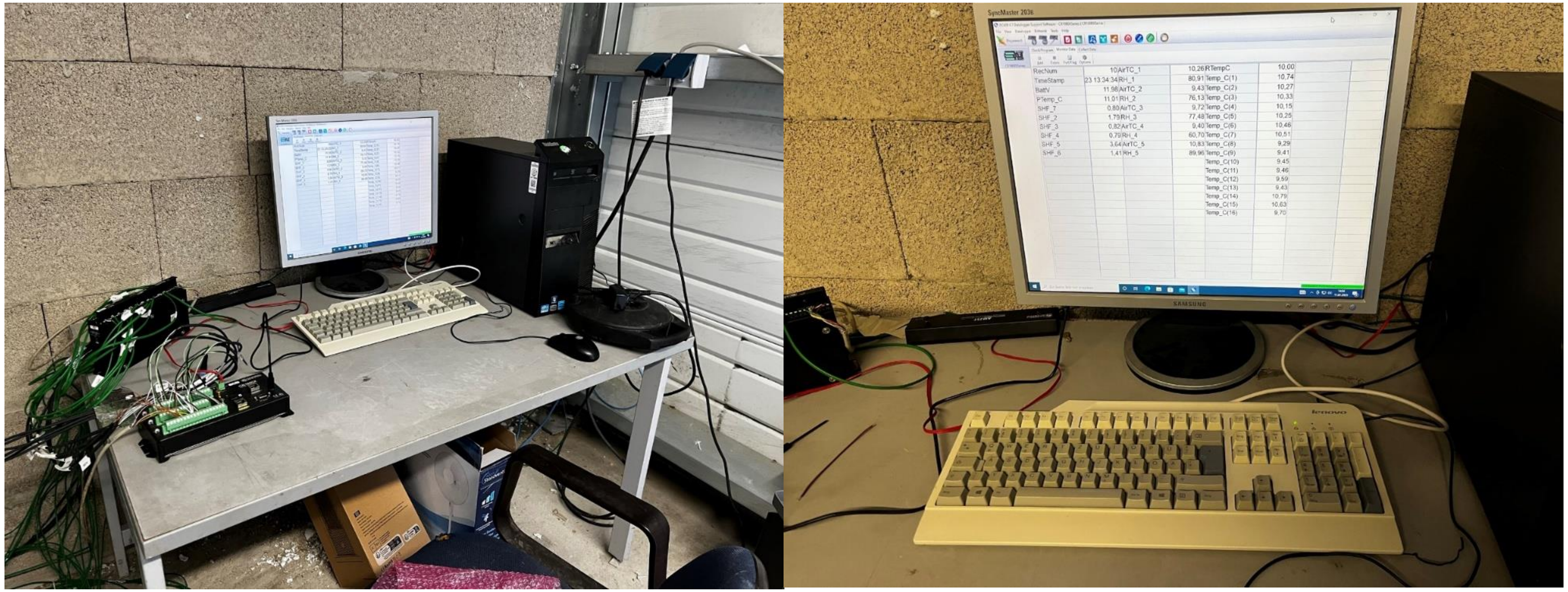
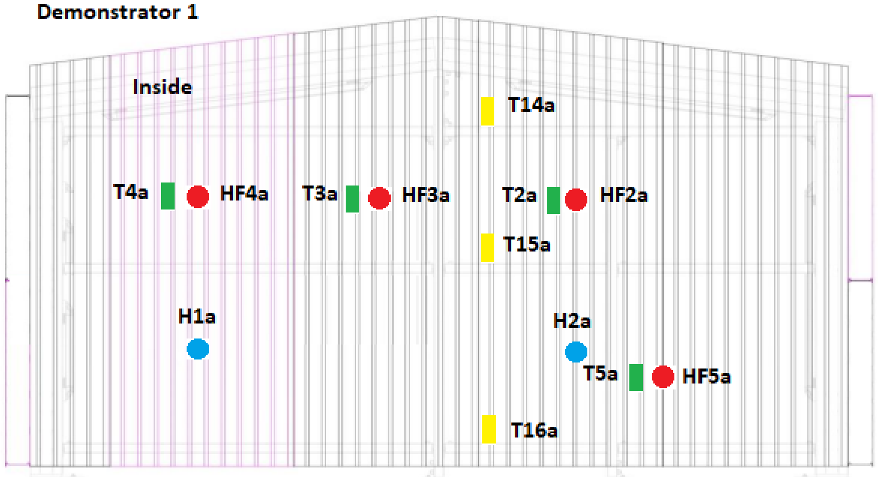
On-site measurements of surface temperature, heat transfer and RH of wood fiber panels and mineral wool panels



✓ **Measures were carried out on Demonstrators 1 and 2, in Darmstadt, from January 2023 to March 2025**

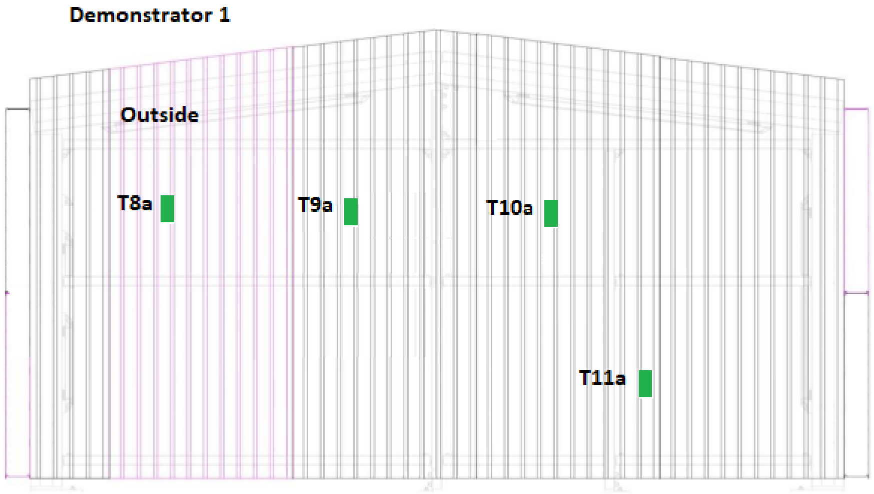
Installation of sensors on Demonstrator 1



Internal view (façade)

- Surface temperature sensor (T)
- Heat Flux sensor (HF)
- Ambient temperature sensor (T)
- Humidity sensor (inside of the panel) (H)
- Wood fiber panels
- Mineral wool panels

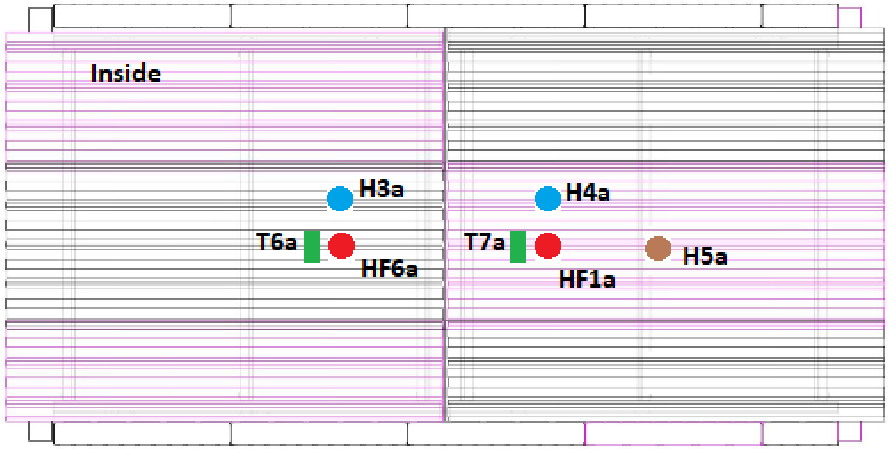
External view (façade)



- Surface temperature sensor (T)
- Wood fiber panels
- Mineral wool panels

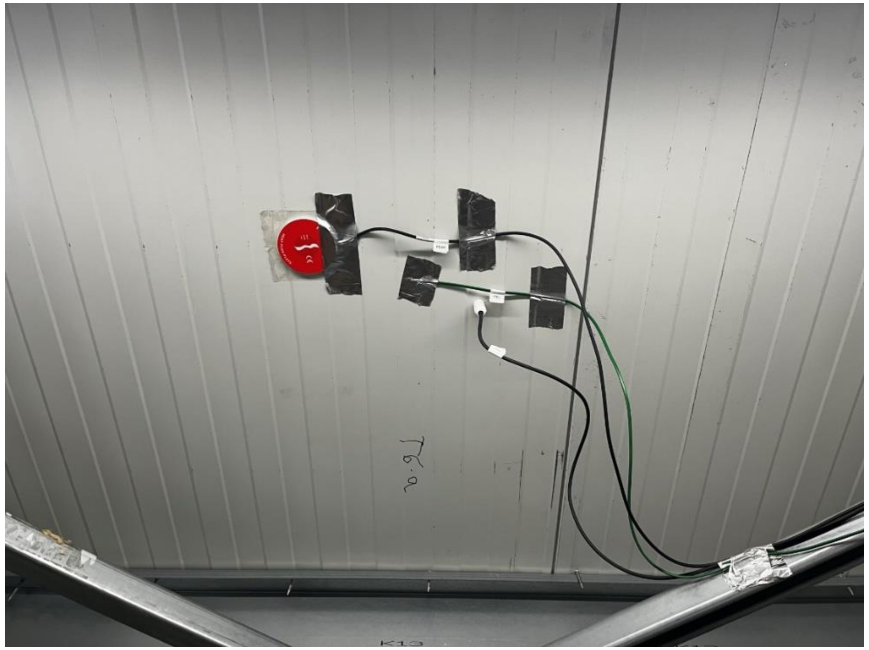
Installation of sensors on Demonstrator 1

Roof

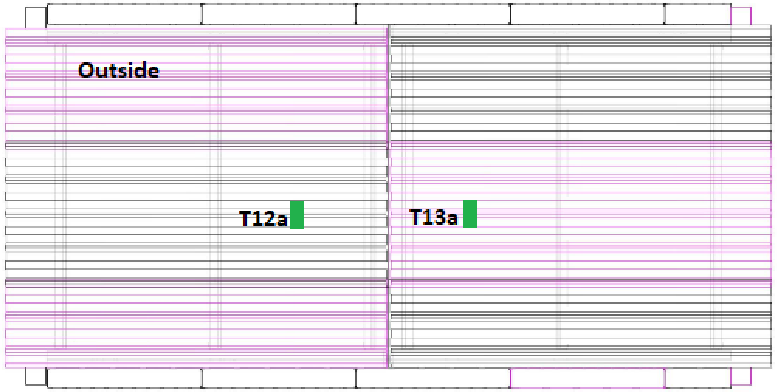


Internal view (roof)

- Surface temperature sensor (T)
- Heat Flux sensor (HF)
- Humidity sensor (ambient) (H)
- Humidity sensor (inside of the panel) (H)
- Wood fiber panels
- Mineral wool panels



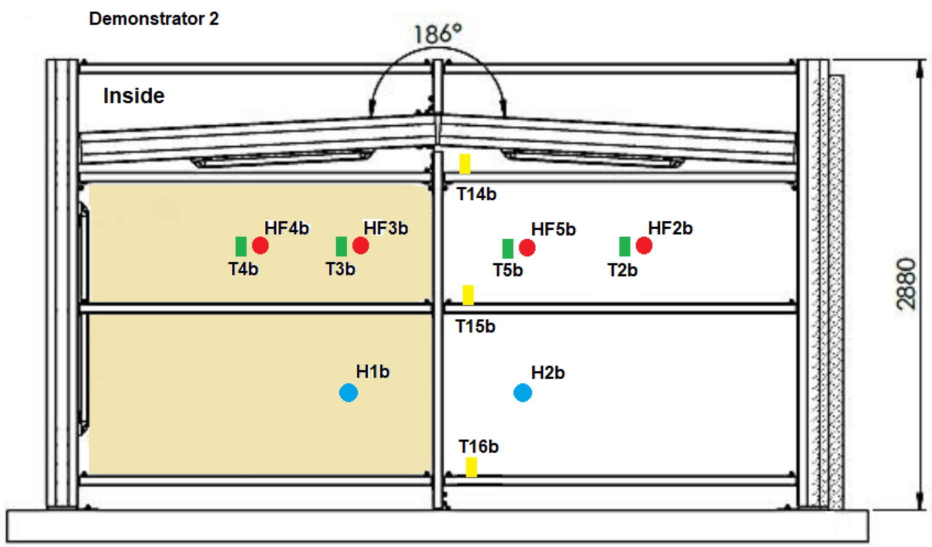
Roof



- Surface temperature sensor (T)
- Wood fiber panels
- Mineral wool panels

External view (roof)

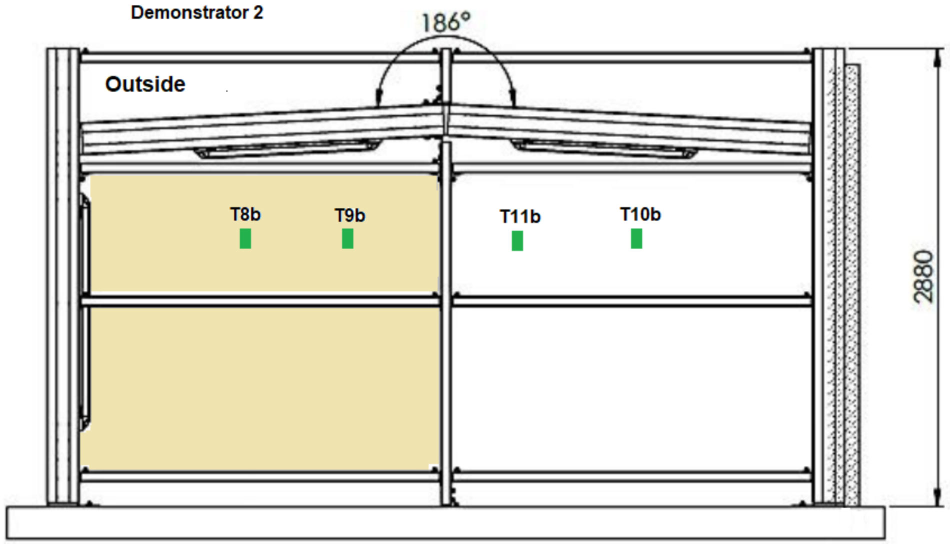
Installation of sensors on Demonstrator 2



Internal view (façade)

- Surface temperature sensor
- Heat Flux sensor
- Ambient temperature sensor
- Humidity sensor (inside of the panel)
- Mineral wool

External view (façade)



- Surface temperature sensor
- Mineral wool

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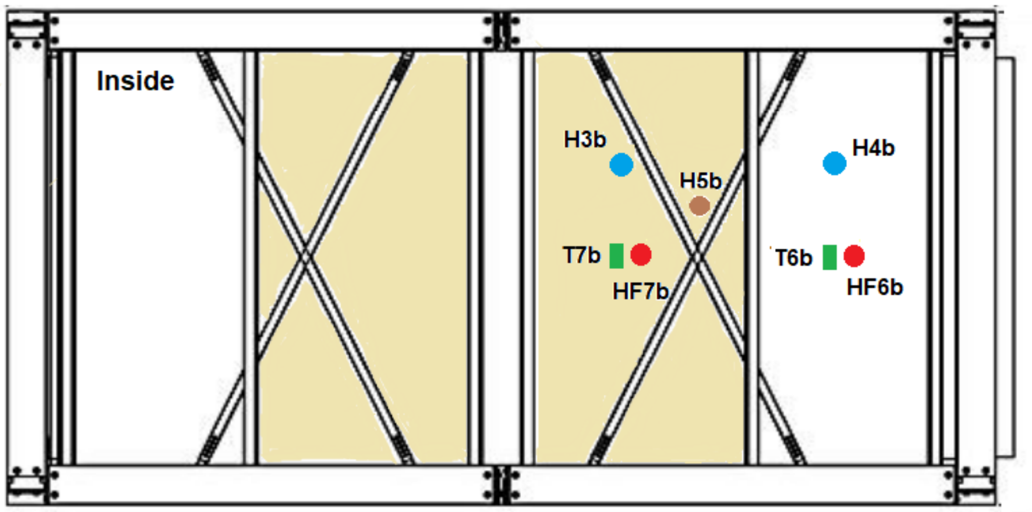
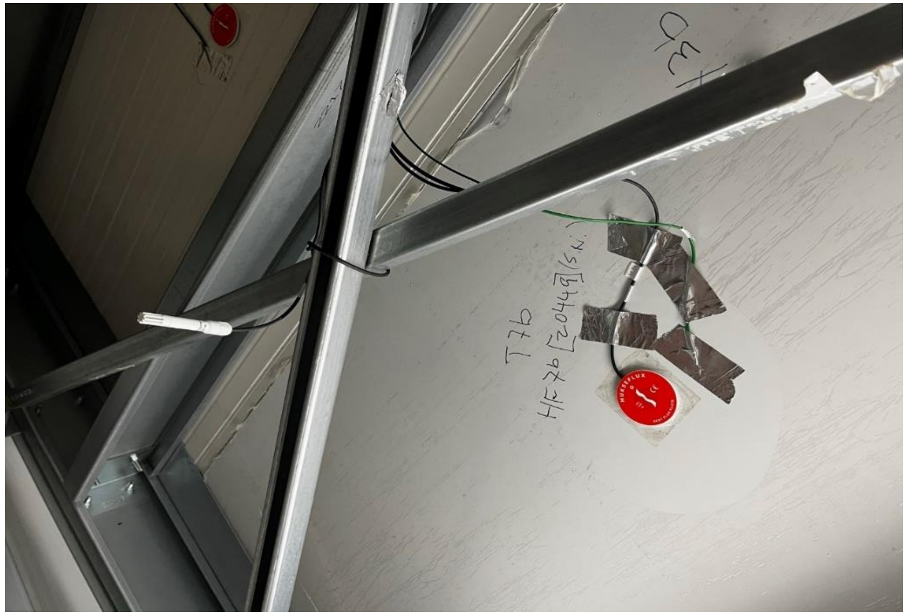
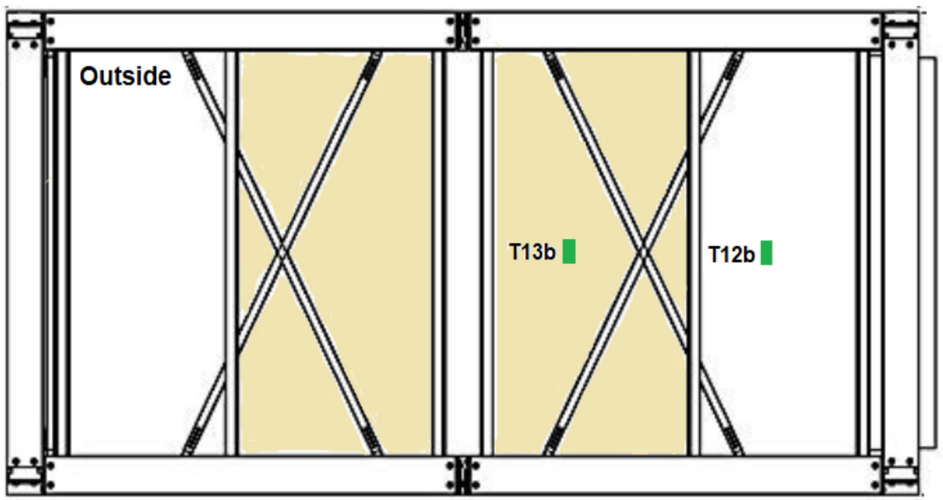
Installation of sensors on Demonstrator 2



Internal view (roof)

- Surface temperature sensor
- Heat Flux sensor
- Humidity sensor (ambient)
- Humidity sensor (inside of the panel)
- Mineral wool



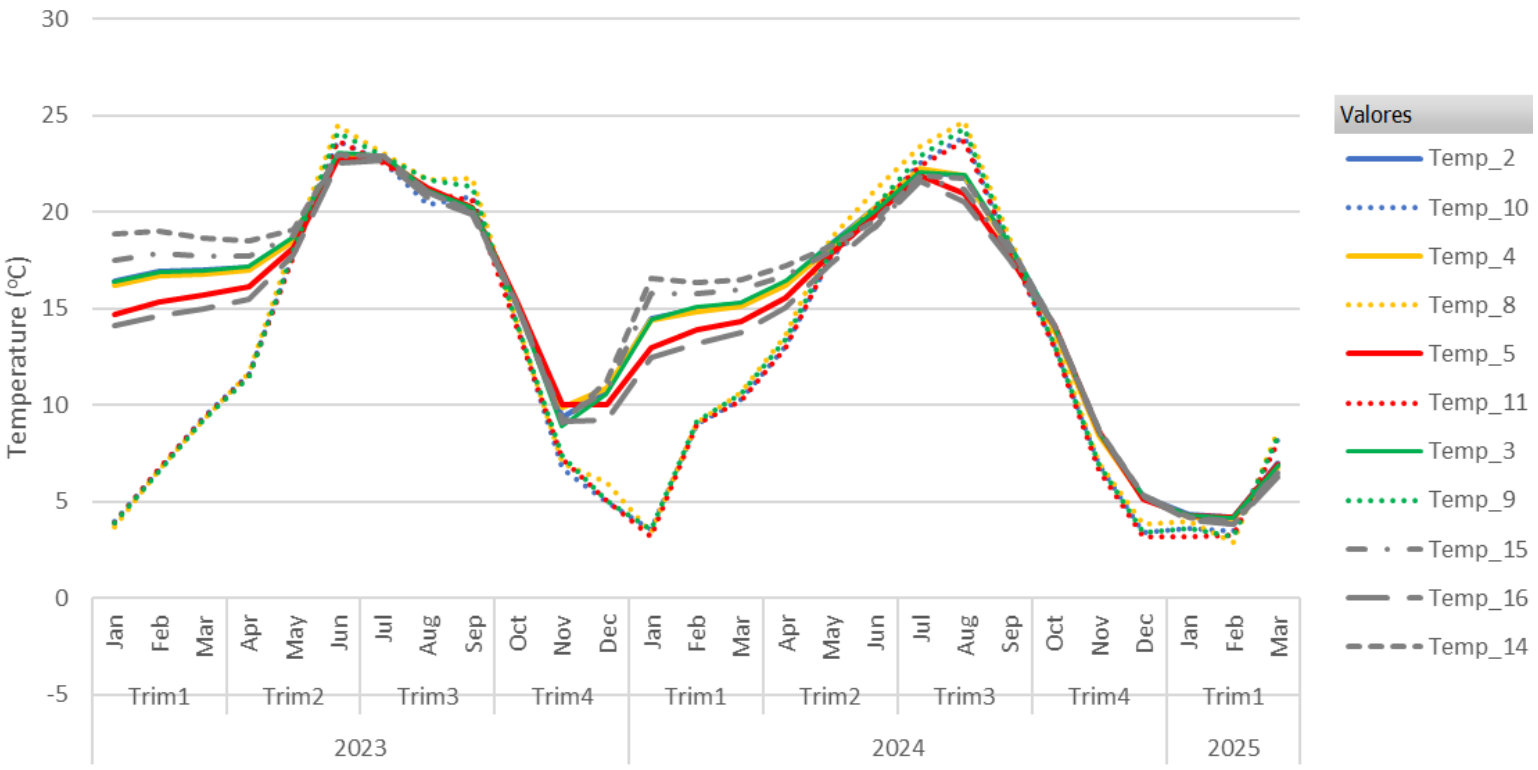


- Surface temperature sensor
- Mineral wool

External view (roof)

Measurements of temperature over time on Demonstrator 1

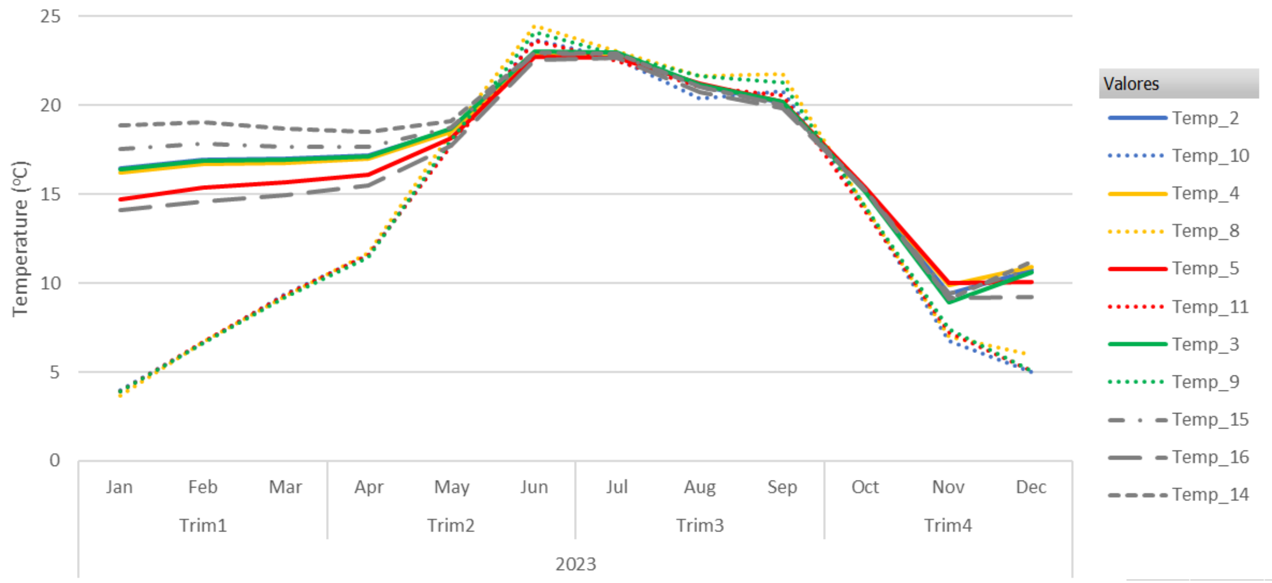
Mean monthly temperature (Jan. 23 to Mar. 25) on the façade

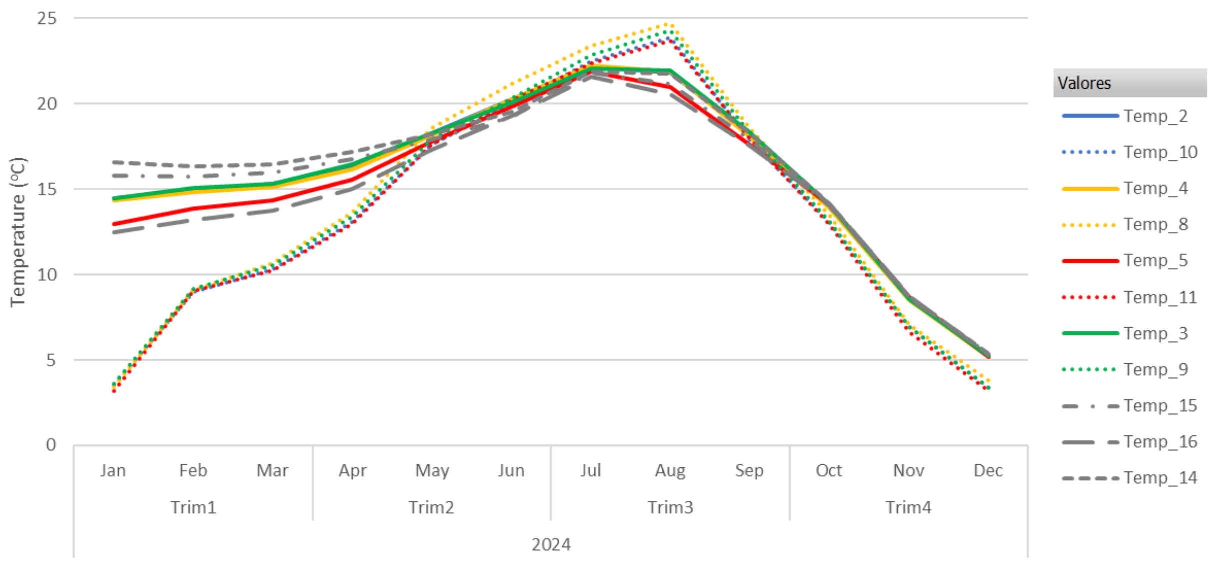


	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp 4
Façade (Outside face)	Temp_10	Temp_8
Façade (Inside face)	Temp_3	-
Façade (Outside face)	Temp_9	-
Façade (Inside face)	Temp_5	-
Façade (Outside face)	Temp_11	-
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13

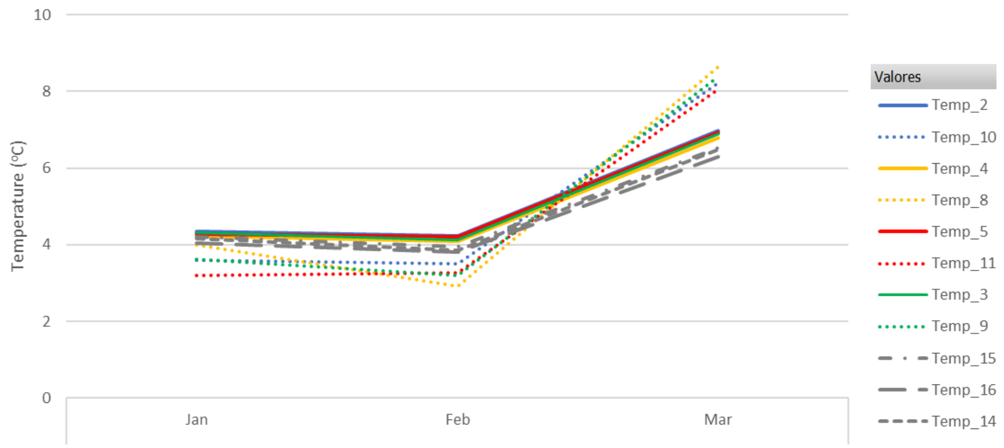
Measurements of temperature over time on Demonstrator 1

Mean monthly temperature (Jan. 23 to Mar. 25) on the façade





	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp 4
Façade (Outside face)	Temp_10	Temp_8
Façade (Inside face)	Temp_3	-
Façade (Outside face)	Temp_9	-
Façade (Inside face)	Temp_5	-
Façade (Outside face)	Temp_11	-
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13



