



MEZeroE

Measuring Envelope products
and systems contributing to next
generation of healthy nearly
Zero Energy buildings

**D3.7: Summary on
experimental campaign on
MEZeroE nZEB Enabler
Envelope Solutions**

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Executive summary

Technological innovation in the construction sector is considerably difficult to implement due to several factors such as the fragmentation and complexity of this sector. Many disciplines are involved at various stages, design and production are usually separated, there is a large number of players with a vast majority of small-medium enterprises (SME), and supply chains are long and variegated. As a result, gathering the different specialists together is difficult, and many potentially effective innovative solutions do not even reach the market.

H2020 MEZeroE project aims at tackling this complex issue by creating an EU distributed open innovation ecosystem for (i) developing nearly Zero Energy Building (nZEB) Enabler Envelope technology solutions; (ii) transferring knowledge; (iii) matching testing needs with existing facilities; (iv) providing monitoring in living labs; and (v) standardizing cutting-edge solutions coming from SMEs and larger industries, to foster inclusive change in the building sector, being accessible via a single-entry point to all users.

MEZeroE ecosystem will be accessed via a single-entry point web-based multi-side virtual marketplace which will include 9 Pilot Measurement & Verification Lines (PM&VL), 3 Open Innovation Services (OIS), and resources for training, business model development, systematic intellectual property (IP) and knowledge management. MEzeroE will fast-track prototypes to the market as fully characterized products.

PM&VLs are test-chains focused on a specific envelope performance of technology to support the development and performance characterization of envelope products by means of experimental measurements and modelling. These have already been defined, as well as the assessment methods that will be carried out in each of them and offered in the virtual marketplace. To validate this procedure, tests have been carried out with the products of the industrial partners participating in MEZeroE project.

This document is the summary of this validation procedure for the set-up of the 9 PM&VLs. One summary sheet has been prepared to give an overview of the test-chain defined by each PM&VL together with the related industrial partner. Main output and conclusions of these experiments are shown.

We hope that this report will be of particular interest to anyone working in the nearly Zero Energy Building (nZEB) Enabler Envelope technology solutions sector, in general, and working in the process of development and validation of these solutions, in particular.

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LIST OF ACRONYMS

BIPV	Building Integrated Photovoltaics
CPR	Construction Product Regulation
EAD	European Assessment Document
IEQ	Indoor Environmental Quality
LL	Living Laboratory
M&V	Measurement and Verification
nEES	nZEB Enabler Envelope Solution
nZEB	Nearly Zero Energy Building
OIS	Open Innovation Service
PM&VL	Pilot Measurement and Verification Line
PV	Photovoltaic
PV/T	Photovoltaic / Thermal
TRL	Technology Readiness Levels

1 Introduction

1.1 MEZeroE project

The aim of H2020 MEZeroE project is to develop an European distributed open innovation ecosystem for: (i) developing **nearly Zero Energy Buildings (nZEB) Enabler Envelope technology solutions**; (ii) transferring knowledge between different partners; (iii) matching testing needs with existing facilities; (iv) providing monitoring in living labs; and (v) standardizing cutting-edge solutions coming from small and medium enterprises (SMEs) and larger industries, to foster inclusive change in the building sector, being accessible via a single-entry point to all users.

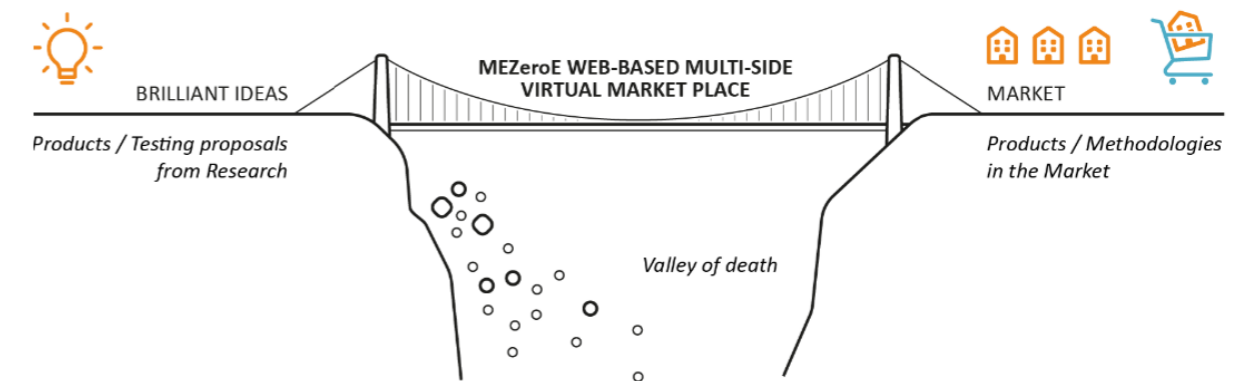


Figure 1: Test bed function illustration¹

The challenge to overcome is the open upscaling of products from lab validation to higher Technology Readiness Levels (TRLs) and successful market entry. Such upscaling allows to reduce the technological risks and to increase investments' attractiveness, by creating general recommendations and providing a "Premium Service Package", driven by marketability, cost-effectiveness and flexibility.

The MEZeroE ecosystem will create a single-entry point web-based multi-side marketplace. It is structured into **Pilot Measurement and Verification Lines (PM&VL)** and **Open Innovation Services (OIS)**, so that the project will offer for building envelope products performance characterization and support in the innovation workflow. PM&VL is defined as a test-chain focused on a specific envelope performance or technology to support the development and performance characterization of envelope products by means of experimental measurements and modelling, while OIS are combination of tools and methods to address a specific transversal topic.

In addition, MEZeroE ecosystem will enable the testing of innovative products in monitored real buildings or **Living Labs (LL)**, providing product developers with real data about the performance of their products. Different type of Living Labs will be available inside MEZeroE, from fully controlled test bed facilities to real buildings as living labs.




In order to define more precisely what services should be included in the single-entry point marketplace, the first step done during MEZeroE project was to collect the market needs. Once better known these needs, the nine Pilot Measurement and Verification Lines (PM&VL) and the three Open Innovation Services have been defined:

¹ MEZeroE Consortium, 2020. Grant Agreement number: 953157 -MEZeroE —H2020-NMBP-TO-IND-2018-2020/H2020-NMBP-TO-IND-2020-twostage

9 Pilot Measurement and Verification Lines (PM&VL) and the responsible project partners:

	PM&VL1 TECNALIA	Advanced Building Integrated Photovoltaic (BIPV) and hybrid Photovoltaic/Thermal (PV/T) systems characterisation facing Efficiency and Safety requirements: Test-chain for a comprehensive advanced BIPV and hybrid PV/T systems characterisation
	PM&VL2 EURAC	Building envelope/Indoor Environment Quality (IEQ) interaction facing Health requirements: Test-chain for a thorough energy demand, indoor occupants' comfort and behaviour analysis and performance characterization
	PM&VL3 LEITAT	Active energy component characterization facing Efficiency requirement: Test-chain for a comprehensive stability characterization of active envelope components for energy production
	PM&VL4 LEITAT	Visual and thermal performance analysis of dynamic glass systems facing Efficiency requirement: Test-chain for testing of innovative dynamic glazing solutions and the definition of new measurements and validation protocols for the assessment of visual and thermal comfort
	PM&VL5 DTU	Building/user interaction characterization facing Efficiency requirement: Test-chain for building/user characterization for the optimization of the mutual behavioural control and interaction through IoT and AI solutions based on building envelope and users' needs and corrections
	PM&VL6 POLIMI	Multi-layers dry nZEB Enabler Envelope Solution (nEES) characterization facing Healthy and Safety requirement: Test-chain for the comprehensive characterisation of building envelope components on: thermal, acoustic and air resistance, coupled with accessibility in use and optimization of the structural performances of the nEES on life cycle focusing on mechanical behaviour when exposed to accidental actions (e.g. wind) and/or extreme conditions (e.g. fire).
	PM&VL7 CUT	Mechanical resistance and stability characterization of connections/joints between component materials and supporting structures facing Safety requirement: Test-chain for durability characterisation of block-walls
	PM&VL8 UIBK	Solar gain control in semi-transparent envelope component, facing Healthy requirement: Test-chain for thermal-optical characterisation of advanced façade system
	PM&VL9 ZAG	Wooden prefab components assessment line facing Safety requirement: Test-chain for fire safety, hygrothermal, and acoustic characterisation of wooden-based prefab façade systems

3 Open Innovation Services (OIS) and the responsible project partners:

	OIS1 ZAG, ITEC, EURAC, TECNALIA	Standard framework procedures for certification and marking: Roadmap for product certification and marking applied to a set of products (provided by industrial partners) and general framework to support the creation of new roadmaps for specific products outside of the consortium.
	OIS2 EURAC, ARBNCO, greenTEG, NUVAP, DTU, POLIMI	Cost-effective Measurement and Verification (M&V) smart kit for living labs: Protocol M&V in living labs to verify and characterise the performance of building envelope products.
	OIS3 INCURVO, EURAC, R2M, POLIMI, TECNALIA	Guidance for open innovation life cycle management: Set of digital services accessible from a unique point of access (Digital Platform), where users can obtain Guidance for support performance-based innovation process by using a common language and standard reference for performance characterisation, while assuring sustainability and feasibility of the product development

Furthermore, other services will be offered, such as training, business model development, systematic IP and knowledge management.

1.2 Aim of the work

As stated above, the single-entry-point virtual marketplace being developed in MEZeroE has been structured into Pilot Measurement and Verification Lines (PM&VL) and Open Innovation Services (OIS). Regarding the PM&VLs, these have been defined to accelerate the route-to-market for innovative building envelope products, which are not-standard or are already on the market without any standardised assessment methods. The 9 PM&VL will characterise these innovative envelope products, considering requirements of the EU regulation about construction products in force as well as of other European and international certification schemes, providing SMEs and larger industries upscale their products from lab validation to higher Technology Readiness Levels (TRL) and go to market, towards the achievement of building performance targets of nZEB and high IEQ.

This report summarizes the work carried out to validate the assessment methods defined in each PM&VL. To achieve this, products developed by the industrial partners from the consortium of the MEZeroE project have been employed. This deliverable is a summary of the design of experiments carried out for each of them, as well as the testing or assessment procedures and the outcome of these procedures.

1.3 Document description

In the following section the relation of products tested by each PM&VL is presented, and then the individual factsheets prepared to disseminate the work carried out are included.

2 Relation of products tested by each Pilot Measurement and Verification Line

In this section the matrix between PM&VLs and the related tested product from the industrial partners are shown.

		FOCCHI	FLEXBRICK	HELIA TEK	HELIA TEK	TECNAN	TECNAN	FLEX&ROBUST	RIKO HISE	RIKO HISE	ROTHOBLAAS	ROTHOBLAAS	ROTHOBLAAS	INDRESMAT	INDRESMAT	PELLINI
		Multifunctional Façade System	Integrated PV in an external skin façade system	Heliasol	Heliapfilm	Durable Advanced Functional Coatings for self-cleaning and air-purification	Advanced Nanomaterials for Energy Efficient Glazing Systems	Flexible structural connectors	Sustainable prefab wooden all-in-one envelope components	Sustainable prefab wooden external cladding components	Tailored roof/facade smart membranes	Tailored roof/facade sealing tapes	Tailored roof/facade fastening system	(bio)Polyurethane insulation foams	Foamed (bio)polyurethane frames	
PM&VL1	Tecnalia		X	X	X											
PM&VL2	Eurac	X				X	X	X			X		X			X
PM&VL3	LEITAT		X	X	X											
PM&VL4	LEITAT															
PM&VL5	DTU	X				X										X
PM&VL6	POLIMI		X				X	X			X	X		X	X	
PM&VL7	CUT		X					X			X	X		X	X	
PM&VL8	UIBK						X							X	X	
PM&VL9	ZAG							X		X						

Validation with external party: Chromogenics

In the following pages, one sheet per each pair of PM&VL and tested product can be found, in order of number of PM&VL.

ASSESSMENT OF AN EXTERNAL SKIN FAÇADE PHOTOVOLTAIC INTEGRATED CONSTRUCTION SYSTEM

FLEXBRICK

Product: Flexbrick with integrated photovoltaics

Tejido Flexbrick® is an industrialized system for flexible ceramic sheets for the construction of cladding and laminated structures. These ceramic textiles open up an endless range of possibilities for dry-assembly cladding systems in architecture.

Flexbrick, in its commitment to the environment, is working on the integration of the photovoltaics in the ceramic sheets.



TR House in Barcelona (Spain).
PMMT Architecture, 2015.

Pilot Measurement & Verification Line 1

Managed by: **TECNALIA Research & Innovation**



PM&VL1

PM&VL1 has set-up a dedicated test chain for a comprehensive Building Integrated Photovoltaic (PV), Solar Thermal (T) and hybrid Photovoltaic/Thermal (PV/T) façade systems characterization, facing both Efficiency and Safety requirements. This PM&VL is managed by TECNALIA, the leading private and independent research and technology organization in Spain, with the goal of transforming knowledge into GDP.



Results

Main results/outcomes of each test/assessment procedure are shown below:

1. Optical tests:

1.1. Normal hemispherical reflectance results

Light reflectance (%)	Solar direct reflectance(%)
4.3	8.0

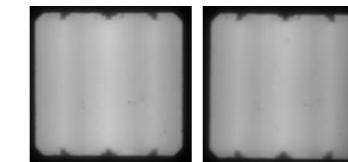
2. Static wind test: The module withstood a static load stress of 2,400 Pa. Another additional test was performed to check electrical performance of PV modules. It was concluded that they did not suffer any anomaly, as voltage was measured at similar values before, during and after the test.

3. Impact test results: Impact use category III was obtained.

4. Reaction to fire: B-s1,d0 classification was obtained.

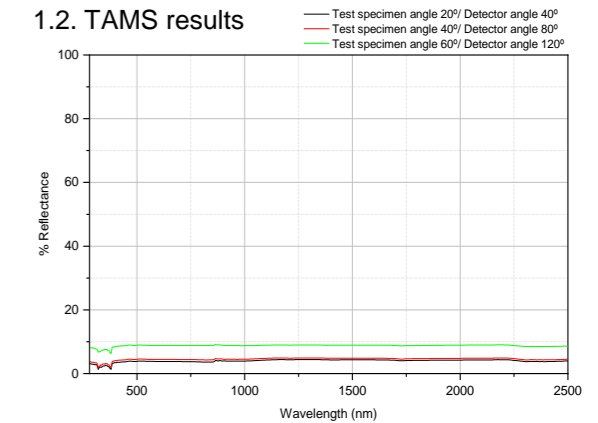
5. Mechanical stresses and environmental actions test sequence

- The samples showed no degradation in terms of short-circuit current after all tests. The modules passed all the insulation tests too. Variations in fill-factor and maximum power were observed due to degradation of the connection to the solar simulator (probably avoided by use of standard connectors upon installation).
- The Flexbrick samples withstood the dynamic wind test with no incidence. Besides, the modules were able to withstand hail impacts of up to 2J.



EL before (left) and after (right) the full sequence, with no change

1.2. TAMS results

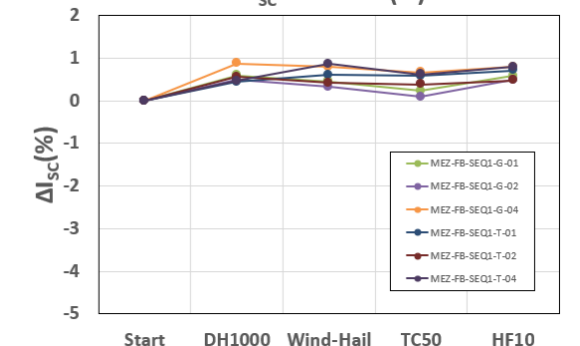


Spectral reflectance at different test specimen angles and detector angles reference



SBI test

I_{sc} variation (%)



I_{sc} variation during mechanical stresses and environmental actions test sequence

Which is the need covered by this service?

These innovative products are usually out of standardized assessment methods and that is why, to offer manufacturers evidences about the safety, liability and robustness of their systems within the building envelope market, new assessment methods have been developed. The design of experiments is based on new assessment methods, intended to cover the following specific needs:

- Optical measurements are typically done at 90°. To know which is the optimal orientation of a BIPV product, it is proposed to do this measurement at any incident angle.
- As part of a façade, BIPV products face stressors that could compromise the safety of the system. The dynamic wind test, impact test and reaction to fire experiment assess the reliability of the products against different stressors.
- During their life cycle BIPV modules must endure environmental actions without major decrease in energy output. The combined test sequence evaluates the power output of the products after various degradation processes.

Design of Experiments

- Optical tests (280-2500 nm normal hemispherical reflectance and directional reflectance for different angles for incidence of radiation and sample)
- Static Wind test according to EAD 090062-01-0404
- Impact test according to EAD 090062-01-0404
- Reaction to fire (according to EN 13823 –SBI- and EN ISO 11925 -ignitability)
- Mechanical stresses and environmental actions ageing sequence (new sequence based on IEC 63092:2020, IEC 61215 and IEC TS 63209-1)



Set-up for dynamic wind load test as part of ageing sequence

Conclusions

Tejido Flexbrick BIPV modules have endured all performed tests, exhibiting resistance to fire, wind, impacts, and a combination of environmental and mechanical stresses.

Regarding the performed assessment methods:

- The new tests provide significant information about the endurance of the BIPV products against different stressors.
- A new mechanical and environmental actions sequence has been tested showing the reliability of the product against a demanding combination of stresses.



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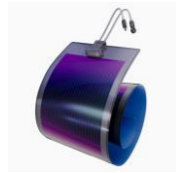
OPTICAL AND ENERGY PERFORMANCE MEASUREMENTS FOR A PHOTOVOLTAIC MODULE FOR BUILDING ENVELOPES

HELIA TEK

Product: HeliaSol®

As the technology leader in organic photovoltaics, Heliatek develops, produces and distributes industrial-grade organic PV solar solutions for virtually any building surface (horizontal, vertical, curved, rigid, and flexible). Heliatek stands for energy

solutions designed for various traditional and never been possible before applications based on its unique features – it is ultra-light, flexible, ultra-thin and truly green.



HeliaSol®

Pilot Measurement & Verification Line 1

Managed by: TECNALIA Research & Innovation



PM&VL1

PM&VL1 has set-up a dedicated test chain for a comprehensive Building Integrated Photovoltaic (PV), Solar Thermal (T) and hybrid Photovoltaic/Thermal (PV/T) façade

systems characterization, facing both Efficiency and Safety requirements. This PM&VL is managed by TECNALIA, the leading private and independent research and technology organization in Spain, with the goal of transforming knowledge into GDP.



SAFETY



EFFICIENCY

Results

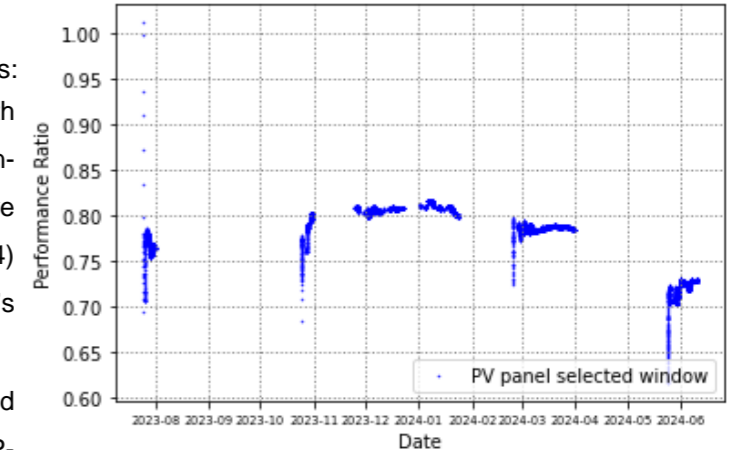
Main results/outcomes of each tests/assessment procedures:

1. Following approximately one year of data collection, with the application of selective filtering to exclude non-representative values and mitigate certain disruptive effects, the Performance Ratio (PR / IEC 61724) indicator has been utilized to assess the system's performance under real-world conditions.

As can be observed, the values range between 0.65 and 0.8, which, according to "Technical Report NREL/TP-5200-57991", are the expected range for this type of component (irradiance sensor* and test panels are in the same orientation and tilt angle (90°)).

2. The determination of the normal-hemispherical reflectance between 280 and 2,500 nm has been done. In this case, only the first sample of each series has been shown. This choice was taken because no significant differences has been detected between

samples of the same series. Directional reflectance for different angles of incidence of radiation and different sample angles have been determined. In this case, only the maximum and minimum angles of each series are shown. This choice was taken to show the maximum and minimum differences. Middle angles are compressed.