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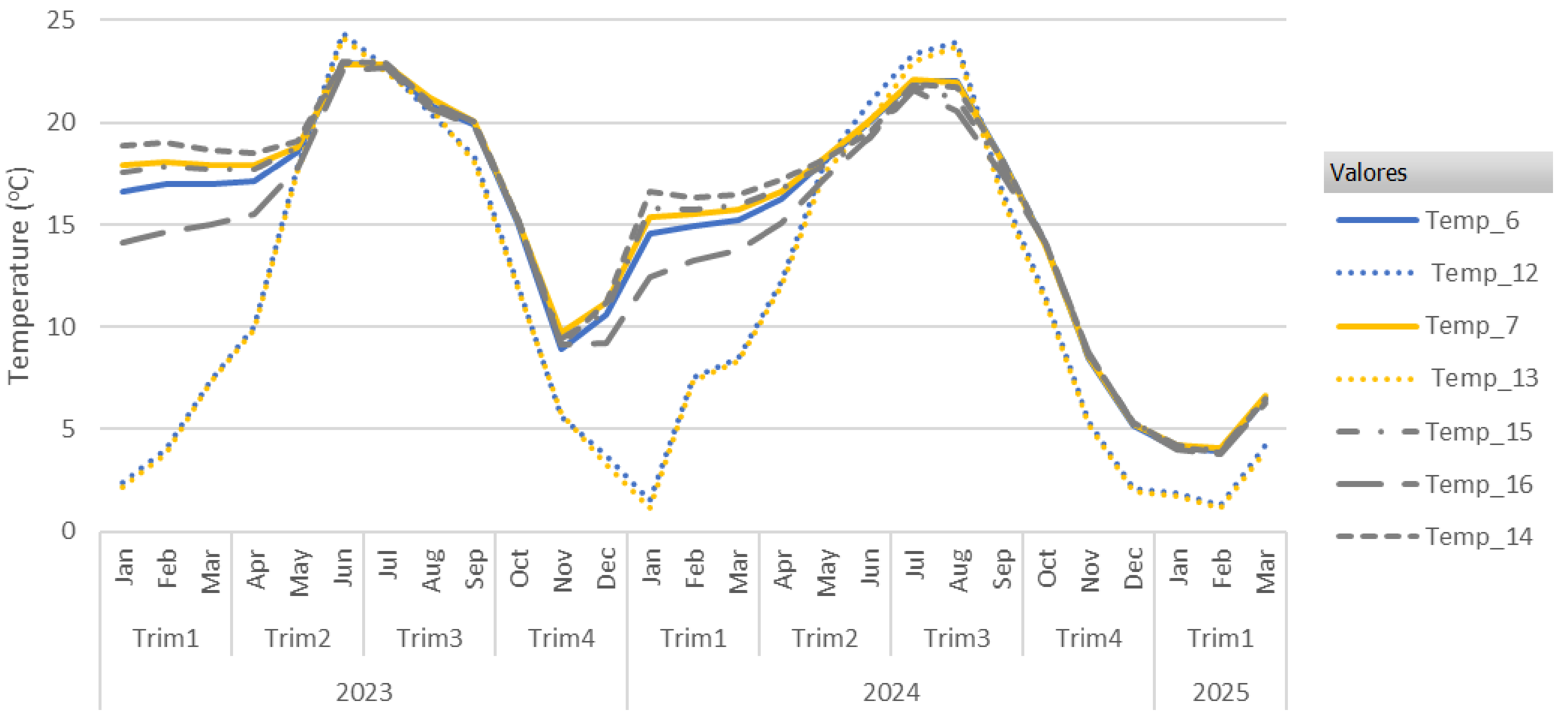
Measurements of temperature over time on Demonstrator 1

Mean monthly temperature (Jan. 23 to Mar. 25) on the roof



	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp 4
Façade (Outside face)	Temp_10	Temp_8
Façade (Inside face)	Temp_3	-
Façade (Outside face)	Temp_9	-
Façade (Inside face)	Temp_5	-
Façade (Outside face)	Temp_11	-
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13

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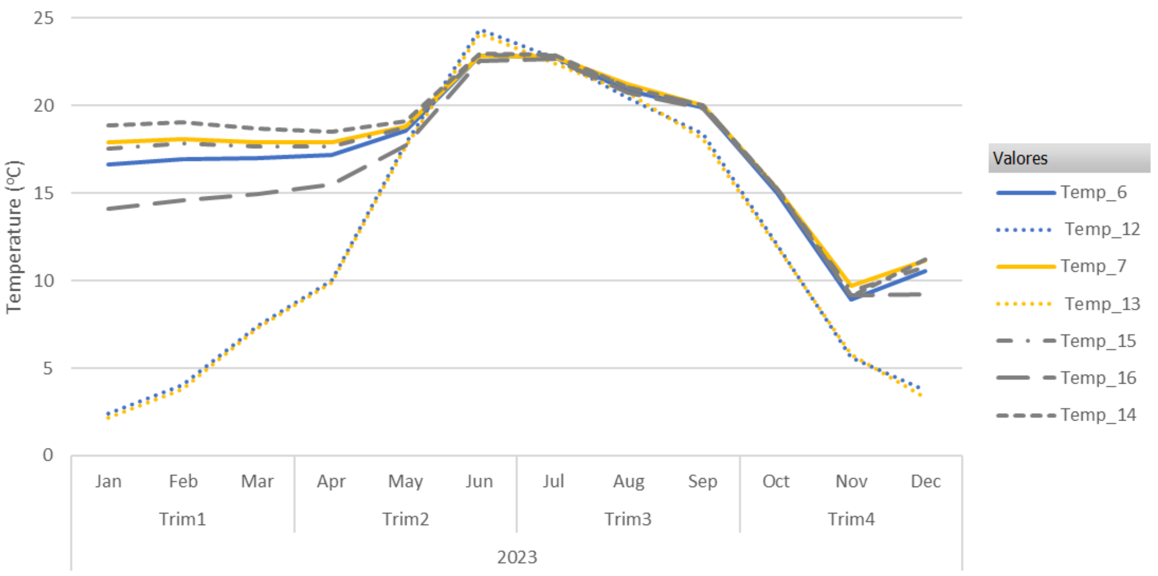
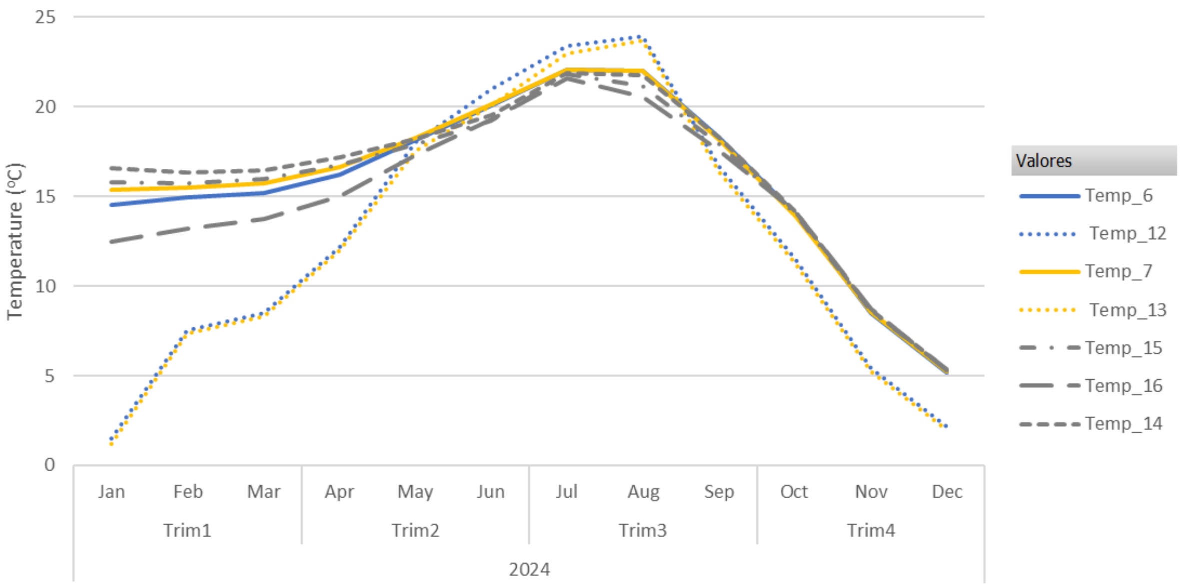
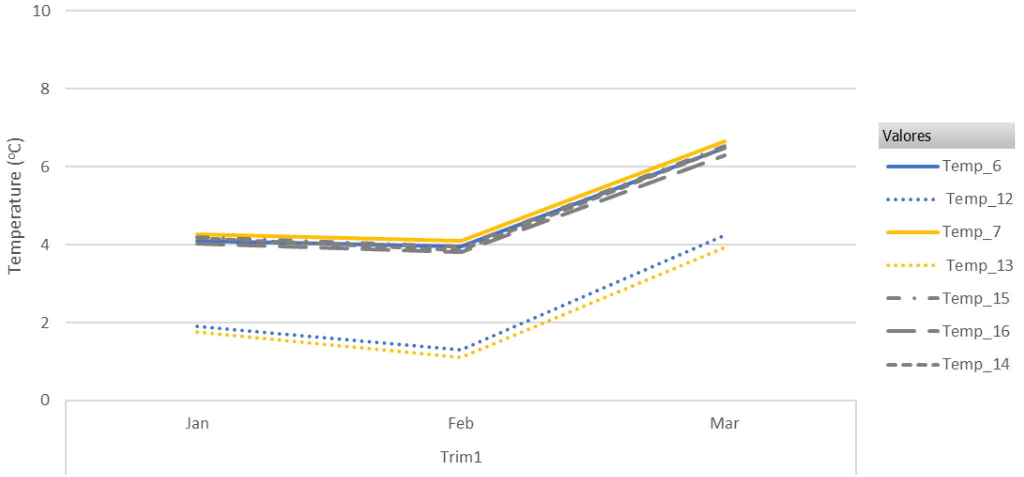
Measurements of temperature over time on Demonstrator 1

Mean monthly temperature (Jan. 23 to Mar. 25) on the roof





	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp 4
Façade (Outside face)	Temp_10	Temp_8
Façade (Inside face)	Temp_3	-
Façade (Outside face)	Temp_9	-
Façade (Inside face)	Temp_5	-
Façade (Outside face)	Temp_11	-
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13



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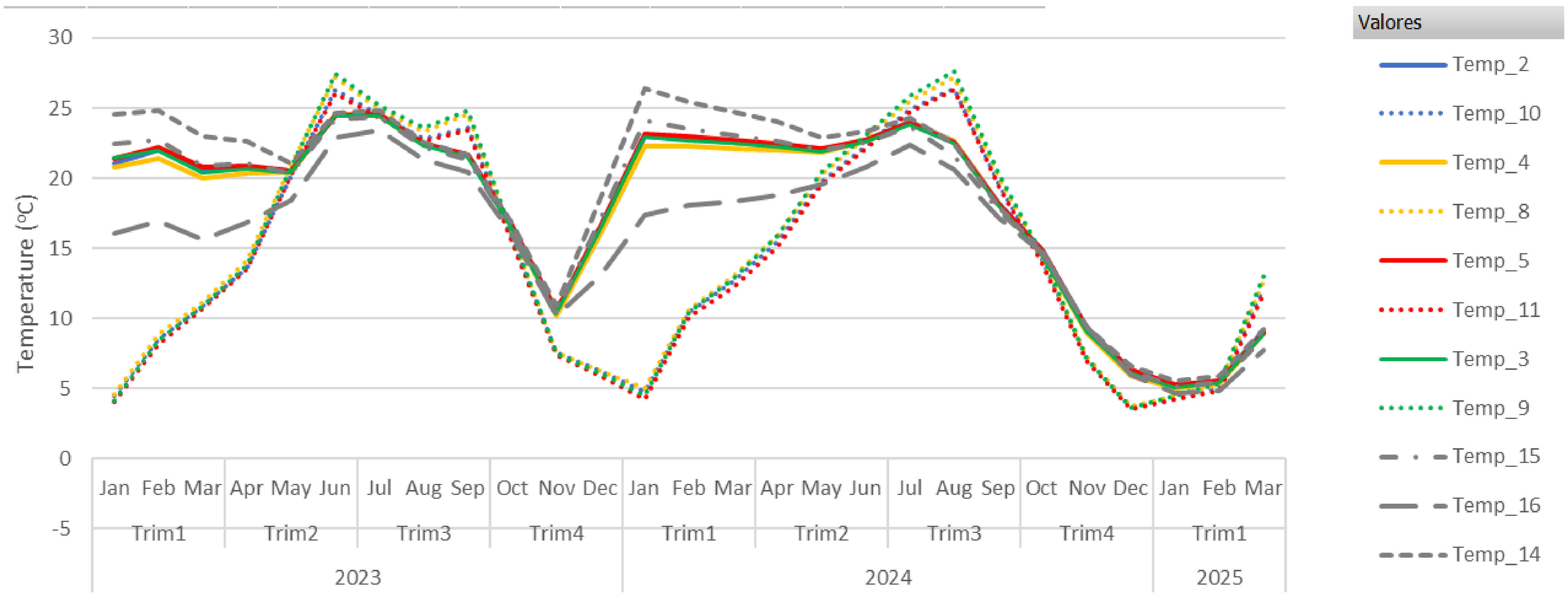
Measurements of temperature over time on Demonstrator 2

Mean monthly temperature (Jan. 23 to Mar. 25) on the façade



	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp_3
Façade (Outside face)	Temp_10	Temp_9
Façade (Inside face)	Temp_5	Temp 4
Façade (Outside face)	Temp_11	Temp_8
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13

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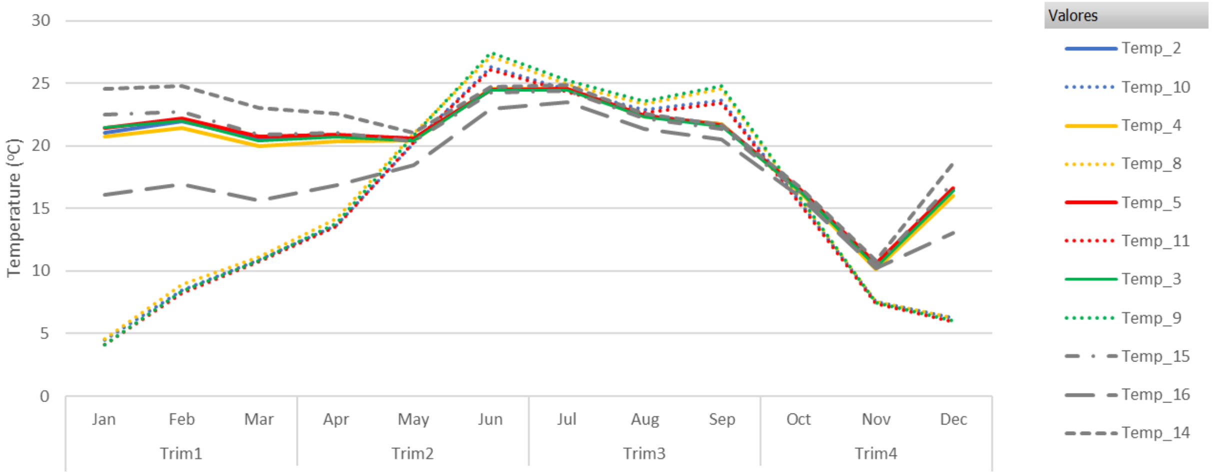
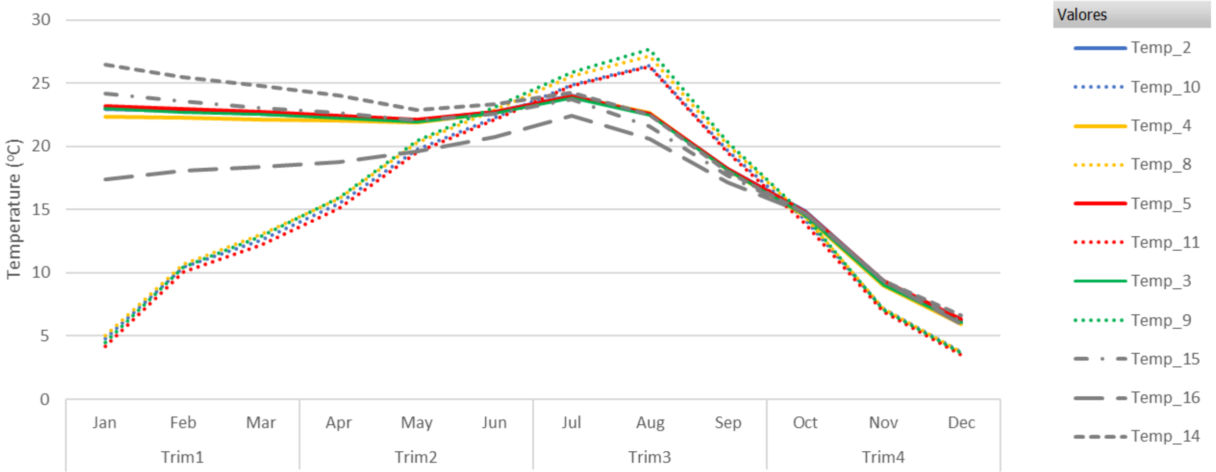
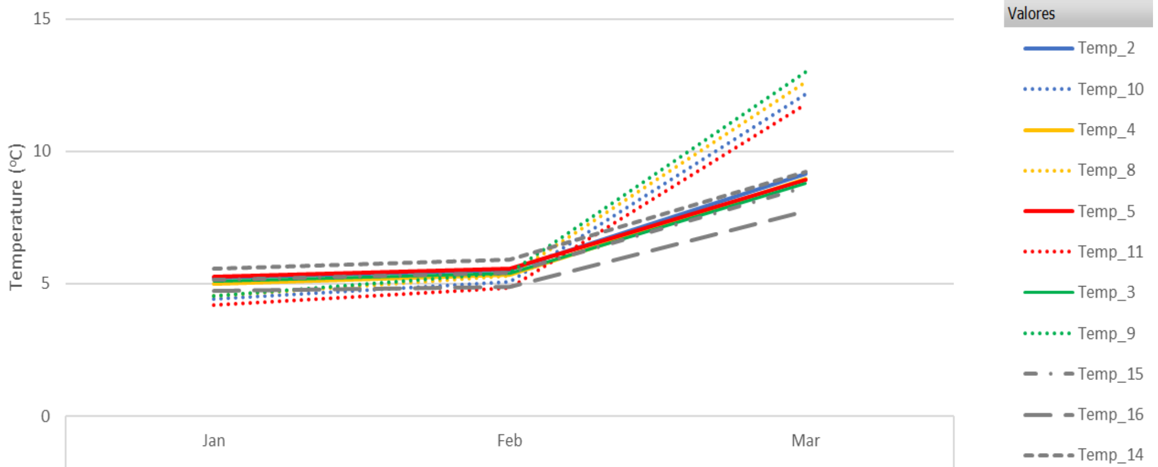
Measurements of temperature over time on Demonstrator 2

Mean monthly temperature (Jan. 23 to Mar. 25) on the façade





	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp_3
Façade (Outside face)	Temp_10	Temp_9
Façade (Inside face)	Temp_5	Temp 4
Façade (Outside face)	Temp_11	Temp_8
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13



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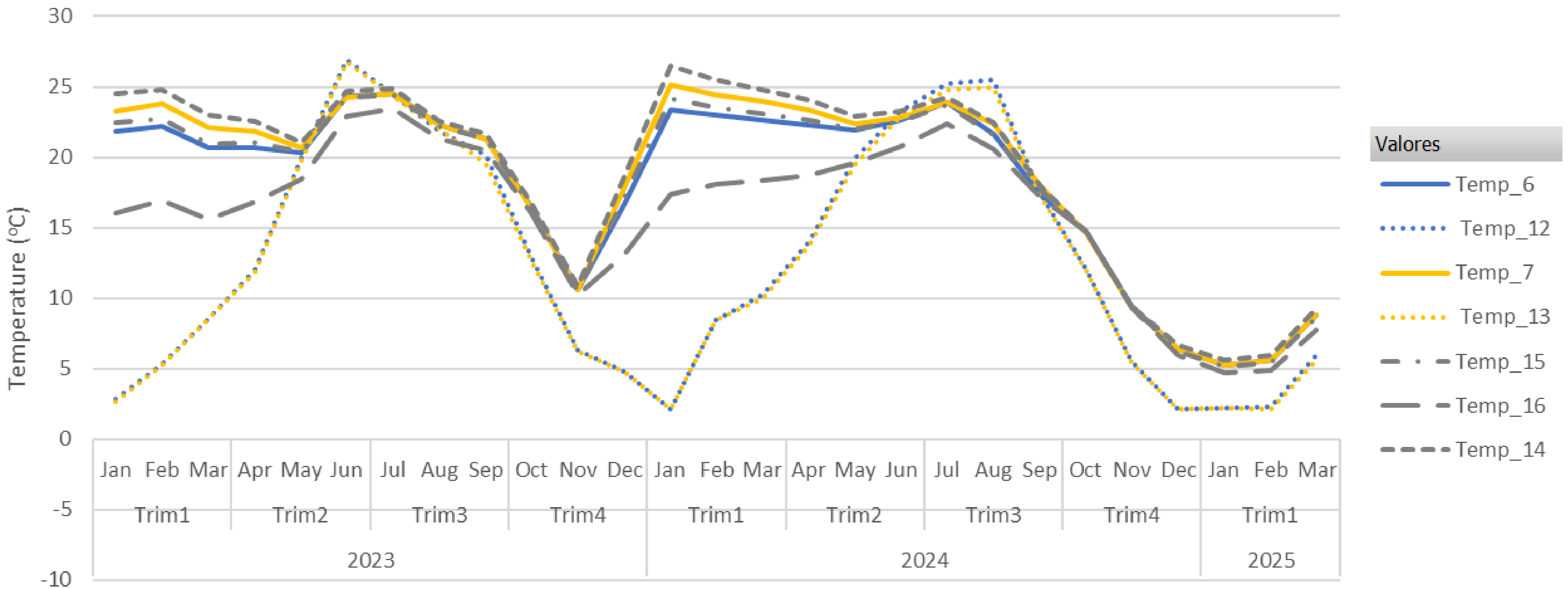
Measurements of temperature over time on Demonstrator 2

Mean monthly temperature (Jan. 23 to Mar. 25) on the roof



	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp_3
Façade (Outside face)	Temp_10	Temp_9
Façade (Inside face)	Temp_5	Temp 4
Façade (Outside face)	Temp_11	Temp_8
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13

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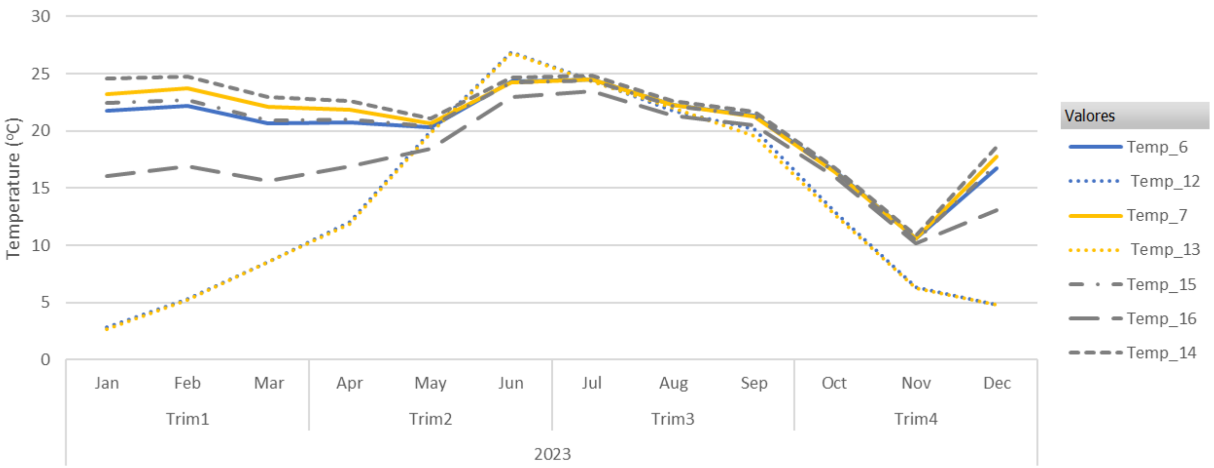
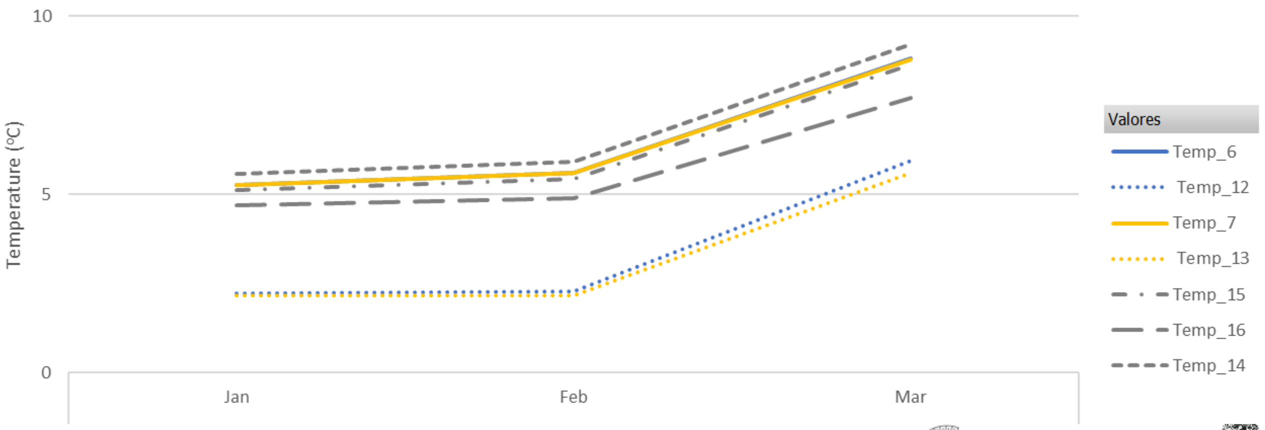
Measurements of temperature over time on Demonstrator 2

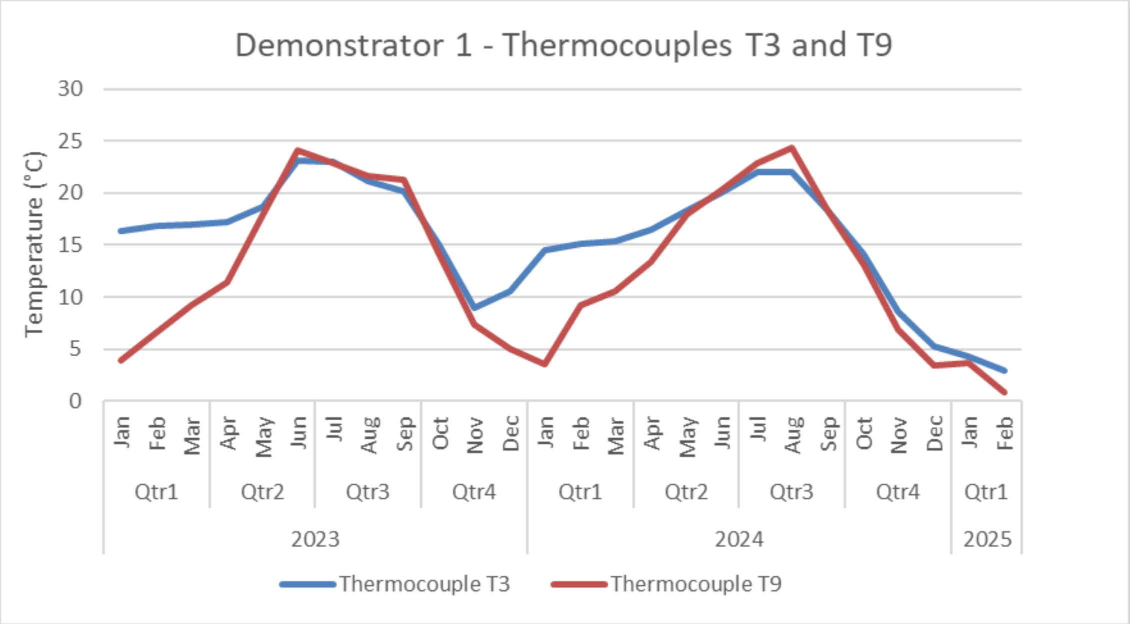
Mean monthly temperature (Jan. 23 to Mar. 25) on the roof

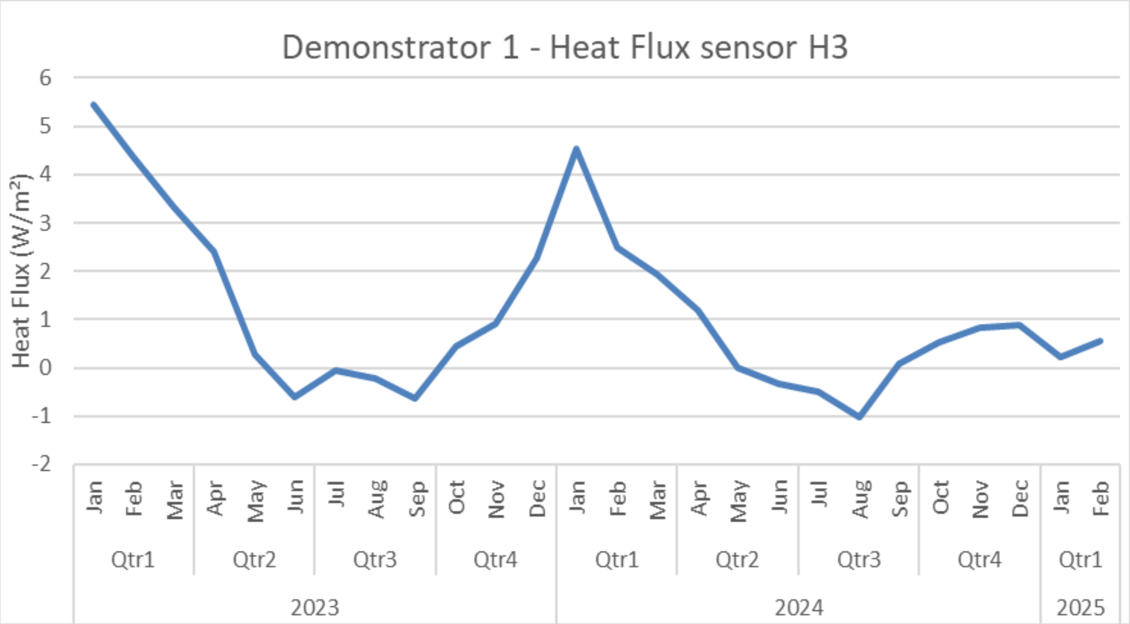


	Wood fibers	Mineral Wool
Façade (Inside face)	Temp_2	Temp_3
Façade (Outside face)	Temp_10	Temp_9
Façade (Inside face)	Temp_5	Temp 4
Façade (Outside face)	Temp_11	Temp_8
Roof (Inside face)	Temp_6	Temp_7
Roof (Outside face)	Temp_12	Temp_13



Comparison of U-values (W/m^{2}K) for Demonstrators 1 and 2



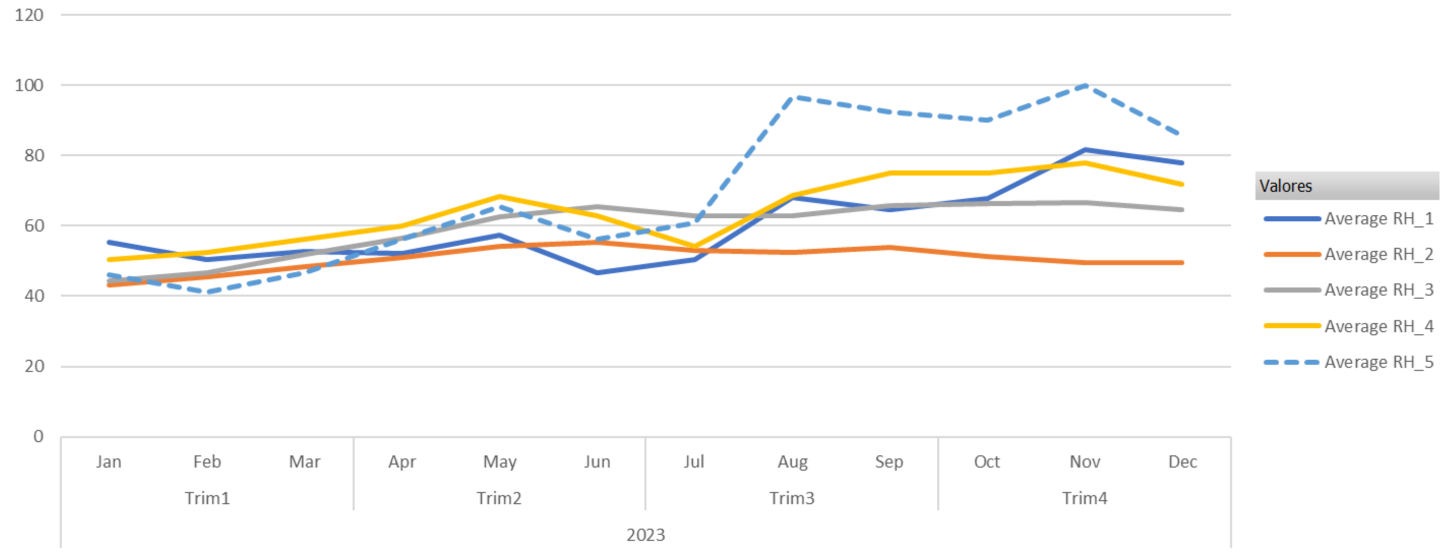


	WP1		WP2	
	Numerical values	Measured values	Numerical values	Measured values
Walls	0.38	0.36	0.26 – 0.31	0.30
Roof	0.35	0.32	0.15 – 0.16	0.15

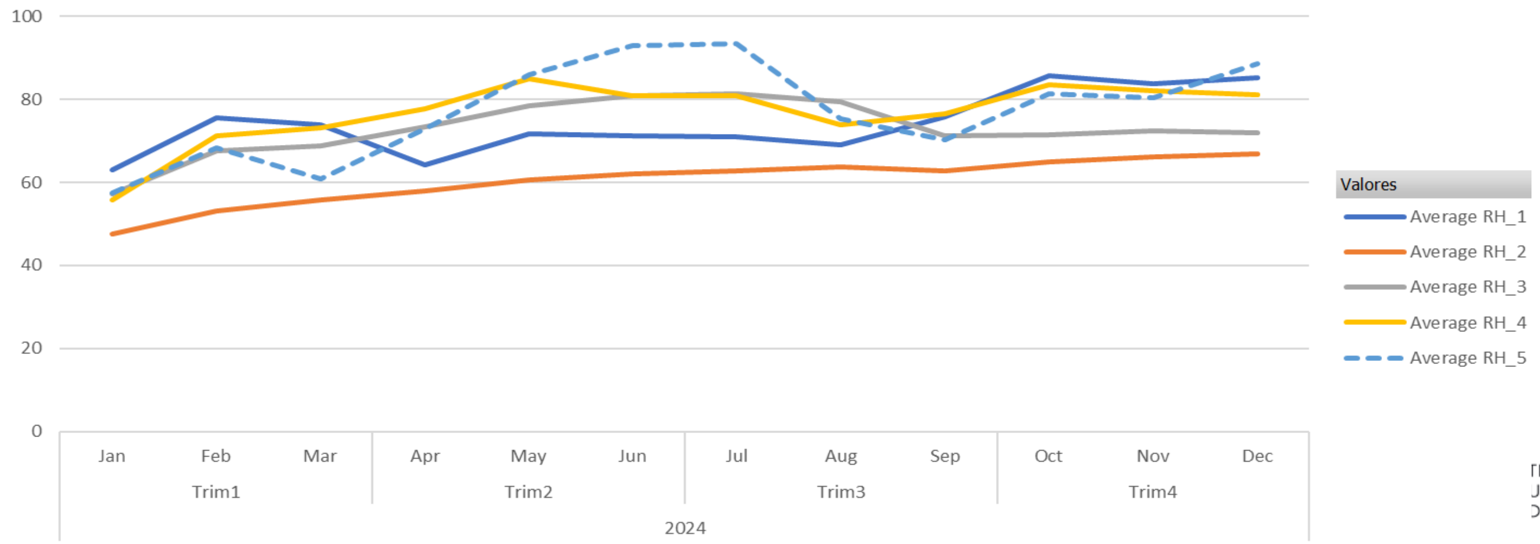
✓ **Values obtained from in-situ measurements showed a very good agreement with the values predicted by the numerical analysis**

Measurements of RH over time on Demonstrator 1

Mean monthly RH (Jan. 23 to Mar. 25)



	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH3	RH4
Ambient	RH5	



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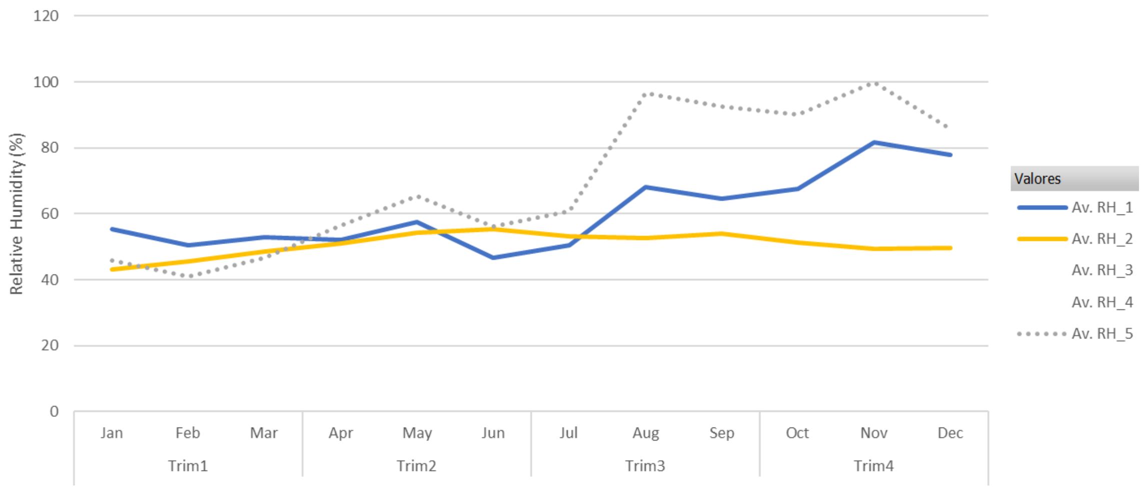
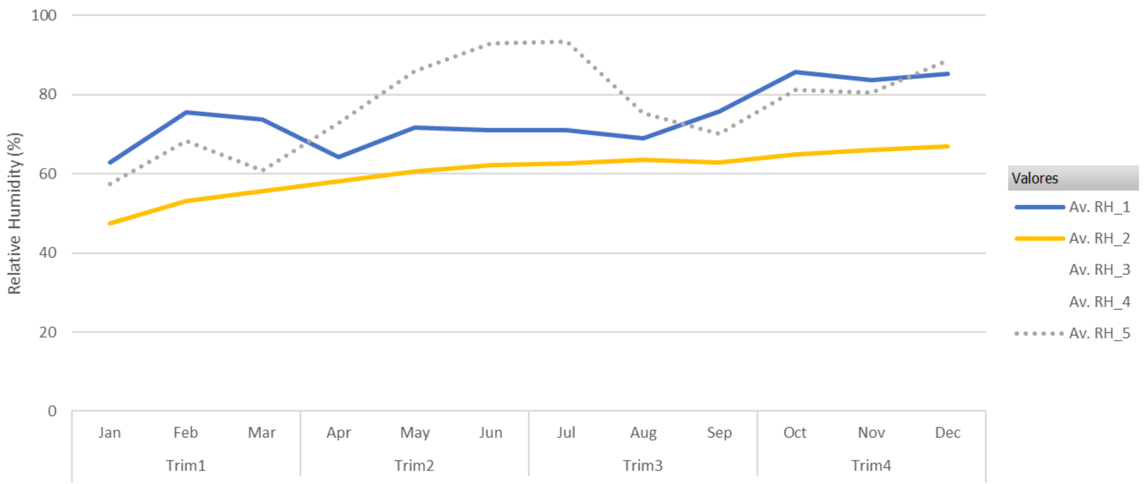
Measurements of RH over time on Demonstrator 1

Mean monthly RH (Jan. 23 to Mar. 25) on the façade

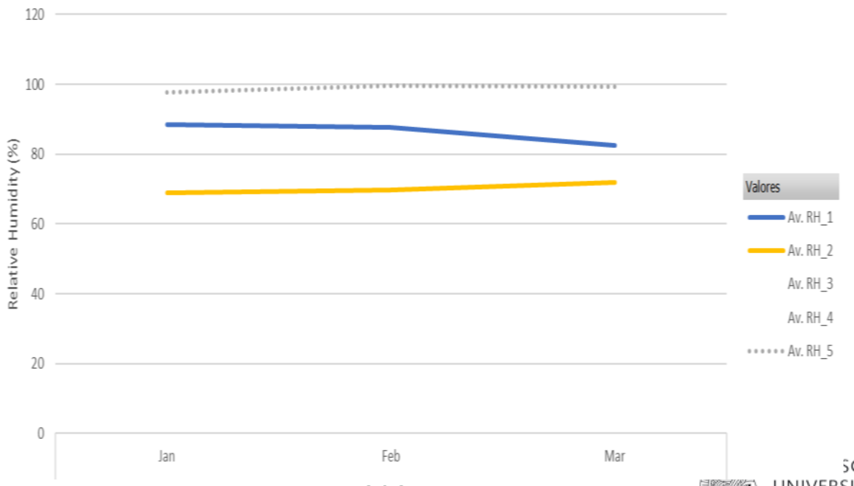


2023



2024

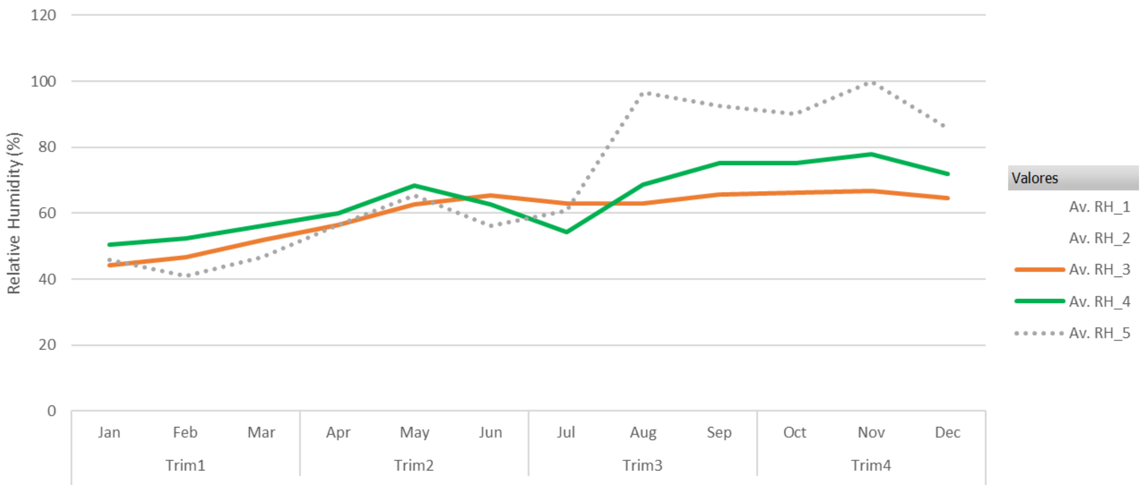
	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH3	RH4
Ambient	RH5	



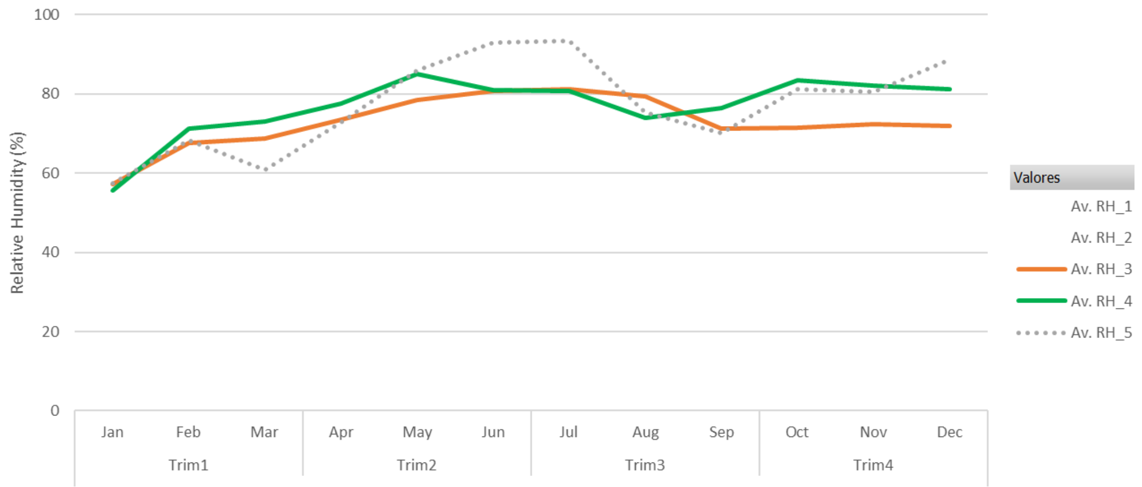
2025

Measurements of RH over time on Demonstrator 1

Mean monthly RH (Jan. 23 to Mar. 25) on the roof

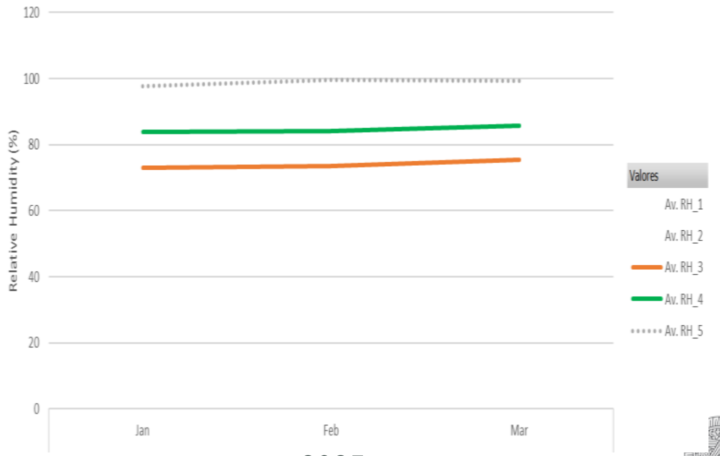


2023



2024

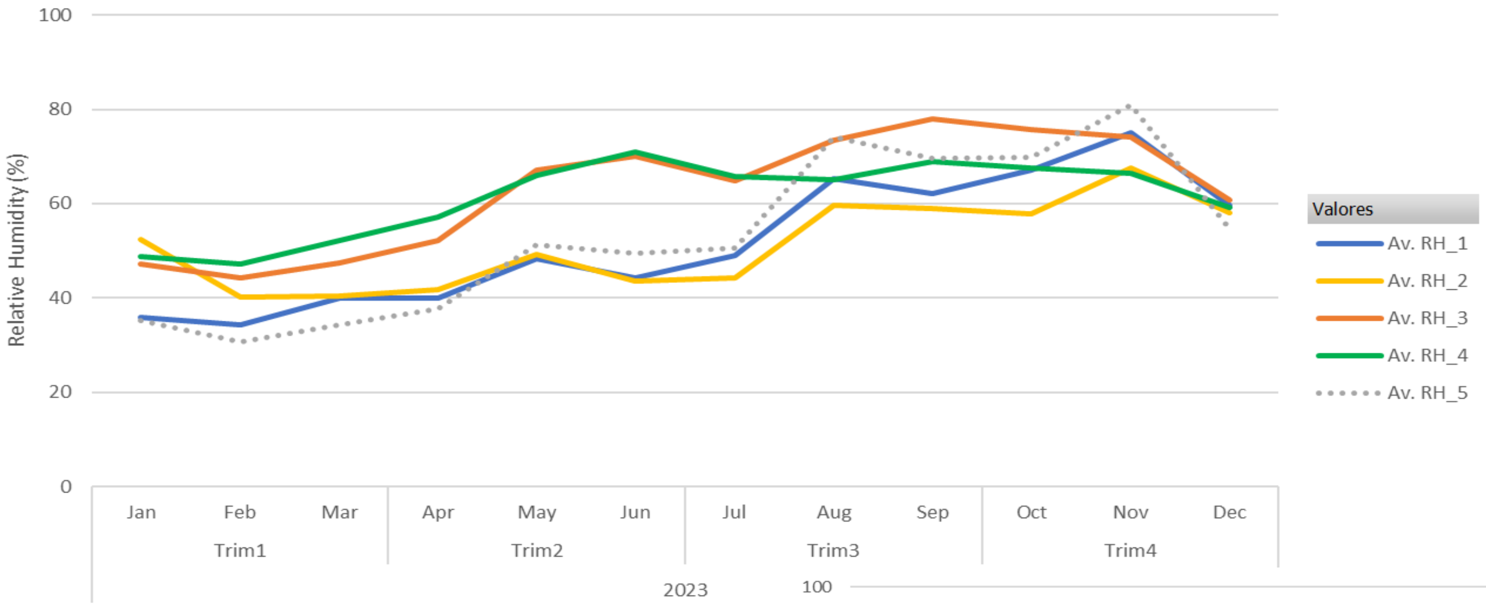
	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH3	RH4
Ambient	RH5	



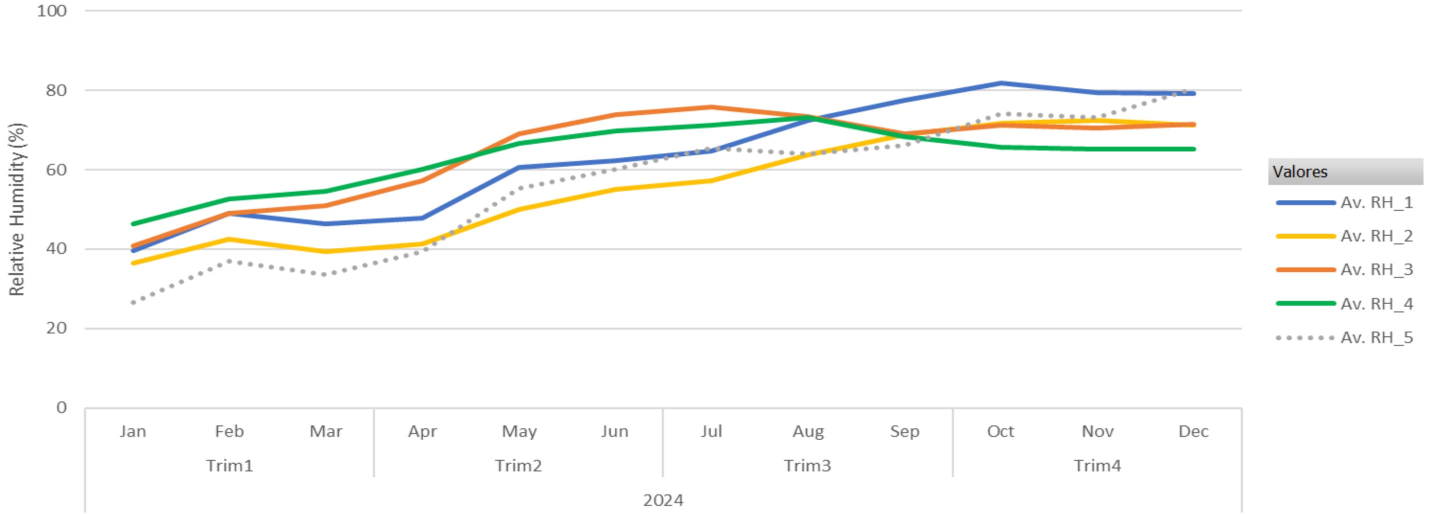
2025

Measurements of RH over time on Demonstrator 2

Mean monthly RH (Jan. 23 to Mar. 25)



	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH4	RH3
Ambient	RH5	



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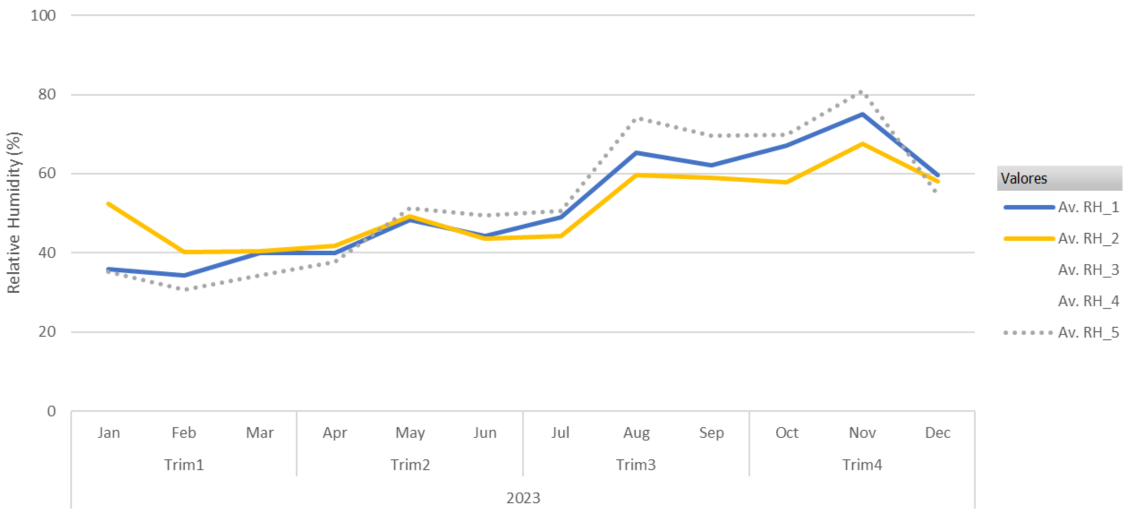
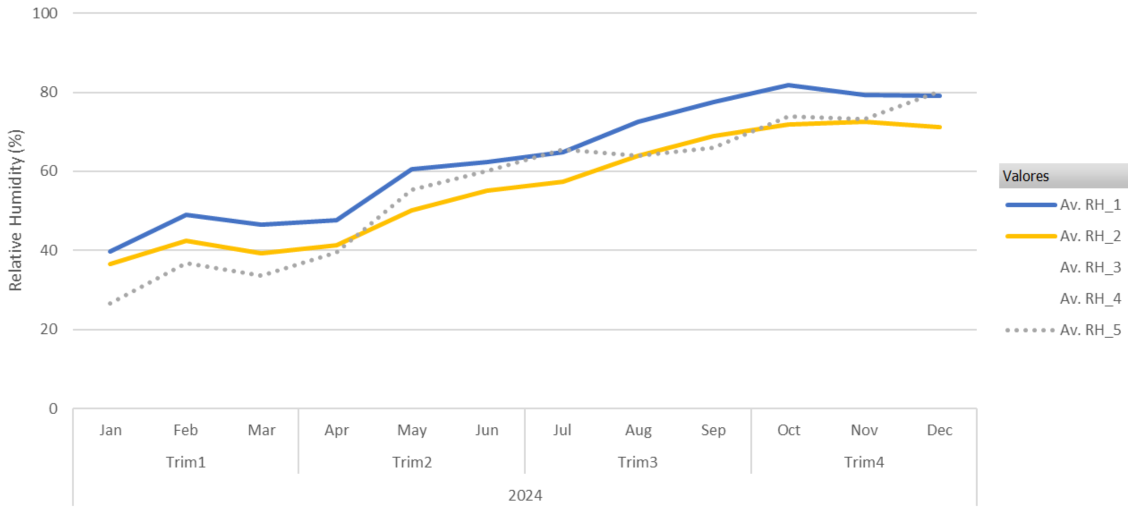
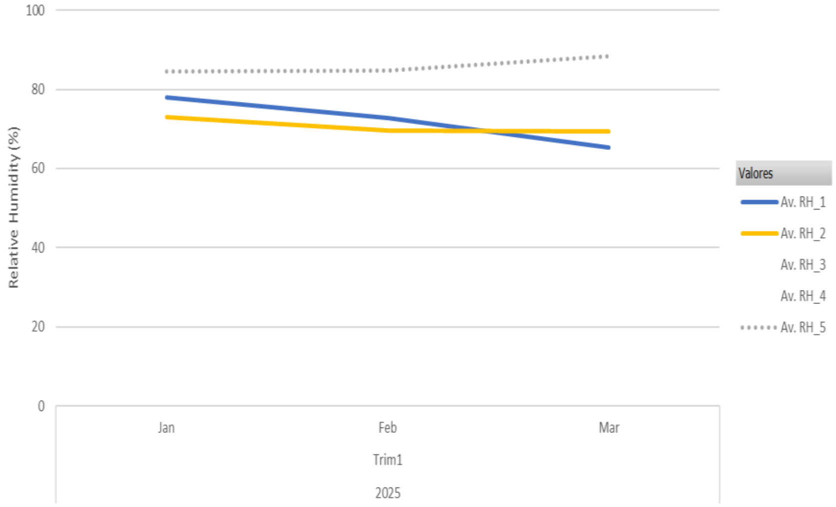
Measurements of RH over time on Demonstrator 2

Mean monthly RH (Jan. 23 to Mar. 25) on the façade



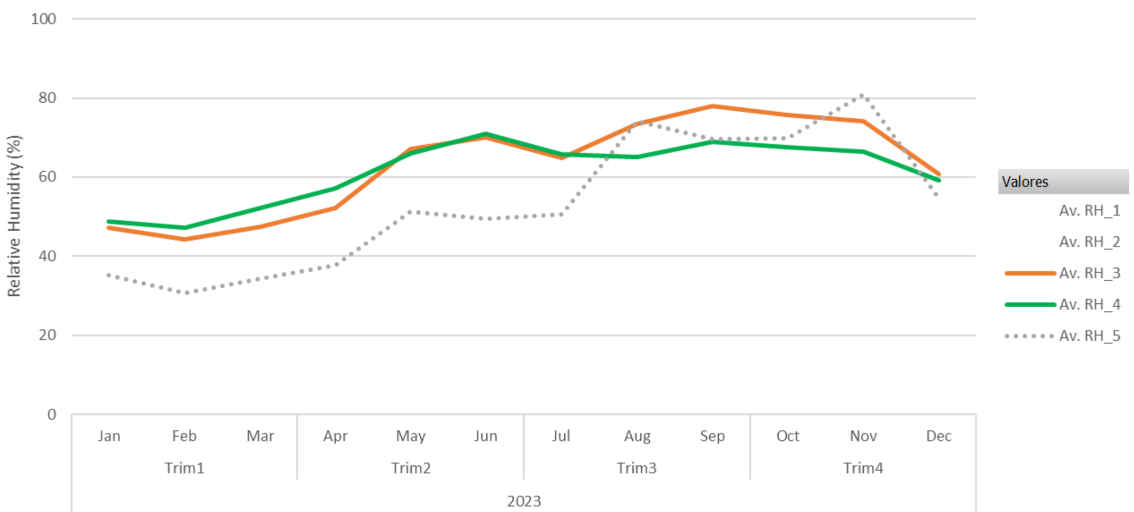


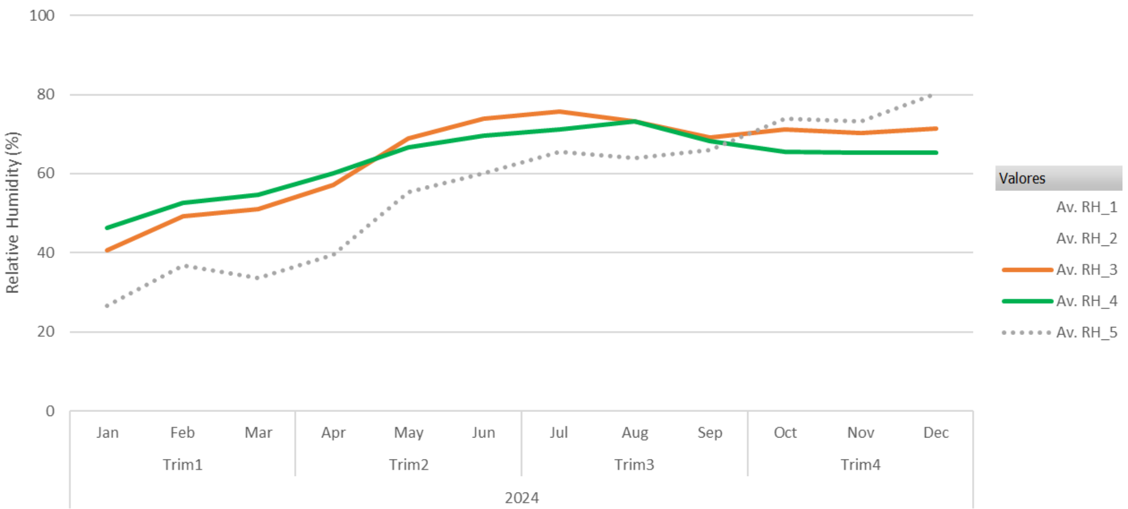
	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH4	RH3
Ambient	RH5	

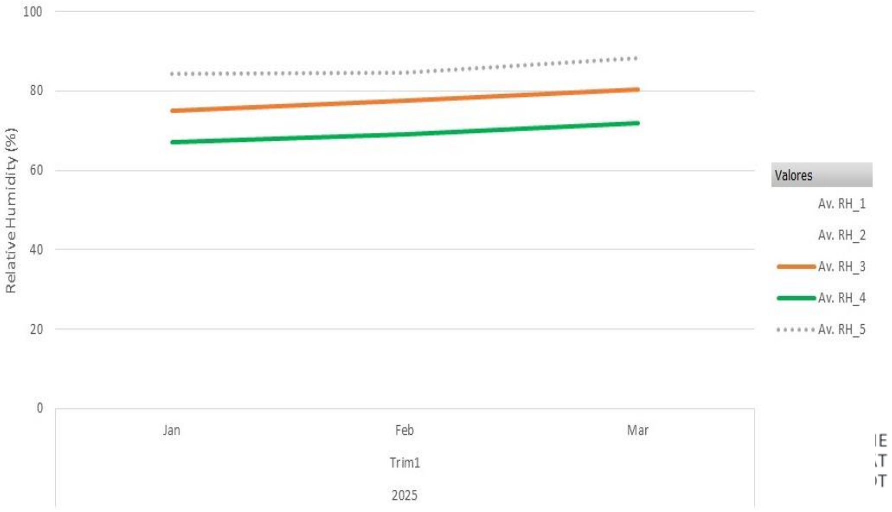


Measurements of RH over time on Demonstrator 2

Mean monthly RH (Jan. 23 to Mar. 25) on the roof







	Wood fibers (WF)	Mineral Wool (MW)
Façade	RH2	RH1
Roof	RH4	RH3
Ambient	RH5	

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Comparison of *in situ* condensations and estimated values