Performance ratio of HeliaSol from 2023 July to 2024 June

* Irradiance sensor = Pyranometer. Hence the drop in PR values in May-June, since a pyranometer will capture more irradiance than the PV panel receives in the months when the sun is higher.

Table. Results of the light normal-hemispherical reflectance and the solar direct normal-hemispherical reflectance.

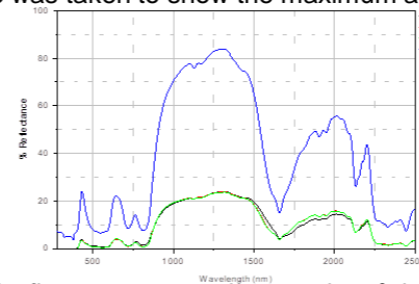
Ref.	Light reflectance (%)	Solar direct reflectance(%)
1.1	8.4	27.6
2.1	9.0	27.9
3.1	7.4	27.2
4.1	7.2	27.1
5.1	10.1	30.4

Which is the need covered by this service?

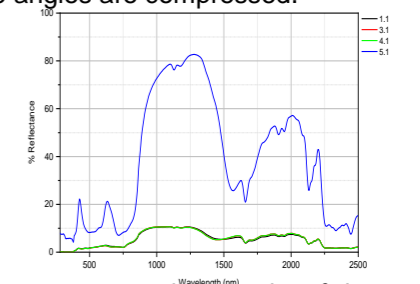
These innovative products are usually out of standardised assessment methods and that is why, to offer manufacturers evidences about the safety, liability and robustness of their systems within the building envelope market, new assessment methods have been developed. In this case the design of experiments is based on two new assessment methods, each of them intended to cover a specific need.

1. There are currently no specific regulations for evaluating façade systems with solar harvesting technology, either from an energy perspective or from the point of view of construction requirements. Test based on new experimental procedure under real weather conditions has been developed to evaluate constructive integration capability, energy production, and simultaneously compare it with certified reference technologies.

2. Optical measurements are typically done at 90°. To know which is the optimal orientation of a BIPV product, it is proposed to do this measurement at any incident angle. Characterizations have been done to know how PV behaves under solar radiation and, also, how energetically they behave.



Spectral reflectance test specimen angle 20° detector angle 40°.



Spectral reflectance test specimen angle 60° detector angle 120°.

Design of Experiments

The following tests have been performed:

- Performance characterization in 'real' conditions – Innovative procedure
- Optical test at different incident angles



Test bench to assess the performance characterization in 'real' conditions

Conclusions

Through the experimental validation in Kubik, the following conclusions have been reached:

- From the energy aspect, the technology has performances within the expected range for this type of technology.
- From a constructive point of view, Heliasol has been well integrated into the façade solution (easy and fast adhesion) and into the building itself (simple assembly).

Regarding optical test, main conclusions are shown below:

- No significant differences had been detected between samples of the same series.
- Series 1,2 3 and 4 are very similar, just number 5 is a little bit different.
- There are differences between angles. In higher angles the reflectance value is lower in all cases.



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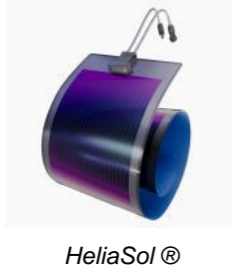


NEW EXTENDED-STRESS SEQUENTIAL TESTING ASSESSMENT OF A BUILDING INTEGRATED PHOTOVOLTAIC CONSTRUCTION SYSTEM

HELIAATEK

Product: Heliapfilm dual-glass

As the technology leader in organic photovoltaics, Heliatek develops, produces and distributes industrial-grade organic PV solar solutions for virtually any building surface (horizontal, vertical, curved, rigid, and flexible). **Heliatek** stands for energy solutions designed for various traditional and never been possible before applications based on its unique features – it is ultralight, flexible, ultra-thin and truly green. As a R&D activity, they hereby propose the integration of **Heliapfilm in a dual-glass laminate**.



Pilot Measurement & Verification Line 1

Managed by: TECNALIA Research & Innovation



PM&VL1

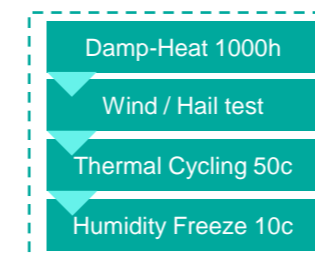
PM&VL1 has set-up a dedicated test chain for a comprehensive Building Integrated Photovoltaic (PV), Solar Thermal (T) and hybrid Photovoltaic/Thermal (PV/T) façade systems characterization, facing both Efficiency and Safety requirements. This **PM&VL is managed by TECNALIA**, the leading private and independent research and technology organization in Spain, with the goal of transforming knowledge into GDP.



Results

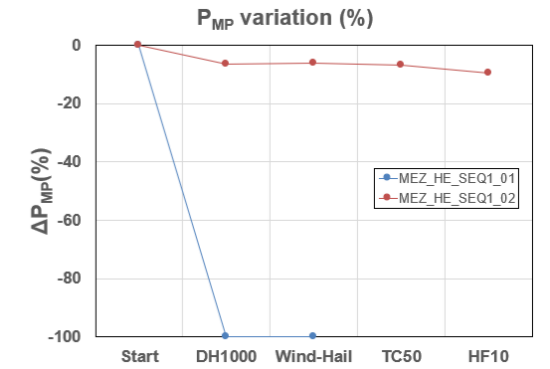
Main results/outcomes of each test sequence procedures are shown below:

1. New mechanical stresses and environmental actions sequence:



The modules withstood the dynamic wind test, and hail impacts up to 20.7 J, without any harm. The biggest perturbation was observed in damp-heat, caused by humidity ingress in the encapsulate (the current updated polymeric barrier of Heliapfilm should solve the problem).

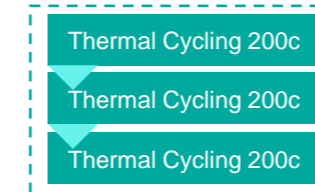
The sample had little degradation in thermal cycling and humidity freeze tests, with a cumulative power loss of 9.6 % through the full sequence. It passed all the insulation tests too.



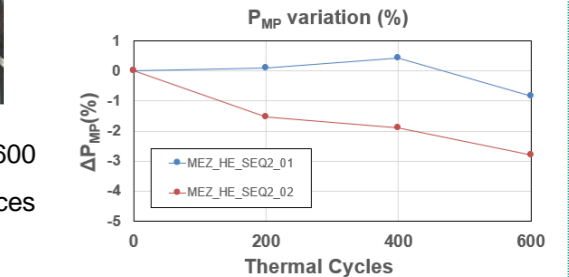
Pmp variation during mechanical stresses and environmental actions test sequence

Set-up of the dynamic wind load test

2. Thermal stresses sequence:

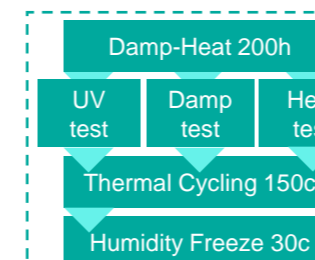


The modules went through the extended 600 thermal cycle sequence with no disturbances and passed all the insulation tests.

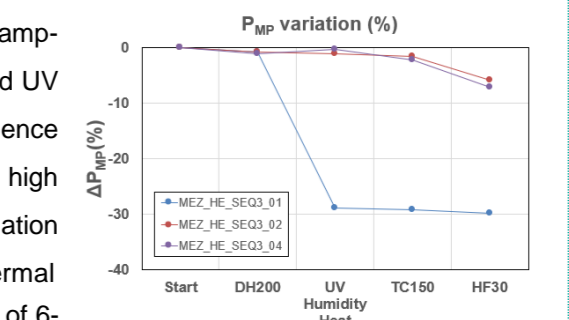


Pmp variation in thermal stresses sequence

3. New UV ageing sequence



The samples went through the 200-hour damp-heat test with no perturbation. The extended UV irradiation was the most exigent subsequence path, whereas the humidity and high temperature tests caused no major degradation of the samples. The power loss in the thermal cycling and humidity freeze test was small, with a cumulative efficiency loss of 6-7 % in the samples of two subsequences.



Pmp variation in UV ageing sequence

Which is the need covered by this service?

Existing qualification test standards such as IEC 61215 standard are not intended or able to demonstrate long term performance in all locations. Thus, new extended-stress sequences have been proposed by IEC TS 63209-1 for common PV, but nothing similar exists for BIPV. Here, **3 new extended-stress sequences** have been developed and applied to **BIPV products** based on the extended-stress sequences for PV and ageing tests for laminated glass (ISO 12543-4):

1. New extended-stress mechanical and environmental actions sequence.
2. Thermal extended-stresses sequence.
3. New extended UV ageing sequence.

The sequences are tough enough to have a 'test to failure' rather than a pass/fail approach. They aim to identify weaknesses rather than replicate field performance.

Design of Experiments

New extended-stress test sequences for BIPV have been performed:

1. New mechanical stresses and environmental actions sequence, based on IEC 63092:2020, IEC 61215 and IEC TS 63209-1, including: damp-heat, hail impact and dynamic wind, thermal cycling and humidity freeze tests.
2. Thermal stresses sequence (IEC TS 63209-1) with intermediate characterizations.
3. New UV ageing sequence, based on IEC TS 63209-1 and ISO 12543-4, including extended UV, humidity and high temperature test, as well as damp-heat, thermal cycling and humidity freeze test.



Test assembly for hail impact test

Conclusions

The experimental Heliapfilm dual-glass product have endured very hard test sequences. It passed the extended thermal cycling sequence with no major degradation, and most individual tests with minor power losses. The module shows more susceptibility to hard UV and extended damp-heat exposure. The latter will be tackled by the new polymeric layer of the product. Regarding the new performed assessment sequences, they provide significant information about the endurance of the BIPV products against demanding combinations of various stresses representative for integration in building façades.



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FOCCHI

Product: Multifunctional active façade

FOCCHI designs, produces and installs complex façade systems for high-quality buildings. The tested solution is an innovative multifunctional façade system integrating IoT, heat pumps, automatic blinds and windows to ensure indoor comfort and energy efficiency.



Focchi's Multifunctional façade

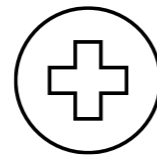
Pilot Measurement & Verification Line 2

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PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The Façade System Interactions Lab aims to assess the interaction between the elements that make up a building and the indoor environmental quality and comfort conditions.



HEALTH



INTERACTION

Which is the need covered by this service?

This node of PM&VL2 covers the testing and development of a multifunctional façade designed for achieving Nearly Zero Energy Building (nZEB) ensuring multi-comfort (thermal, visual, and acoustic comfort) with good indoor air quality (IAQ). The prefabricated façade integrates heating/cooling systems, ventilation, automated controls, and sensors for optimal performance. Testing procedure involves thermal characterization and assessing integrated component performance in controlled as well as semi-controlled conditions.

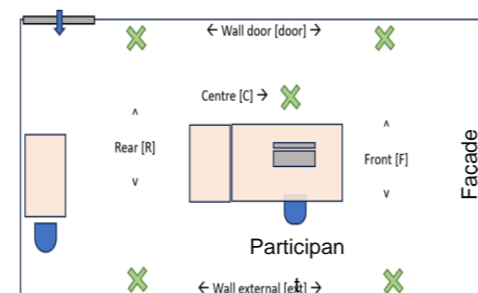
FSIL allows to test the façade in realistic operating conditions, by verifying the quality of the indoor environment as affected by façade systems, while using different system configurations. The laboratory allows the study, on a real scale, of the influence of these systems on perceived and measured comfort.

Design of Experiments

The experiment involved assessing the façade in summer conditions within an office setting. The primary goal was to examine how the façade influences the quality of the indoor environment. The participants could engage with the façade web application, as it autonomously establishes the indoor conditions.

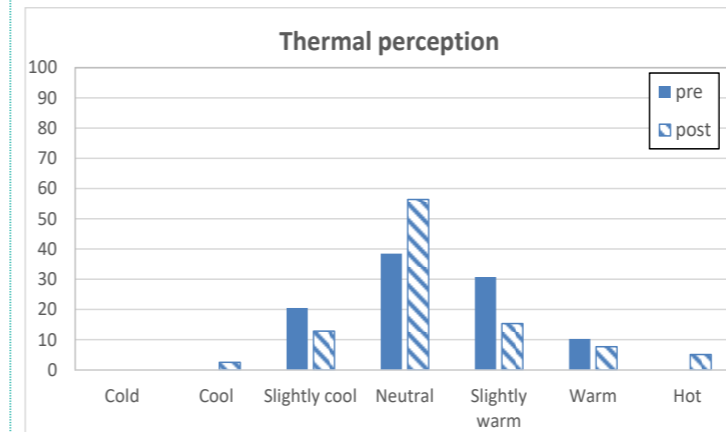
Indoor monitoring – air temperature, relative humidity, CO2, air speed, globe temperature, surface temperatures.

Subjective feedback – 39 participants were recruited, and questionnaires were administered for: perception, preference and acceptability of the different domains of IEQ (thermal, air quality, ventilation, lighting, acoustic, and global perception), completed twice at the beginning and end of the test.

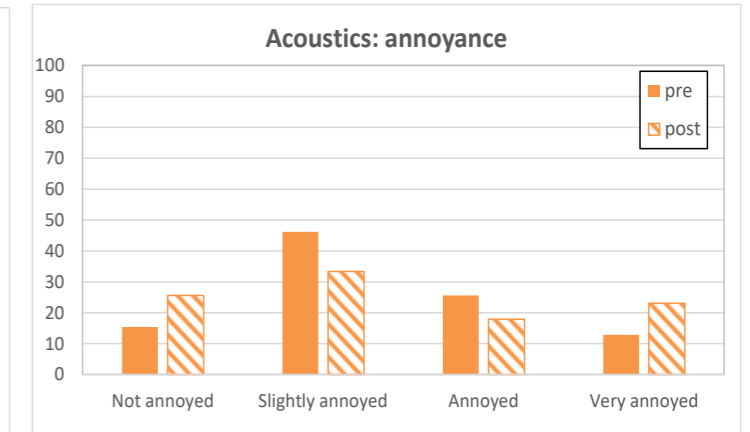


Results

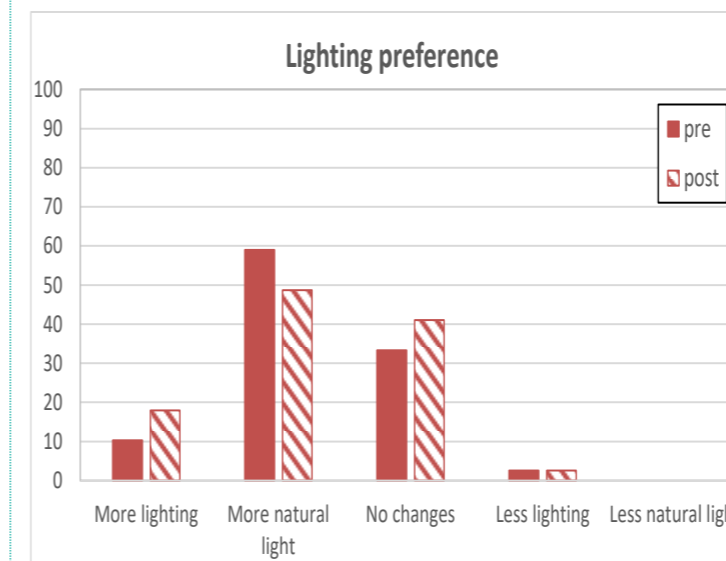
Results from the questionnaires administered by the participants:



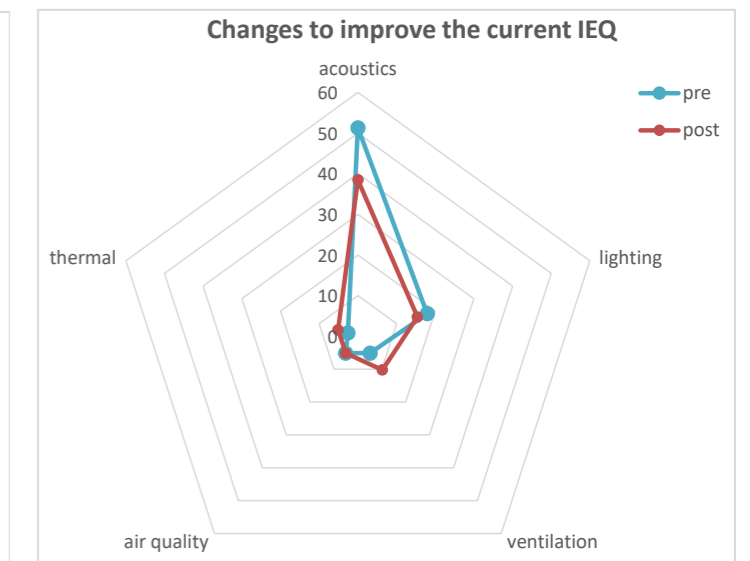
As compared to the beginning of the test, after interacting with the façade, participants judging their thermal state as close to thermal neutrality increased by 18 percentage points.



The participants reported to be "slightly annoyed" by the acoustic environment, indicated their preference for a "quieter" or even "much quieter" acoustic environment.



The preference judgement indicated that the frequency of "More natural lighting" was higher than the other categories, even though a slight decrease was observed at the end of the experiment, after the participants had the possibility to interact with the façade by giving a judgment on the illuminance of the room.



When asked what changes should be done to improve the indoor environment, the participants indicated clearly the necessity to improve the acoustic environment (i.e., reduce the noise emitted by the ventilation system) and the lighting (i.e., increase the amount of natural lighting from the windows).

Conclusions

The experiment assessed the summer performance of the façade system in an office setup, focusing on its influence on indoor environmental quality. Using a web application, participants engaged with the façade's automatic regulation of the indoor environment.

In addition to objective data, feedback from 39 participants on thermal comfort, air quality, ventilation, lighting, acoustics, and overall perception was collected through questionnaires administered at the beginning and end of the test. The findings offer insights for future improvements and optimizations of the façade's functionality.



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FOCCHI

Product: Flexible structural connectors

FOCCHI designs, produces and installs complex façade systems for high-quality buildings.

The tested solution is an innovative multifunctional façade system integrating IoT, heat pumps, automatic blinds and windows to ensure indoor comfort and energy efficiency.



Multifunctional façade

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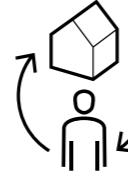
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PM&VL2



EFFICIENCY



INTERACTION

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The Multifunctional Façade Lab (MFL) node verifies the thermal and energy performances of envelope systems such as doors and windows, opaque walls and façade modules under both stationary and dynamic conditions.

Which is the need covered by this service?

This node of PM&VL2 covers the testing and development of a multifunctional façade designed for achieving Nearly Zero Energy Building (nZEB) balance and ensuring multi-comfort (thermal, visual, and acoustic comfort) with Indoor Air Quality (IAQ). The prefabricated façade integrates heating/cooling systems, ventilation, automated controls, and sensors for optimal performance. The goal is to offer an energy-efficient building envelope applicable to both new and existing structures. Testing procedure involves thermal characterization and assessing integrated component performance in controlled environments.

Design of Experiments

Experiments included testing the sample under summer and winter design conditions to evaluate possible critical temperatures to be reached by façade and its integrated components, as well as testing the proper functioning of the integrated heat-pump.