Monthly values of inner surface temperature factors (f_{Rsi}) for Demonstrator 1

	Month	Internal Temperature	Psat	Highest HR	frsi max	frsi	
Demonstrator 1 – Wall	January	8.5	1109.269416	87.9	-0.127180987	0.950609756	GOOD
	February	16.56	1883.305227	53.79	-0.037256036	0.749668874	GOOD
	March	16.75	1906.17964	65.49	-1.140633531	0.724295775	GOOD
	April	16.55	1882.108001	73.73	0.209040686	0.864031621	GOOD
	May	16.26	1847.677249	87.4	0.752312258	0.924284913	GOOD
	June	19.26	2232.025771	82.8	0.580063761	0.969188634	GOOD
	July	20.05	2344.193714	91.2	0.599623783	0.958927553	GOOD
	August	21.52	2566.085148	100	0.914759055	1.155091384	GOOD
	September	18.35	2108.663237	100	0.942084231	1.200970874	GOOD
	October	13	1496.957508	100	0.968087587	1.09223301	GOOD
	November	10	1227.309865	100	0.696586599	2.344	GOOD
	December	2.82	747.7641635	100	0.979481396	1.277697842	GOOD
	January	13.57	1553.691372	84.4	0.649240963	0.872262027	GOOD
	February	14.35	1634.381298	82.7	0.544702739	0.828775268	GOOD
	March	14.46	1646.051363	73.5	0.463178881	0.886545455	GOOD
	April	14.68	1669.610956	89.6	0.794852636	0.936984754	GOOD
	May	15.79	1793.047115	99.3	0.947284637	1.085391958	GOOD
	June	15.71	1783.890758	100	0.951542279	1.117112843	GOOD
	July	19.54	2271.232193	100	0.913868796	1.106343826	GOOD
	August	22.1	2658.556298	100	0.893564505	1.173333333	GOOD
	September	18.34	2107.34145	87.8	0.660383834	1.002750191	GOOD
	October	16.01	1818.439833	95.1	0.539492135	1.200875274	GOOD
	November	5.79	921.1263252	93.4	0.826202534	0.949540079	GOOD
	December	3.217	769.1279038	95.5	0.933985461	0.971581383	GOOD
	January	4.186	823.5505897	100	0.979924839	0.996965227	GOOD

- ✓ The methodology from EN ISO 13788 was adapted to calculate the f_{Rsi} parameter and compare 'in situ' results with the values previously estimated by Tecnalia

	Month	Internal Temperature	Psat	Highest HR	frsi max	frsi	
Demonstrator 1 – Roof	January	8.5	1109.269416	87.9	0.374622495	0.933016175	GOOD
	February	16.56	1883.305227	53.79	-4.25369095	0.43464837	GOOD
	March	16.75	1906.17964	65.49	-3.22180502	0.51875	GOOD
	April	16.55	1882.108001	73.73	-1.217315307	0.707479224	GOOD
	May	16.26	1847.677249	87.4	0.770165369	0.921311475	GOOD
	June	19.26	2232.025771	82.8	0.776156618	0.959269144	GOOD
	July	20.05	2344.193714	91.2	0.783976759	0.966759003	GOOD
	August	21.52	2566.085148	100	0.937231854	1.001153569	GOOD
	September	18.35	2108.663237	100	0.836125507	1.003532009	GOOD
	October	13	1496.957508	100	0.977438157	1.003432003	GOOD
	November	10	1227.309865	100	0.783082466	1	GOOD
	December	2.82	747.7641635	100	0.982421658	1.152850539	GOOD
	January	13.57	1553.691372	84.4	0.403495945	0.832898172	GOOD
	February	14.35	1634.381298	82.7	-0.209810415	0.734597156	GOOD
	March	14.46	1646.051363	73.5	-0.148559652	0.796936543	GOOD
	April	14.68	1669.610956	89.6	0.826232155	0.933709981	GOOD
	May	15.79	1793.047115	99.3	0.966343558	1.029918969	GOOD
	June	15.71	1783.890758	100	0.96335832	1.035053329	GOOD
	July	19.54	2271.232193	100	0.935810552	1.042874543	GOOD
	August	22.1	2658.556298	100	0.951037341	1.024534502	GOOD
	September	18.34	2107.34145	87.8	0.474168627	0.982967399	GOOD
	October	16.01	1818.439833	95.1	0.674096641	1	GOOD
	November	5.79	921.1263252	93.4	0.316486453	0.702325581	GOOD
	December	3.217	769.1279038	95.5	0.948832976	0.969076233	GOOD
	January	4.186	823.5505897	100	0.924735497	0.931022222	GOOD

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Comparison of *in situ* condensations and estimated values

Monthly values of inner surface temperature factors (f_{Rsi}) for Demonstrator 2

	Month	Internal Temperature	Psat	Highest HR	frsi max	frsi	
Demonstrator 2 – Walls	January	21.62	2581.825017	54.77	0.199390457	0.954223433	GOOD
	February	20.4	2395.44356	43.85	-0.744965442	0.98511502	GOOD
	March	19.09	2208.511836	52.87	-0.162703553	0.751636504	GOOD
	April	19.38	2248.755424	51.76	-1.534721878	1.004874086	GOOD
	May	22.65	2748.919579	66.67	0.488290913	1.024384236	GOOD
	June	21.44	2553.55368	60.74	-0.014992229	0.951950719	GOOD
	July	22.72	2760.610542	67.59	-0.074727895	0.958422175	GOOD
	August	24.72	3113.503346	82.6	0.009230325	0.927871772	GOOD
	September	22.73	2762.284219	77.41	0.347740005	1.067669173	GOOD
	October	14.29	1628.04645	83.5	0.659881995	0.983252698	GOOD
	November	6.274	952.5043538	86.6	0.791465493	0.975416133	GOOD
	December	5.899	928.1122423	86.7	0.8388608	0.974924699	GOOD
	January	21.32	2534.856734	49.23	0.115084486	0.971101276	GOOD
	February	21.72	2597.649166	51.34	-0.422339101	0.952401939	GOOD
	March	22.37	2702.586897	46.86	-0.554286222	1.081771721	GOOD
	April	22.96	2801.024074	55.76	-0.653110748	1.065068493	GOOD
	May	21.14	2507.035604	66.29	0.506160724	0.96278626	GOOD
	June	25.5	3261.437313	70.35	0.06335556	0.950892857	GOOD
	July	22.12	2661.7962	74.15	0.00425163	0.903409091	GOOD
	August	18.24	2094.163414	79.89	0.146585114	1.067833698	GOOD
	September	17.41	1987.540434	87.2	0.738845145	1.025746653	GOOD
	October	16.92	1926.852147	88.6	0.719780305	0.981519507	GOOD
	November	10	1227.309865	83.9	0.784867919	1.010835913	GOOD
	December	10	1227.309865	85.4	0.748321042	0.999003984	GOOD
	January	8.71	1125.168812	90.4	-0.511951245	0.964809384	GOOD

✓ The methodology from EN ISO 13788 was adapted to calculate the f_{Rsi} parameter and compare 'in situ' results with the values previously estimated by Tecnalia

	Month	Internal Temperature	Psat	Highest HR	frsi max	frsi	
Demonstrator 2 – Roof	January	21.62	2581.825017	54.77	0.650791892	0.987877347	GOOD
	February	20.4	2395.44356	43.85	0.25746864	0.974088292	GOOD
	March	19.09	2208.511836	52.87	0.332845531	0.856827221	GOOD
	April	19.38	2248.755424	51.76	-1.094122572	0.929530201	GOOD
	May	22.65	2748.919579	66.67	0.770893373	0.976841641	GOOD
	June	21.44	2553.55368	60.74	0.470542828	0.9781491	GOOD
	July	22.72	2760.610542	67.59	0.625522004	0.97269688	GOOD
	August	24.72	3113.503346	82.6	0.650114986	0.940566038	GOOD
	September	22.73	2762.284219	77.41	0.747267067	0.948652586	GOOD
	October	14.29	1628.04645	83.5	0.853729661	0.992317542	GOOD
	November	6.274	952.5043538	86.6	0.931453935	0.991161616	GOOD
	December	5.899	928.1122423	86.7	0.922894719	0.992145088	GOOD
	January	21.32	2534.856734	49.23	0.471883081	0.979024239	GOOD
	February	21.72	2597.649166	51.34	0.380083093	0.97176335	GOOD
	March	22.37	2702.586897	46.86	0.135607757	0.958787305	GOOD
	April	22.96	2801.024074	55.76	0.258892009	0.960081883	GOOD
	May	21.14	2507.035604	66.29	0.76188472	0.988267771	GOOD
	June	25.5	3261.437313	70.35	0.548043276	0.956917185	GOOD
	July	22.12	2661.7962	74.15	0.553435612	0.983012458	GOOD
	August	18.24	2094.163414	79.89	0.56601194	0.96884273	GOOD
	September	17.41	1987.540434	87.2	0.848094231	0.971246006	GOOD
	October	16.92	1926.852147	88.6	0.883241794	0.945071869	GOOD
	November	10	1227.309865	83.9	0.884667781	1	GOOD
	December	10	1227.309865	85.4	0.889913299	0.98475167	GOOD
	January	8.71	1125.168812	90.4	0.77790308	0.958629893	GOOD

Comparison of *in situ* condensations and estimated values

	f_{Rsi}	$f_{Rsi.max}$	
		Hygrometry 3	Hygrometry 4
Demonstrator 1 – wall	0.952	0.92	0.77
Demonstrator 1 – roof	0.953	0.92	0.77
Demonstrator 2 – wall	0.978	0.92	0.77
Demonstrator 2 – roof	0.981	0.92	0.77

- ✓ **The results obtained for the f_{Rsi} calculations show that no internal condensation occurred in both demonstrators, thus confirming the estimations done by Tecnalia.**
- ✓ **This was expected as the RH values obtained from the sensors positioned within the walls and roof of both demonstrators never achieved 100%.**

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Demolition of the demonstrators

Dismantling of Demonstrator 1

Dismantling of Demonstrator 1

Dismantling of Demonstrator 1

Condition of the sandwich panels

Dismantling of Demonstrator 1

Removal of the substructure for reuse

Dismantling of Demonstrator 2

Dismantling of Demonstrator 2



Dismantling of Demonstrator 2

Condition of the membrane and mineral wool insulation boards

Dismantling of Demonstrator 2

Condition of the wood fibre insulation boards

Dismantling of Demonstrator 2

Dismantling of the cassettes

ISISE

Dismantling of Demonstrator 2

Dismantling of the roof sandwich panels

Dismantling of Demonstrator 2

Condition of the roof panels

Dismantling of Demonstrator 2

Shifting the steel substructure and dismantling for reuse

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Dismantling of Demonstrators

Waste and material for recycling

Analysis of the products' end-of-life

Although the aim was to maximize the number of materials/products for reuse, 3 different paths were foreseen for products: reuse, recycle and other end-of-life:

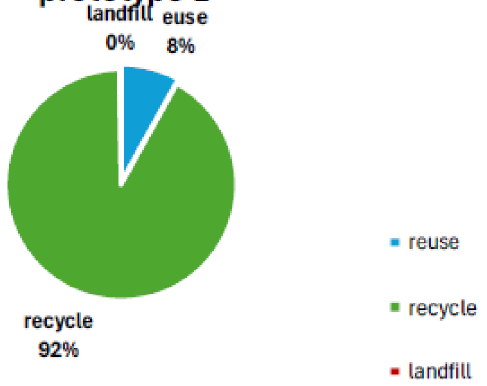
- ✓ *Steel substructures of both prototypes were taken to be reused (e.g. in cabins for storage or agricultural purposes);*
- ✓ *Selected steel sheets, in particular the trapezoidal sheets and the cassettes, and the door were also taken for reuse;*
- ✓ *In general, sandwich panels were suitable for reuse;*
- ✓ *Selected wood fiber boards will be reused to insulate the roof of a residential building.*

Analysis of the products' end-of-life

End-of-life scenario for Demonstrator 1

Prototype 1 (MONOPANEL)			end-of-life scenario weight in kg			
#	description/ material	weight in kg	reuse	recycle	landfill	sum
1	steel frame	801	801	0	0	
2	steel sheets	179	0	179	0	
3	wood fibre sandwich panel	889	0	889	0	
4	mineral wool sandwich panel	465	0	0	465	
5	mineral wool insulation (cladding/ roof)	50	0	0	50	
5	concrete (foundation)	8000	0	8000	0	
6	other (sealing tape, foam, etc.)	32	0	32	0	
7	door	30	30	0	0	
8	other (electric, light, etc.)	10	10	0	0	
			841	**9100**	**515**	**10,46 t**

end-of-life by weight prototype 1



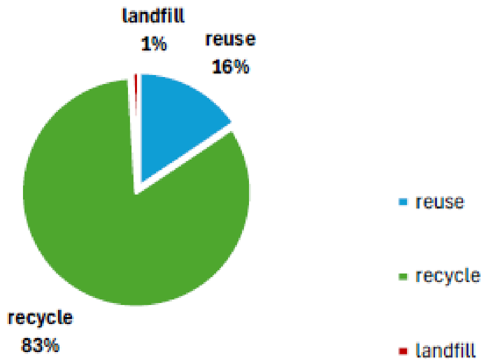
Analysis of the products' end-of-life

End-of-life scenario for Demonstrator 2

Prototype 2 (JORIS)

#	description/ material	weight in kg	end-of-life scenario weight in kg: reuse	recycle	landfill	sum
1	steel frame	835	835	0	0	
2	steel sheets, cassettes, etc.	855	855	0	0	
3	wood fibre insulation boards (selection)	235	235	0	0	
4	other wood fibre insulation	608	0	608	0	
5	mineral wool insulation (cladding/ roof)	206	0	206	0	
6	concrete (foundation)	8000	0	8000	0	
7	concrete blocks (wall)	1323	0	1323	0	
8	mineral wool sandwich panel (roof)	182	0	182	0	
9	wood fibre sandwich panel (roof)	200	0	200	0	
10	other (membrane roof/ cladding, sealing tape, foam, etc.)	120	0	0	120	
11	door	30	30	0	0	
12	other (electric, light, etc.)	10	10	0	0	
			1965	**10519**	**120**	**12,6 t**

end- of- life by weight
prototype 2



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Comparison between lab and real observation

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Condition of Demonstrator 1 after demolition

Condition of the wood fibre insulation boards on the walls and roof

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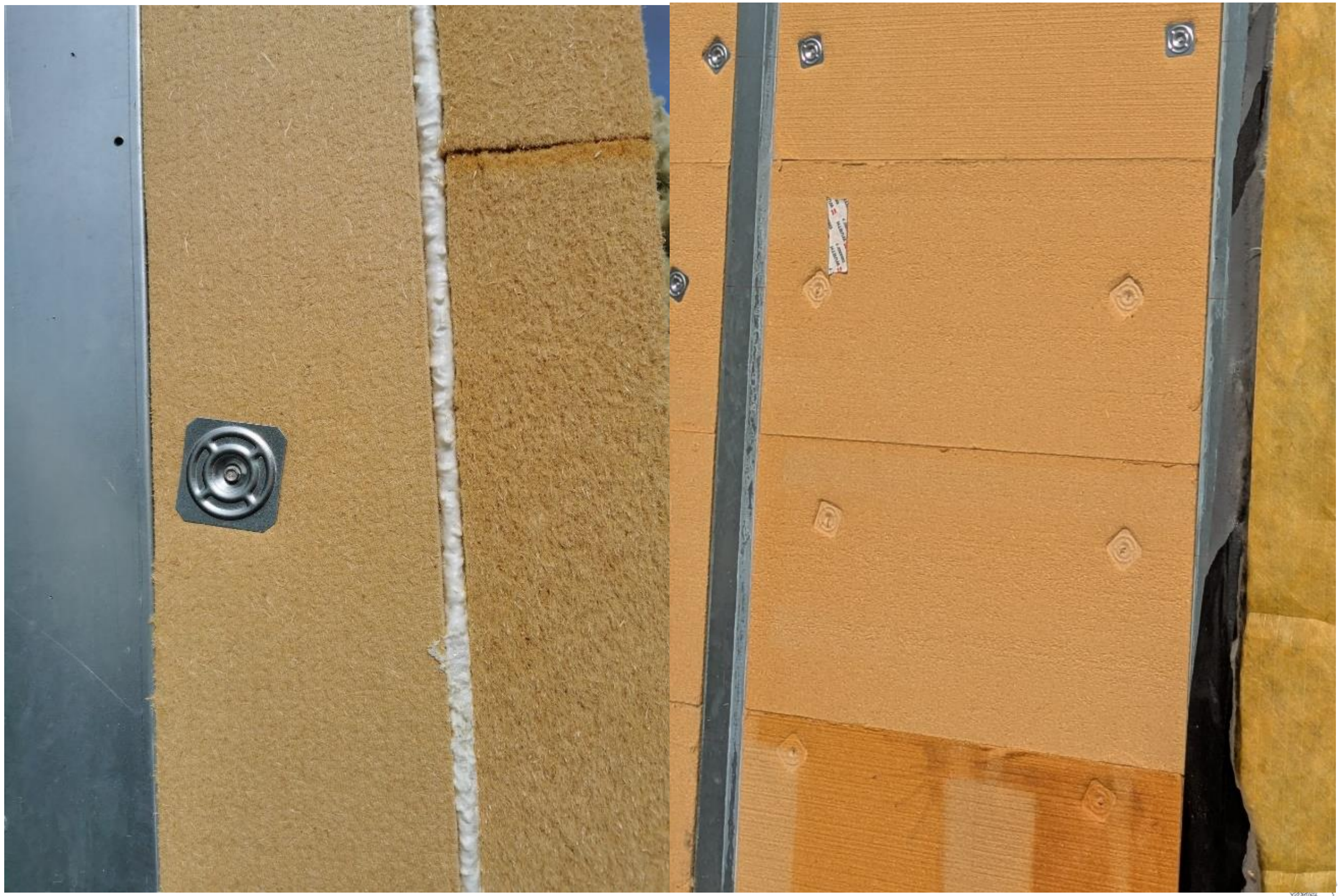
Condition of Demonstrator 1 after demolition

Condition of the wood fibre insulation (left) and mineral wool (right)

Condition of Demonstrator 2 after demolition

Condition of the wood fibre insulation boards on the walls and roof



Condition of Demonstrator 2 after demolition

Condition of the mineral wool, wood fibre insulation and steel cassettes

Summary on the condition of the panels

- ✓ In general, the condition of all materials and products was very good;
- ✓ The steel sheets, including the ones from the sandwich and siding panels, were as good as new;
- ✓ The insulation materials, both of wood fibre and mineral wool, were also mostly in very good condition.



- ✓ In Demonstrator 1, production-related blisters were found in two wood fibre sandwich wall panels (left);
- ✓ In Demonstrator 2, moisture was only visible in the first 10-15mm from the bottom (right).

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Conclusions

Conclusions

- ✓ From the durability tests made on small-scale samples, it was concluded that rock wool was very durable against fungal attack, while organic wool ranged from not very durable to not very durable at all.
- ✓ On the other hand, the durability tests (DUR2) carried out on the panels led to good results for all panels, i.e., all panels fulfilled the criteria.
- ✓ In addition, the results of the tests to obtain the hygrothermal cycle resistance led to the conclusion that all panels met the requirements.
- ✓ Finally, after the dismantling of both demonstrators, it was observed that the condition of all materials and products was, in general, very good.

Acknowledgements

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ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

LIFE CYCLE ASSESSMENT (LCA) FOR THE 5 INNOVATIVE STEEL ENVELOPE SYSTEMS

Thursday 12 June 2025

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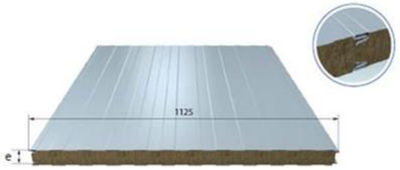
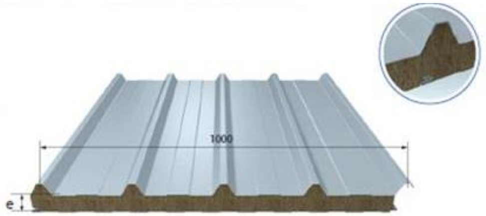
INTRODUCTION

Environmental indicators of life cycle assessment (LCA) including Global Warming Potential (GWP) covering all life cycle stages for the five ultra-low carbon steel envelop were determined:

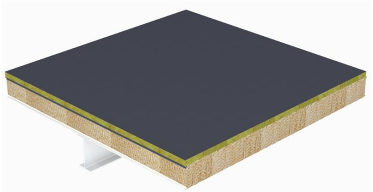
1. Cladding sandwich panel



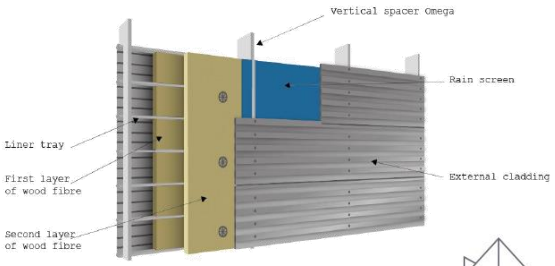
2. Pitch roofing sandwich panel



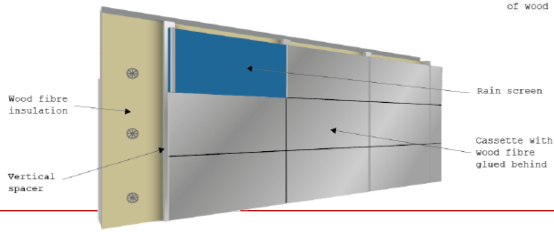
3. Flat roofing sandwich panel



4. Double skin cladding system



5. Façade cladding system



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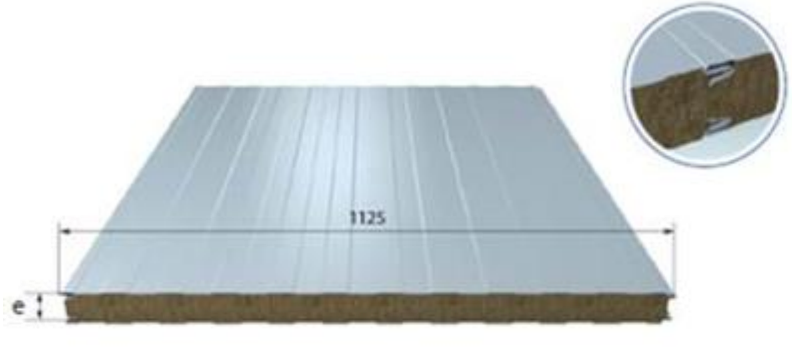
5 INNOVATIVE STEEL ENVELOPE SYSTEMS

1. Cladding sandwich panel

Components:

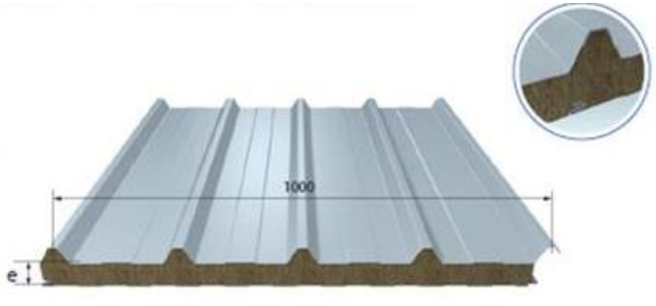
- 2 steel facings (MONOLAINE B (0,5; 0,63; 9,6kg/m²))
- wood fiber core (2 thicknesses 150mm and 200mm, 115kg/m³)
- polyurethane glue



2. Pitch roofing sandwich panel

Components:

- 2 steel facings (MONOLAINE T (0,5; 0,63; 10,3kg/m²))
- wood fiber core (2 thicknesses 150mm and 200mm; 115kg/m³)
- mineral wool in the trapezoidal part in the ribs (0,65 kg/m²)
- polyurethane glue



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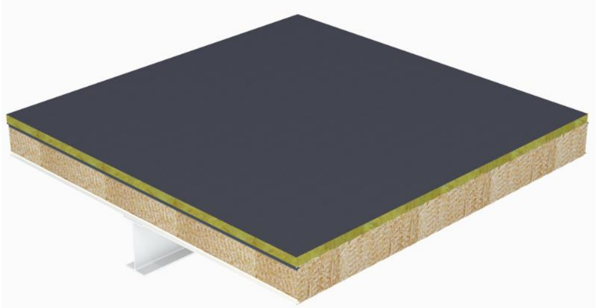
5 INNOVATIVE STEEL ENVELOPE SYSTEMS

3. Flat roofing sandwich panel

Components:

- 2 steel facings (vulcasteel FT (0,5mm ;0,55mm; 8,9kg/m²))
- wood fiber core (200mm; 110kg/m³)
- mineral wool (thickness 50mm, density 150kg/m3)
- polyurethane glue
- PVC waterproof membrane Danopol HS 1.2 LIGHT GREY



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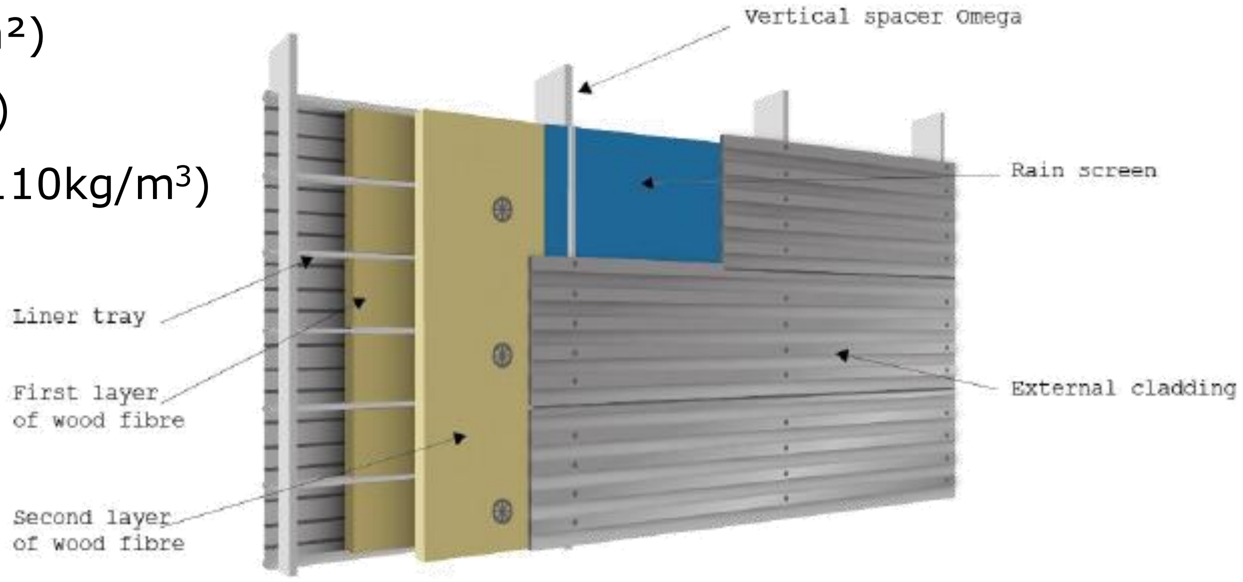
4. Double skin cladding system

Components:

- steel liner tray (0,75mm; 90x500mm; 8,8kg/m²)
- wood fiber in the liner tray (90 mm; 110kg/m³)
- wood fiber in front of the liner tray (120 mm; 110kg/m³)
- steel spacer (spacing 2m)
- polypropylene rain screen
- Omega spacer (spacing 2m)
- steel cladding (0,75mm; 6,62kg/m²)



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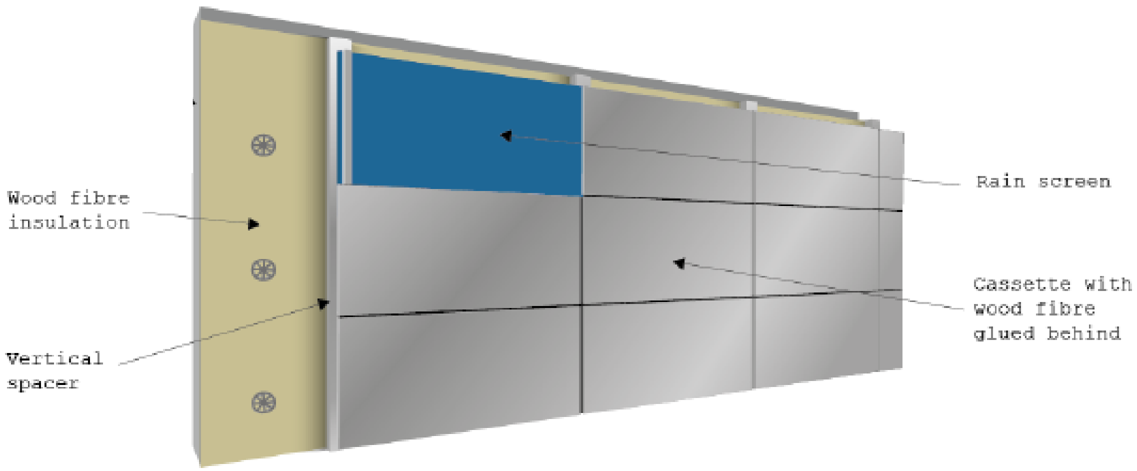
5 INNOVATIVE STEEL ENVELOPE SYSTEMS

5. Façade cladding system

Components:

- wood fiber glued to the siding (30 mm; 110kg/m^3)
- wood fiber in front of the wall (200 mm; 110kg/m^3)
- steel spacer (spacing 2m)
- polypropylene rain screen
- Omega spacer (spacing 2m)
- steel siding (JI GREGALE B300 (1mm; 11,1kg/m^2))



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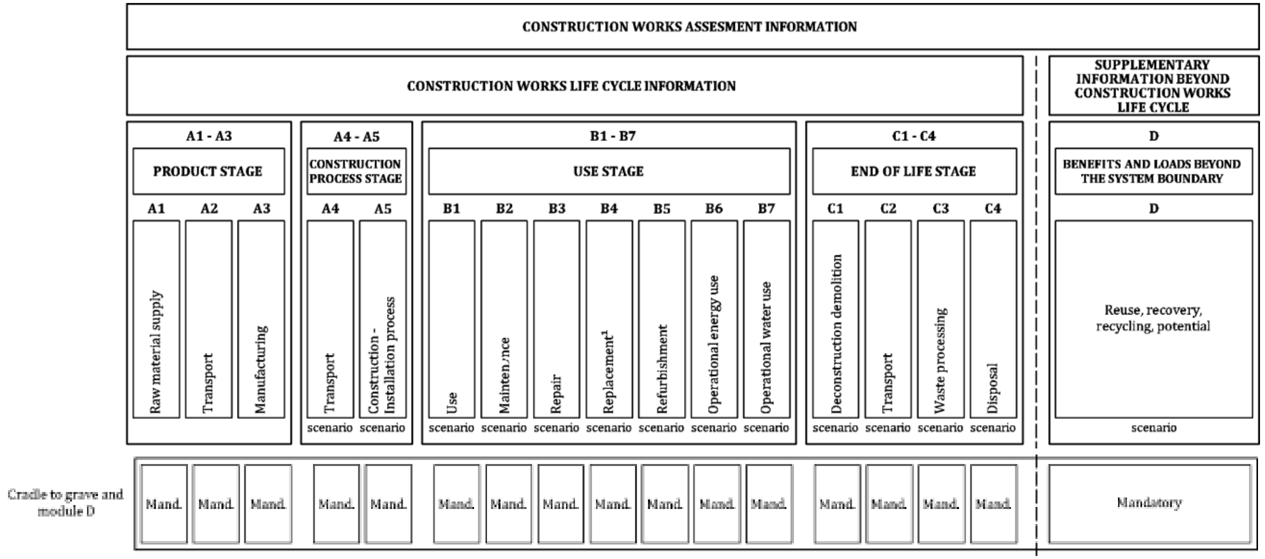
Life Cycle Assessment (LCA)

- The environmental indicators are based on EN 15804 + A2 and are calculated according to EN 15804 + A2 (all impact indicators are dertermined)
- The reference service life of the five systems is 50 years.
- Functional unit is 1m² of area (vertical or horizontal)
- All life stages and all modules are declared. It means according to EN 15804+A2 the declaration is cradle to grave and module D.



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SELECTION OF DATA

- Indicators are provided by EPDs when the component has an EPD according to EN 15804+A2 (only EPD- A2 for the waterproof membrane, for steel spacer and omega spacer are currently available)

- Manufacturer specific data and generic data when the component has no EPD according to EN 15804+A2. The manufacturer specific data is representative of the product and is provided by the supplier. The generic data is issued from ECOINVENT version 3.9.1 (2022) database and SPHERA (2023) for wood fiber (very close in terms of climate change and density to the insulation "PAVATHERM" tested in the project).

- Based on this specific and generic data the indicators of each component are calculated with LCA software tool "TEAM".

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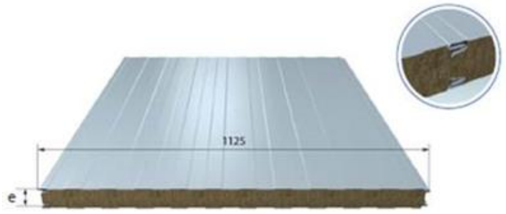
RESULTS : CLADDING SANDWICH PANEL 150mm

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	3,18E+00	7,28E+00	1,19E-02	3,10E+01 **75%**	4,15E+01	-1,89E+01
Climate change - fossil *kg CO2 equiv/UF*	3,70E+01	3,41E+00	1,15E-02	1,08E+00	4,15E+01	-1,87E+01
Climate change - biogenic *kg CO2 equiv/UF*	-3,38E+01	3,88E+00	3,37E-04	3,00E+01	1,88E-02	-2,73E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	5,39E+02 **90%**	4,59E+01	2,39E-01	1,64E+01	6,01E+02	-2,49E+02

Climate change at end-of-life stage is much higher than at production stage:

- Climate change at production stage is mainly the result of steel coil production (22,8 kg CO2 equiv/UF) and wood fiber production (**-20,4** kg CO2 equiv/UF). ➔ Climate change at production stage is reduced by the negative value of the wood fiber production due to carbon storage.
- Climate change at end-of-life stage is mainly the result of wood fiber recycling and disposal. **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production (271 MJ/UF; 45%) and wood fiber production (160 MJ/UF; 27%)).

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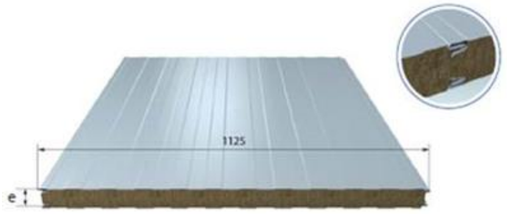
RESULTS : CLADDING SANDWICH PANEL 200mm

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	-3,41E+00	7,71E+00	1,19E-02	4,13E+01 **91%**	4,56E+01	-2,18E+01
Climate change - fossil *kg CO2 equiv/UF*	4,04E+01	3,83E+00	1,15E-02	1,35E+00	4,56E+01	-2,14E+01
Climate change - biogenic *kg CO2 equiv/UF*	-4,38E+01	3,88E+00	3,37E-04	4,00E+01	1,92E-02	-3,73E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	5,95E+02 **89%**	5,24E+01	2,39E-01	2,09E+01	6,69E+02	-3,01E+02

Climate change at end-of-life stage is much higher than at production stage:

- Climate change at production stage is mainly the result of steel coil production (22,8 kg CO2 equiv/UF) and wood fiber production (**-27,2** kg CO2 equiv/UF). ➔ Climate change at production stage is reduced by the negative value of the wood fiber production due to carbon storage.
- Climate change at end-of-life stage is mainly the result of wood fiber recycling and disposal. **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production (271 MJ/UF; 41%) and wood fiber production (214 MJ/UF; 32%)).

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ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

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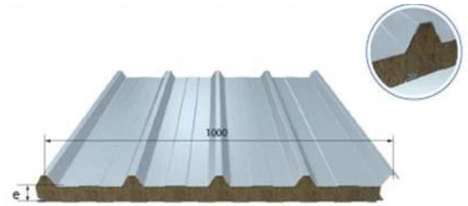
LOW CARBON STEEL ENVELOPE SYSTEMS

RESULTS : PITCH ROOFING SANDWICH PANEL 150mm

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	5,72E+00	7,46E+00	1,19E-02	3,11E+01 **70%**	4,43E+01	-1,97E+01
Climate change - fossil *kg CO2 equiv/UF*	3,95E+01	3,58E+00	1,15E-02	1,13E+00	4,43E+01	-1,94E+01
Climate change - biogenic *kg CO2 equiv/UF*	-3,38E+01	3,88E+00	3,37E-04	3,00E+01	2,03E-02	-2,71E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	5,69E+02 **90%**	4,80E+01	2,39E-01	1,72E+01	6,34E+02	-2,55E+02

Climate change at end-of-life stage is much higher than at production stage:

- Climate change at production stage is mainly the result of steel coil production (24,5 kg CO2 equiv/UF) and wood fiber production (<u>**-20**</u> kg CO2 equiv/UF). ➔ Climate change at production stage is reduced by the negative value of the wood fiber production due to carbon storage.
- Climate change at end-of-life stage is mainly the result of wood fiber recycling and disposal . **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production (291 MJ/UF; 46%) and wood fiber production (160 MJ/UF; 25%)).

L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

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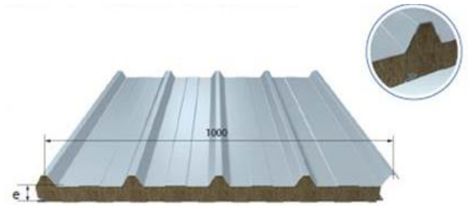
LOW CARBON STEEL ENVELOPE SYSTEMS

RESULTS : PITCH ROOFING SANDWICH PANEL 200mm

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	-8,64E-01	7,88E+00	1,19E-02	4,14E+01 **85%**	4,84E+01	-2,25E+01
Climate change - fossil *kg CO2 equiv/UF*	4,29E+01	4,00E+00	1,15E-02	1,41E+00	4,84E+01	-2,21E+01
Climate change - biogenic *kg CO2 equiv/UF*	-4,38E+01	3,88E+00	3,37E-04	4,00E+01	2,07E-02	-3,71E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	6,26E+02 **89%**	5,43E+01	2,39E-01	2,18E+01	7,02E+02	-3,07E+02

Climate change at end-of-life stage is much higher than at production stage:

- Climate change at production stage is mainly the result of steel coil production (24,5 kg CO2 equiv/UF) and wood fiber production (**-27** kg CO2 equiv/UF). ➔ Climate change at production stage is reduced by the negative value of the wood fiber production due to carbon storage.
- Climate change at end-of-life stage is mainly the result of wood fiber recycling and disposal . **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production (291 MJ/UF; 41%) and wood fiber production (214 MJ/UF; 30%)).

L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

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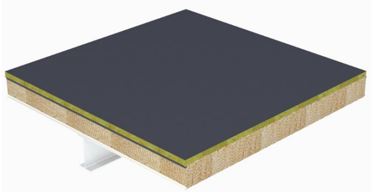
LOW CARBON STEEL ENVELOPE SYSTEMS

RESULTS : FLAT ROOFING SANDWICH PANEL

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	1,21E+01	6,90E+00	4,76E+00	3,96E+01 **62%**	6,34E+01	-2,01E+01
Climate change - fossil *kg CO2 equiv/UF*	5,03E+01	6,89E+00	4,75E+00	1,37E+00	6,33E+01	-1,97E+01
Climate change - biogenic *kg CO2 equiv/UF*	-3,82E+01	1,02E-02	6,93E-03	3,82E+01	4,41E-02	-3,59E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	7,41E+02 **78%**	8,99E+01	1,02E+02	2,20E+01	9,55E+02	-2,82E+02

Climate change at end-of-life stage is higher than at the production stage:

- Climate change at production stage is mainly the result of steel coil production (20,6 kg CO2 equiv/UF), mineral wool production (9,9 kg CO2 equiv/UF) and wood fiber production (**-26** kg CO2 equiv/UF). ➔ Climate change at production stage is reduced by the negative value of the wood fiber production due to carbon storage.
- Climate change at end-of-life stage is mainly the result of wood fiber recycling and disposal. **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production (245 MJ/UF; 26%) and wood fiber production (204 MJ/UF; 21%)).

L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

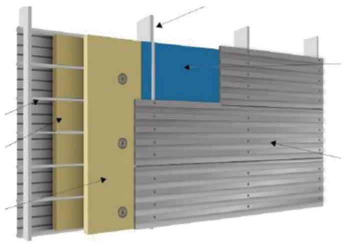
The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

RESULTS : DOUBLE SKIN CLADDING SYSTEM

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	4,58E+01	-2,07E+01	5,14E-01	4,16E+01	6,72E+01	-3,09E+01
Climate change - fossil *kg CO2 equiv/UF*	4,77E+01	1,74E+01	5,24E-01	1,44E+00	6,71E+01	-3,05E+01
Climate change - biogenic *kg CO2 equiv/UF*	-1,99E+00	-3,81E+01	1,69E-04	4,02E+01	4,41E-02	-3,55E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	5,96E+02 (64%)	2,92E+02 (31%)	1,77E+01	2,35E+01	9,30E+02	-371,80

Climate change at production stage and at end-of-life stage are similar.

- At production stage it is due to steel coil production (for liner tray, cladding and spacers)
- At construction stage it is negative because of the carbon storage in wood fiber which is installed in the system during the construction stage.
- At end-of-life stage it is due to wood fiber recycling and disposal. **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**



Total use of non-renewable primary resources is mainly due to production stage (steel coil production for liner tray, cladding and spacers) and to construction stage (wood fiber production).

L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

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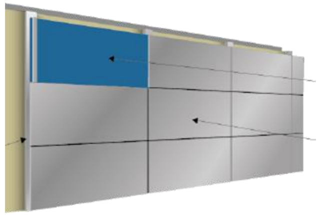
RESULTS : FACADE CLADDING SYSTEM

Impact category	Product stage	Construction process stage	Use stage,	End-of-life stage	Total	D Benefits and loads beyond the system boundary
CORE ENVIRONMENTAL IMPACT INDICATORS						
Climate change – total ***kg CO2 equiv/UF***	3,58E+01	-2,30E+01	5,14E-01	4,71E+01	6,04E+01	-2,84E+01
Climate change - fossil *kg CO2 equiv/UF*	3,81E+01	2,00E+01	5,24E-01	1,45E+00	6,02E+01	-2,80E+01
Climate change - biogenic *kg CO2 equiv/UF*	-2,34E+00	-4,31E+01	1,69E-04	4,57E+01	2,71E-01	-4,23E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) ***MJ/UF***	4,70E+02 (55%)	3,41E+02 (40%)	1,77E+01	2,43E+01	8,53E+02	-3,64E+02

Climate change at production stage and at the end-of-life stage are similar.

- At production stage it is due to steel coil production (for siding and spacers)
- At construction stage it is negative because of the carbon storage in wood fiber which is installed in the system during the construction stage.
- At end-of-life stage it is due to wood fiber recycling and disposal. **Both wood fiber landfilling and wood fiber recycling generate carbon emission due to carbon release.**

Total use of non-renewable primary resources is mainly due to production stage (steel coil production for sidding and spacers) and to construction stage (wood fiber production).



L'ENVELOPPE MÉTALLIQUE DU BÂTIMENT
ASSOCIATION DES FABRICANTS DE PANNEAUX, PROFILS ET SYSTÈMES

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CONCLUSION

Environmental indicators of life cycle assessment (LCA) including Global Warming Potential (GWP) covering all life cycle stages for the five ultra-low carbon steel envelop were determined.

Climate change for the "sandwich panel" systems is mainly due to end-of-life stage due to carbon release from wood fiber disposal and recycling. Climate change at production stage is very low because it is reduced by the negative value of wood fiber production due to carbon storage.

Climate change for double skin and façade systems is due almost equally to production stage and to end-of-life stage. Climate change at production stage is due to steel coil production (for liner tray, cladding, siding and spacers). Climate change at end-of-life stage is the result of wood fiber disposal and recycling due to carbon release. In construction stage the climate change is negative because of the carbon storage in wood fiber which is installed in the system during the construction stage.

Total use of non-renewable primary resources is mainly due to steel coil and wood fiber production.

The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

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LOW CARBON STEEL ENVELOPE SYSTEMS

DETERMINATION OF THE CARBON FOOTPRINT (GWP) BENEFITS OBTAINED AT A BUILDING LEVEL

Helena Gervasio

12th June 2025

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Contents

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Case studies

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Case studies

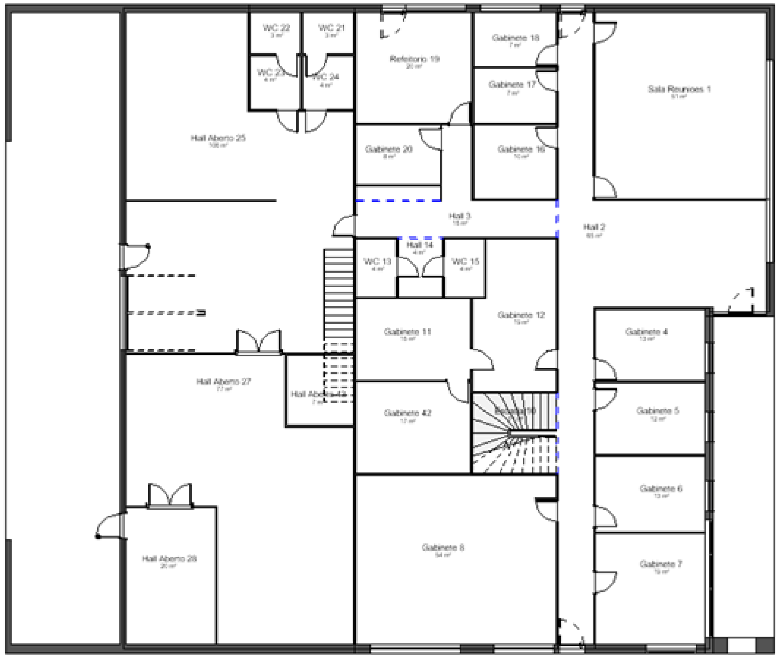
Five different case studies were considered with different panel configurations. The main characteristics of the reference building, except the façade and roof, were kept constant for all case studies.

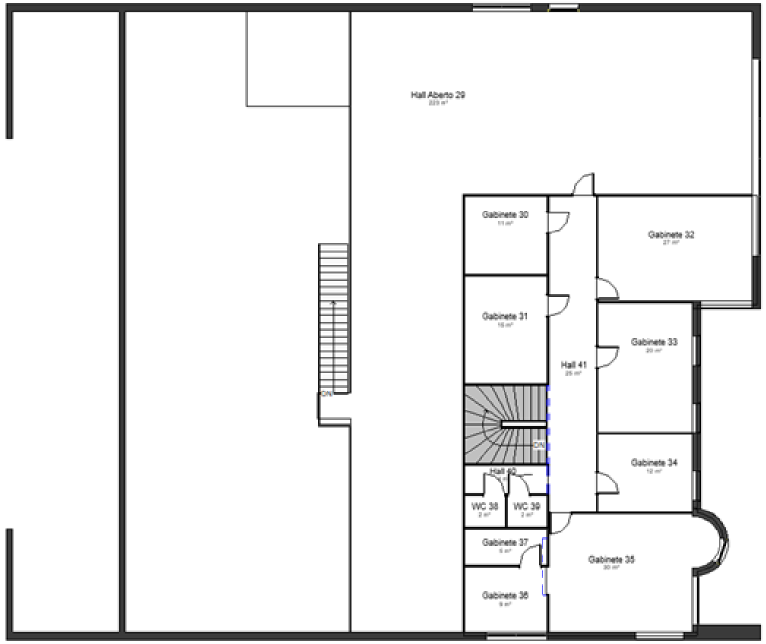
Scenario	Source	Façade	Roof
Reference building		PUR sandwich panels	Glass wool insulation
Building 1A	WP1 (Monopanel)	Cladding sandwich panel (150 mm)	Pitch roofing sandwich panel
Building 1B	WP1 (Monopanel)	Cladding sandwich panel (200 mm)	Pitch roofing sandwich panel
Building 2	WP2 (JorisIde)	Double skin cladding system	Flat roofing sandwich panel
Building 3	WP2 (JorisIde)	Double-skin + façade cladding system	Flat roofing sandwich panel

✓ The reference building, an office building, was assumed to be located in France.

Case studies

- ✓ The total area of the building is 981 m^2. The building has two different areas, one area dedicated to office rooms, and an open space that serves as a warehouse and other facilities.
- ✓ Only the former area was considered in terms of energy requirements (conditioned area), with a total area of about 491 m^2.





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Thermal performance

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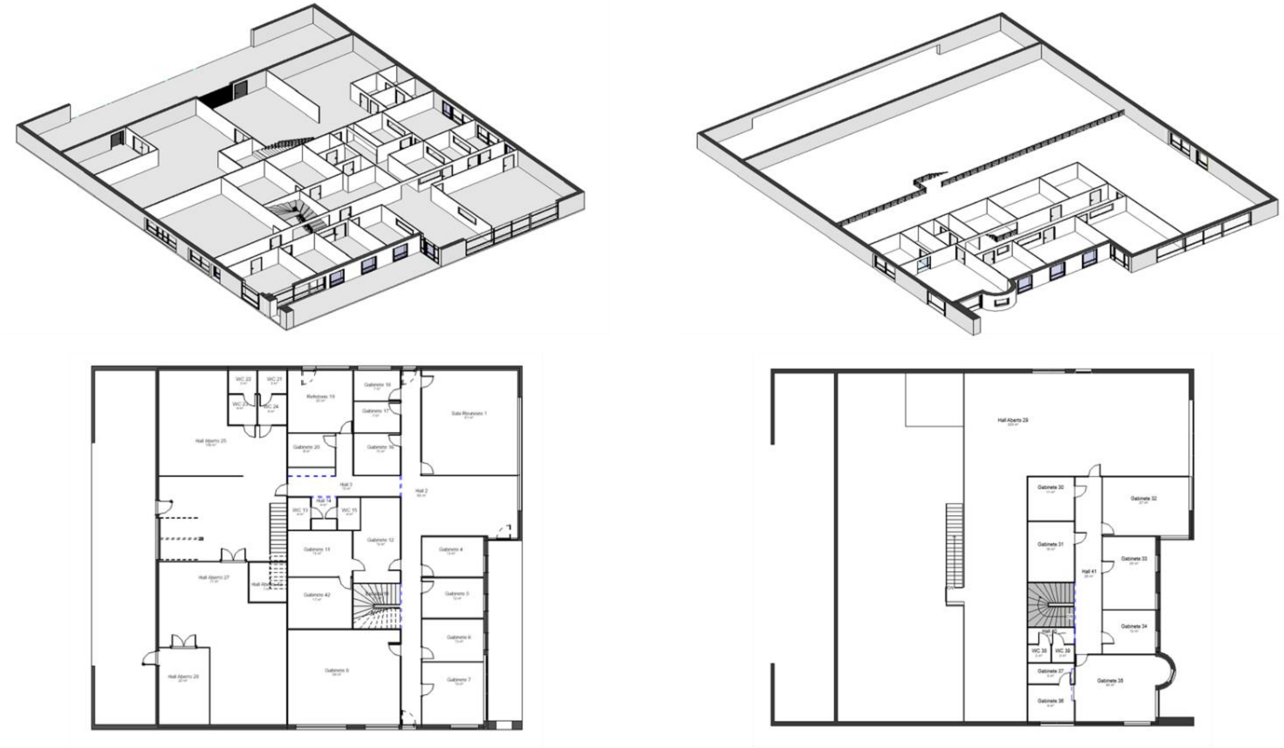
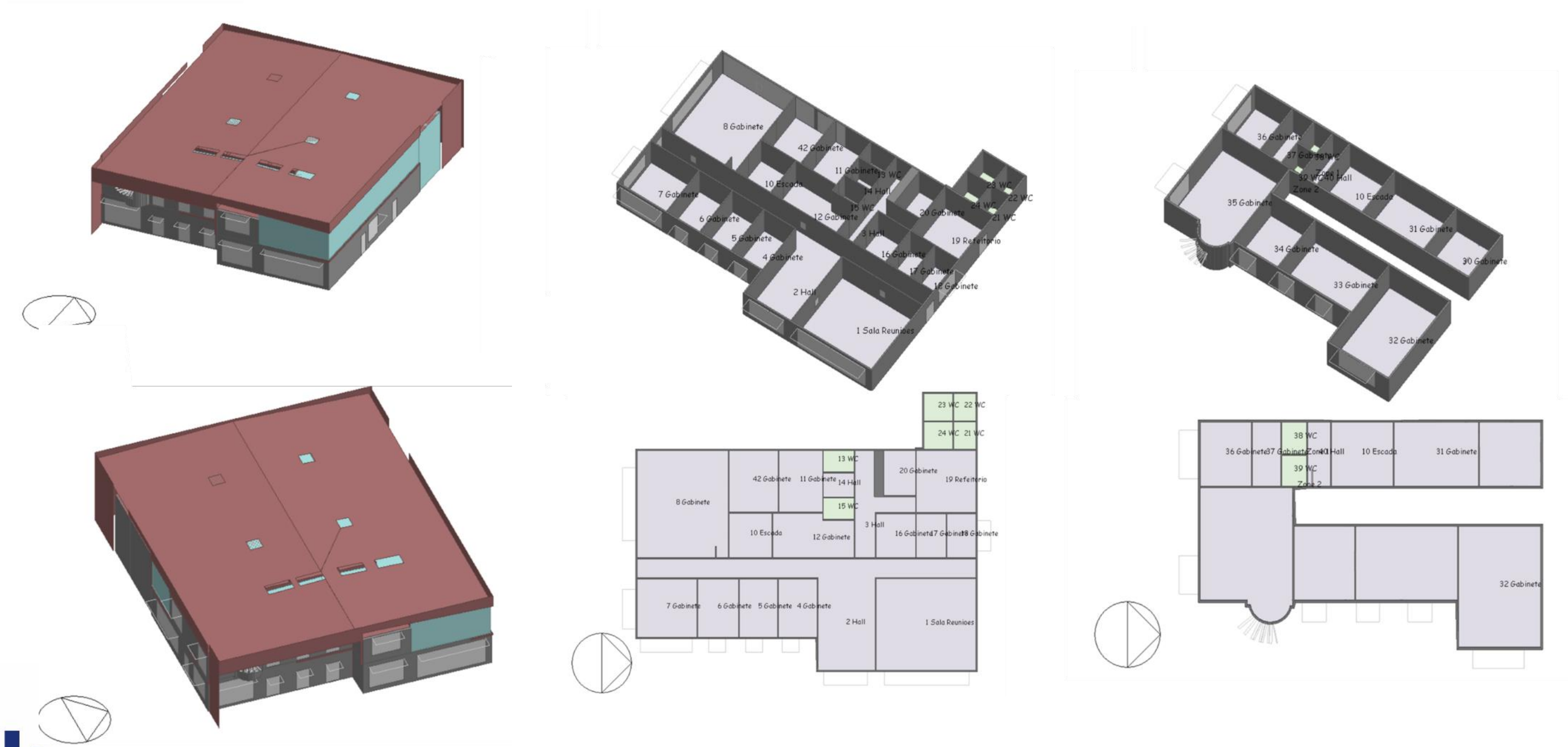
Thermal performance

- ✓ **Numerical simulations to characterize the thermal behaviour of the office building were carried out using the advanced dynamic simulation software DesignBuilder v5.5.0.012.**
- ✓ To build the 3D model for the thermal analysis of the buildings, a BIM model in Revit software was created and exported to DesignBuilding software.
- ✓ **The model allowed to estimate the energy requirements of the different buildings, in terms of heating and cooling, over the year.**



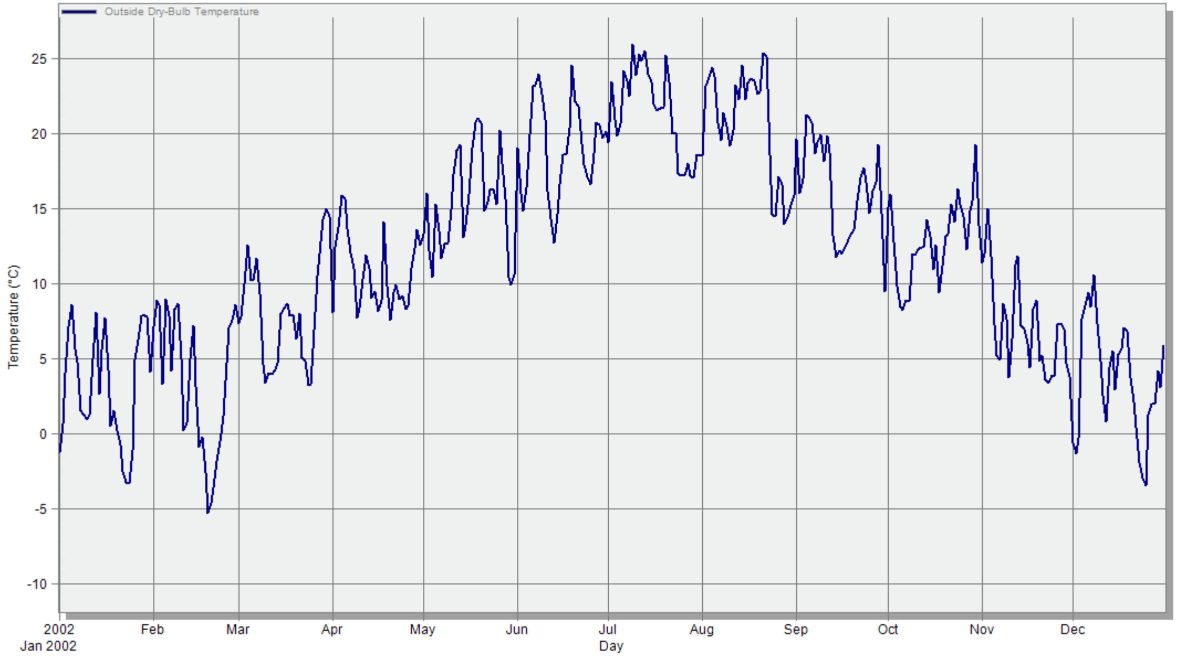
Thermal performance

3D building in Design Builder

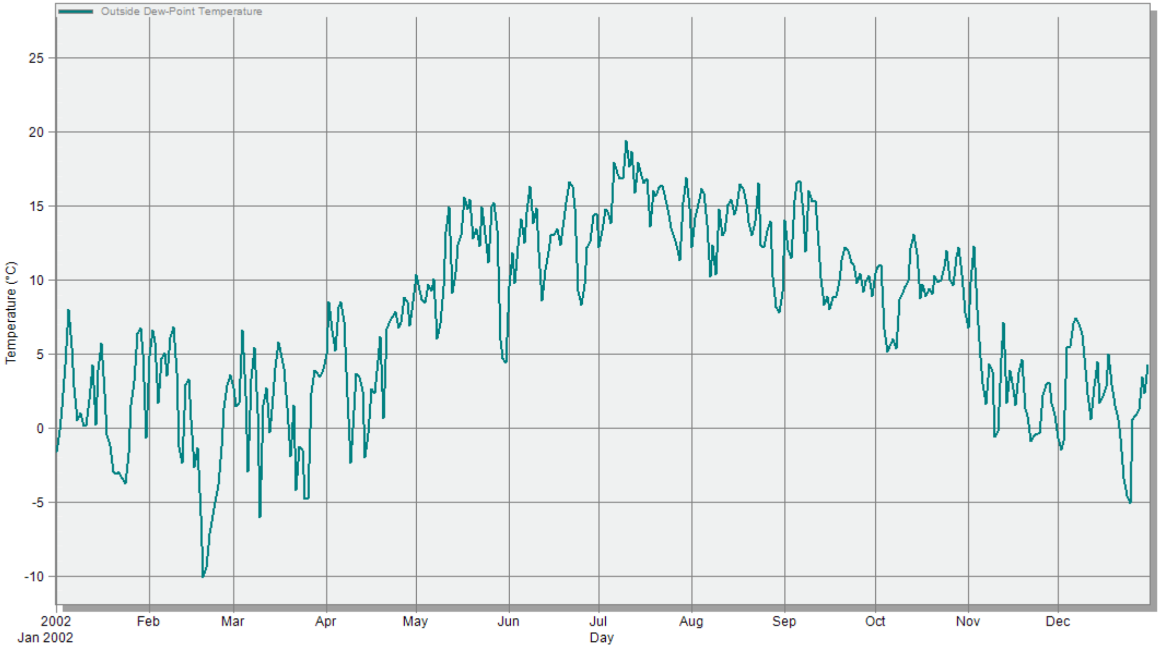


Thermal performance

- ✓ The building was located in the city of Valence, in southeast France, but Lyon was considered, as this was the closest city to Valence with climate data available.
- ✓ The respective climate data was obtained from the **DesignBuilder database**.