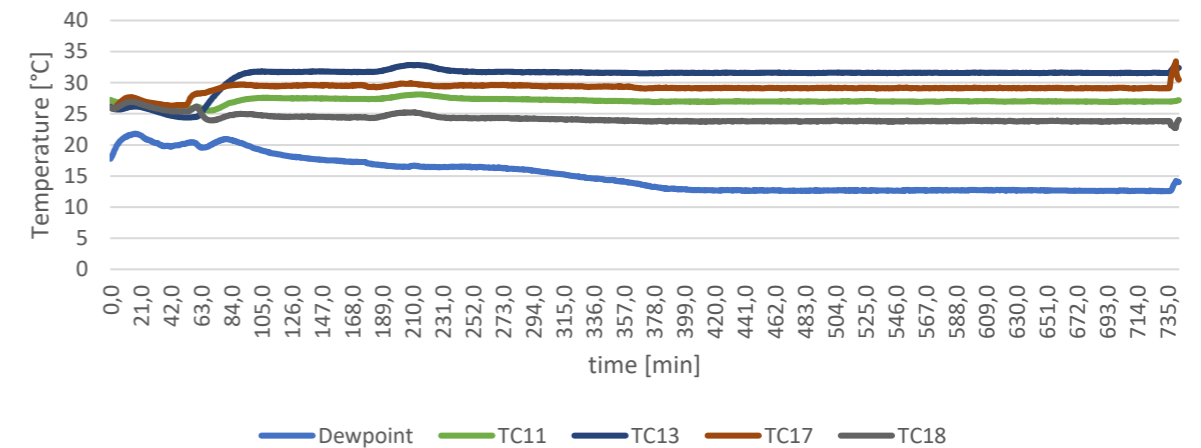
MFL, one of the nodes of PM&VL2

Results

Results of the testing procedures are reported in the table below:

Test	T in	T out	Solar radiation	Shading	Heat pump	Results
1	32 °C	38 °C	600 W/m ²	0°-off	off	Maximum temperature of 49.5°C measured on the outdoor frame.
2a	free floating	38 °C	600 W/m ²	0°-off	on	HVAC unit did not manage to reach the design indoor temperature.
2b	free floating	38 °C	600 W/m ²	90°-off	on	HVAC unit did not manage to reach the design indoor temperature.
3a	25.5 °C	38 °C	off	0°-off	on	No condensation risk was found due to heat pump components.
6	18.5 °C	-12 °C	off	0°-off	on	No condensation risk was found on the frame and glazing of the façade, at both sides. Minimum temperature of around -11°C on external side of the façade.
7	18.5 °C	-12 °C	off	0°-off	off	No condensation risk was found on the frame and glazing of the façade, at both sides. Minimum temperature of around -11°C on external side of the façade.
8	free floating	-1 °C	off	0°-off	on	HVAC unit did not manage to reach the design indoor temperature.
10a	20°C	20°C→0°C 0°C→20°C	off	up	off	No condensation risk was found.

Test 3a - Condensation risk



Example of a test result: temperature profiles were measured by a set of thermocouples (TC11, TC13, TC17, and TC18), and the dewpoint temperature profile was calculated. Since the dewpoint temperature never exceeds the measured temperatures, no condensation risk is expected.

Conclusions

The testing of the facade system aimed to assess its operation under various conditions but encountered some technical challenges. Tests under winter and summer conditions highlighted the system's ability to mitigate condensation risks, though challenges were noted in maintaining setpoint temperatures. Overall, the results offer valuable insights into the facade system's performance, providing a basis for future improvements and optimizations.



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TECNAN

Product: Heat barrier coating

TECNAN produces and commercializes new raw materials (high performance nanoparticles) for various industrial applications

TECNADIS HEATSHIELD is a nanotechnology-based heat barrier treatment for glass surfaces, which blocks infrared solar radiation (IR) by more than 40%.



Glazed façades

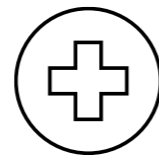
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PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The G-Value Lab node offers a characterization of the solar factor in standard and tailor-made boundary conditions for a complete assessment of transparent and semi-transparent products.



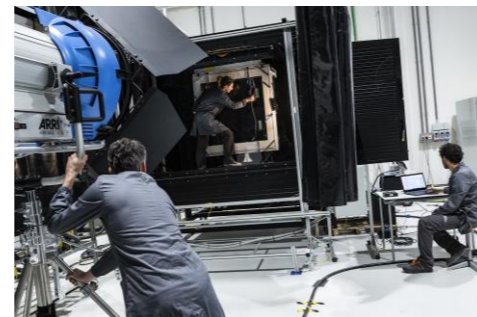
HEALTH



EFFICIENCY

Which is the need covered by this service?

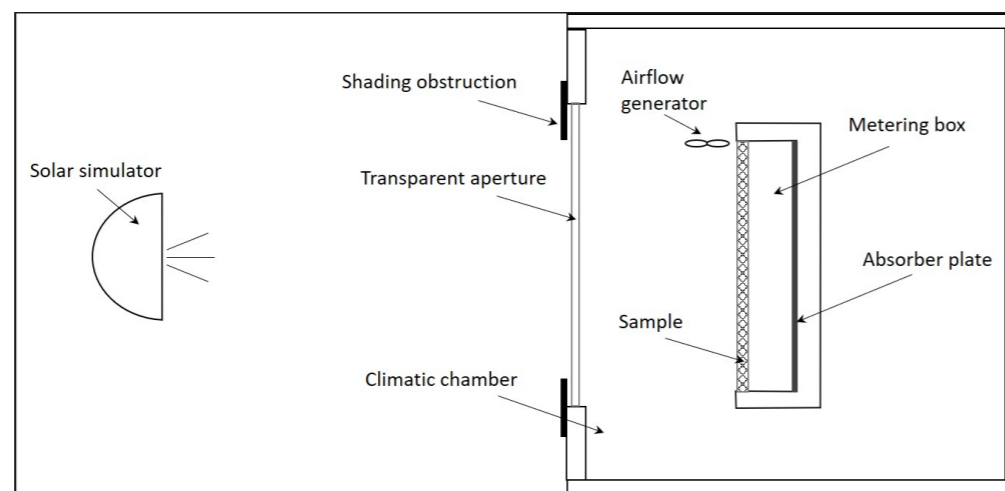
The analysis aimed at evaluating the g-value (i.e., Solar Heat Gain Coefficient), which is the indicator of the heat solar gains through the glazed envelope, of a double-glazing unit with and without heatshield coating under different environmental conditions (intensity and incidence angle of solar radiation and air temperature).



G-Value Lab, one of the nodes of PM&VL2

Design of Experiments

Measurement of the g-Value under different conditions of a DGU before (nohs) and after (hs) the application of the heatshiled coating.



Results

The heatshield coating applied on the glazing reduced the g-value of around the 30-37%. As also shown in the table below, the variability of the conditions (i.e. incident irradiance, operating temperature and angle of incidence) does not affect the coating functionality

Configuration	Solar irradiance	Air temperature	Tilt angle	g-value DGU	g-value DGU+coating
	W/m^2	$^{\circ}C$	$^{\circ}$		
1	600	20	0	0.81 ± 0.03	0.54 ± 0.03
2	600	20	30	0.76 ± 0.03	0.49 ± 0.03
3	600	20	45	0.71 ± 0.03	0.45 ± 0.03
4	400	20	0	0.80 ± 0.03	0.54 ± 0.03
5	600	30	0	0.77 ± 0.03	0.54 ± 0.03

Conclusions

The heatshield coating applied on the glazing reduced the g-value of around the 30-37%. Additionally, the test showed that the variability of the conditions (i.e. incident irradiance, operating temperature and angle of incidence) does not affect the coating functionality; the trends are very similar between the DGU with and without the heatshield coating.



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TECNAN

Product: Photocatalytic coating

Tecnan produces different kinds of active nanoparticles, and its catalogue includes several ranges of products such as hydro and oleo repellent coatings, specific water repellent products, anti-soiling self-cleaning products and easy-to-clean as well as protective coatings.



Photocatalytic coating

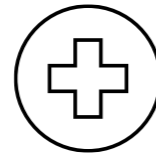
This specific formulation contains photoactive nanoparticles that, when irradiated, are able to degrade formaldehyde molecules present in the indoor atmosphere.

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PM&VL2



HEALTH

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The VOC (Volatile Organic Compounds) Lab node offers a characterization of the VOC emissions of building materials under standard or customized environmental conditions.

Which is the need covered by this service?

The analysis aimed at evaluating the potential capability of the coating developed by Tecnan of removing formaldehyde from an indoor space, when irradiated with simulated solar light.

Formaldehyde is a well-known carcinogenic compound ubiquitously found in indoor spaces. Reducing occupants' exposure to this pollutant would greatly increase the salubrity of indoor spaces, where we nowadays spend the majority of our time.

Design of Experiment

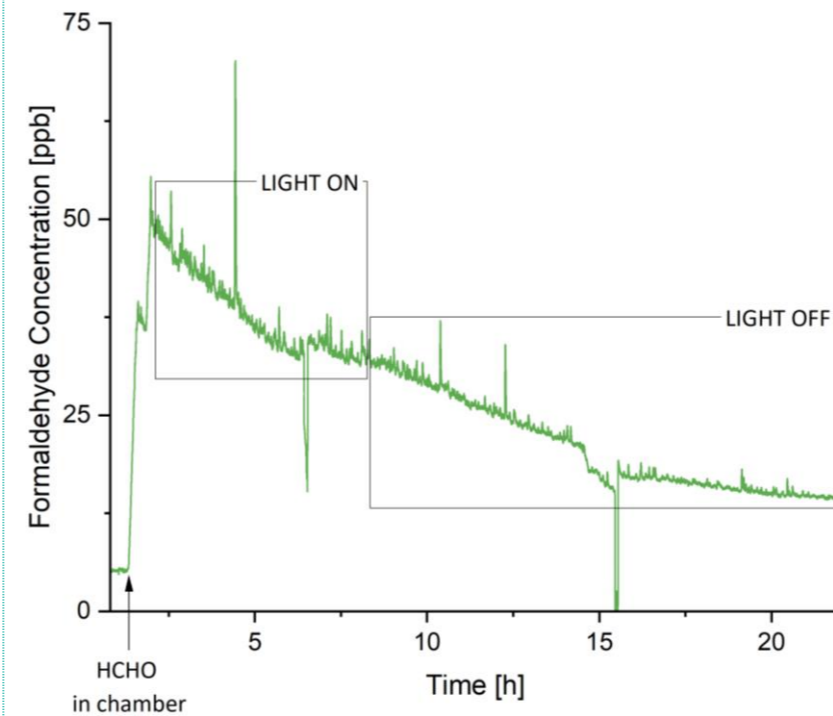
The test procedure employed is based on the ISO 18560-1:2014 standard with several modifications:

- the light source was positioned inside the test chamber,
- an adequate amount of formaldehyde was injected to achieve the desired target concentration,
- a dedicated formaldehyde analyser for measuring the concentration of formaldehyde in continuum was employed.

In order to determine the performance for formaldehyde removal by the photocatalytic coating the reference decay curve of formaldehyde concentration in the chamber is obtained and it is later compared with the decay curve obtained in the presence of the test specimens and with the light source turned on.



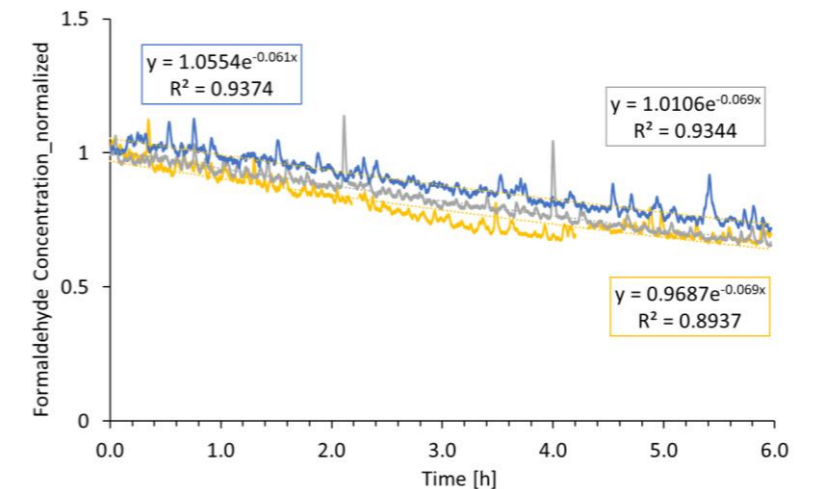
Test specimens in the test chamber with the experimental set-up



Photocatalytic test with light on and light off periods highlighted.

The same decay rate constant was obtained both under illumination and in dark conditions (0.069), a value that resulted to be however higher than the constant obtained by normalizing the reference decay curve (0.61).

This indicates that, with respect to the reference curve, the decay of formaldehyde during the photocatalytic test resulted to be faster, but no sensible difference in this degradation rate was detected between the curves recorded in presence and absence of irradiation



Normalized decay curves with light turned ON (yellow line) and OFF (grey line) and reference decay curve (blue line)

Conclusions

The analysis of the results, in particular the calculation of the decay rate constants in dark and under illumination, did not yield results consistent with an accelerated formaldehyde degradation when the test specimens were irradiated with a light source. The photocatalytic properties of the tested coating could be further characterized by varying some experimental conditions, such as the illumination source and by increasing the surface/volume ratio by increasing the area coated with the photocatalytic product.

Results

The formaldehyde concentration in the test chamber was monitored for more than 20 hours, of which 6 hours consisted in the photocatalytic HCHO decay test performed with the artificial illumination source turned on.

In order to assess whether the coating applied to the test specimens was actively degrading the formaldehyde present in the test chamber, a fitting curve was calculated for the HCHO decay both in presence and absence of light, and both were then compared with the previously obtained reference decay curve.



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TECNAN

Product: Nanoparticle coating

TECNAN was created in December 2007 and offers a wide spectrum of nanoparticle materials, which can be employed as catalysts for the automobile industry and the energetic sector, sensors for gases and atmospheric pollutants, photocatalysts, materials for lighting devices, and many other uses. But also, multifunctional nanoparticle-based coatings addressed for sectors as renewable energies, buildings, medicine, 3D printing, automotive or wood among many others.



Hydrophobic Coating by TECNAN applied to porous building materials

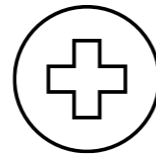
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PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. An important feature the PM&VL2 will offer is the coupling of testing and modelling activity, hence exploiting the tests in order to calibrate models and broadening the analyses.



HEALTH

Results

1. COATING B reduces drastically the water absorption coefficient by partial immersion, A_w , for both substrates. The ratio between the average A_w value of the treated samples and the one of the untreated samples is 0.02.
2. COATING B does not increase the water vapour resistance factor, μ , for both substrates even if with a difference from the quantitative point of view. As regards the stone substrate the ratio between average μ value of the treated samples and the one of the untreated samples is 1.14 (value obtained removing one outlier) while, for plaster, the same ratio is 1.03.
3. COATING A has a different impact on the two substrates as regards the water uptake coefficient by partial immersion, $A_{w,p}$. For the plaster substrate the observed $A_{w,p}$ is on average even higher for the treated samples than the untreated ones. For the stone substrate there is a reduction of $A_{w,p}$ and on average the ratio between the treated and the untreated $A_{w,p}$ is 0.09.
4. COATING A has a negligible impact on the vapour diffusion properties of the two substrates. In the case of the stone a slight increase of μ value is observed on average while in the case of the plaster a slight decrease.

Which is the need covered by this service?

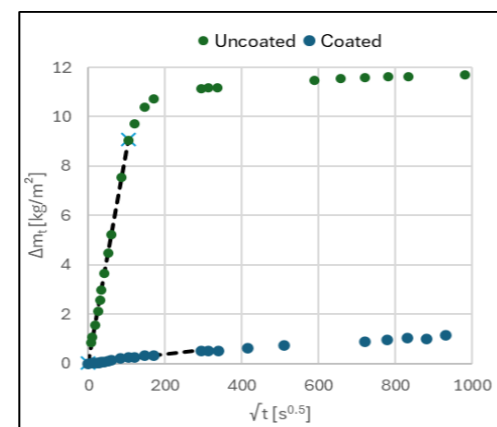
The main purpose of a hydrophobic coating, as regards the hygric properties, is to reduce the water absorption of the substrates on which they are applied and at the same time do not modify its vapour diffusion properties. The test performed in PM&VL2 aims to quantify these two effects. The innovative coatings under investigation are two hydrophobic treatments combined with photocatalytic nanoparticles active also in the visible range. The two coatings differ because COATING A is water based while COATING B is solvent based. Both coatings are tested when applied to two different type of substrates: a stone and a lime plaster.

Design of Experiments

The tests were carried out according to the following procedures

1. The water absorption properties were determined measuring the water uptake coefficient by partial immersion according to the standard EN ISO 15148:2016.
2. The vapor transmission properties were determined using the cup method according to the standard EN ISO 12572:2016

The substrates were tested both before and after the application of the coatings.



Comparison of the water absorption curve for an uncoated specimen of lime plaster and one treated with COATING B.

Conclusions

1. Both coatings are addressed to avoid water contact with surface of the substrate. However, they have not been developed to work at immersion conditions, hence the test conditions are representing an extreme exposure for the specimens. However, even under extremely harsh conditions both coatings have revealed good performances on top of two substrates. More in detail, COATING B has proven to be promising for use as a water-repellent coating, as it reduced the water absorption coefficient by approximately 98%, while modifying the vapour resistance factor to a limited extent.
2. By its part, characterization of COATING A has also exhibited a great vapour transmission; since vapour resistance factor is completely comparable to non-treated samples on both substrates. But also, has shown a significant reduction of the water absorption coefficient in for stone substrate (up to 91%). Meanwhile, due to porosity of the plaster, a further optimization in terms of dosage and application has to be completed to reach previous values.



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FLEX&ROBUST

Product: Flexible structural connectors

Flex And Robust (FAR) produces and commercializes Polyurethane Flexible Joints. FAR offers flexible structural connections in civil engineering, carrying loads and high deformations simultaneously and dissipating energy. Solutions offered by FAR are suitable for seismic and hurricane areas.



Polyurethane Flexible Joints specimens

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PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The VOC (Volatile Organic Compounds) Lab node offers a characterization of the VOC emissions of building materials under standard or customized environmental conditions.



HEALTH

Results

The results reported in the table below show the low level of VOC emissions emitted by the polyurethane PM flexible joints in terms of specific emission rate or emission factor per area of the sample (SERA), mass concentration of single VOC in the air of the European Reference Room (Cr), and R values according to the German LCI/NIK list (RD) and Belgian LCI list (RB) after 28 days.

Parameter	CAS No.	SER _A 28days [µg/m ² h]	C _r 28days [µg/m ³]	EU-LCI [µg/m ³]	R _D	R _B
2-Ethyl-1-hexanol	104-76-7	5.53	< 1	800	-	-
2-Ethoxyethyl acetate	111-15-9	48.83	< 1	50	-	-
1-Butanol	71-36-3	41.74	< 1	11000	-	-
1,2,4-Trimethylbenzene	95-63-6	21.05	< 1	450	-	-

SER_A: specific emission rate; C_r: concentration in the air of the European Reference Room; EU-LCI: European Lowest Concentration of Interest.

Which is the need covered by this service?

The analysis aimed at evaluating the potential VOC emissions emitted by polyurethane flexible joints under common indoor environmental conditions (air temperature, relative humidity, air exchange and air velocity).

The emissions tests of the polyurethane joints provided by Flex&Robust are assessed using the emission chambers of the Volatile Organic Compounds lab (VOC lab). The emissions from the investigated materials were evaluated in different contexts representing real conditions including: fresh materials and cured materials.

From the following table we can observe how all the tested cured joints emit concentrations of total volatile organic compounds (TVOC) well below the A+ class identified by the French labelling scheme.

	Parameter	Cr 28days [µg/m ³]	French Regulation Class A+
PM	TVOC	10	< 1000
PT	TVOC	13	< 1000
PS	TVOC	136	< 1000
PTS	TVOC	22	< 1000

C_r: concentration in the air of the European Reference Room.

Design of Experiments

Volatile Organic Compounds (VOC) emissions from materials are measured in accordance with the standard EN 16516:2017 (Construction products: Assessment of release of dangerous substances - Determination of emissions into indoor air)

Parameter	Value
Air temperature	23 °C
Relative Humidity	50%
Air Exchange	0.5 ACH
Air velocity	0.1-0.3 m/s

Standard test conditions

Conclusions

The concentration of chemical compounds measured in the air of the European Reference Room (C_r) for the tested products were found to be consistently below the established limits set by the main European regulations and EU-LCI values. This indicates that the emissions from the tested material have a low risk of adverse health effect from long-term exposure to the general population.



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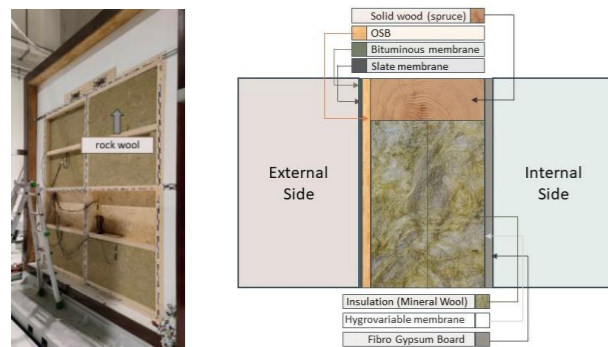


VAPOR CONTROL MEMBRANE PERFORMANCE ASSESSMENT THROUGH HYGROTHERMAL SENSOR

ROTHOBLAAS

Product: Vapor control membranes

Rothoblaas is an Italian multinational company from the Alpine region, leader in the development and supply of high-tech solutions for the areas of beam and post and Mass Timber construction systems, energy efficiency, zero emissions and other building best practices.



Test facade built to test the behaviour of the hygrovariable membrane and installation methods for capacitive sensors

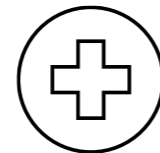
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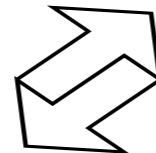


PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions, both involving human subjects or thermal manikin. An important feature the PM&VL2 will offer is the coupling of testing and modelling activity, hence exploiting the tests in order to calibrate models and broadening the analyses.



HEALTH



EFFICIENCY

Which is the need covered by this service?

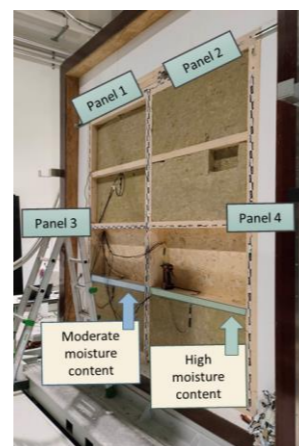
The study aims to evaluate the hygrothermal behaviour of moisture-adaptive membranes (CLIMA CONTROL 80) relative to standard roof solutions in the context of a flat roof assembly. Moreover, the investigation focuses on an innovative membrane that adapts its water permeability in response to variations in the relative humidity of the surrounding air, thereby optimizing the behaviour of the roof's moisture response. The study encompasses an analysis that compares various sensor installation techniques for on-site monitoring, with the goal of identifying a suitable method for integrating sensors into already renovated walls.

Design of Experiments

The experiment involves testing a moisture-adaptive membrane (CLIMA CONTROL 80) when used in the context of a flat roof, using a double climatic chamber to reproduce an exterior and interior environments of a building. Combined temperature and relative humidity sensors are used to monitor the hygrothermal behavior of the roof in critical positions.

The experiment's setup includes beams preconditioned to specific moisture levels, crucial for evaluating the membrane's response to different humidity environments and to verify that the membrane allows the roof structure to dry effectively.

The boundary conditions are structured into three phases to simulate different seasonal conditions: summer conditions, winter conditions and a free-floating phase.

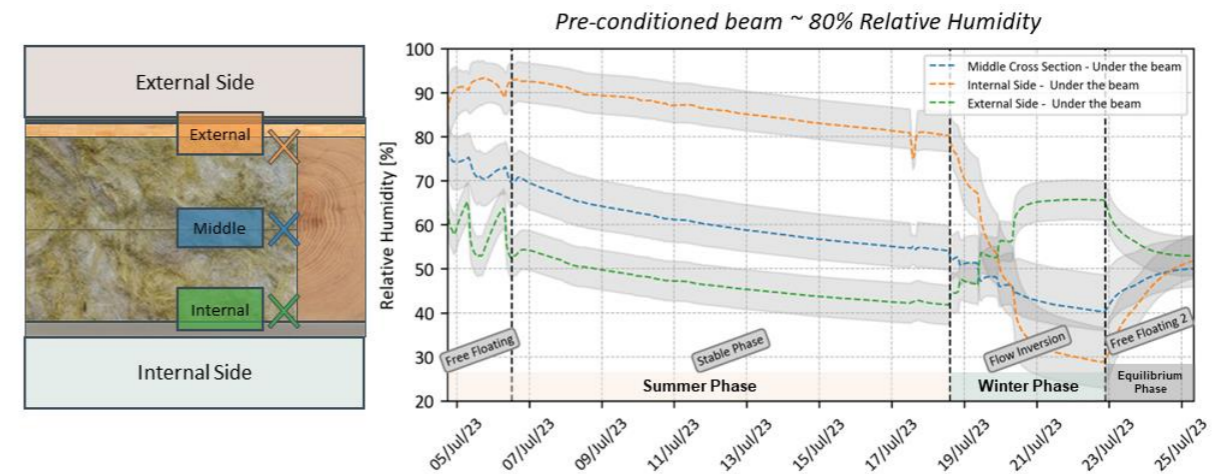


Tested stratigraphy showing the 4 panels and the preconditioned beams

Results

- Summer Phase:** The membrane functioned as a vapor-open layer during the drying phase, allowing the construction to dry out. This was reflected in the significant decrease of relative humidity values across all positions from the start of the drying phase to the Stable Phase.
- Winter Phase:** In the winter phase, or 'Flow Inversion' phase, the membrane operated as a vapor retarder. It effectively prevented moisture transfer from the interior environment to the roof structure. In fact, after an initial redistribution of the moisture within the roof no significant growth of the relative humidity levels were observed.
- Equilibrium Phase:** During the 'Free Floating 2' phase, with no active vapor pressure gradient, the membrane contributed to a third redistribution of moisture within the sample. The sensors converged towards an average relative humidity of 50%, significantly lower than the initial levels, indicating the membrane's role in achieving a consistent drying of the roof throughout the experiment.

These points capture the membrane's adaptability and effectiveness in managing moisture under varying environmental conditions



Displaying relative humidity at the three positions monitored on the DL and DR panels, with the beam pre-conditioned. The plots depict the average sensor readings as dashed lines, with the shaded areas around these lines indicating the range of measurement uncertainty.

Conclusions

The experiment using the moisture-adaptive membrane (CLIMA CONTROL 80) demonstrated its ability to regulate moisture effectively. This was particularly evident in the significant drying observed across all three monitored positions, showcasing the membrane's adaptability and efficiency in various environmental conditions. These results underline the membrane's effectiveness and suggest that its use is promising in the context of flat-roofs, but further studies are needed. Future studies should consider comparing a flat-roof incorporating the moisture adaptive membrane with one with a traditional membrane, to provide a more comprehensive understanding of its benefits and performance in different settings. Moreover, longer experiments (several years) would be needed to investigate the long-term behavior, this is however not possible in a laboratory testing facility as the Multifunctional Facade Lab and ideally should be conducted in a monitoring project within a real building (Living Lab).



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ROTHOBLAAS

Product: DGZ screw with double thread

Rothoblaas is an Italian multinational company from the Alpine region, leader in the development and supply of high-tech solutions for the areas of beam and post and Mass Timber construction systems, energy efficiency, zero emissions and other building best practices.



DGZ screws for continuous connection of the insulation layer

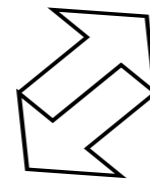
Pilot Measurement & Verification Line 2

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PM&VL2

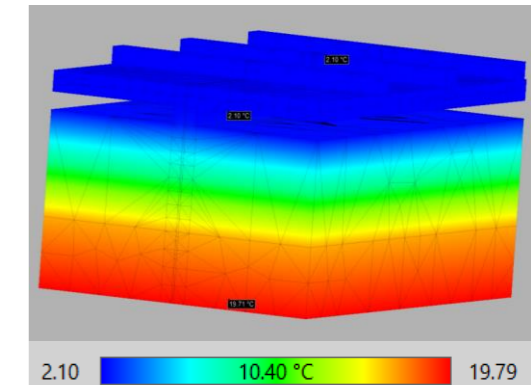
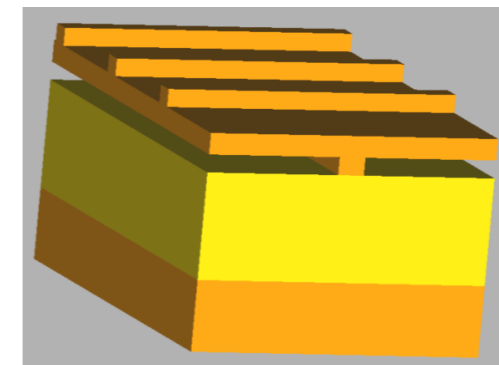
An important feature the PM&VL2 will offer is the coupling of testing and modelling activity, hence exploiting the tests in order to calibrate models and broadening the analyses.



EFFICIENCY

Results

1. The thermal bridge effect using the DGZ screws is always smaller than the one using partially threaded screws. The reduction of the thermal transmittance U of the roof using the DGZ screws in comparison to the roof structure with the partially threaded screws, $\Delta U_{DGZ-partially\ threaded}$, ranges from $0.014 \frac{W}{m^2K}$ to $0.033 \frac{W}{m^2K}$.
2. The difference between the two roof structures using the two types of screws is more visible for the cases with timber beams than for the cases with CLT.
3. Increasing the thickness of insulation, the effect of the thermal bridge decreases.
4. The estimation of the additional thickness of insulation required to compensate the increased thermal transmittance in the case of partially threaded screws compared to the DGZ screws, $\Delta t_{DGZ-partially\ threaded}$, ranges from 1.1 cm to 3.0 cm.



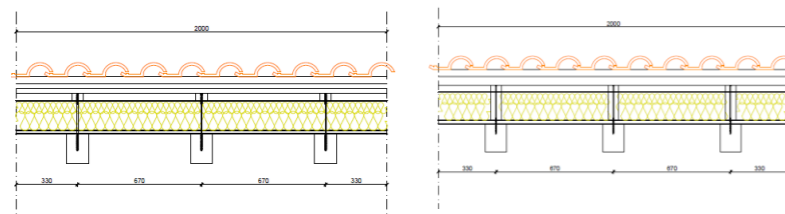
Example of 3D thermal bridge simulation: geometry (on the left) and temperature trends (on the right)

Which is the need covered by this service?

The analysis aims to evaluate the thermal performance of the roof construction using DGZ screws, an innovative type of screw with double thread that allows continuous and uninterrupted fastening of the roof insulation package, when compared to an equivalent construction using partially threaded screws in the context of an insulated timber roof. The simulations were performed on the DGZ wood screws limiting the thermal bridges in accordance with energy saving regulations.

Design of Experiments

3D thermal simulations of the roof structure with the screw are carried out in accordance with the standard UNI EN ISO 10211:2018 with the software "Mold 3D 5 Dynamic". The simulations are performed varying many parameters, including type of roof substructure, insulation thermal conductivity and insulation thickness.



Roof construction with DGZ screws (left) and partially threaded screws (right)

Conclusions

Calculations have shown an advantage in using DGZ screws instead of partially threaded timber batten screws because the insulation is not interrupted. This advantage, in terms of thermal transmittance (U-value), is seen more for structures with timber beams than for CLT. In addition, the advantage is greater for fewer centimetres of insulation, again in terms of thermal transmittance of the whole package. The U-value advantage is also greater for higher-performance insulation (lower thermal conductivity).



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PELLINI

Product: Glazing Integrated Venetian Blinds

ScreenLine® venetian blinds integrated within an insulating glass unit designed to optimise heat and light gain according to the year's seasons and to improve the window system's transmittance.



ScreenLine® venetian blinds
Pellini SpA

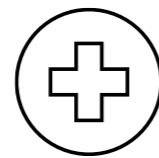
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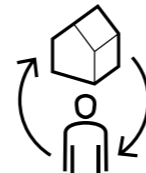


PM&VL2

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The Façade System Interactions Lab aims to assess the interaction between the elements that make up a building and the indoor environmental quality and comfort conditions



HEALTH



INTERACTION

Which is the need covered by this service?

This node of PM&VL2 covered the need to evaluate the performance of façade systems under controlled indoor conditions and real outdoor environmental conditions. The tests assessed the thermal and optical properties of glazing systems with integrated venetian blinds featuring different surface treatments (silver, white, and retroreflective). Various performance indicators, such as solar and visible transmittance, g-value, and heat flux, were measured across multiple blind tilt angles. These measurements provide critical insights into how different configurations influence energy efficiency, daylight control, and thermal comfort, supporting the development and optimization of advanced façade solutions for sustainable building design.

Design of Experiments

Thermal and optical performance assessment of three glazing systems with integrated venetian blinds featuring different surface treatments (silver, white and retroreflective), across four blind configurations: blinds up, blinds down at 0°, 30°, and 45° tilt angles.

Measured parameters:

- Internal and external vertical irradiance and illuminance
- Internal and external air temperatures
- Internal and external glazing surface temperatures
- Internal heat flux sensor



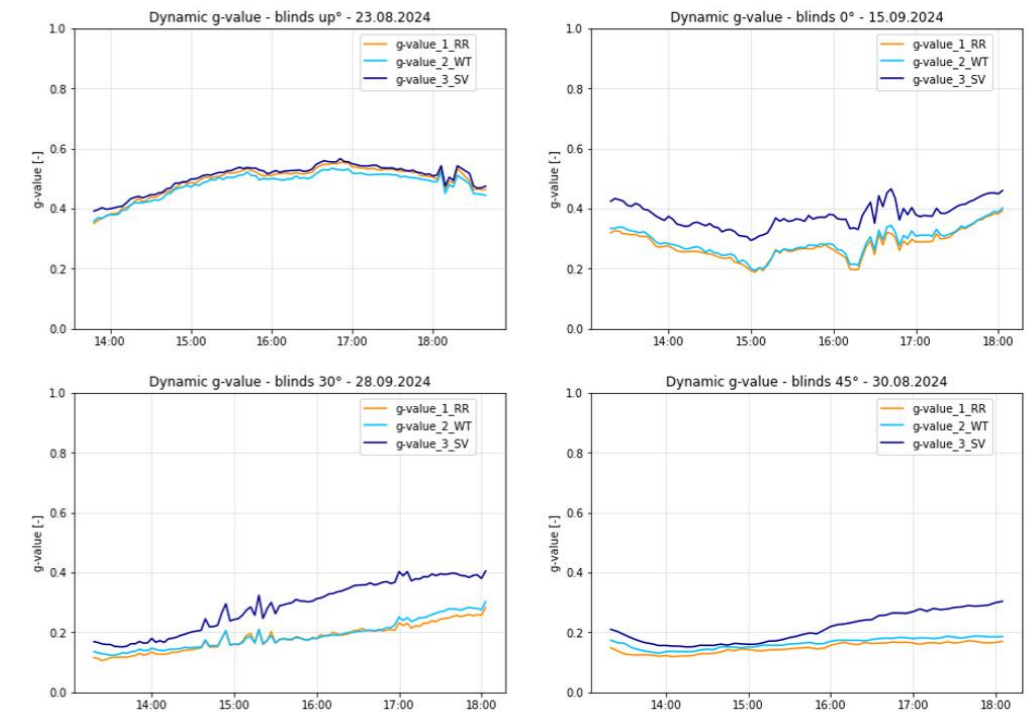
Façade with test setup, view from inside

Results

- **Solar & Visible Transmittance:** Silver blinds (SV) exhibited the highest solar and visible transmittance, followed by white (WT) and retroreflective (RR) blinds. Transmittance varied with the vertical solar angle, with silver blinds exhibiting major changes in transmittance at different solar angles.
- **Solar Gains & g-Value:** The dynamic g-value was assessed and analyzed throughout the day, reflecting variations in solar angle, with silver blinds consistently exhibiting higher values across all configurations.

- **Direct & Secondary Solar Gains:** At low tilt angles or in the blinds-up configuration, secondary gains were limited (5-8% of total solar gain for the blinds-up and 16-20% for the 0° tilt). At higher blind tilt angles, secondary gain increased significantly, contributing 25-35% at 30° tilt and 32-44% at 45° tilt.

- Thermal and optical properties of glazing systems with integrated venetian blinds significantly depend on the type of blind finish and the tilt angle.



Dynamic g-value for different blind configurations (up, 0°, 30°, 45°)

Conclusions

The study demonstrates that the type of blind finish and tilt angle significantly influence the thermal and optical performance of glazing systems. Additionally, the thermal and optical properties are not constant throughout the day. They vary significantly based on the incidence angle of solar radiation, affecting both the transmittance and solar gains. While proper glazing system design is crucial, the appropriate control of shading systems throughout the day and across seasons is even more important. Effective management of blinds can enhance energy efficiency and improve indoor comfort by optimizing solar gains and minimizing thermal loads.



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PELLINI

Product: *Wave* – Glazing Integrated Roller Shading System

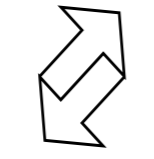
Wave is the innovative integrated shading solution for ScreenLine® systems consisting of a thin wave film (23 microns) made of polyester that can be incorporated within 20-mm or 22-mm insulating glass units. Its horizontal wave geometry gives a pleasant aesthetic impact, the PVD coating is expected to reduce the solar factor and to increase thermal insulation and, when the blind is completely lowered, it protects from solar gains and provides privacy.

Pilot Measurement & Verification Line

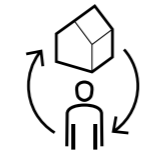
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PM&VL2



EFFICIENCY



INTERACTION

The scope of the PM&VL2 is a complete characterization of all the envelope parts and their effects on internal occupants in real operating conditions. The Multifunctional Façade Lab (MFL) node verifies the thermal and energy performances of envelope systems such as doors and windows, opaque walls and façade modules under both stationary and dynamic conditions.

Results

Table 1 summarizes the key test results, focusing on the thermal transmittance of the two configurations of the Double Glazing Unit (DGU) equipped with an integrated *Wave* roller shading system. When the shading system was fully raised, the DGU achieved a standardized thermal transmittance of 1.55 W/(m²K). In contrast, with the shading system fully lowered, the thermal transmittance improved to 1.26 W/(m²K), representing a 19% reduction.

Table 1. Thermal transmittance results for DGU with roller shade UP and DOWN

		DGU with shading UP	DGU with shading DOWN
Hot chamber air temperature	°C	22.64	22.68
Cold chamber air temperature	°C	1.8	1.85
Total measured surface thermal resistance	m²K/W	0.14	0.14
Measured thermal transmittance	W/(m²K)	1.62	1.31
Uncertainty on thermal transmittance	W/(m²K)	0.16	0.14
Total standard surface thermal resistance	m²K/W	0.17	0.17
Standardized thermal transmittance	W/(m²K)	1.55	1.26

Which is the need covered by this service?

This node of PM&VL2 covered the need to evaluate the thermal performance of a fenestration system under controlled indoor and outdoor environmental conditions. The tests assessed the thermal transmittance of an insulated glazing system (IGU) incorporating an integrated roller shading system. Comparative analysis was conducted between two configurations: one with the shading system fully lowered and the other with the shading system fully raised, highlighting the impact of shading position on thermal efficiency.

Design of Experiments

The determination of thermal transmittance was carried out following the guarded hot box method, as described in UNI EN ISO 12567-1:2010. The test was performed in a double-chamber guarded hot box. The sample size was 123 cm (width) x 148 cm (height) The sample was installed in a 130 mm tick insulation support panel (EPS) placed in the frame of the hot box that avoids heat exchanges with the environment. The air temperature on the cold side was 1.85°C / 1.80°C, the one on the warm side 22.68°C / 22.64°C.



MFL, Eurac Research

Conclusions

This test activity demonstrated that integrating the *Wave* shading system into Double Glazing Units significantly enhances thermal performance. Lowering the shading system reduced thermal transmittance by 19%, highlighting its effectiveness in improving insulation and energy efficiency. This emphasizes the potential of the *Wave* integrated roller shade as an innovative solution for optimizing the thermal and energy performance of building envelopes.



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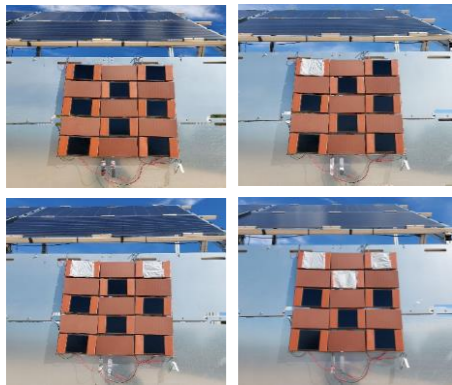
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Flexbrick

Product: Solar Mesh

Flexbrick designs flexible modular systems for architectural facades and roofs, combining ceramics and photovoltaic cells to deliver innovative and energy-efficient solutions for modern buildings.



Flexbrick module outdoor shadowing test.

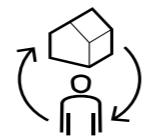
Pilot Measurement & Verification Line 3

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PM&VL3

PM&VL3 focuses on modeling and validating active energy components, covering key aspects of PV-integrated building envelope elements under various environmental conditions, and analysing product stability and degradation.



INTERACTION

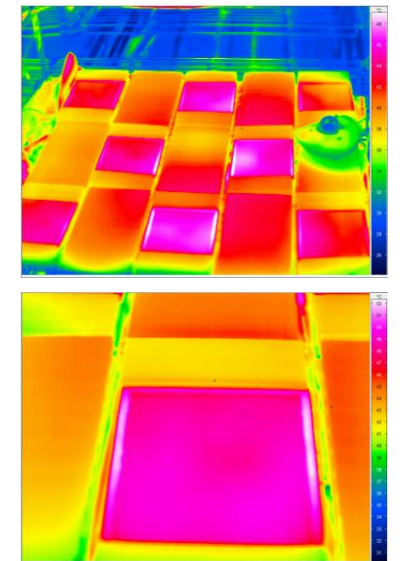


EFFICIENCY

Results

The Flexbrick module was extensively tested indoors and outdoors:

1. LID test: Minimal degradation, with key parameters such as P_{mpp} and V_{oc} showing less than 5% variation, confirming stability under light exposure.
2. Shadowing tests: Efficiency decreased by 9%–35% with 1/8 to 3/8 of the cells shaded, but recovered to 18.1% after shading was removed.
3. Outdoor tests: The module achieved 18.37% efficiency under real-world conditions, confirming its robustness and suitability for BIPV applications.