Daily Outside Dry-Bulb Temperature for the Lyon region in 2022



Daily Outside Dew-Point Temperature for the Lyon region in 2022

Thermal performance

Characteristics of the envelope of the building

Case study	λ (W/mK)	U (W/m²K)	
		Façade	Roof
Reference	**0.028**	**0.33**	**0.252**
Building 1A	0.06	0.38	0.35
Building 1B	0.06	0.29	0.28
Building 2	0.044	0.24	0.15
Building 3	0.044	0.30	0.15

Other characteristics:

- ✓ non-opaque envelope (windows), low emissivity clear double glazing (3mm /13mm Argon /3mm) was used, with a solar factor of 0.624, thermal transmittance of 1.96 W/(m^2·K) and light transmission of 74.4%.
- ✓ window frame [U = 3.633 W/(m^2·K)].

Building services	Values
Air conditioning	COP heating =3.4
(Set-point 22-24 C)	COP cooling = 3.0
Ventilation and infiltration rate	0.6 ac/h (heating mode)
(constant values)	1.2 ac/h (cooling mode)

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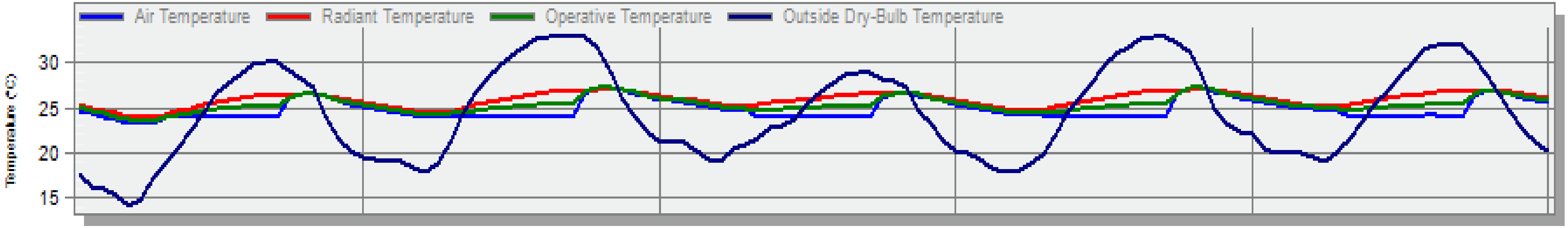
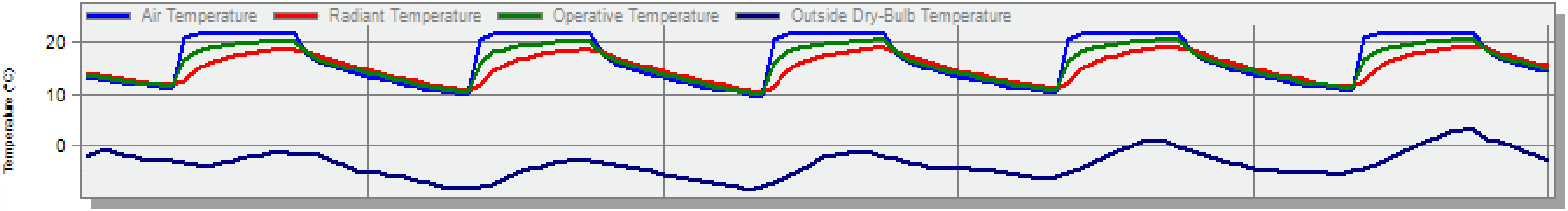
Thermal performance

Reference building

Summer Design Week Summary of Energy Performance of the reference building



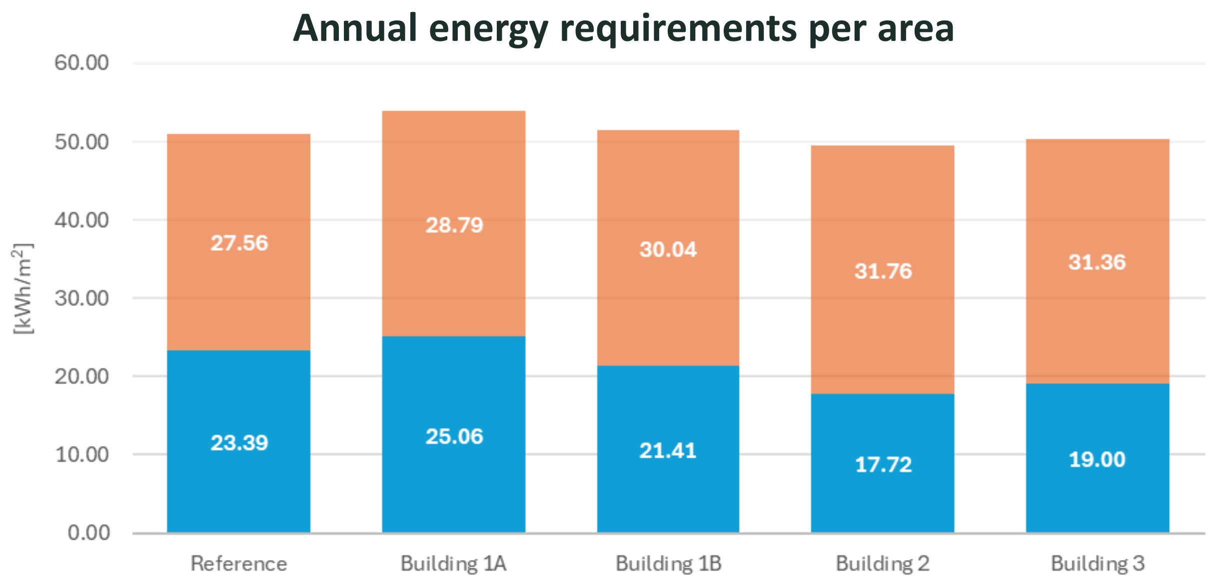
Winter Design Week Summary of Energy Performance of the reference building

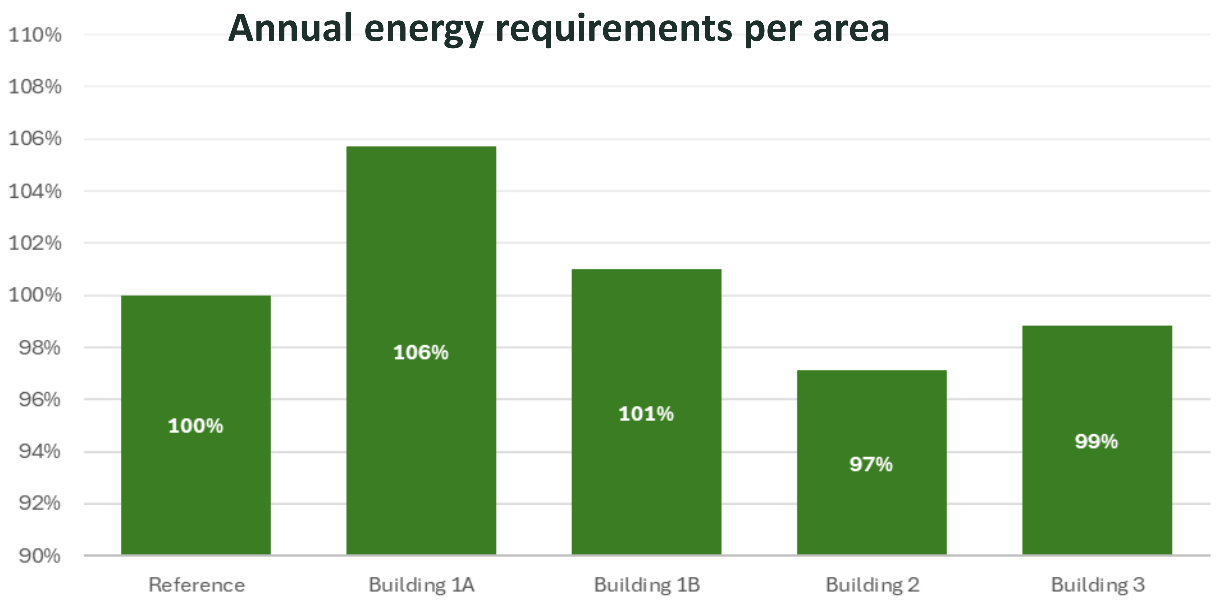


Thermal performance

Annual energy requirements of the buildings (comparative analysis)

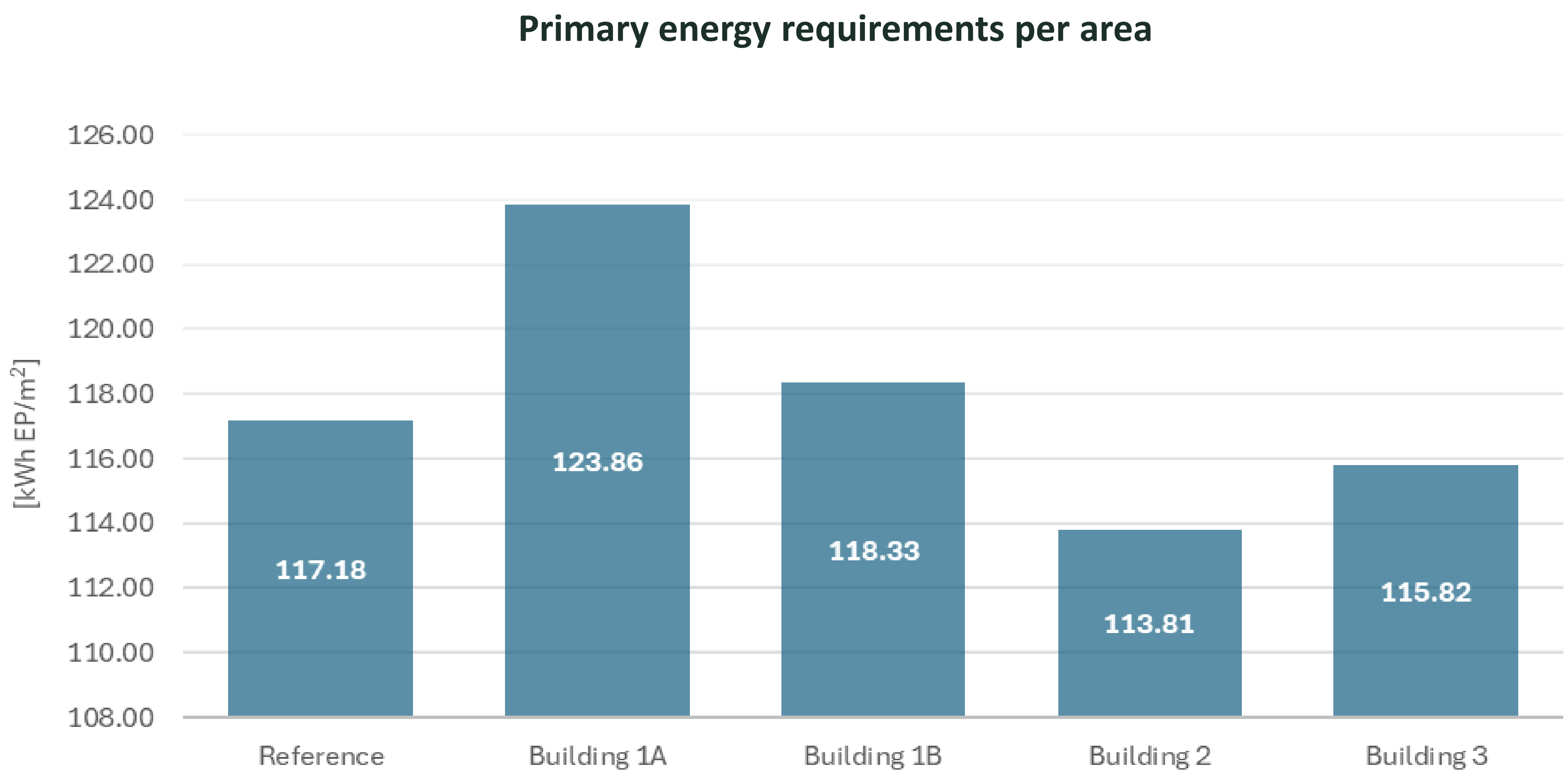
	Reference	Building 1A	Building 1B	Building 2	Building 3
Cooling (kWh)	11601.00	12118.74	12643.73	13367.84	13199.96
Heating (kWh)	9844.13	10548.80	9012.33	7460.06	7995.53
Total (kWh)	21445.13	22667.54	21656.06	20827.90	21195.49





Thermal performance

Annual energy requirements of the buildings (comparative analysis)



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Environmental performance

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Environmental performance

Environmental indicators:

Impact Category	Acronym	Unit
Climate Change - total	GWP_T	kg CO_2 eq.
Climate Change, fossil	GWP_F	kg CO_2 eq.
Climate Change, biogenic	GWP_B	kg CO_2 eq.
Climate Change, land use, and land use change	GWP_L	kg CO_2 eq.

GWP_F - accounts for GWP from greenhouse gas emissions and removals to any media originating from the oxidation or reduction of fossil fuels or materials containing fossil carbon by means of their transformation or degradation (e.g. combustion, incineration, landfilling, etc.).

GWP_B - accounts for GWP from removals of CO2 into biomass from all sources except native forests, as transfer of carbon, sequestered by living biomass, from nature into the product system declared as GWP_B.

GWP_L - accounts for GHG emissions and removals (CO_2, CO and CH_4) originating from changes in the defined carbon stocks caused by land use and land use changes associated with the declared/functional unit.

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Environmental performance

LCA model

- ✓ LCA model according to EN 15804:2012+A2:2019 and EN 15978:2011, and implemented into the software 'LCA for Experts" (Sphera).
- ✓ All modules are considered, except Modules B1 to B7 and C1.

Product stage			Const. stage		Use stage							End-of-life stage				
A1	A2	A3	A4	A4	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction	Transport	Waste processing	Disposal	Reuse-recycling-recover
√	√	√	√	√	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	√	√	√	√

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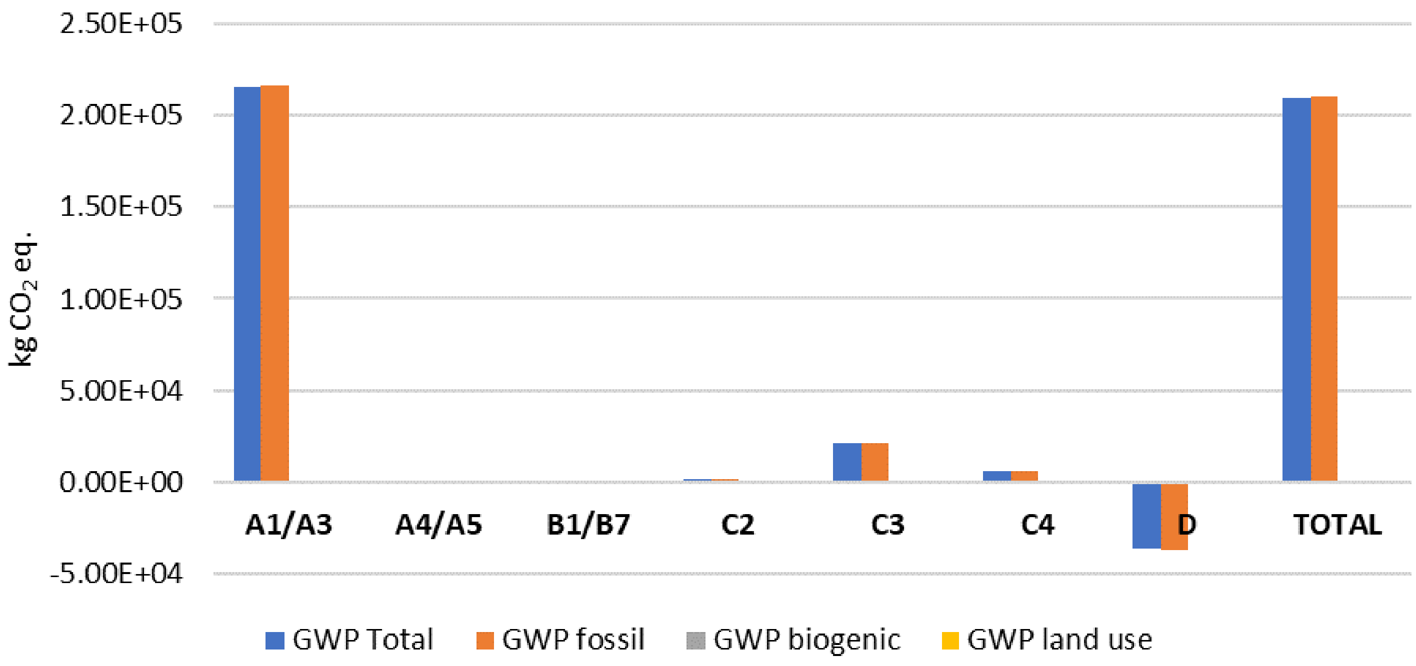
Environmental performance

Reference building



- ✓ The two most relevant indicators were GWP total and GWP fossil, which led to total life cycle values of 209822.21 kg CO_2 eq. and 210430.34 kg CO_2 eq., respectively.

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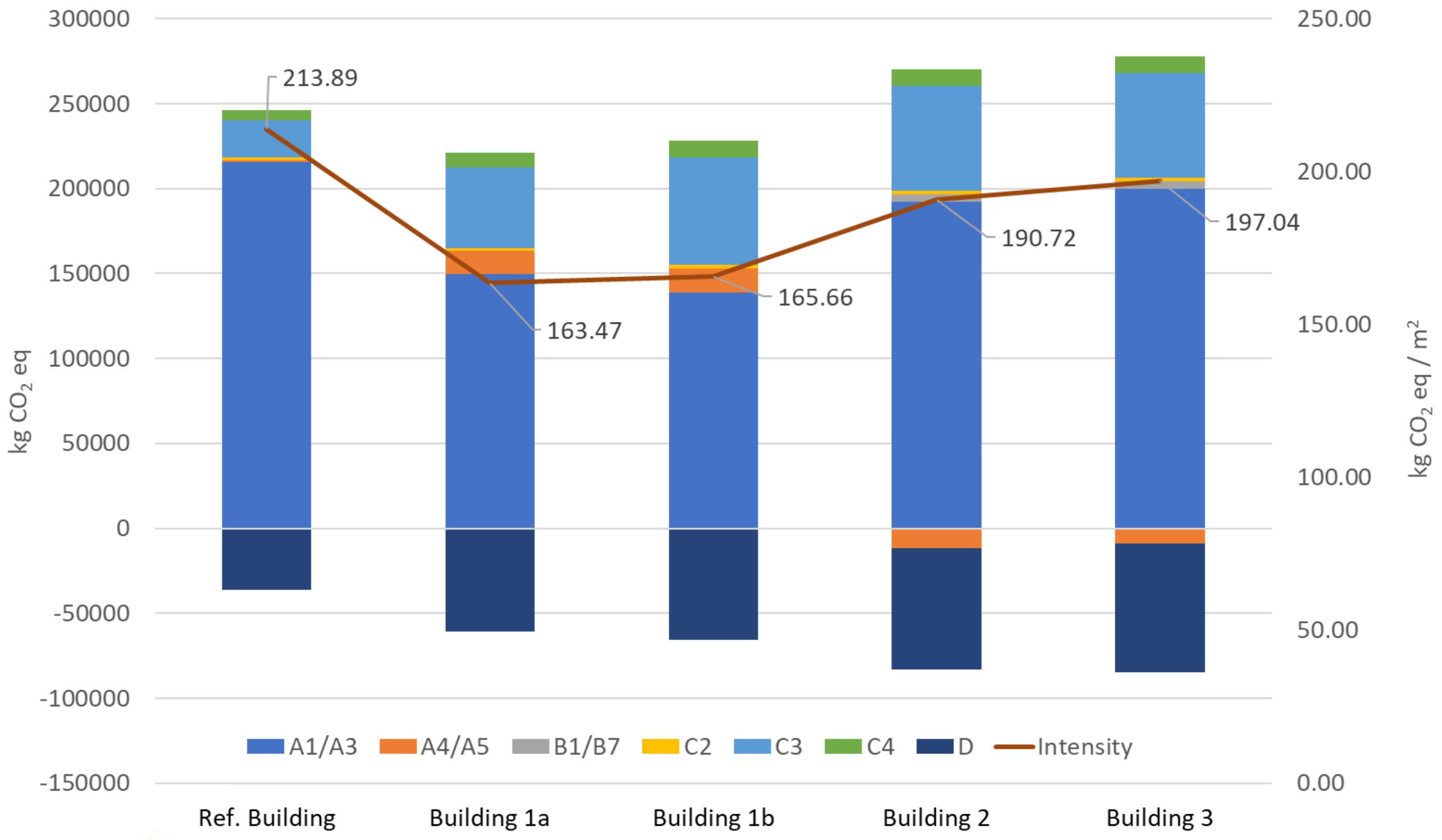
Environmental performance

GWP_T (in kg CO_2 eq. and kg CO_2 eq./m^2) for the different building solutions



- ✓ **Building 1a and Building 1b have a reduction of 23.6% and 22.5% concerning the reference building, respectively.**
- ✓ **The cutbacks of Building 2 and Building 3 are 10.8% and 7.9%, respectively.**

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Conclusions

Conclusions

- ✓ In terms of **energy requirements for heating and cooling** (annual values), it was observed that the buildings with InCSEB panels have very similar thermal performance in relation to the reference building. There were only small differences for Building 1A, with a slight increase of 6%, and for Building 2, with a slight reduction of 3%.
- ✓ On the other hand, in terms of **life cycle carbon emissions**, Building 1A and Building 1B showed a reduction of 23.6% and 22.5% to the reference building, respectively, while the reductions of Building 2 and Building 3 were 10.8% and 7.9%, respectively.

Acknowledgements

The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

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ECONOMIC ASSESSMENT FOR THE FIVE INNOVATIVE STEEL ENVELOPE SYSTEMS

The InCSEB project has received financial support from the European Community's Research Fund for Coal and Steel (RFCS) under grant agreement N° 101033984

What's innovative about the Incseb project?

✓ *A third family of steel envelope systems is now available:*

Steel envelop systems with wood fibre insulation PEFC label

➡ *An additional offer to expand the market share of steel envelope*

PEFC label means that wood fibre comes from sustainably managed forests

Overview of the current steel envelope market in France and Germany

French market

Mainly a market of profiled sheeting, with more than 62 million m² put on the market per year, all profiles included

Over 14 million m² of sandwich panels with polyurethane (80%) or mineral wool (20%) core are sold every year in France.

The market for steel envelopes is predominantly for non-residential buildings, with a strong focus on several types of building

Non-residential buildings	Façade	Roofing
Retails	42%	79%
Offices	31%	47%
Sports & leisure & culture	25%	57%
Storage/logistics	82%	94%
Industrials	91%	96%

Market share of steel cladding and roofing
(Source BATIETUDE- Construiracier)

German market

Major market for sandwich panels. For 2024 about 18 million m² of steel sandwich panels with polyurethane (85%) or mineral wool (15%) core were sold in Germany..

Profiled sheeting is about 28 million m² in 2024. Double skin represents a small share of this overall market with less than 1 million m² liner trays sold in 2024.

The most popular building where sandwich panels are currently used are warehouses, production halls, and agricultural buildings, together accounting for over 70.3% of the total usage of panels

Comparison of costs supplied and installed of conventional and innovative solutions for the French and German markets

Currently, the price of wood fibre is higher than that of traditional insulation materials, because:

- wood fibre insulation is rarer than traditional insulation materials, which are produced on an industrial scale
- demand for wood fibre is growing, so prices are rising

The price comparisons below are made for systems with equivalent thermal performance:

	Cladding sandwich panel	Pitch roofing sandwich panel	Double skin system	Facade cladding	Flat roofing sandwich panel
Wood fiber (New)	70-105€/m² (200 mm)	75-110€/m² (200 mm)	88- 118 €/m² (210 mm)	104-140€/m² (230 mm)	96- 134 €/m² (200 mm)
Mineral wool (Conventional)	65-100€/m² (150 mm)	65-100 €/m² (150 mm)	61-86 €/m² (120 mm)	75-95€/m² (145 mm)	67-108 €/m² (240 mm)
Polyurethane (Conventional)	80-85 €/m² (80 mm)	75-80 €/m² (60 mm)			110-120 €/m² (140 mm)

They are prices negotiated for the systems used in the Incseb research project
They are purely indicative as they cannot be usefully compared with the commercial price of existing traditional systems.

A FAVOURABLE CONTEXT FOR THE MARKET LAUNCH OF THIS NEW FAMILY OF STEEL ENVELOPES WITH BIO-SOURCED INSULATION

- In Europe, the regulatory framework (Green Deal)encourages the use of sustainable, renewable and recyclable construction products:
  - The Eco-design for Sustainable Products Regulation-ESPR
  - The EU Taxonomy Regulation, which defines environmentally sustainable economic activities
  - The new Construction Product Regulation (CPR) requires the disclosure of information on products concerning their impact on the climate
  - Etc ...
- In France, several regulations promote the use of bio-sourced construction products , such as:
  - The RE2020 gives products that use bio-sourced components products a competitive advantage (specific dynamic LCA), in meeting the carbon thresholds required by regulations.
  - From 1 January 2030, the use of bio-sourced or low-carbon construction products will be required in at least 25% of major renovations and new buildings commissioned by the public sector (Environment Code)
- In Germany, the use of bio-based materials is actively supported at both federal and regional level:
  - the use of bio-sourced materials can give access to subsidised loans or grants
  - Etc ...

CONCLUSION

A combination of favourable factors will facilitate the entry of this new family into the market, in particular:

- a highly favourable regulatory context

- a comprehensive new offering covering all sub-families:
  - ✓ sandwich panels,
  - ✓ double skin,
  - ✓ facade claddings

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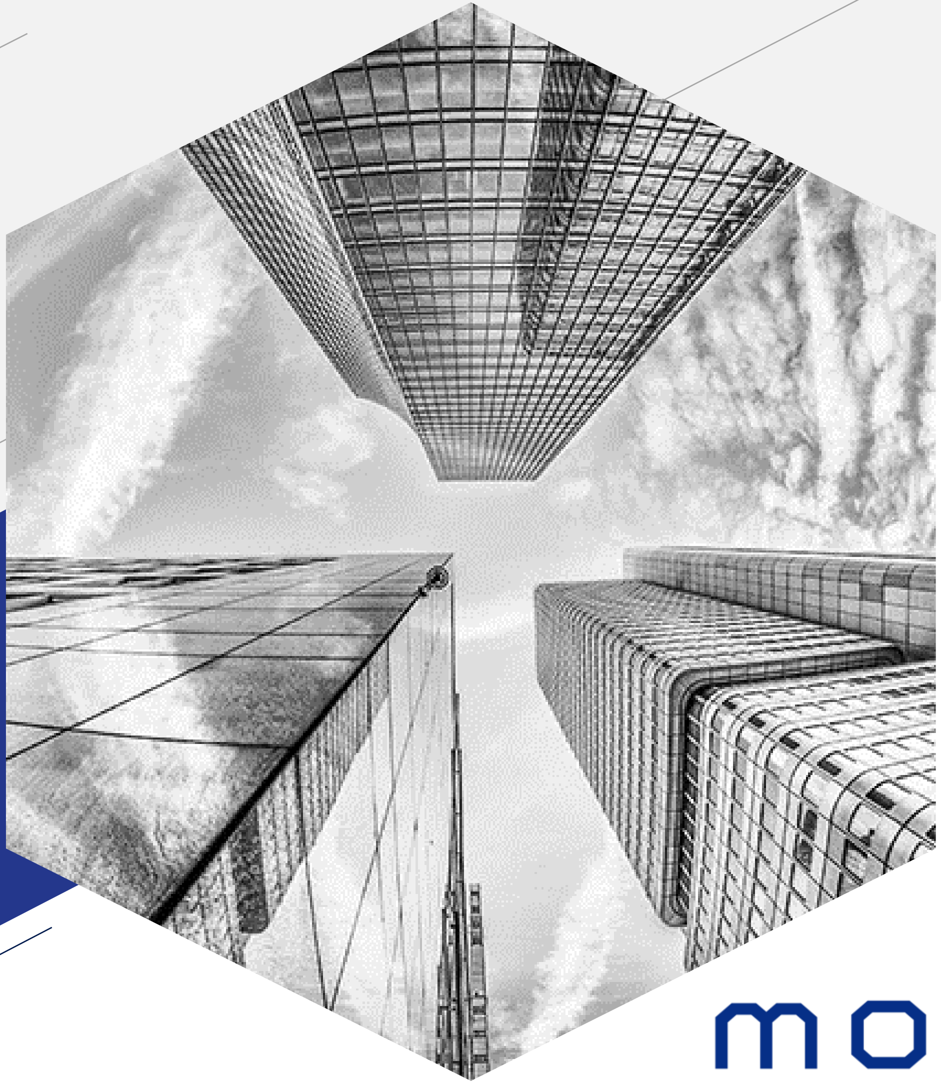


Incseb

LOW CARBON STEEL ENVELOPE SYSTEMS

INCSEB Workshop

Main deliverables

monopanel BUILDING ENVELOPE

MONOPANEL: main deliverables

3 key questions to be answered while developing a new building component:

1. **How to calculate** the wood fibre sandwich panels ?
   ⇒ Design guides

2. **How to install** the wood fibre sandwich panels ?
   ⇒ Installation guides

3. **How to integrate** the wood fibre sandwich panels **easily within a practical building project?**
   ⇒ BIM objects

Design guides

- Based on the results of all the tests performed according Annex A EN 14509: the wood fibre sandwich panels provide **equivalent level of performances** than the current sandwich panels technologies (PUR and mineral wool core)

➢ **Recommended design method according EN 14509**

Requirement of EN14509 modifications to integrate new low carbon core insulation material

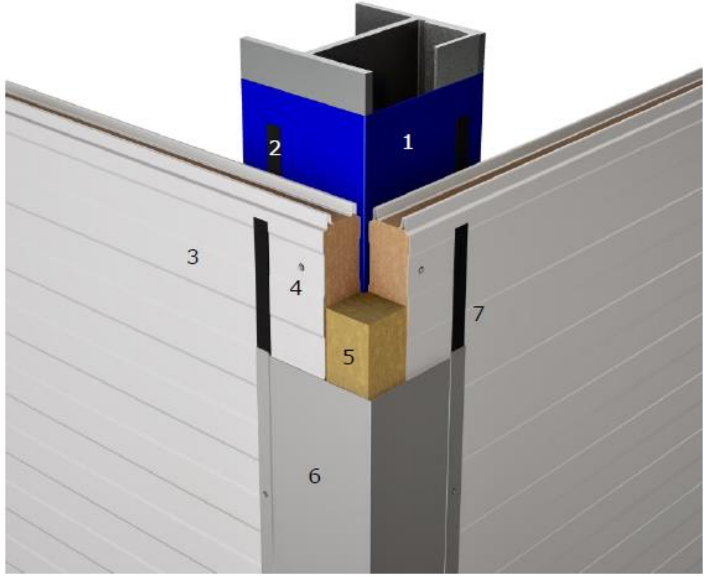
➢ Design note example based on the demonstrator conditions