Thermal Images of the module under normal conditions in the climatic chamber.

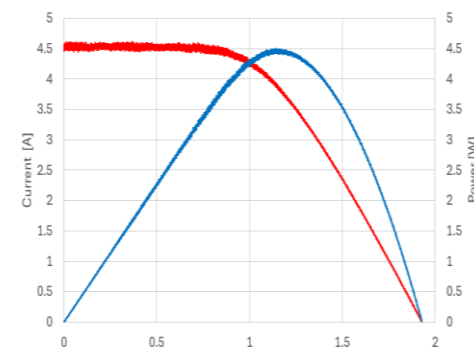
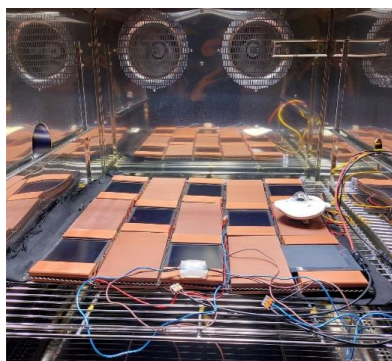
Which is the need covered by this service?

This service meets the demand for rigorous testing and validation of BIPV systems, focusing on their durability and efficiency across a range of environmental scenarios. It delivers key information on degradation and performance, enabling manufacturers to refine products for practical use in building facades and rooftops.

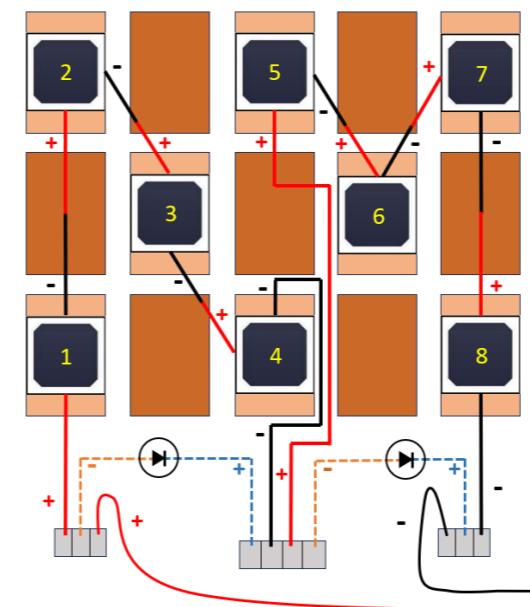
Design of Experiments

The testing aims to evaluate the performance and stability of the Flexbrick product under:

- LID test: Assessing degradation from continuous light exposure.
- Shadowing tests: Measuring efficiency loss under indoor and outdoor partial shading.
- Outdoor performance: Monitoring real-world durability and efficiency in natural conditions.

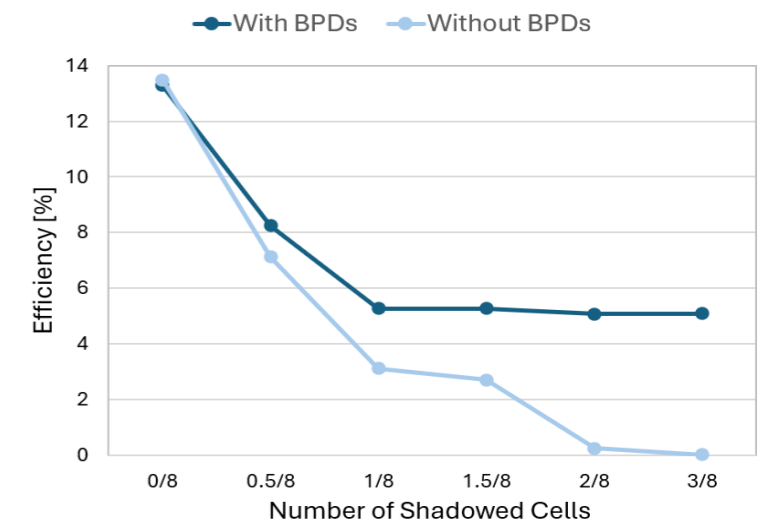


Indoor and outdoor tests of Flexbrick modules, measuring their characteristic IV and PV curves.



Flexbrick module representation in the BPDs electrical configuration.

BPDs Module Efficiency Impact



Plot of Shadowing Test Effects on Module Efficiency with and without BPDs.

Conclusions

PM&VL3 successfully completed a comprehensive set of tests on photovoltaic samples from MEZeroE partners, including Flexbrick. The tests, covering LID, LeTID, and shadowing, provided detailed insights into the stability and degradation of these products under various environmental conditions. These findings are essential for understanding long-term performance, particularly in building-integrated photovoltaic (BIPV) applications. The tests confirm the durability and efficiency of these products, ensuring they meet performance standards for sustainable, nearly Zero Energy Buildings.



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STRESS TEST AND ENERGY PERFORMANCE CHARACTERIZATION

Heliatek

Product: HeliaSol

Heliatek's organic solar films are lightweight, flexible, and easy to install on façades, roofs, and curved surfaces. They generate up to 65W/m² and have a low carbon footprint, making them ideal for sustainable energy solutions.



Heliatek modules outdoor shading test.

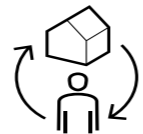
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PM&VL3

PM&VL3 focuses on modeling and validating active energy components, covering key aspects of PV-integrated building envelope elements under various environmental conditions, and analysing product stability and degradation.



INTERACTION

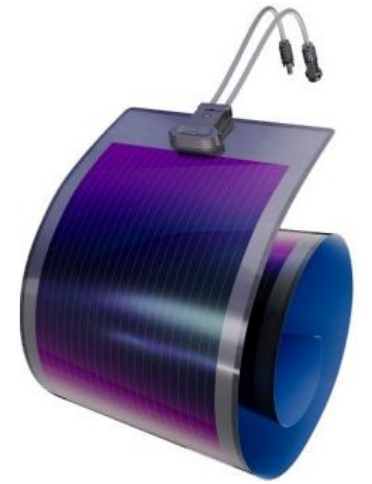


EFFICIENCY

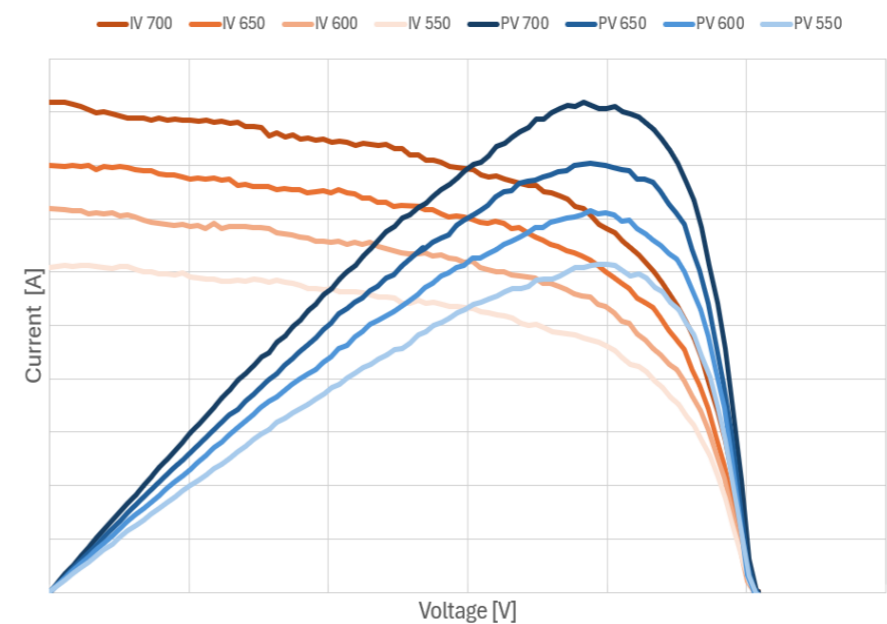
Results

The HeliaSol tests highlighted:

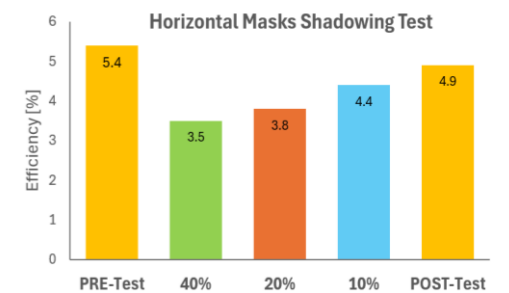
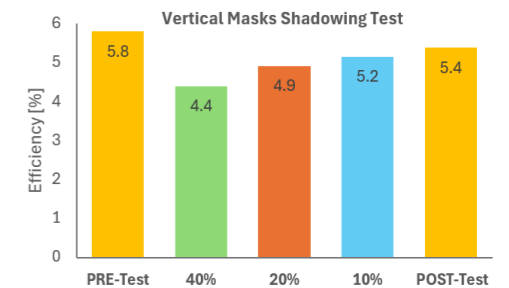
- Indoor Performance: With 20% shading by solar masks with 0% transmittance, the panels retained significant power, dropping from 5.2W to 2.7W, showcasing efficiency under limited light conditions.
- Outdoor Adaptability: In outdoor tests, vertical shading led to a 24% reduction in power output, and horizontal shading caused a 35% decrease, demonstrating the panels' adaptability to environmental variations.
- Consistent Outdoor Efficiency: HeliaSol panels consistently delivered a 5.81% efficiency in outdoor environments, proving their stable and reliable performance.
- Rigorous Characterization: Comprehensive evaluations under both indoor and outdoor conditions, including thermal tests, showed the panels performing well even with temperatures exceeding 50°C.



HeliaSol module picture.



IV curve characterization of small HeliaSol panels under varying irradiation intensities indoors.



Efficiency histograms for outdoor shading tests.

Which is the need covered by this service?

The service addresses the need for thorough testing and validation of BIPV products, specifically focusing on their long-term stability and performance under various environmental conditions. It provides essential data on degradation, efficiency, and durability, helping manufacturers optimize designs for real-world applications, such as façades and rooftops.

Design of Experiments

- Indoor and Outdoor Shadowing Tests: Evaluating performance under partial shading in both controlled and natural environments.
- Outdoor Performance Test: Monitoring long-term energy output and stability in real-world conditions.
- Product Characterizations: Pre- and post-test IV curve measurements and thermal imaging to analyze efficiency and detect hotspots during testing



Indoor and outdoor tests of HeliaSol modules, and image of their thermal Characterization.

Conclusions

The testing and validation of Heliatek's HeliaSol product provided essential insights into its performance under various environmental conditions, including shadowing and outdoor exposure. The tests highlighted the product's durability and energy generation capabilities, particularly for building-integrated photovoltaic (BIPV) applications. These findings confirm HeliaSol's suitability for sustainable energy solutions, meeting the required standards for long-term efficiency and resilience in nearly Zero Energy Buildings (nZEBs).



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Heliatek

Product: HeliaFilm

Heliatek's organic solar films are lightweight, flexible, and easy to install on façades, roofs, and curved surfaces. They generate up to 65W/m² and have a low carbon footprint, making them ideal for sustainable energy solutions.



Heliatek modules outdoor shadowing test.

Pilot Measurement & Verification Line 3

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PM&VL3

PM&VL3 focuses on modeling and validating active energy components, covering key aspects of PV-integrated building envelope elements under various environmental conditions, and analysing product stability and degradation.



INTERACTION



EFFICIENCY

Which is the need covered by this service?

This service fulfills the need for comprehensive testing and validation of BIPV modules, assessing their performance and durability under diverse environmental conditions. It helps manufacturers understand how factors like shading, temperature changes, and prolonged light exposure affect product efficiency and stability.

Design of Experiments

The testing plan for HeliaFilm involves:

- Conducting outdoor performance tests to track energy output and stability over time in natural conditions.
- Performing product characterizations, including IV curve measurements and thermal imaging before and after testing, to evaluate efficiency and identify potential hotspots.



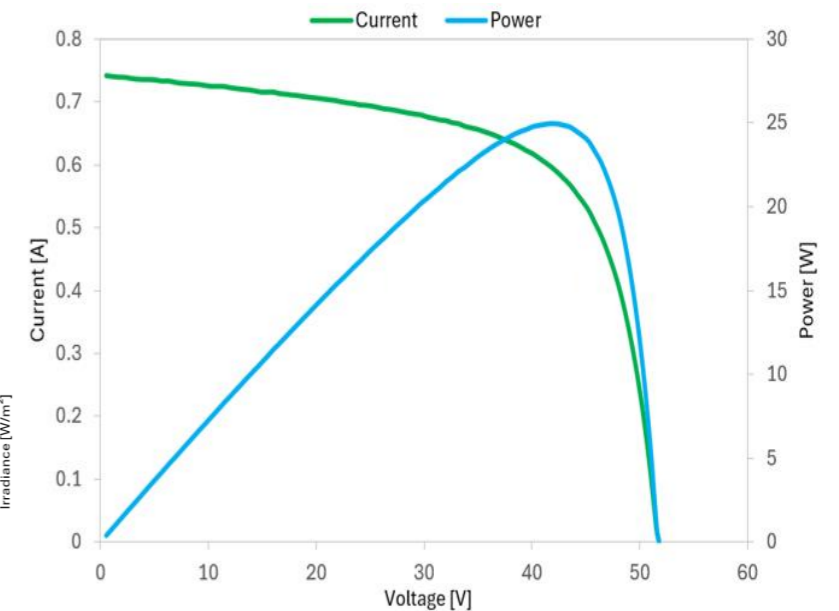
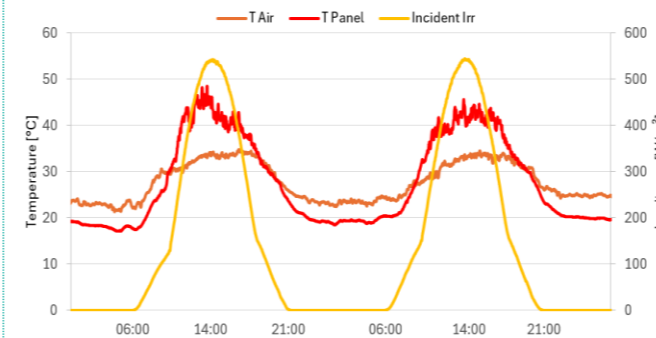
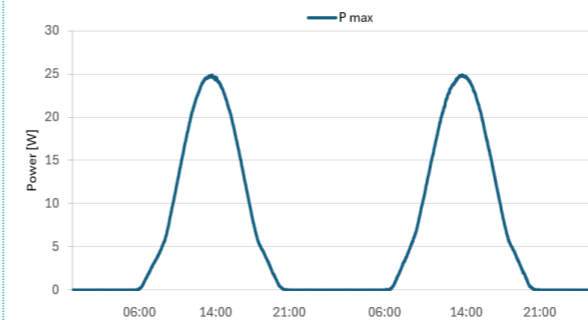
Indoor and outdoor tests of HeliaFilm modules, and image of their thermal Characterization.

Results

The tests conducted on HeliaFilm effectively highlighted its robust performance attributes. In outdoor settings, the film demonstrated a commendable performance rate of 6.7% under real conditions, underscoring its efficiency in energy conversion. The evaluation process was comprehensive, incorporating IV curve measurements and thermal imaging to meticulously assess the product's efficiency and pinpoint potential hotspots. Additionally, the testing regimen included monitoring the energy output and stability over extended periods in natural conditions, ensuring a thorough appraisal of HeliaFilm's behaviour in real-world scenarios.



HeliaFilm module façade installation picture.



IV curve at maximum power output and daily weather data plots for a large HeliaFilm panel installed vertically, simulating a real-world, south-facing building facade installation.

Conclusions

The testing and validation of Heliatek's HeliaFilm product offered valuable insights into its performance across different environmental conditions and outdoor exposure. The tests emphasized the durability and energy output of the product, particularly in building-integrated photovoltaic (BIPV) applications. These findings confirm HeliaFilm's effectiveness as a sustainable energy solution, meeting the necessary standards for long-term efficiency and reliability in nearly Zero Energy Buildings (nZEBs).



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Industrial partner:



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Chromogenics

Product: ConverLight 75

ChromoGenics is the biggest European company in the market of smart electrochromic glazing systems. Its unique technology ConverLight® provides sustainable solar control for increased indoor comfort and energy efficiency.



Dynamic variation of the visible transmittance of the Chromogenics ConverLight® 75 TGU under the application of three different bias voltages.

Pilot Measurement & Verification Line 4

Managed by: LIETAT

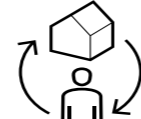


PM&VL4

The PM&VL4 line in the MEZeroE project aims to validate dynamic glazing systems for buildings, focusing on enhancing energy efficiency and occupant comfort by evaluating solar control and thermal and visual performance.



HEALTH



INTERACTION



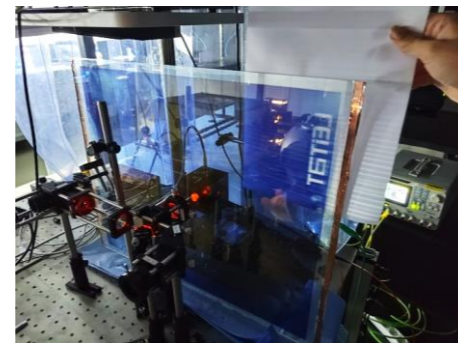
EFFICIENCY

Which is the need covered by this service?

The PM&VL4 service in the MEZeroE project evaluates dynamic glazing systems, ensuring they enhance energy efficiency and occupant comfort by effectively managing natural light and solar heat. This service aids architects and builders in integrating cutting-edge, eco-friendly glazing technologies into modern buildings, aligning with the increasing focus on environmental sustainability and energy-conscious construction. Another relevant objective of this service is to implement innovative occupant centered control algorithms capable of quantifying and minimizing thermal actions.

Design of Experiments

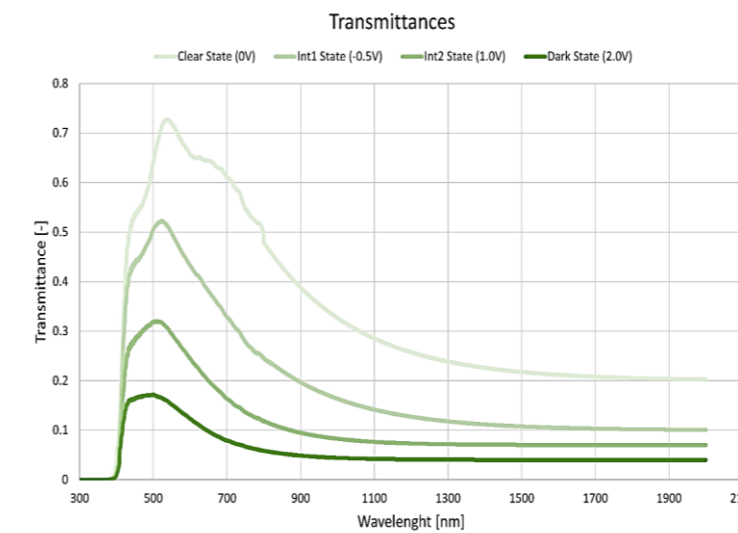
1. Optical Transmittance Test: Measurement of visible light modulation range under controlled optical conditions.
2. Solar Energy Transmittance Test: Evaluation of solar energy transmittance using EN 410 standards.
3. IGU Performance Simulation: Simulation of dynamic glazing performance under varying climate conditions.
4. Electrochromic Switching Test : Analysis of IGU switching behavior through cyclic voltammetry



Optical set-up for measurements of UV-VIS-NIR transmittance/reflectance spectra.

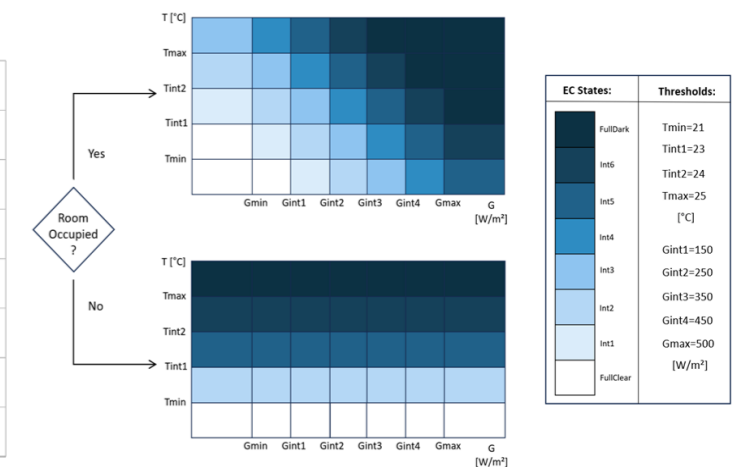
Results

1. Optical measurements demonstrated the ability of Chromogenics ConverLight 75 IGU to modulate light transmission effectively across a considerably wide range ($14\% < T_{LUM} < 71\%$)
2. Energy Performance Simulation. The smart window technologies, when simulated in different European climates, showed a significant reduction (of the order of 25-35%) in the annual overall energy consumption for heating, cooling and artificial lighting efficiency compared to the best static solar control glazing in the market.
3. To maximize the performances of the smart dynamically switchable IGUs we implemented and simulated two different algorithms, both driven by the following three basic design criteria: 1. guarantee a satisfactory visual comfort in the office by keeping the Indoor Illuminance between 300 lux and 3000 lux. 2. guarantee a satisfactory thermal comfort in the office by keeping the Indoor temperature between 20°C and 26°C. 3. minimize the overall annual energy

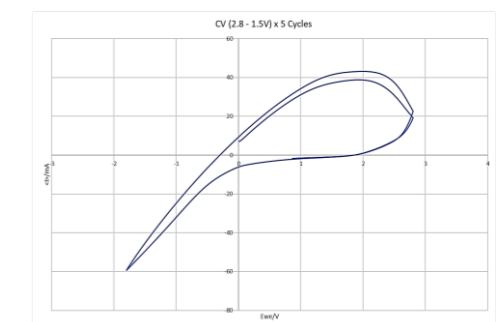


Transmittance curves of the selected states.

Solar transmittance measured according to the EN 410. Cyclic voltammetry measured in the range -2.8/+1.5V. In addition to the experimental measurements of the line, a modelling task for the component under study and building-level simulations are conducted to assess its building-wide effects. This is achieved using software tools such as Optics, WINDOW, and EnergyPlus.



Rule-based Control strategy adopted in the building simulations



Cyclic Voltammetry graph

Conclusions

The PM&VL4 testing campaign showed that dynamic glazing, as exemplified by the Chromogenics ConverLight 75 IGU can provide notable improvements in light control and energy efficiency. The adaptability of these technologies to different climates and their potential to enhance thermal comfort in buildings suggest a practical role in sustainable building design. This research offers valuable insights into the ongoing development of energy-efficient glazing solutions.



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FOCCHI

Product: multifunctional active façade

The multifunctional façade system developed by FOCCHI integrates several advanced features aiming to enhance both indoor comfort and energy efficiency. The tested solution is a system that incorporates IoT, heat pumps, automatic blinds, and window openings.

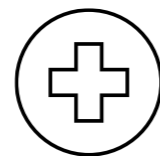
Pilot Measurement & Verification Line 5

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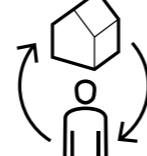


PM&VL5

The aim of PM&VL5 is a deep analysis of building envelope systems with respect to the four components defining indoor environmental quality and impact on building occupants so that they can be optimized during the operation phase as well as design or redesign stage considering users' experience.



HEALTH



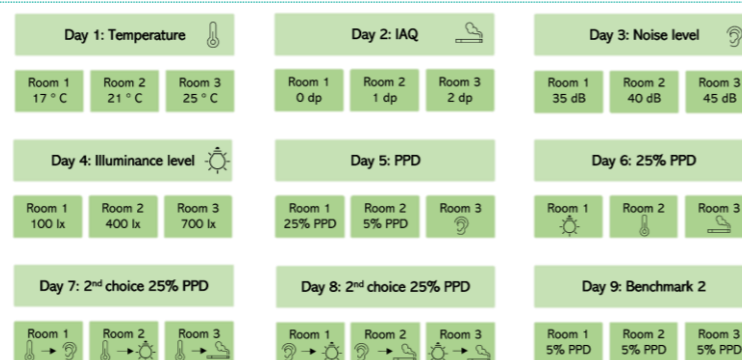
INTERACTION

Which is the need covered by this service?

Most façade products will have an impact on all four components of the indoor environment. These are thermal, acoustic and visual environment as well as indoor air quality. Installing an operable window will affect the amount of daylight, the indoor temperature will be influenced due to solar radiation and heat transmission through the window. The air quality will be influenced by the tightness of the window and by the window operation thanks to dilution ventilation. Finally, the acoustic environment will be influenced by noise penetration from the outside. PM&VL5 will attempt to characterize all four components in relation to the advanced façade component (or the entire façade) and subsequent effect on indoor environmental quality and the building occupants' comfort. The goal of the experiment was, at which hierarchical order one would restore a deteriorated indoor domain, when the subjects find each domain equally dissatisfactory.

Design of Experiments

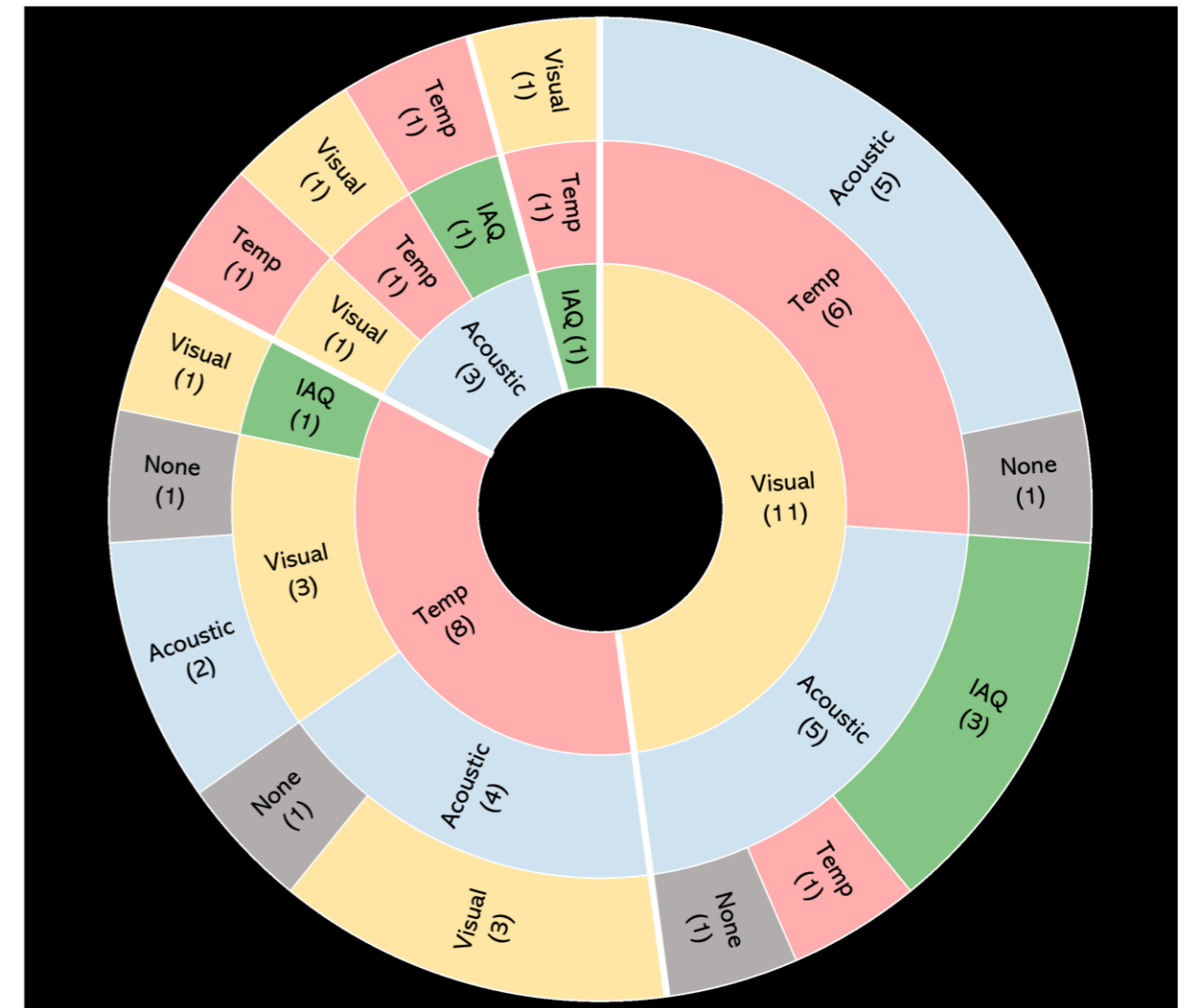
The goal of the experiments in week 1 was to establish how each subject reacted to impairments in each domain. Week two began with the subjects entering a chamber with all domains in good conditions. Thereafter, they entered a chamber where all domains were deteriorated, so the estimated level of dissatisfaction in each domain was 25%. Just before leaving the second room, they were asked, if one domain should be improved, and if yes, which one.



Overview of experimental design

Results

Most subjects opted to improve the visual environment as a first choice followed by the thermal environment. For the second choice, the most popular domain to improve was the acoustic followed by the thermal. In general, the subjects chose to improve the domain, they were most dissatisfied with.



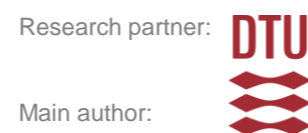
The subjects' First, second, and third choice of improvement. The inner layer represents their first choice, the middle layer being their second choice, and their third choice in the outermost layer.

Conclusions

The hierarchical order of the first improvement was visual, thermal, acoustic, and IAQ. Therefore, the visual domain should be one of the main focuses when predicting annoyances within the indoor environment. The same hierarchy is present when investigating the four domains' effect on themselves. In general, subjects improved the domain they voted least acceptable in the first and second improvement.



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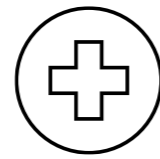
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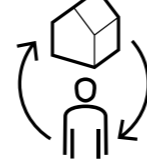


PM&VL5

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HEALTH



INTERACTION

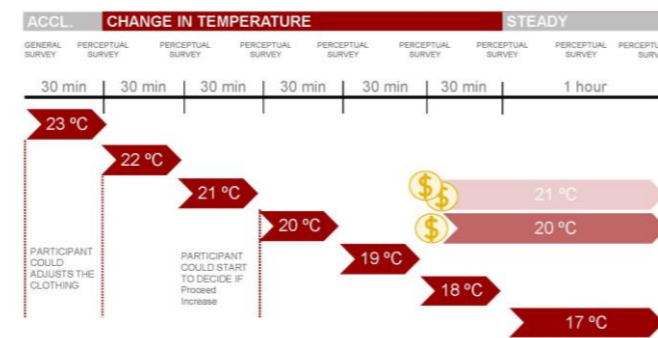
Which is the need covered by this service?

Most façade products will have an impact on all four components of the indoor environment. These are thermal, acoustic and visual environment as well as indoor air quality. Installing an energy efficient façade product will provide opportunities for providing comfortable conditions at a lower energy cost. The way the products are controlled will influence the energy efficiency which will in turn influence both energy costs and indoor environmental quality.

PM&VL5 will attempt to characterize all four components in relation to the advanced façade component (or the entire façade) and subsequent effect on indoor environmental quality and the building occupants' comfort. The goal of the test was to investigate the influence on the heating price on the occupant behaviour and decision-making process in a slightly cold controlled environment.

Design of Experiments

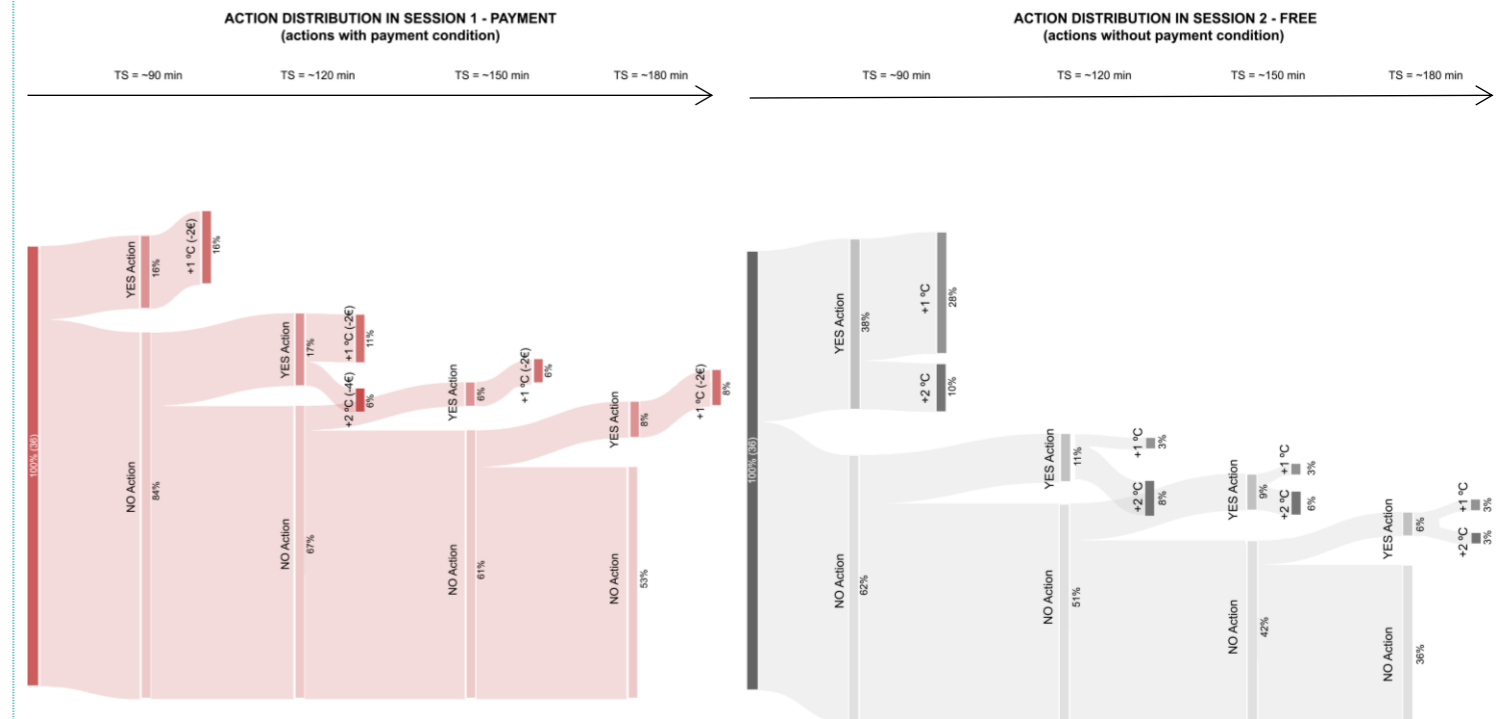
36 participants undergo a two-session experiment in an office space. They experience a gradual decrease in temperature from 23°C to 17°C. Starting from the 2nd hour, they can choose every 30 min. whether to continue the temperature decrease or raise it back to a higher level (+1°C or +2°C). In one session, they can interrupt the ramp freely, while in the other, this action comes with a payment condition (+2°C = -4€, +1°C = -2€). After the adjustment, the temperature is kept stable.



overview of a session based on the experimental design

Results

A different distribution was observed across the sessions. Specifically, when participants were asked to pay for increasing the temperature, 47% opted to make this change, while the remaining 53% chose not to adjust the indoor environment. In contrast, in the session without a payment condition, 64% of participants increased the temperature, while 36% allowed the temperature to decrease without making any adjustments. A more marked behavioral difference was observed in the choice to increase the temperature by one or two degrees. Only 6% of participants opted to raise the indoor temperature by two degrees Celsius when it was associated with a €4 charge, compared to 25% in the session where no payment was required. In contrast, the choice to increase the temperature by one degree Celsius showed less variation between the two conditions. It was selected by 42% of participants when associated with the €2 payment and by 39% when the action was free.



Distribution of participants' choices: right side shows sessions with payment conditions while left side shows sessions with free actions. Total number of participant 36, total number of sessions 72.

Conclusions

The presence of a price factor reduced the likelihood of desire to raise the temperature by 12%, as participants were more inclined to tolerate slight discomfort. A more significant difference was observed in the decision to increase the temperature by 2°C, with a 19% decrease in this choice under the 4€ payment compared to the free session. Indeed, with price factor, participants showed a slightly preference for increasing the temperature by only 1°C when it required a lower payment, suggesting a tendency to balance cost with mild discomfort.



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MULTIFUNCTIONAL ACTIVE FAÇADE

FOCCHI

Product: multifunctional active façade

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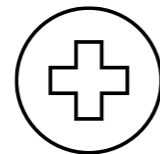
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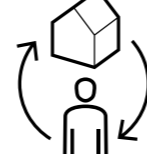


PM&VL5

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HEALTH



INTERACTION

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Design of Experiments

To quantify this interactive effects on human perception and human performance, an experiment was conducted with three parameters in control – temperature (23 °C, 28 °C), noise (quiet, babble noise), and glare (absent, present). The two levels for each for each represented comfort and discomfort conditions. Four groups of participants were randomized in a full factorial within-subjects design. The participants performed cognitive tasks as for productivity assessment, as well as subjectively assessed the indoor environment.

Week-1	T A L (Baseline)	TAL	TAL
Week-2		TAL	TAL
Week-3		TAL	TAL
Week-4		TAL	TAL

Overview of experimental design

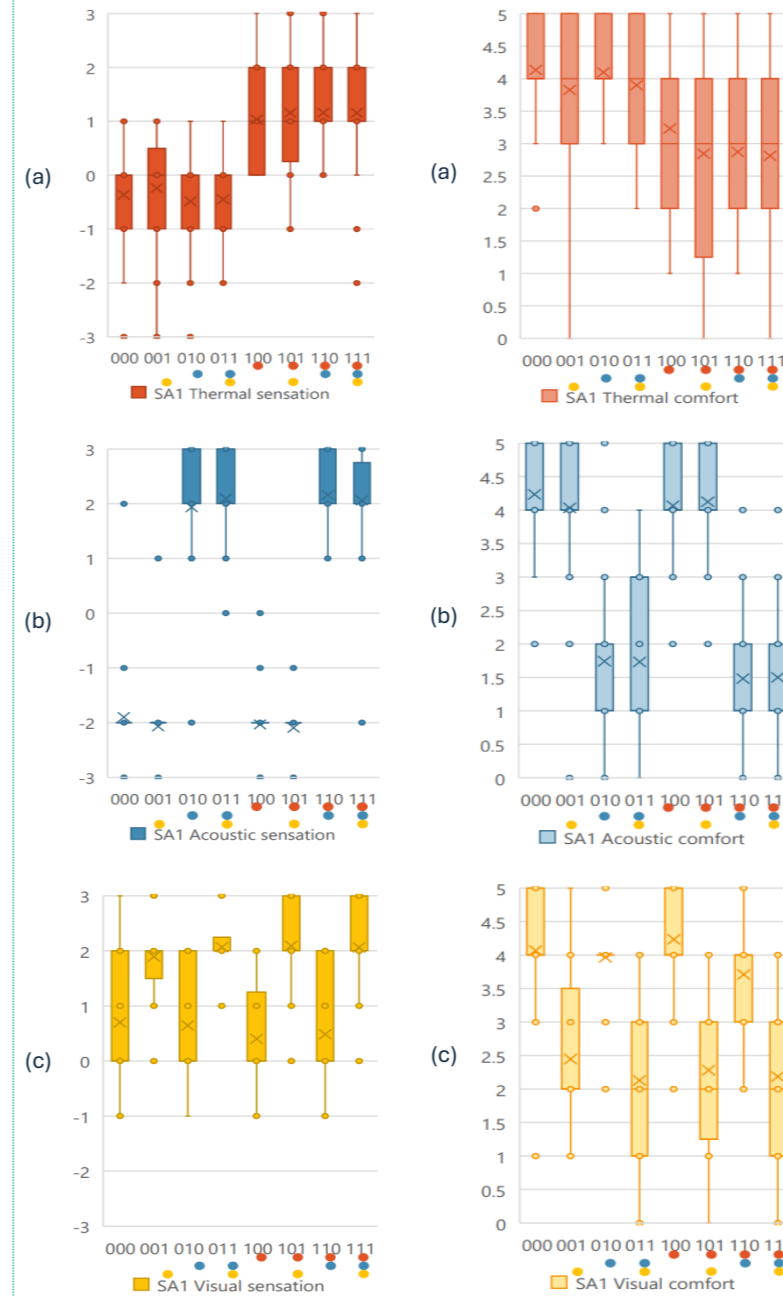


Figure 1: Sensation votes for (a) thermal, (b) acoustic, and (c) visual environment

Figure 2: Comfort votes for (a) thermal, (b) acoustic, and (c) visual environment

Results

To simplify the understanding of the two levels for each of the domains, a code was formulated, with binary digits representing comfortable and uncomfortable conditions. TAL represents the three domains, with each having a value of 0 (comfortable) or 1 (uncomfortable), depending on the condition. A preliminary analysis of the subjective assessment was done, for the three domains in consideration.