Design situation	Specific case to be verified	Values	verdict
ELU with wind in pressure	Shear stresses in the core at end support	$\tau = 0.007 < \frac{f_{cv}}{\gamma_m} = 0.05$	PASS
	Compression stresses in the core at end support	$\sigma_c = 0.018 < \frac{f_{cc}}{\gamma_m} = 0.078$	PASS
	Bending moment at mid span	$\sigma_{L/2} = 7.11 < \frac{\sigma_w}{\gamma_m} = 69.55$	PASS
ELS with wind in pressure and thermal gradient	Shear stresses in the core at end support	$\tau = 0.005 < \frac{f_{cv}}{\gamma_m} = 0.07$	PASS
	Compression stresses in the core at end support	$\sigma_c = 0.018 < \frac{f_{cc}}{\gamma_m} = 0.1$	PASS
	Bending moment at mid span	$\sigma_{\frac{L}{2}} = 4.74 < \frac{\sigma_w}{\gamma_m} = 69.55$	PASS
	Deflections criteria	$\max\left(combi\left(f_{vent}; f_{\Delta Tété}; f_{\Delta Thiver}\right)\right) = 0.0026 < fadm = 0.016$	PASS
ELU with wind in suction and thermal gradient	Shear stresses in the core at end support	$\tau = 0.009 < \frac{f_{cv}}{\gamma_m} = 0.05$	PASS
	Bending moment at mid span	$\sigma_{L/2} = 11 < \frac{\sigma_w}{\gamma_m} = 81$	PASS
	Fixing resistance at end support	$R_{end} = 154 * \left(\frac{0.86}{0.76}\right) = 174.3 < \frac{F_{Rd\,fix}}{\gamma_m} = 756$	PASS
ELS with wind in suction and thermal gradient	Shear stresses in the core at end support	$\tau = 0.006 < \frac{f_{cv}}{\gamma_m} = 0.07$	PASS
	Bending moment at mid span	$\sigma_{\frac{L}{2}} = 7.32 < \frac{\sigma_w}{\gamma_m} = 81$	PASS
	Deflections criteria	$\max\left(combi\left(f_{vent}; f_{\Delta Tété}; f_{\Delta Thiver}\right)\right) = 0.0021 < fadm = 0.016$	PASS
	Fixing resistance at end support	$R_{end} = 102 * \left(\frac{0.86}{0.76}\right) = 115.4 < \frac{F_{Rd\,fix}}{\gamma_m} = 756$	PASS

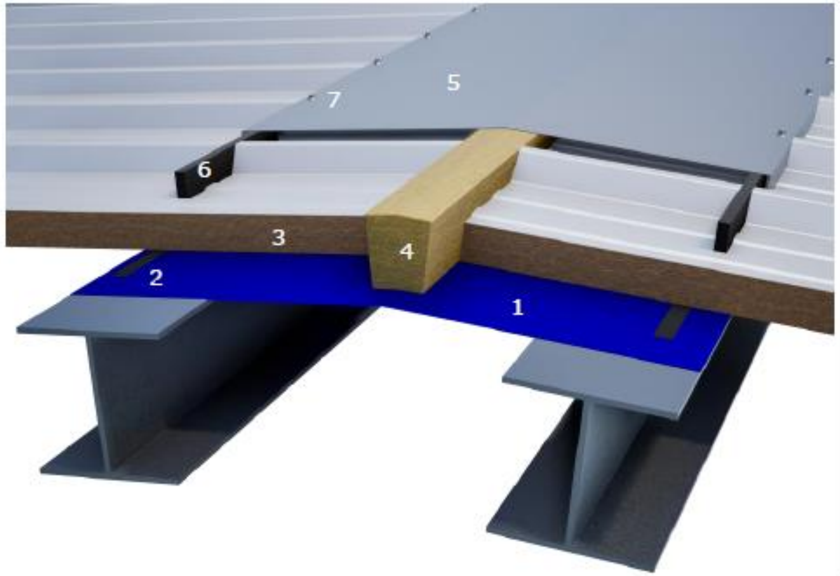
Table 3 design criteria verification for the cladding sandwich panel

Installation guides

- Mounting instructions for cladding and roofing sandwich panels based on wood fibres core
- Recommendations about :
  - Deliveries and storage (handling the panels & storage at the construction site)
  - Cutting and drilling
  - Erection of sandwich panels, including fixing and minimum support conditions
  - Maintenance and reparation
- Highlight: the wood fibre core is sensitive to moisture => attention should be paid into details during installation



(1) Internal corner lining plate
(2) Sealants
(3) Sandwich panels
(4) Fasteners
(5) Additional insulation
(6) External flashings corner with sealants (7)



(1) Ridge lining plate
(2) Sealants on purlins
(3) Sandwich panels
(4) Additional insulation
(5) Roof ridge
(6) Profile closer flashings
(7) Fasteners of the top panels

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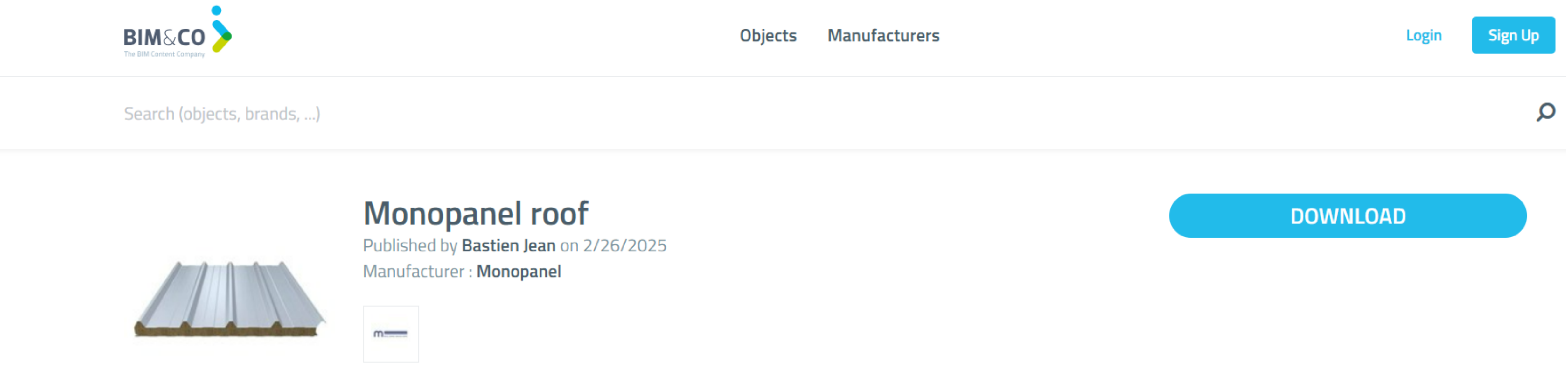
BIM objects: wood fibres sandwich panels

- Elaboration of 2 generic BIM objects to facilitate the integration of these new systems in the design of future buildings

- Available on:

https://incseb.eu/resources/

https://www.bimandco.com/en/bim-objects



BIM object: cladding wood fibre sandwich panel

- DOP of the cladding WF sandwich panels

MONOWOOD B - wood fibers sandwich panel for cladding

Panel thickness	50, 60, 80, 100, 120, 150, 200, 240, 300 mm	**Fire reaction**	B,s_1-d_0
Steel sheets	Outer steel face thickness (F1) : 0.63 mm Inner steel face thickness (F2) : 0.50 mm	**Fire resistance**	External wall EI 30 Partition EI 45
Insulated core	Wood fibers	**Facade test fire propagation**	Positive conclusion with the interposition of a mineral wool panel
Standards length	Up to 12 m	**Smouldering**	Sensitive
Geometry of the steel sheets	Outer steel face type of geometry : flat, Ribbed, Micro ribbed, Macro ribbed Inner steel face type of geometry : flat, Ribbed	**Water permeability**	Class A 1200 Pa
Coatings	Organic coatings protection applied to steel sheet metal Wide range of colour finishes – see MONOPANEL colour chart	**Air permeability**	$1.1 \leq n \ p \leq 1.5 \ c=0$ $1.3 \leq n \ s \leq 1.7 \ c=0$
Fastening	Cross-through fasteners	**Acoustic**	Rw(C ;Ctr) = 29(-1 ;-3) dB
Mechanical span	6m – 14.97 kN	**Fungi test**	Sensitive
Diaphragm effect	Maximum 4.8 kN @ 150 mm	**Durability**	DUR 2 test pass Pass the 2 years demonstrator
Seismic	Displacement of 150 mm Acceleration 2.25 m/s^2 6m maximum span	**Environmental impact indicator**	Panel 200 mm: 23,9 kg CO2 equiv/UF Panel 150 mm: 22,6 kg CO2 equiv/UF
Thermal conductivity	0.06 W/mK	**Wood fiber sourcing**	PEFC label
Thermal Up	0.38 W/m^2K for 150 mm thick 0.29 W/m^2K for 200 mm thick		

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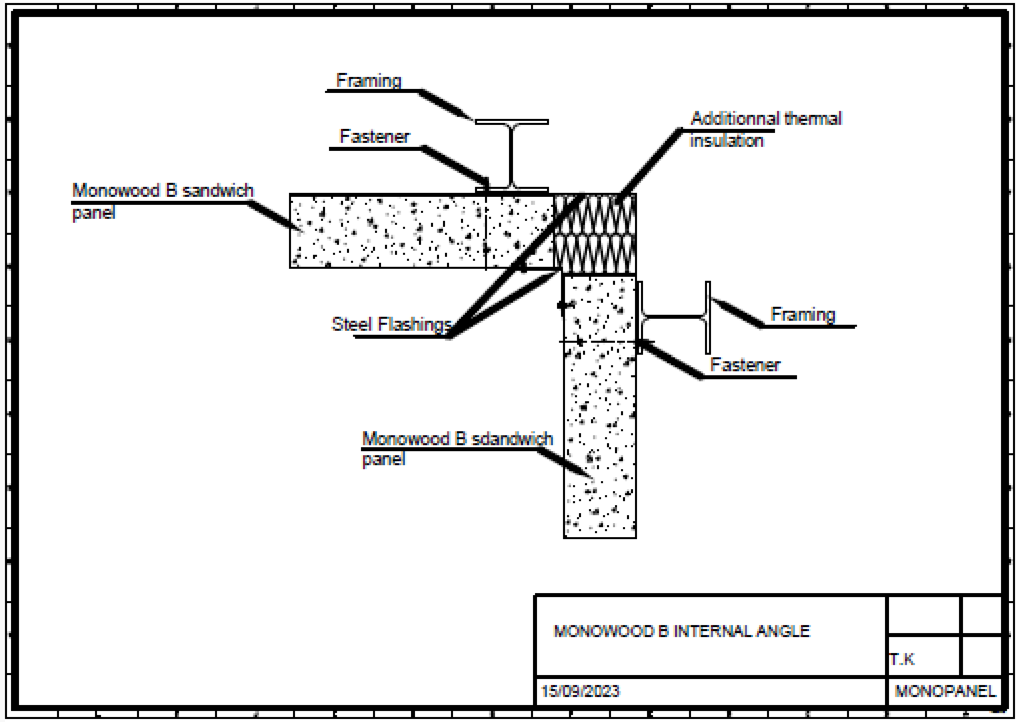
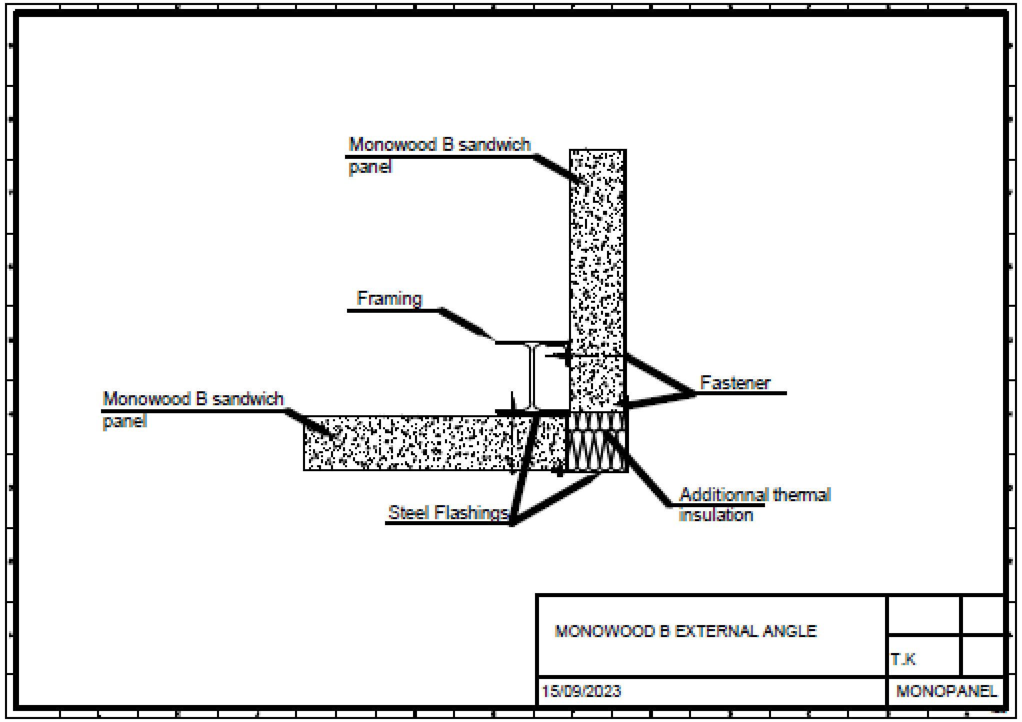
BIM object: cladding wood fibre sandwich panel

- Technical 2D details in dwg format of junctions

MONOWOOD B - wood fibers sandwich panel for cladding





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BIM object: roofing wood fibre sandwich panel

- DOP of the roofing WF sandwich panels

MONOWOOD T - wood fibers sandwich panel for roofing

Panel thickness	50, 60, 80, 100, 120, 150, 200, 240 mm	**Fire reaction**	B,s_1-d_0
Steel sheets	Outer steel face thickness (F1) : 0.63 mm Inner steel face thickness (F2) : 0.50 mm	**Fire resistance**	REI30 with a loading of 25 kg/m^2
Insulated core	Wood fibers	**Facade test fire propagation**	not relevant
Standards length	Up to 15 m	**External fire roof performance**	Tendency Broof t1
Geometry of the steel sheets	Outer steel face type of geometry : flat, Ribbed, Micro ribbed, Macro ribbed Inner steel face type of geometry : flat, Ribbed	**Smouldering**	Sensitive
Coatings	Organic coatings protection applied to steel sheet metal Wide range of colour finishes – see MONOPANEL colour chart	**Water permeability**	Class A 1200 Pa
Fastening	Cross-through fasteners	**Air permeability**	n = 1.4 c = 0 (positive pressure) n = 1.2 c = 0 (negative pressure)
Mechanical span	6m – 19.29 kN	**Acoustic**	Rw(C ;Ctr) = 30(-1 ;-3)
Diaphragm effect	Maximum 8.2 kN @ 150 mm	**Fungi test**	Sensitive
Seismic	Displacement of 150 mm Acceleration 1.85 m/s^2 6m maximum span	**Durability**	DUR 2 test pass – Pass the 2 years demonstrator
Thermal conductivity	0.06 W/mK	**Environmental impact indicator**	Panel 200 mm: 25,9 kg CO2 equiv/UF Panel 150 mm: 24,6kg CO2 equiv/UF
Thermal Up	0.35 W/m^{2}K for 150 mm thick 0.28 W/m^{2}K for 200 mm thick	**Wood fiber sourcing**	PEFC label

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BIM object: roofing wood fibre sandwich panel

- Technical 2D details in dwg format of junctions

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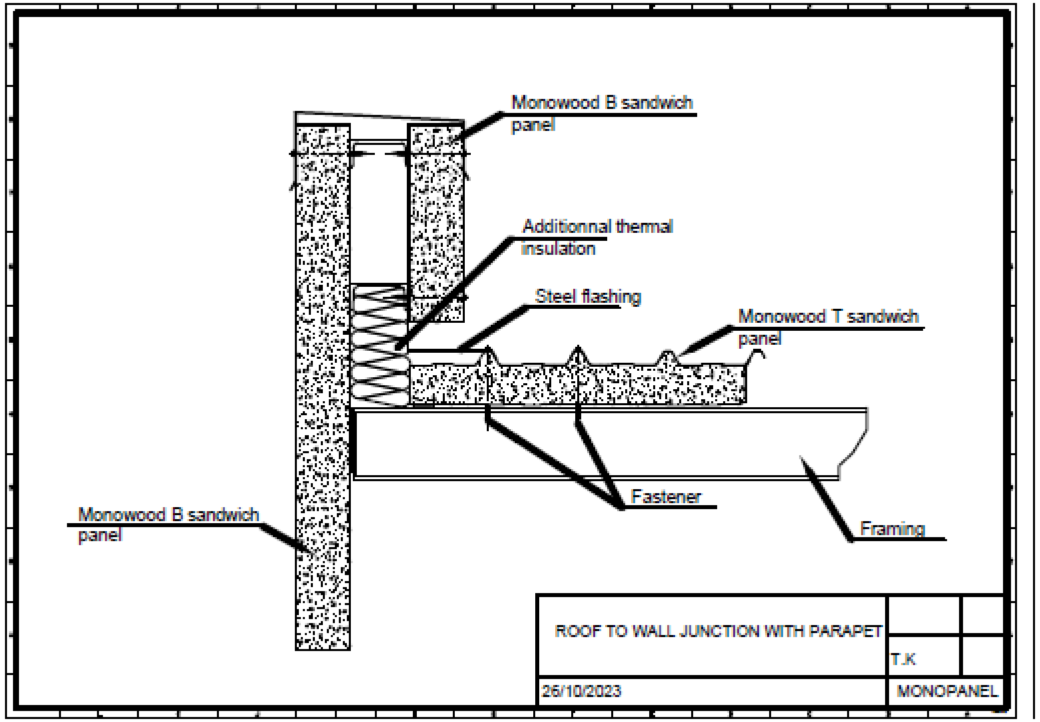

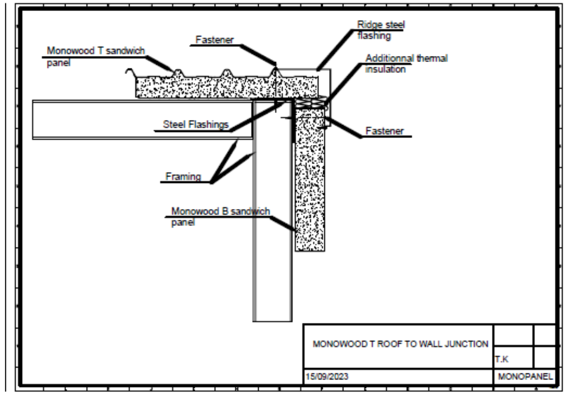

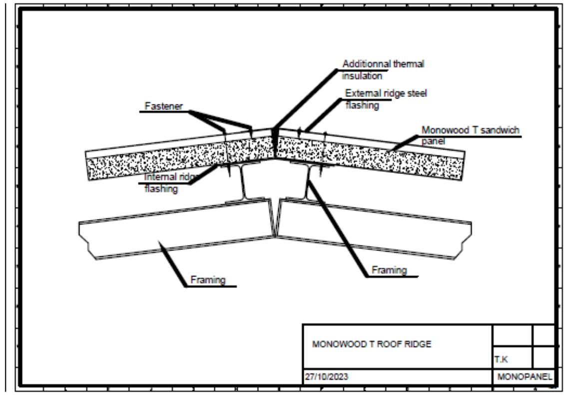

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Any questions ?

Thank you for your attention,

Valerie.huet@monopanel.com

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Site-assembled systems using WF insulation

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LOW CARBON STEEL ENVELOPE SYSTEMS

Tools, guides and data for designing, mounting and implementing

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JORISIDE
THE STEEL FUTURE

Topics

01 Design Guides

Generalities

- All design methods given in a dedicated deliverable of the project
- Preliminary consideration are formulated: field of application and technological provisions,
- Referential for basics technological requirement and material properties are provided
- Referential is mainly European with national standards/regulations when relevant
- Detailed design examples are given too in this deliverable for each site-assembled solution
- Environmental design not covered by the “design method” deliverable because object of a dedicated working package

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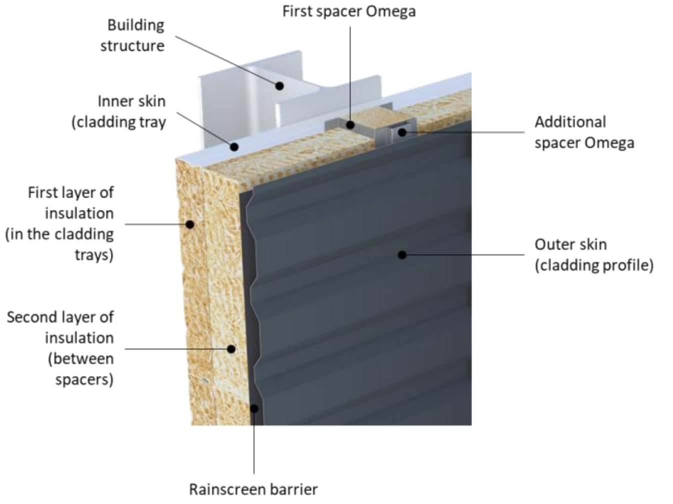
Double skin cladding with WF insulation (1/2)

Strength design (mechanic)



State of the art

- Steel elements are CE marked (EN 14782+EN 508-1). Strength is acc. §4.3.2 of EN 508-1
- EU examples of design of steel elements can be found in ECCS documents
- FR design of steel elements are given by "Règles RAGE"
- PROFEEL report = a "kick off" for biobased insulation

Main results coming from INCSEB project:

The comparison between WP2 tests results and double skin cladding with mineral wool insulation shows that both are similar ➡determination of the strength of steel element isn't reconsidered

Scope: for steel elements compliant to EN 14782 and Wood Fibre compliant to EN 13171

Field of application: steel elements with geometrical properties given by EN 1993-1-3

Main steps:

- Design resistance obtained by test of calculation acc. EN 1990 and EN 1993-1-3
- Effect of actions is determined according relevant parts of EN 1991 mainly EN 1991-1-1 and EN 1991-1-4

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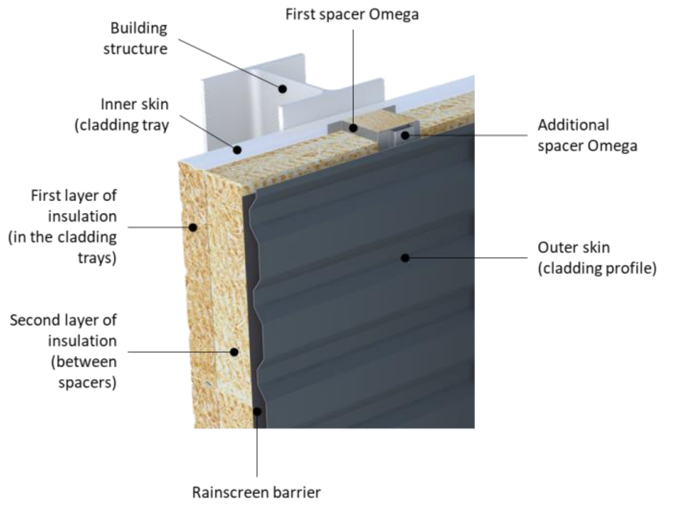
Double skin cladding with WF insulation (2/2)

Other designs (physical, etc.)



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Fire reaction design: Based on SBI tests following annex C of EN 14782 + classification according §5.2.3 of EN 14782

Fire resistance design: Based on tests following EN 1364-1 completed by a classification report according EN 13501-1

Fire reaction of façade design: Fire reaction + intermediate scale tests according ISO 13785

Seismic design: see member states regulations

Thermal design: according ISO 6946, EN ISO 10211, EN ISO 13788, EN 12114 and member states regulations

Acoustic design: EN ISO 10140-1, -2, -4 and -5, EN ISO 717-1

Durability design: steel elements according EN 10169 and EN 10346. WF insulation according EN 12865

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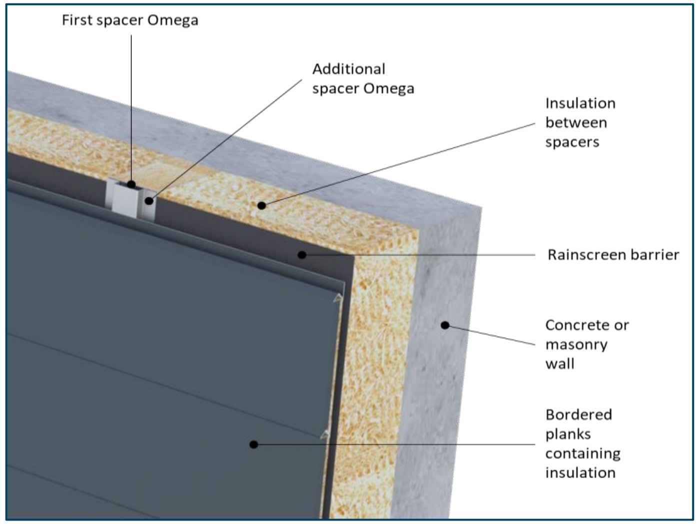
Façade cladding with WF insulation (1/2)

Strength design (mechanic)



State of the art

- No normative documents
- Steel elements are CE marked (EN 14782)
- Various answers are provided at European country level – FR example: CSTB technical book 3747_V2
- French specific attestation relevant to CSTB technical book 3747_V2
- Deliverable 3.1 of GRISPE PLUS project

Main results coming from INCSEB project:

Both Experimental characterizations with vacuum chamber tests and linear loading tests showed the **added value provided by the WF insulation who annihilates the dislocation failure mode of the bordered planks**.

Design based on linear loading tests, performed acc. EN 1993-1-3, is relevant.

Scope: for steel elements compliant to EN 14782 and Wood Fibre compliant to EN 13171

Field of application: steel elements with nominal thick. Between 0,75- and 1,00-mm. Height of bordered plank between 25 and 40 mm.

Main steps:

- Design resistance obtained by test of calculation acc. EN 1990 and EN 1993-1-3
- Effect of actions is determined according relevant parts of EN 1991 mainly EN 1991-1-1 and EN 1991-1-4

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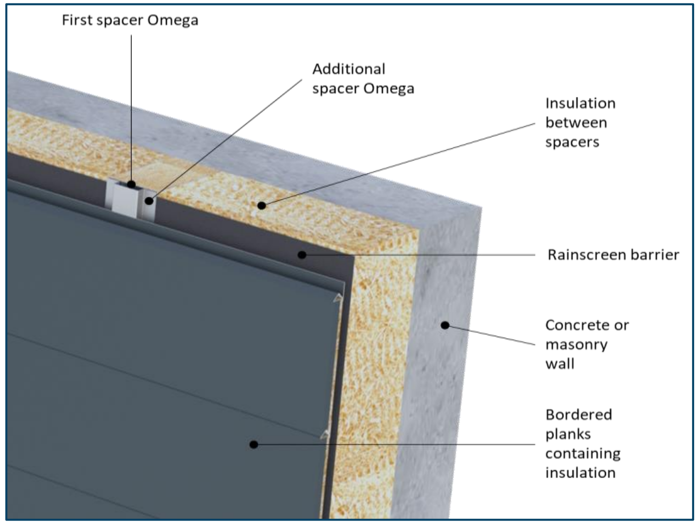
Façade cladding with WF insulation (2/2)

Other designs (physical, etc.)



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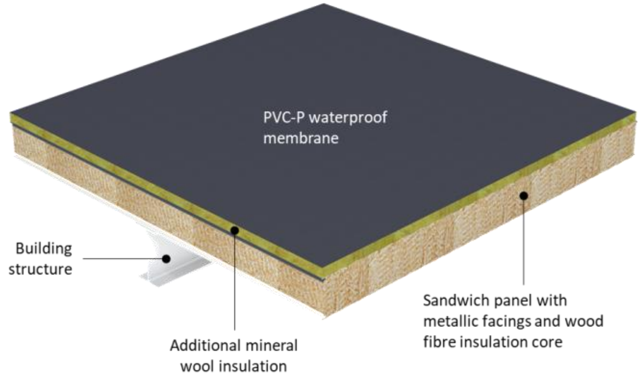
Flat roofing WF insulation core sandwich panel + add. insulation + waterproof membrane(1/2)

Strength design (mechanic)



State of the art

- Various research studies on sandwich panel with WF insulation core but not with steel facings
- PU and mineral wool insulation core sandwich panels with steel facings are covered by EN 14509
- EN 14509 provide design information but not covers WF insulation
- Loading of sandwich panels: ECCS Nb 401
- Design of fixings of sandwich panels: ECCS Nb 127/CIB320 and ECCS Nb 142

Main results coming from INCSEB project:

Determination of the strength given by EN 14509 with tests acc. to Annex A, can be applied with a key point of attention about the interpretation of repeated loads test, paragraph A.9.2.4 (of EN 14509)

DUR2 test acceptance criteria should be adapted to the case of WF core

Technological provisions needed for limiting smouldering effect

Scope: WF sandwich panel can be marked following principles of EN 14509

Field of application: 200 mm WF (110 kg/m^3) sandwich panels with:

- Slightly profiled facings
- Outer face thick. ≥ 0,55 mm / inner face thick. ≥ 0,50 mm

Design procedure: the complete design is performed according Annex E of EN 14509)

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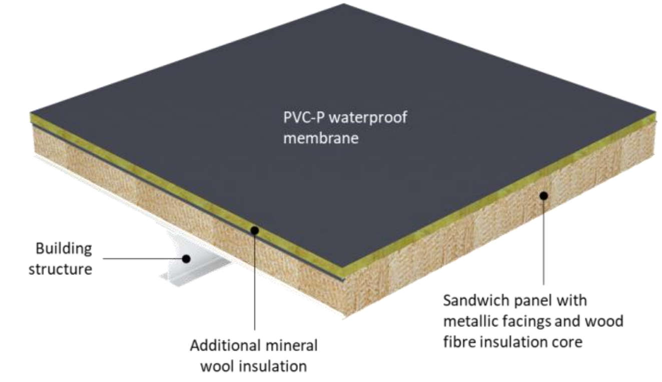
Flat roofing WF insulation core sandwich panel + add. insulation + waterproof membrane(2/2)

Other designs (physical, etc.)



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- Loading of sandwich panels: ECCS Nb 401
- Design of fixings of sandwich panels: ECCS Nb 127/CIB320 and ECCS Nb 142

Fire reaction design: requirements formulated by §5.2.4.1 of EN 14509 based on tests defined by Annex C of EN 14509.

Fire resistance design: information of §5.2.4.2 of EN 14509 considering flat roofing application

External fire behaviour for roofing application: according §5.2.4.3 of EN 14509

Seismic design: see member states regulations

Thermal design: according ISO 6946, EN ISO 10211, EN ISO 13788, EN 12114 and member states regulations

Acoustic design: EN ISO 10140-1, -2, -4 and -5, EN ISO 717-1

Durability design: following procedure B.2 of EN 14509

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Mounting instructions

Generalities

All mounting instructions are given in a dedicated deliverable of the project containing for each site – assembled solutions:

- Information on reference document(s) to consider,
- Preliminaries about design; technical specifications for materials and fixings, conditions for installation and permissible tolerances

- Provisions for handling and storage
- Provisions for cutting, drilling and fixing
- Provisions for maintenance, repairs and reuse

- Illustrated mounting sequence
- 3D perspectives of specific details

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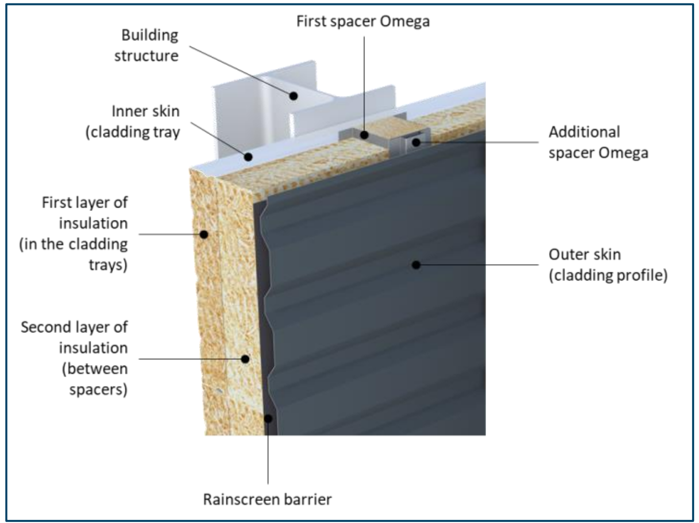
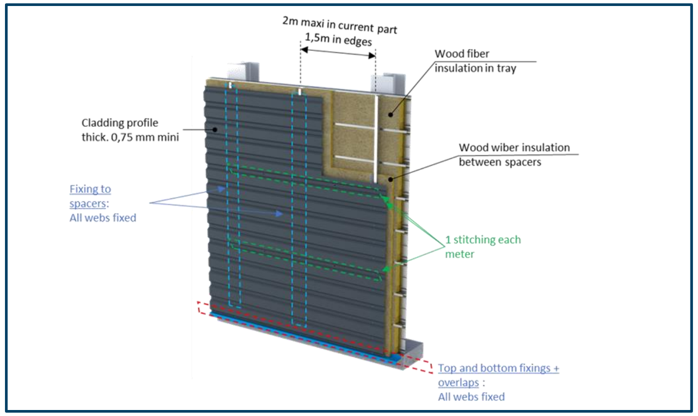
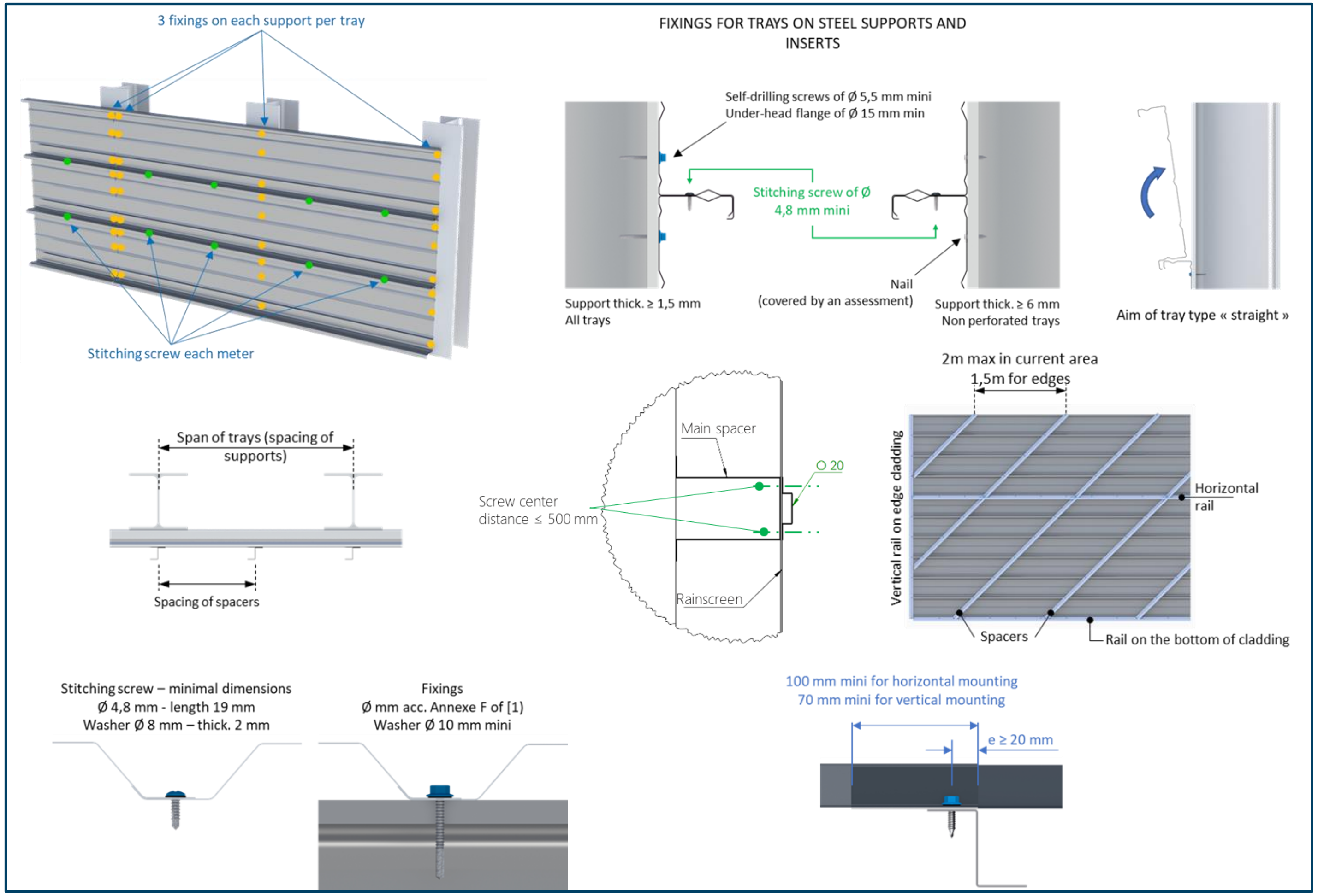
Double skin cladding with WF insulation

Some extracts from the deliverable







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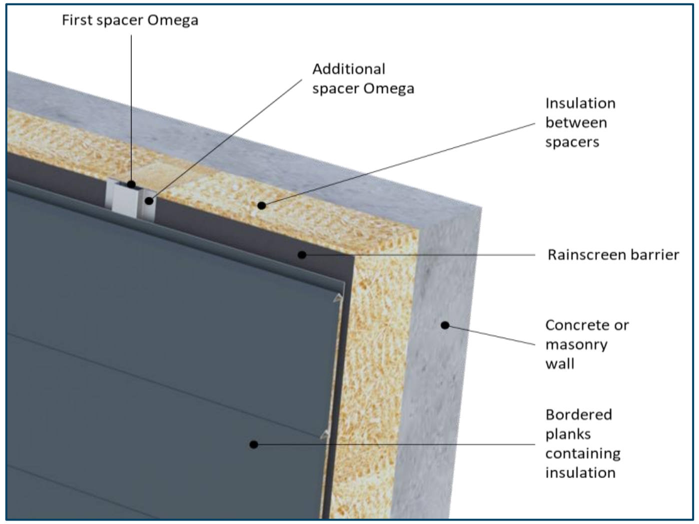
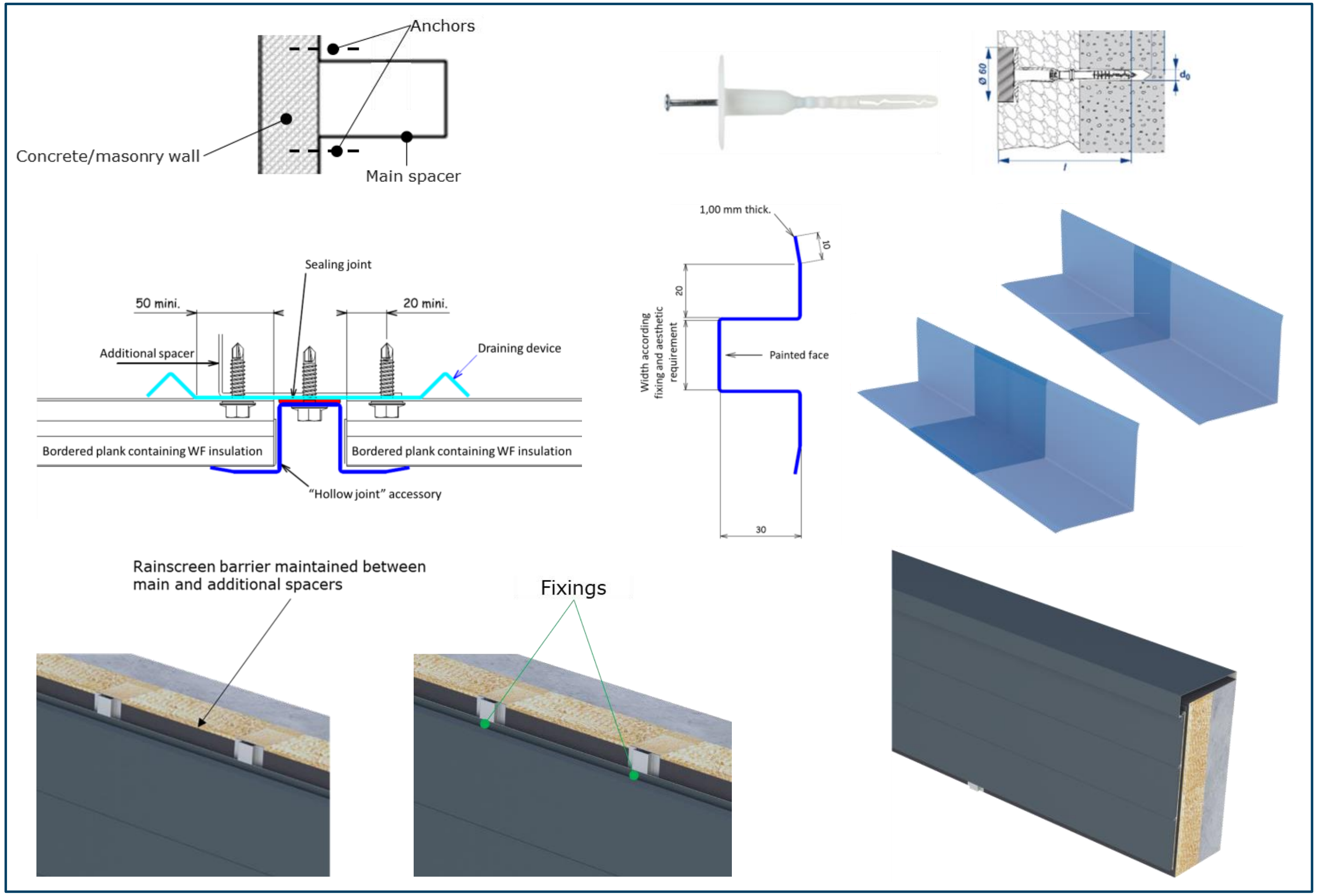
Façade cladding with WF insulation

Some extracts from the deliverable





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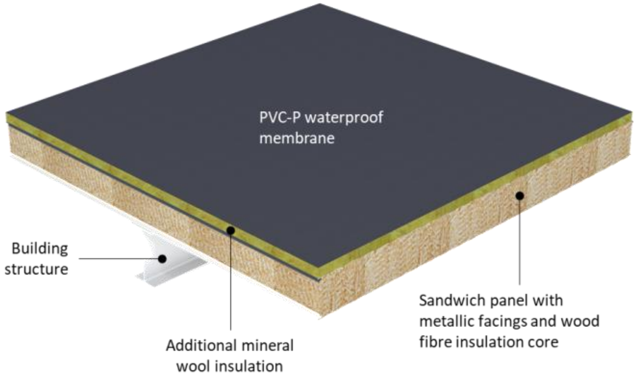
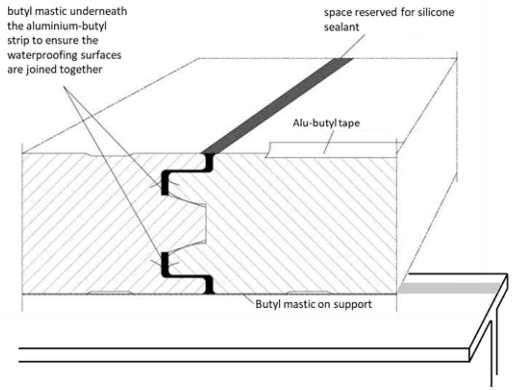
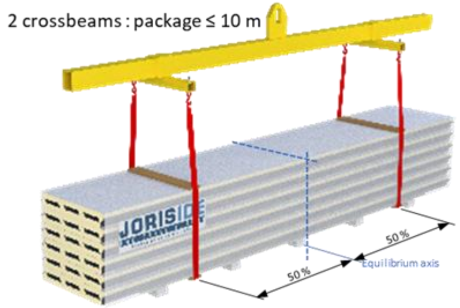
Flat roofing WF insulation core sandwich panel + add. insulation + waterproof membrane

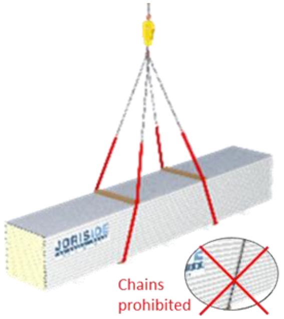
Some extracts from the deliverable

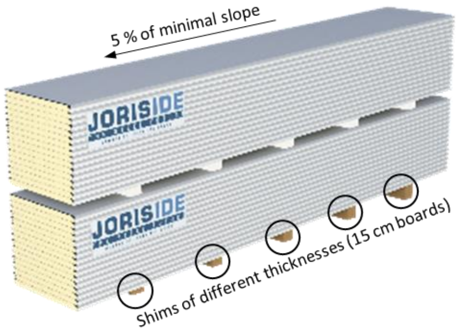


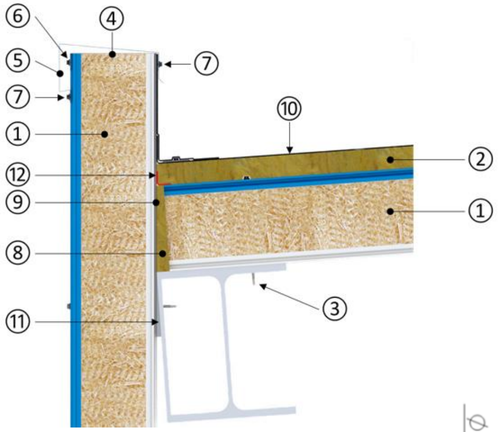


Characteristics of the room inside the building		lower side of the panel	upper side of the panel
Premises with air ventilation and uncontrolled humidity.	Low and medium humidity	-	Butyl mastic
	High humidity	Butyl mastic	Butyl mastic
Premises with fixed and regulated temperature and humidity.	Less than 5 mmHg	-	Butyl mastic
	Between 5 and 10 mmHg	Butyl mastic	Butyl mastic
	Between 10 and 15 mmHg.	Butyl mastic	Butyl mastic

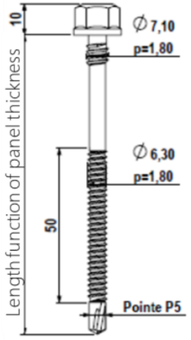


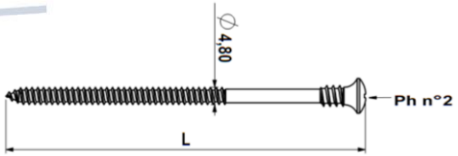






1-Sandwich panels
2-Additional rock wool insulation of 50 mm thick.
3-Self-drilling screw of Ø5,5 mm with washer of 22 mm minimal diameter
4-U profile in steel 30-x-30 mm
5- Sloping watertight parapet cover
6-Self-drilling screw Ø4,8 mm x 16 mm
7-Self-drilling screw Ø4,8 mm x 16 mm with washer
8-Rock wool insulation or injected PU mounted on site
9-Eventual thermal break
10-PVC waterproof membrane
11-Metallic piece
12-Aluminu-butyl tape





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BIM Objects

Generalities

- BIM objects for site-assembled solutions: REVIT
- Each BIM object contains 2D sketches for most common details
- Each BIM object contains a table summarizing all performances obtains during project
- All BIM objects are downloadable from:
  - Dedicated web site of the project www.incseb.eu
  - The website of Joris Ide Group https://www.joriside.com/fr-fr/telechargements
  - BIM platform: https://www.bimobject.com/

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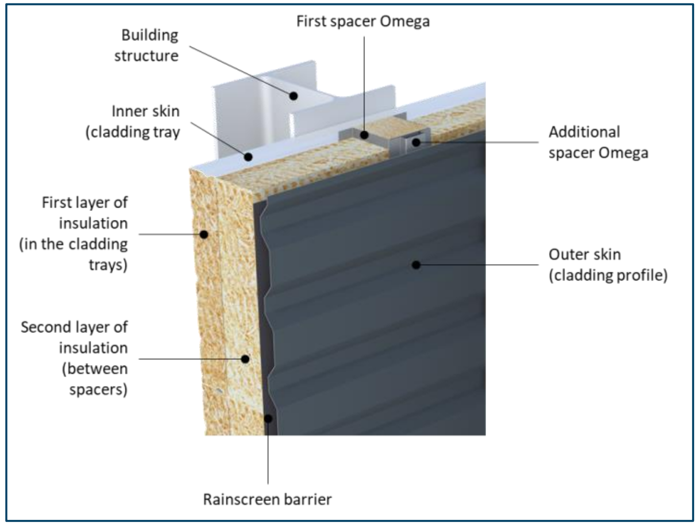
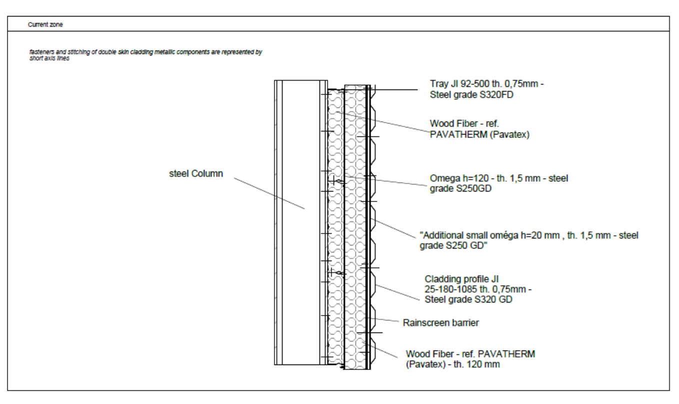
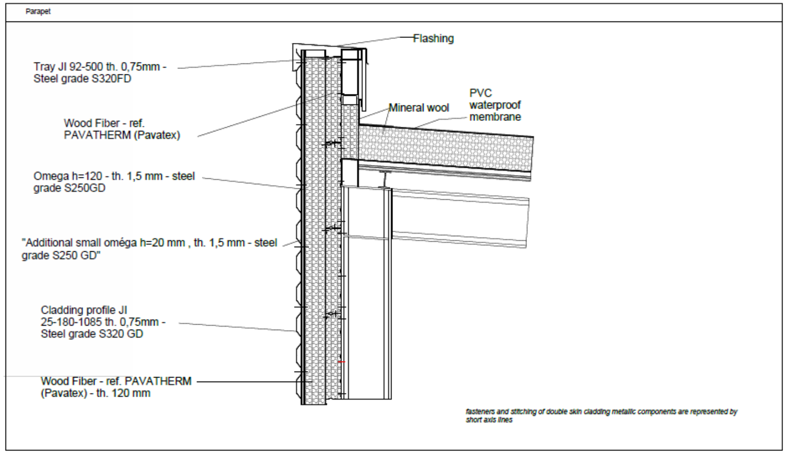
Incseb LOW CARBON STEEL ENVELOPE SYSTEMS

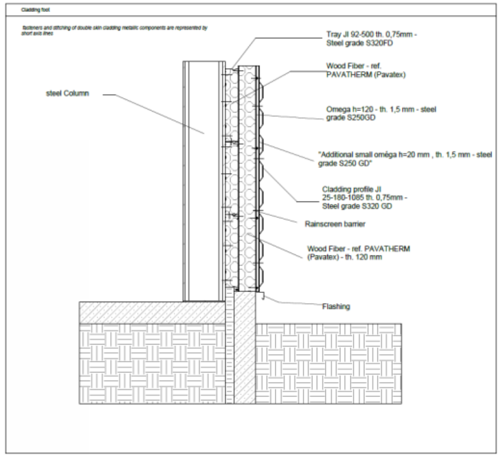
Double skin cladding with WF insulation

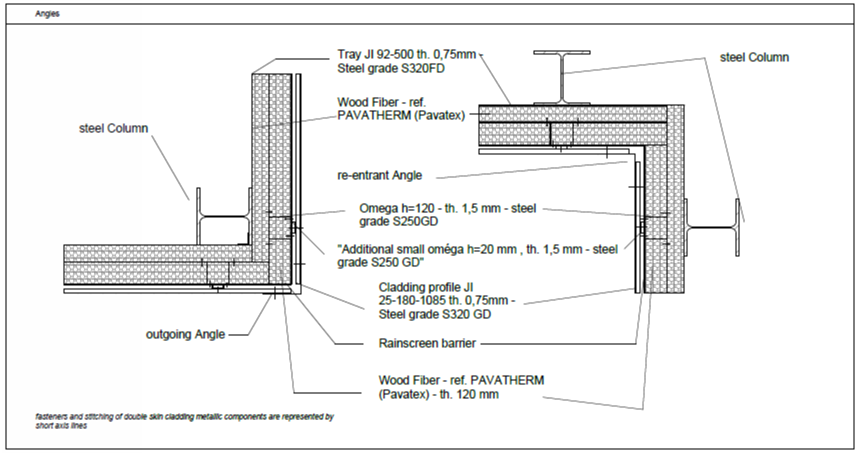
BIM Object











Topic	Referential	Performance
Mechanical span	EN 1993-1-3:2006 EAD 090062-00-0404	2m
Diaphragm 3m x3m	-	Not relevant depend of wall
Seismic	-	-
Thermal (Up)	EN ISO 6946:2017	>0.25 W/m².K with wall
Themal choc	-	Not relevant
Reaction to fire	EN 13823 EN 14782 EN 13501-1	Not tested
Resistance to fire	EN 1364-1 EN 1363-1 EN 13501-2	Not tested depend on wall
Facade test propagation	ISO 13785-1	Not pass Necessity to have mineral wool strip to the x meters
External fire roof performance	EN 13501-5 CEN/TS 1187	Not relevant
Smouldering		Yes
Water permeability	EN 12865:2002	Mounted in double skin configuration : Class A 1200 Pa
Air permeability	EN 12114:2000	Mounted in double skin configuration: Pressure: n=0.6 and c=1.0 Suction: n=0.7 and c=0.6
Acoustic	ISO 10140	>30 db (effect of wall)
Fungi test		Sensible
Durability	-	Not relevant Pass demonstrator 2 years
Core environmental impact indicator - Climate change - total (module D included)	EN 15804+A2	36,3 kg CO2 equiv/UF (mounted in façade cladding configuration)
Wood fiber sourcing	PEFC	Yes

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Tables of performances

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Incseb LOW CARBON STEEL ENVELOPE SYSTEMS

Performances of the 3 site-assembled solutions

Performances	Double skin system
Mechanical span validated	6m
Diaphragm 3m x3m	29.8 kN / 150mm
Seismic	Rigidity of the system tested greater than the rigidity of the test bench. Test stopped
Thermal (Up)	0.24 W/m².K with profile 0.30 W/m².K with cassettes
Thermal choc	Not relevant
Reaction to fire	Bs2d0
Resistance to fire	External wall: E90 EI30 (io) Partition: E90 EI45
Facade test propagation	Not pass Necessity to have mineral wool strip to the x meters
External fire roof performance	Not relevant
Smouldering	Yes
Water permeability	Class A 1200 Pa
Air permeability	n p 0.8 c = 0.3
Acoustic	Rw(C,Ctr) 49 (-2 ;-9) dB
Fungi test	Sensitive
Durability	Not relevant Pass demonstrator 2 years
Climate change- total A-D (kg CO2 equiv/UF)	36,3
Wood fiber sourcing	PEFC label

Performances	Facade cladding
Mechanical span validated	2m
Diaphragm 3m x3m	Not relevant. Depends on the wall that supports the plank elements
Seismic	Not tested
Thermal (Up)	>0.25 W/m².K with wall
Thermal choc	Not relevant
Reaction to fire	Not tested
Resistance to fire	Not tested Depends on the wall that supports the plank elements
Facade test propagation	Not tested
External fire roof performance	Not relevant
Smouldering	Yes
Water permeability	Pass Depends on the wall that supports the plank elements
Air permeability	Pass Depends on the wall that supports the plank elements
Acoustic	>30 db (effect of wall)
Fungi test	Sensitive
Durability	Not relevant Pass Demonstrator 2 years
Climate change- total A-D (kg CO2 equiv/UF)	32,0
Wood fiber sourcing	PEFC label

Performances	Flat roofing sandwich panel (200mm)
Mechanical span validated	3m
Diaphragm 3m x3m	10 KN / 150mm
Seismic	Pass
Thermal (Up)	0.15 W/m². K
Thermal choc	Pass for use in facade
Reaction to fire	Bs1d0
Resistance to fire	No pass in the case of roof (80kg/m²) EI 60 cladding
Facade test propagation	Not relevant
External fire roof performance	Broof t1 with insulation and membrane
Smouldering	Yes
Water permeability	Class A 1200 Pa
Air permeability	Results for panel: N p 0.8 c 0.2 N s 0.9 c 0.1 Results for panel+insulation+membrane: N p 2.1 c 0 N s 2.0 c 0
Acoustic	Rw(C,Ctr) 33(-1 ;-4) dB
Fungi test	Sensitive
Durability	Pass Dur2 EN 14509 Pass demonstrator 2 years
Climate change- total A-D (kg CO2 equiv/UF)	43,3
Wood fiber sourcing	PEFC label

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THE STEEL FUTURE

Thank you for your attention

Conclusion
Synthesis of the performances of the INCSEB solutions

David Izabel

12 June 2025

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Mechanical

SUMMARY OF THE PERFORMANCES OF THE FIVE INNOVATIVE SYSTEMS					
	Cladding sandwich panel (150mm)	**Pitch roofing sandwich panel (150mm)**	**Double skin system**	**Facade cladding**	**Flat roofing sandwich panel (200mm)**
Mechanical span validated	6m 14.97 kN	6m 19.29 kN	6m	2m	3m
Diaphragm 3m x3m	4.8 kN/150mm	8.2 kN / 150mm	29.8 kN / 150mm	n/a	10 KN / 150mm
Seismic	Pass	Pass	Test stopped (System too rigid)	Test pending	Pass

Competitive with the other types of panels and double skin systems

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Fire

SUMMARY OF THE PERFORMANCES OF THE FIVE INNOVATIVE SYSTEMS

	Cladding sandwich panel (150mm)	Pitch roofing sandwich panel (150mm)	Double skin system	Facade cladding	Flat roofing sandwich panel (200mm)
Reaction to fire	Bs1d0	Bs1d0	Bs2d0	Not tested	Bs1d0
Resistance to fire	External wall: EI 30 (i→o) Partition: EI 45	REI 30 25kg/m²	External wall: E90 EI30 (i→o) Partition wall: E90 EI45	Not tested depend on type of wall	No pass in the case of roof (80kg/m²) EI 60 cladding
Facade test propagation (with specific test protocol)	Pass	n/a	Not pass (performance dependent on design strategy: implementation and evaluation needed)	Not pass (performance dependent on design strategy: implementation and evaluation needed)	n/a
External fire roof performance	n/a	Tendency Brooft1	n/a	n/a	Broof t1 with insulation and membrane
Smouldering	Yes	yes	Yes	Yes	Yes

Competitive with the other types of panels and double skin systems

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Building Physics

Summary of the performances of the five innovative systems

	Cladding sandwich panel (150mm)	Pitch roofing sandwich panel (150mm)	Double skin system	Facade cladding	Flat roofing sandwich panel (200mm)
Thermal (Up)	0.38 W/m². K (150mm) 0.29 W/m². K (200mm)	0.35 W/m². K (150mm) 0.28 W/m². K (200mm)	0.24 W/m². K with profile. 0.30 W/m². K with cassettes.	>0.25 W/m². K with wall	0.15 W/m². K
Thermal choc	Pass	Not tested	n/a	n/a	Pass for use in facade
Water permeability	Class A 1200 Pa	Class A 1200 Pa	Class A 1200 Pa	Pass Depend on wall	Class A 1200 Pa
Air permeability	$1.1 \le n\,p \le 1.5$ c=0 $1.3 \le n\,s \le 1.7$ c =0	n p 1.4 c = 0 n s 1.2 c = 0	n p 0.8 c = 0.3	Pass Depend on wall	Results for panel: N p 0.8 c 0.2 N s 0.9 c 0.1 Results for panel+insulation+membrane: N p 2.1 c 0 N s 2.0 c 0
Acoustic	$R_{w(C,Ctr)}$ 29 (-1 ;-3) dB	$R_{w(C,Ctr)}$ 30 (-1 ;-3) dB	$R_{w(C,Ctr)}$ 49 (-2 ;-9) dB	>30 db (effect of wall)	$R_{w(C,Ctr)}$ 33(-1 ;-4) dB
Fungi test	Sensitive	Sensitive	Sensitive	Sensitive	Sensitive
Durability	Pass Dur2 EN 14509	Pass Dur2 EN 14509	n/a	n/a	Pass Dur2 EN 14509
	Pass demonstrator 2 years	Pass demonstrator 2 years	Pass demonstrator 2 years	Pass demonstrator 2 years	Pass demonstrator 2 years

Competitive with the other types of panels and double skin systems

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Sustainability

SUMMARY OF THE PERFORMANCES OF THE FIVE INNOVATIVE SYSTEMS					
	Cladding sandwich panel	Pitch roofing sandwich panel	Double skin system	Facade cladding	Flat roofing sandwich panel (200mm)
Climate change-total A-D (kg CO2 equiv/UF)	Panel 200 mm 23,9 Panel 150 mm 22,6	Panel 200 mm 25,9 Panel 150 mm 24,6	36,3	32,0	43,3
Wood fiber sourcing	PEFC label	PEFC label	PEFC label	PEFC label	PEFC label

Competitive with the other types of panels and double skin systems

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The future…

- Industrial production
  - Optimisation of the wood fiber orientation (thermal/mechanic) and density,
- Carry out work sites to have a feed back experience
- Introduction of wood fiber as insulation in the product standards EN 14509 and EN 14782 (normative reference, specific test of durability, fungic tests)
- Introduction of the wood fiber technics into the good practice rules (protection during erection , protection of the bottom of the construction wall and extremity in roof),
- Introduction of specific dispositions of fire engineery (mineral wool barrier all the xx m to be discussed with firemen) and extended applications rules in 15254-5 and 15254-7

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