Figure 1. shows the occupant sensation for the three domains. Since the conditions were distinctively different, as in outside and within the comfort range, there was negligible interaction observed on the sensation votes.

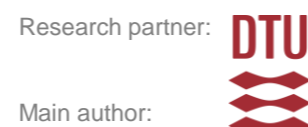
Figure 2. shows the occupant comfort votes arrange on a 5-point scale. In this case, there are some interaction effects observed. For example, from Figure 2(a), it can be seen that occupant thermal comfort decreased to a slightly in glazed environment (001 or 101) compared to non-glare (000 or 100) environments. Furthermore, the thermal comfort votes also observed a higher standard deviation in the presence of glare. For acoustic comfort as well, glare shows a slight interaction in thermally comfortable environment (010 and 011).

Conclusions

- The results confirm the evident knowledge the occupant comfort is multi-modal, since all the stimuli from various domains are perceived concurrently.
- In cases when the stimuli are as distinct as the ones causing comfort and discomfort, the interaction can be observed on occupant comfort, but not on occupant sensation.



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Industrial partner:



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TECNAN

Product: Photocatalyst Nanomaterials

Photocatalyst nanomaterial developed by TECNAN is able to interact with different indoor VOC pollutants (e.g., formaldehyde) and reduce their concentration. The test is to verify the formaldehyde removal capacity of the product.



Pilot Measurement & Verification Line 5 Managed by: DTU - Technical University of

Denmark



PM&VL5

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HEALTH



INTERACTION

Which is the need covered by this service?

Indoor formaldehyde poses a significant risk to the health of residents. While numerous materials on the market claim to efficiently remove formaldehyde, their actual performance often varies widely. Some materials perform well in dry conditions or at high formaldehyde concentrations but show a marked decline in effectiveness in humid environments. Others, particularly photocatalytic materials, may produce toxic byproducts if the reaction is incomplete or fail to remove formaldehyde entirely. Therefore, it is crucial for companies to conduct rigorous standardized testing on newly developed materials to verify their effectiveness in formaldehyde removal.

Design of Experiments

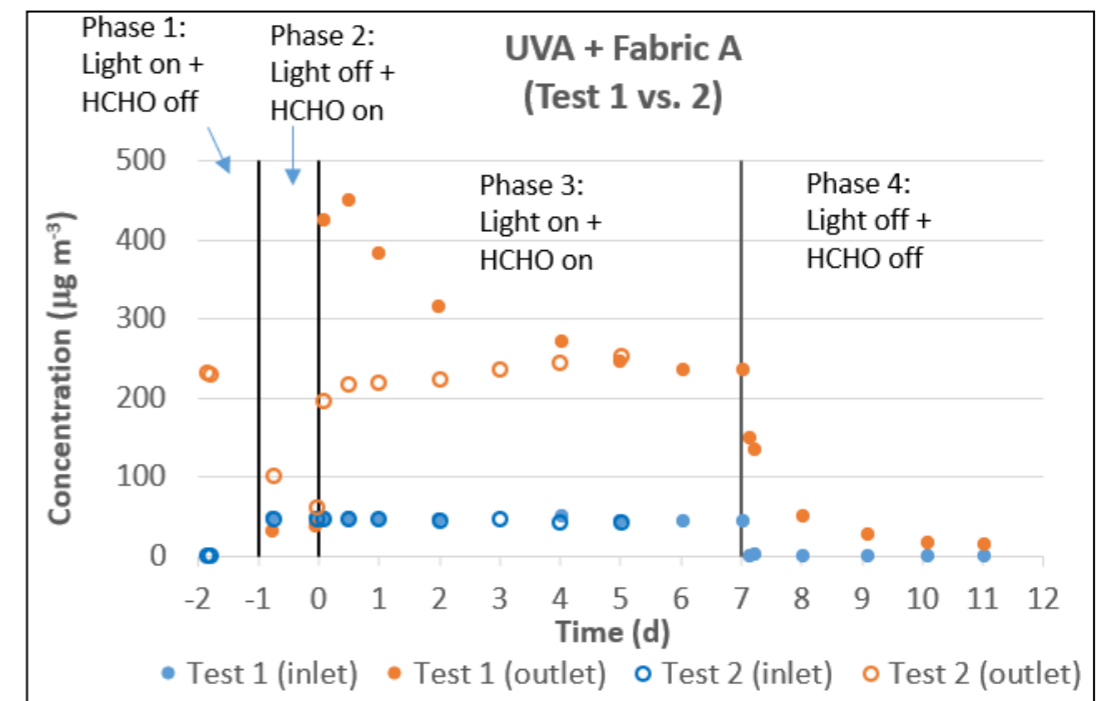
The chamber tests are performed in the stainless-steel small-scale chamber with the standard test procedure in ISO 16000-23. The temperature, relative humidity, and ventilation rate of the test are $23 \pm 1^\circ\text{C}$, $50 \pm 5\%$, and 1 ACH, respectively. The formaldehyde sorption tests are conducted with formaldehyde injection concentrations at $50 \mu\text{g}/\text{m}^3$. The formaldehyde concentrations at the inlet and the outlet of the chamber under the conditions with and without UV lights are measured. The test period depends on the surface characteristics and sorption capacity of the test specimen. The test period is 24 hours and/or 7 days.



Results

Main results/outcomes of each tests/assessment procedures:

- Phase 1** involves the sample in the chamber with the UV light on and HCHO off. The outlet concentration was increased to $\sim 230 \mu\text{g}/\text{m}^3$ with the inlet concentration of $0 \mu\text{g}/\text{m}^3$.
- Phase 2** involves the sample in the chamber with the UV light off and HCHO on. The outlet concentration was slightly lower than the inlet concentration (possibly due to the adsorption by fabric).
- Phase 3** involves the sample in the chamber with the UV light on and HCHO on. The outlet concentration was increased to $\sim 230 \mu\text{g}/\text{m}^3$ with the inlet concentration of $50 \mu\text{g}/\text{m}^3$. Newly, probably, produced by the substrate.
- Phase 4** involves the sample in the chamber with the UV light off and HCHO off. The outlet concentration was decreased to $\sim 10 \mu\text{g}/\text{m}^3$ with the inlet concentration of $0 \mu\text{g}/\text{m}^3$.
- All tests were repeated twice, and the results were almost the same.



Formaldehyde concentrations at the inlet and outlet for different tests

Conclusions Experimental test results indicate that the product sample did not achieve the expected formaldehyde adsorption performance. On the contrary, when UV lamp was turned on, the material itself (substrate) released a significant amount of HCHO. This is the reason further investigation is needed in different lines. On the one hand, experiment design can be improved 1) including a non-treated sample, to evaluate HCHO emission from the substrate, 2) if this emission exists, alternative substrates can be used to eliminate it; 3) as coating is addressed to porous materials for indoor spaces where UV part of solar light is window filtered (harmful wavelength percentage is minimum) and artificial light barely contains UV component, experiment can be performed using alternative illumination (visible range) and/or increase phase without light + HCHO on (Phase 2) where small reduction of HCHO has been observed. On the other hand, product development can be investigated A) increasing the dosage in application procedure; B) increase the concentration of catalyst and/or C) including additional active materials looking for synergies to reduce activation gap.



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TECNAN
TECNOLOGIA NAVARRA DE NANOPRODUCTOS, S.L.

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FLEXBRICK

Product: BRICKS FAÇADE SYSTEMS and BRICKS-PV cells

The façade systems consists of a grid of steel wires in where ceramic pieces (with or without PV cells) are inserted.

FLEXBRICK is an innovative company that has developed an award-winning construction system featuring patented ceramic fabrics.



Specimens and testing at M&S Lab

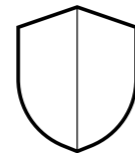
Pilot Measurement & Verification Line 6

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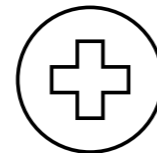


PM&VL6

PM&VL6 offers a comprehensive characterization of building envelope components, thanks to its two infrastructures: the Materials & Structures Laboratory (**M&S Lab**, mechanical characterization) and the **BEEpilot** (thermal, hygrothermal, air quality and airtightness performances).



SAFETY



HEALTH



EFFICIENCY

Which is the need covered by this service?

The characterization of damage and deformations in façade systems subjected to cyclic loads, along with the mechanical characterization of the individual elements composing the façade system.

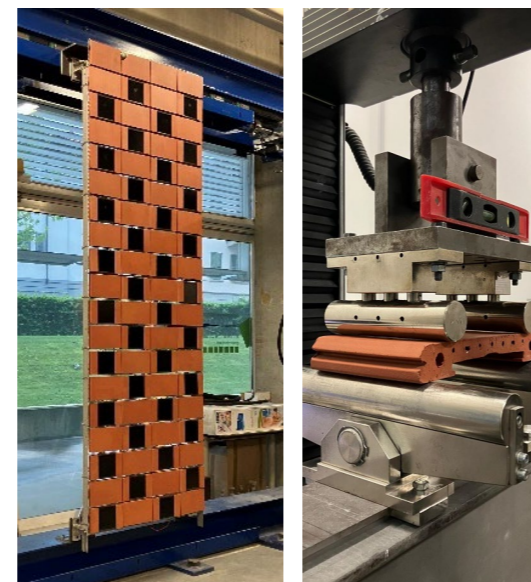
Design of Experiments

In-plane cyclic load tests

The tests involved the application of horizontal cyclic displacements, reaching maximum amplitudes of 3 cm, 6 cm, and 12 cm, simulating the inter-story drifts experienced during seismic events. The façade systems were fixed through their anchorage system to a steel frame equipped with a jack.

Bending tests

The four-point bending tests performed on bricks-PV cells aimed to evaluate the bending properties of the element. The test setup consists of two support points spaced 210 mm apart and two loading points positioned 150 mm apart. The test is conducted under cross-head displacement control at a rate of 1×10^{-3} mm/s. The PV cells are removed from the element before the execution of the test.



Execution of in-plane cyclic load test (left) and pull-out test (right).

Results

In-plane cyclic load tests

Figures 1 and 2 show the load vs. displacement history of bricks façade system with and without PV cells, respectively. In Figure 1 the slope of the loading phase for amplitudes of 60 mm and 120 mm exhibits similar behavior, whereas a very minimal stiffness degradation is observed in the case of the 240 mm amplitude. Both façade systems do not show any obvious signs or effects due to the imposed cyclic stresses. Only a slight shifts between the ceramic pieces and a grid of steel wires (Figure 3), and a residual deformation at the anchorage point (Figure 4) can be observed.

Bending tests

Figure 5 represents the load vs. displacement curve of each sample subjected to four-point bending tests. Table 1 summarizes the peak load of each curve, along with the average value and the standard deviation (SD). All specimens failed due to shear (Figure 6), approximately in correspondence of one of the two loading points (only sample Cell_PV_2 failed due to bending, as visible in Figure 7).

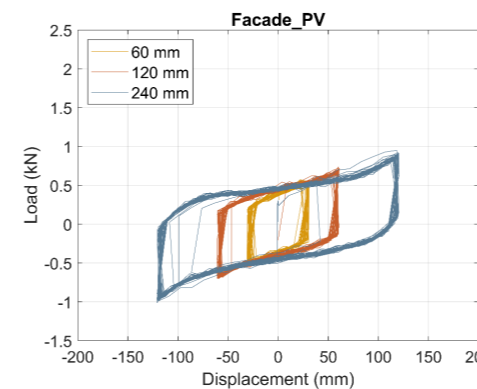


Figure 1

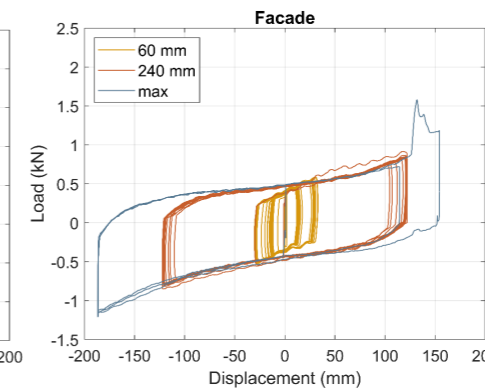


Figure 2



Figure 3

Figure 4

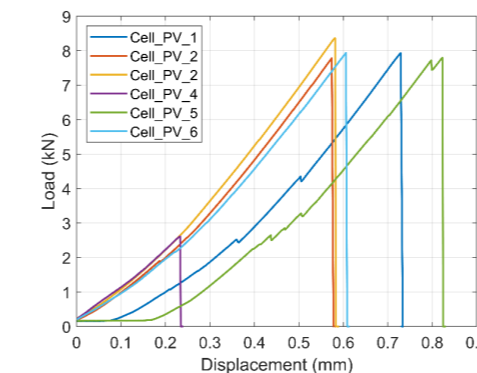


Figure 5

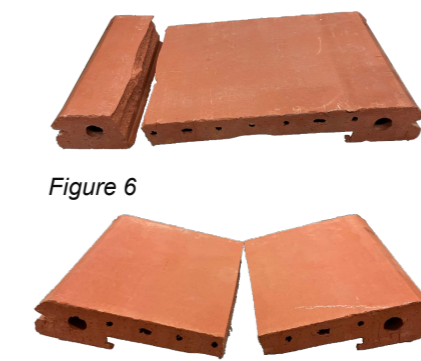


Figure 6

Figure 7

Sample name	Peak load [kN]
Cell PV 1	7.93
Cell PV 2	7.78
Cell PV 3	8.36
Cell PV 4	2.61
Cell PV 5	7.80
Cell PV 6	7.93
Average	7.07
SD	2.19

Table 1

Conclusions

It was possible to evaluate the deformations and the potential presence and evolution of damage in façade systems subjected to in-plane cyclic loads through the analysis of load-displacement histories and visual inspection. Moreover, it was possible to mechanically characterize the bending behavior of the bricks-PV cells that compose the façade systems.



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THERMAL MONITORING OF A HEAT BARRIER TREATMENT FOR GLASS SURFACES

TECNAN

Product: TECNADIS HEATSHIELD

TECNAN offers a wide spectrum of nanoparticle materials, which can be employed in several different industries and applications.

Their **TECNADIS HEATSHIELD** is a thermal protective coating for glazed surfaces, designed to block the transmission of infrared solar radiation.



Application of the product within the BEEpilot test facility

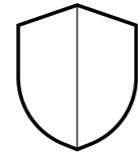
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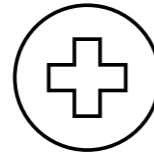


PM&VL6

PM&VL6 offers a comprehensive characterization of building envelope components, thanks to its two infrastructures: the Materials & Structures Laboratory (**M&S Lab**, mechanical characterization) and the **BEEpilot** (thermal, hygrothermal, air quality and airtightness performances).



SAFETY



HEALTH



EFFICIENCY

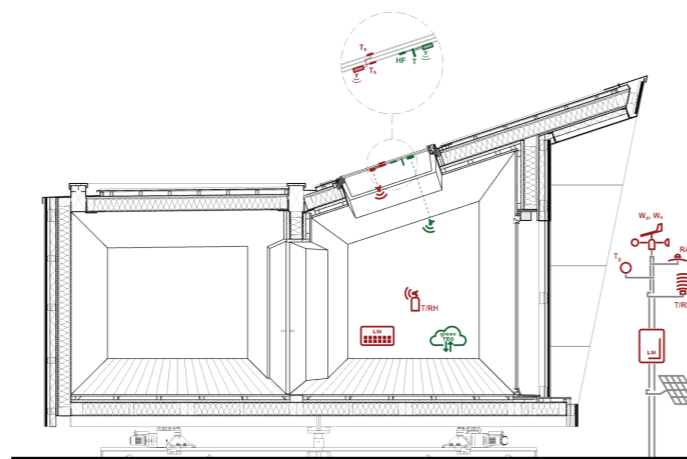
Which is the need covered by this service?

Buildings are the biggest energy end-use sector, with heating and cooling as key factors contributing to such trend, thus representing commonly poorly performing envelopes. This could be generally predicted and prevented during the design-phase, but on-site measurements have shown wide gaps in the actual operative performance of buildings. The real-life performance assessment is thus a powerful way to evaluate and potentially prevent such gaps. In that context, the activity aimed to **accurately assess the performance and behavior of the TECNAN product in real-life conditions.**

Design of Experiments

The product was applied on the **exterior glass surface of one of the two roof windows** (facing SW), according to instructions provided by the manufacturer. The assessment was based on the simultaneous monitoring and comparison of glass surfaces with and without protective coating.

The monitoring started in spring 2023 and was conducted for 5 months under real-life outdoor conditions. The product was applied in the office portion of the **BEEpilot**, in Lecco (IT), and was hence subject to real-life indoor conditions as well (split system operated according to user comfort).

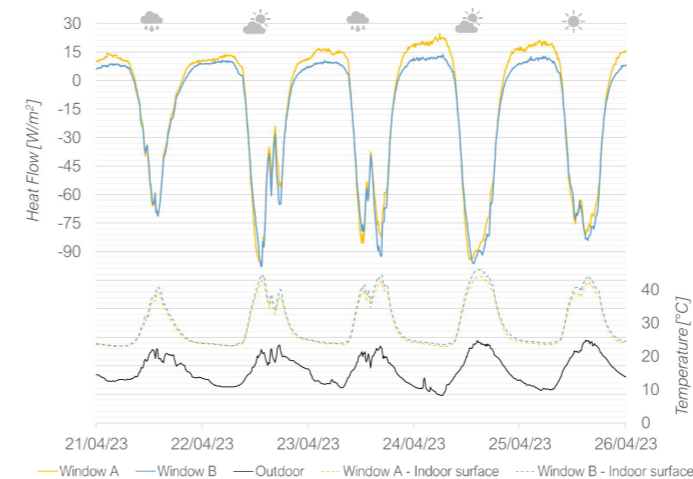


Monitoring setup for the thermal performance assessment

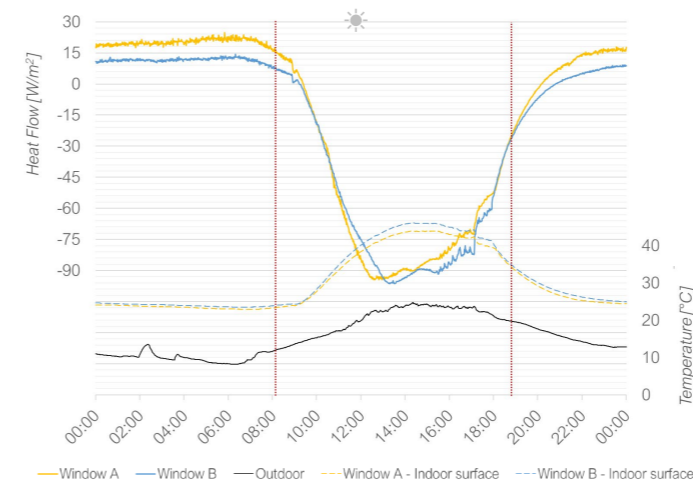
Results

April 2023

During daylight hours, the coating reduces heat flows compared to a standard roof window with no coating. The product has a positive effect in lowering the temperatures recorded on the inner surface of the roof window.



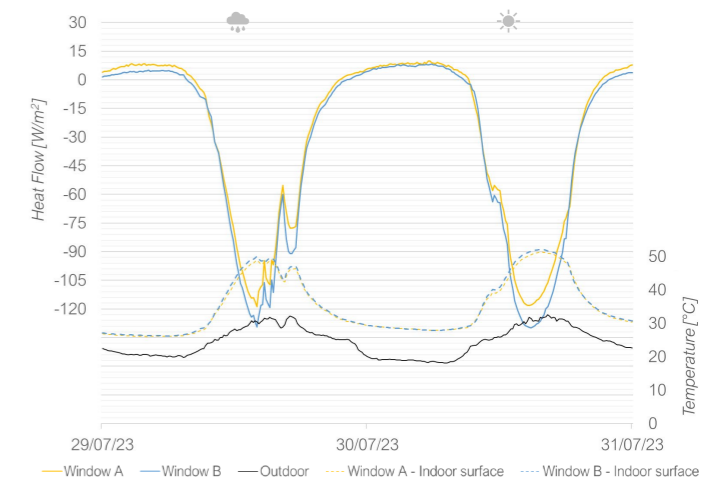
21st-25th April 2023 - Comparison between Window A (with coating, yellow) and Window B (without coating, blue).



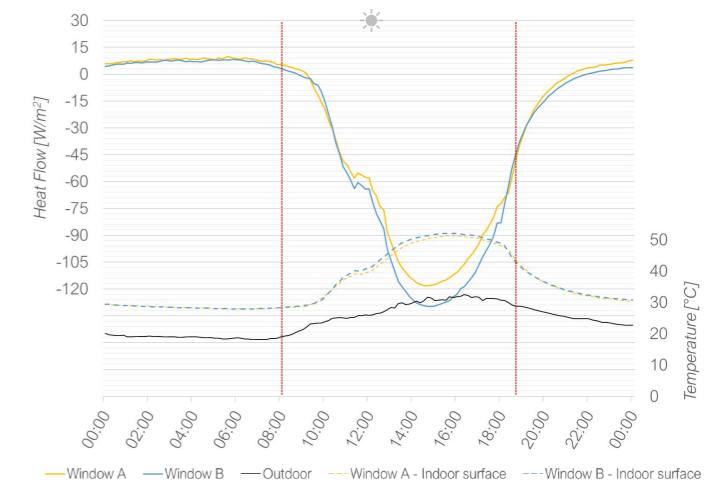
26th April 2023 - Comparison between Window A (with coating, yellow) and Window B (without coating, blue).

July 2023

During daylight hours, the product remarkably reduces heat flows if compared to the roof window with no coating applied. This happens, at different degrees, both on days with clear sky as well as on cloudy and/or rainy days.



29th-30th July 2023 - Comparison between Window A (with coating, yellow) and Window B (without coating, blue).



30th July 2023 - Comparison between Window A (with coating, yellow) and Window B (without coating, blue).

Conclusions

The thermal monitoring has allowed to understand the real-life coating behavior and contribution in terms of effectively blocking the transmission of infrared solar radiation through the glazing surface. This performance has, in particular, shown higher contributions during daylight hours in summer, thus ensuring higher thermal comfort levels indoor.



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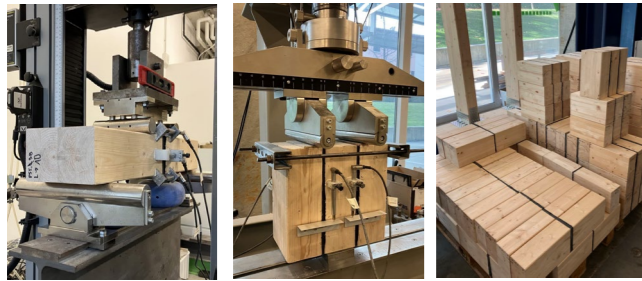


FLEX&ROBUST

Product: FLEXIBLE PU JOINTS

The flexible structural connectors are made of four types of prefabricated polyurethane layers (PM, PS, PST, PTS), bonded with a new PU adhesive.

FLEX&ROBUST is a technology company established in 2016 and based in Poland, offering polymer flexible connectors developed by scientists from the Krakow University of Technology.



Specimens and testing at M&S Lab

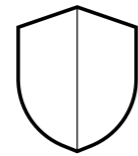
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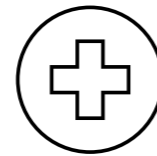


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SAFETY



HEALTH



EFFICIENCY

Which is the need covered by this service?

The mechanical characterization of different types of products, differing in material and thickness, to compare their properties and behavior.

Design of Experiments

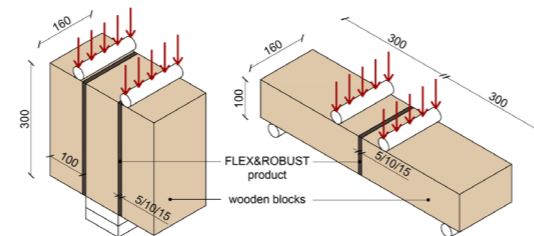
Bending strength

The samples, composed by a polymer layer located at the point of contact between two wooden blocks, were tested with an electromechanical press using a 4-point bending setup in displacement control (with different rates) to determine the bending strength.

Shear strength

The samples, composed by two polymer layer located at the point of contact between three wooden blocks, were tested with a hydrodynamic press using two loading points on the two outer wooden blocks and one support point on the middle block. The tests were performed in displacement control to determine the shear strength.

Were tested four different types of polymer characterized by three different thickness.



Execution of a bending strength test and setup of the two tests

Results

Bending strength

Table 1 summarizes the average values of the bending strength, expressed in MPa, and the corresponding displacement, expressed in mm.

The stresses were calculated using the formula: $\sigma = M/W$, where M is the bending moment and w is the resistance modulus calculated with $W = (b \cdot h^2)/6$. The displacements considered were measured by the two LVDTs placed on the lower edge of the sample and are denoted as d-bot.

Shear strength

Table 2 summarizes the average values of the nominal shear strength, expressed in MPa, with the corresponding slip, expressed in mm and calculated from the average of the four LVDTs. Maximum shear strength is calculated, according to the formula: $\tau = V/(2 \cdot A)$, where V is the shear.

Sample name	Bending strengths [MPa]	Corresponding d-bot [mm]
PM_5_B	0.117	0.292
PM_10_B	0.167	0.855
PM_15_B	0.986	4.456
PS_5_B	0.263	0.267
PS_10_B	0.375	0.301
PS_15_B	0.295	0.685
PST_5_B	0.494	0.718
PST_10_B	0.593	1.138
PST_15_B	0.798	2.066
PTS_5_B	0.230	0.152
PTS_10_B	0.245	0.852
PTS_15_B	1.249	3.161

Table 1

Sample	Shear strengths [MPa]	Corresponding average slip [mm]
PM_5_S	0.235	5.346
PM_10_S	0.214	5.485
PM_15_S	0.193	4.662
PS_5_S	0.482	2.523
PS_10_S	0.648	4.803
PS_15_S	0.177	1.323
PST_5_S	0.282	2.348
PST_10_S	0.340	2.616
PST_15_S	0.340	5.213
PTS_5_S	0.839	8.098
PTS_10_S	0.749	9.647
PTS_15_S	0.487	6.846

Table 2

Conclusions

It was possible to mechanically characterize the new adhesive working with prefabricated PU layers, specifically defining the bending and shear strengths. Thanks to the instrumentation used, vertical and horizontal displacements in the case of the bending test and slip in the case of the shear test were also taken into account. It is also possible to compare the mechanical properties of the adhesive influenced by the four different polymers and the three different thicknesses of each polymer.



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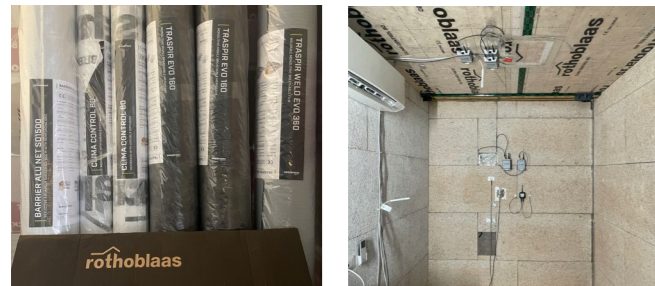
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ROTHO BLAAS

Products: CLIMA CONTROL 80, BYTUM BASE 2500, BYTUM SLATE 3500, TRASPIR EVO 160, TRASPIR WELD EVO 360, GROUND BAND

ROTHO BLAAS is an Italian multinational, leading developer and provider of high technology products and services dedicated to wood carpentry, amongst which membranes, tapes and soundproofing profiles.



Application of the membranes within the BEEpilot test facility

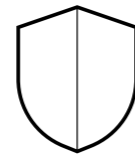
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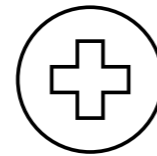


PM&VL6

PM&VL6 offers a comprehensive characterization of building envelope components, thanks to its two infrastructures: the Materials & Structures Laboratory (M&S Lab, mechanical characterization) and the BEEpilot (thermal, hygrothermal, air quality and airtightness performances).



SAFETY



HEALTH



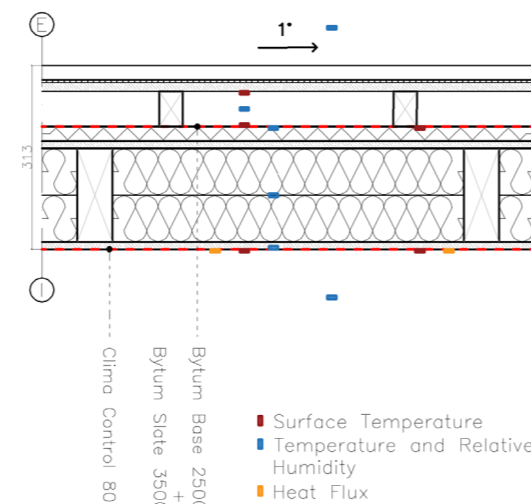
EFFICIENCY

Which is the need covered by this service?

The interaction between the building envelope and all the interior and exterior boundary conditions determines the hygrothermal properties of a building. The real-life monitoring of the resulting hygrothermal behavior of a building is essential for the development of solutions that would avoid critical conditions, improve hygrothermal comfort, and reduce energy consumption. In that context, the activity aimed to **accurately assess the performance and behavior** of four different combinations (two for façades, two for roofs) of ROTHO BLAAS membranes in **real-life conditions**.

Design of Experiments

The products were installed within **4 different building components**, according to instructions provided by the manufacturer. The assessment was based on the simultaneous monitoring and comparison of values recorded by the same continuous monitoring system in both test rooms. The monitoring started in August 2022 and was conducted for 18 months under real-life outdoor conditions. The products were applied in the two Test Rooms of the BEEpilot, in Lecco (IT), that also feature two direct air humidifiers (power up to 0.5 kg/h) to control their indoor relative humidity levels. At first their operation was manual; from late January 2023, although, a threshold value of 65-70% RH was set.



Example of monitoring set-up (Test Room A, roof)

Results

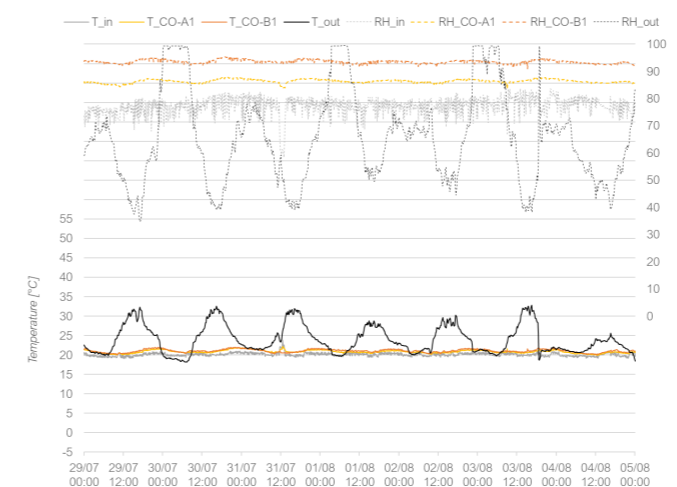
Test Room A and Test Room B – Building component: ROOF

Inner membranes

Winter: comparable behavior in both Test Rooms A-B.
Summer: roof system in Test Room A (yellow in charts below) ensures lower RH values (about 10% less than Test Room B, orange).



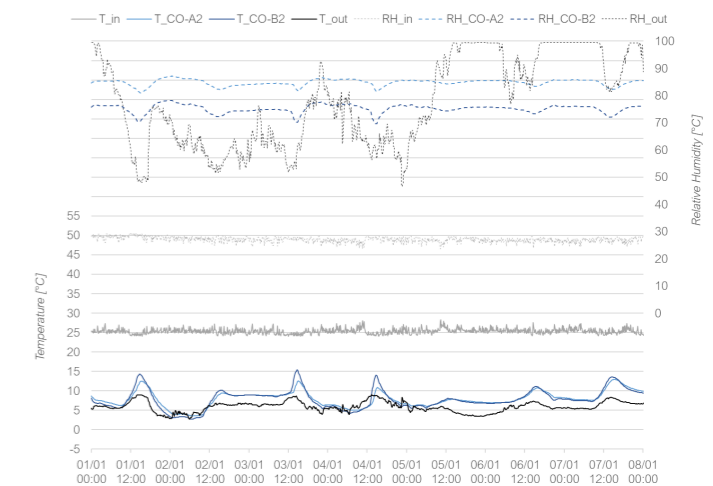
Winter, inner membranes: temperature [°C] and RH [%]



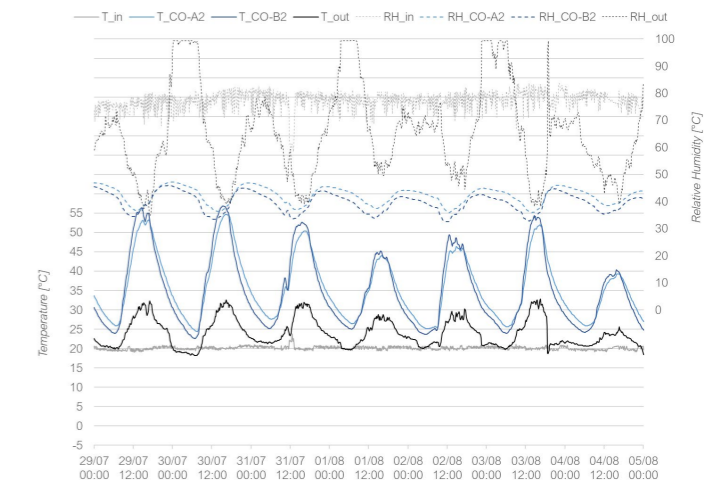
Summer, inner membranes: temperature [°C] and RH [%]

Outer membranes

Winter: bituminous membranes in roof system of Test Room A (light blue in charts below) result in higher RH values (about 15% more than Test Room B, blue).
Summer: comparable behavior in both Test Rooms A-B.



Winter, outer membranes: temperature [°C] and RH [%]



Summer, outer membranes: temperature [°C] and RH [%]

Conclusions

The 18-months monitoring has allowed an in-depth study of the real-life hygrothermal behavior of the four different sets of products object of test. Dealing with membranes with varying and variable vapor resistance properties, and considering the respective different real-life environmental conditions, the comparison between winter and summer season was found of particular relevance.



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ROTHO BLAAS

Product: FLEXI BAND UV tape + TRASPIR EVO UV 115 membrane and SMART BAND tape + TRASPIR EVO 160 membrane

The tapes are universal single-side adhesive and the membranes are highly breathable monolithic.

ROTHO BLAAS is an Italian multinational, leading developer and provider of high technology products and services dedicated to wood carpentry.



Preparation and testing of tape-membrane joints at M&S Lab

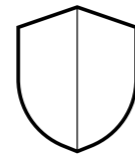
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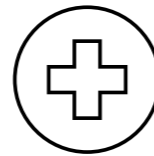


PM&VL6

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SAFETY



HEALTH



EFFICIENCY

Which is the need covered by this service?

The mechanical characterization of different types of products to compare their properties and characteristics and evaluate the possible influence of different external conditioning on the mechanical properties of the elements.

Design of Experiments

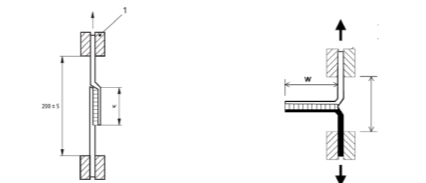
Shear resistance of joints

The samples were clamped in an electromechanical press and a tensile force, sufficient to cause the failure or the separation of the joints, was applied vertically to pull the samples in shear. The shear resistance of joint was determined (EN 12317-1:2010)

Peel resistance of joints

The samples were clamped in an electromechanical press and a tensile force, sufficient to cause the failure or the separation of the joints, was applied vertically. The resistance to peeling of joints was determined (EN 12316-1:2000).

The tests were performed after standard conditioning, after one year of UV exposure and after freeze and thaw cycles.



Shear and Peel resistance of joint test

Results

Shear resistance of joints

Table 1 summarizes the average values of the shear resistance of joint, expressed in N/50mm. The repeatability of tests for each type of sample was equal to three.

Peel resistance of joints

Table 2 summarizes the mean values of the maximum peel resistance and of the average peel resistance, expressed in N/50mm. The repeatability of tests for each type of sample was equal to three.

Sample name	Average shear resistance [N/50mm]
FLEXI+EVO115_S	118.1
FLEXI+EVO115_S_UV	107.4
FLEXI+EVO115_S_FT	141.3
SMART+EVO160_S	82.6
SMART+EVO160_S_UV	86.1
SMART+EVO160_S_FT	132.0

Table 1

Sample name	Maximum peel resistance [N/50mm]	Average peel resistance [N/50mm]
FLEXI+EVO115_P	45.9	43.3
FLEXI+EVO115_P_UV	47.1	44.5
FLEXI+EVO115_P_FT	88.8	76.9
SMART+EVO160_P	30.6	28.5
SMART+EVO160_P_UV	35.8	31.5
SMART+EVO160_P_FT	60.5	53.6

Table 2

The sample name is composed of a first part that represents the abbreviation of the product name and 'S' or 'P' which represents the type of test (shear resistance or peel resistance of joints). If there is no additional letters after 'S' or 'P', it means that the test is performed under normal conditions, otherwise 'UV' represents the samples exposed to UV radiation for one year, and 'FT' represents the samples subjected to freeze-thaw cycles.

Conclusions

It was possible to mechanically characterize the component, specifically defining the shear and the peel resistance of the joint. It is also possible to compare the various types of specimens by evaluating the influence of different conditioning processes on the mechanical properties of the component. In this case, the influence is negligible, demonstrating the good durability of the products after one year of UV exposure or freeze and thaw cycles.



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Testing of tapes and membranes at M&S Lab

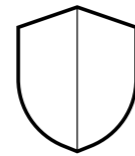
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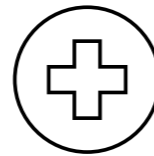


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SAFETY



HEALTH



EFFICIENCY

Which is the need covered by this service?

The mechanical characterization of different types of products to compare their properties and characteristics and evaluate the possible influence of different external conditioning on the mechanical properties of the elements.

Design of Experiments

Tensile resistance (on tapes and membranes)

The samples were subjected to a tensile force, sufficient to cause the failure, applied in the direction of the longitudinal axis of the sample. The tensile properties were determined (tapes: EN ISO 29864, method A) (membranes: EN 12311-1:2000).

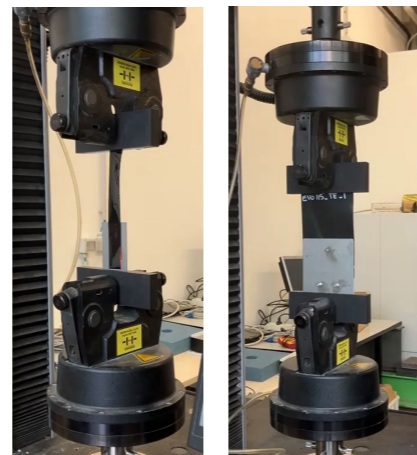
Peel adhesion on steel 180° (on tapes)

The samples, consisting of a portion of the tape fixed on a steel plate, were tested by applying a tensile force to the free end of the tape at an angle of 180° to the plate. The peel adhesion properties were determined (EN ISO 29862:2019, method 1).

Tearing resistance (on membranes)

The portion of membrane was placed in a close-fitting stirrup, and a sharpened nail was inserted so that shank pierces the membrane. The samples were subjected to a tensile force and the tearing resistance was determined (EN 12310-1:2000).

The tests were performed with an electromechanical press after standard conditioning, after one year of UV exposure and after freeze and thaw cycles



Tape and membrane tests

Results

Tensile resistance

Table 1 summarizes the average values of the breaking strength, expressed in N/10mm for tapes and in N/50 mm for membranes, and the corresponding elongation, expressed as a percentage of the original sample length. If the failure is not reached, the maximum resistance value is provided (sample values that reached failure are marked in the table with an asterisk).

Peel adhesion on steel 180°

Table 2 summarizes the average values of the peel adhesion, expressed in N/10mm.

Tearing resistance

Table 3 summarizes the average values of the maximum tearing force, expressed in N.

Tensile resistance (on tapes)		
Sample name	Max. or breaking* strength [N/10mm]	Corresponding elongation [%]
FLEXI T	24.4	32.8
FLEXI T s	25.6 (21.3*)	42.1 (736.4*)
FLEXI T UV	19.7	13.8
FLEXI T FT	28.3	32.1
FLEXI T FT s	28.6 (24.4*)	36.3 (651.9*)
SMART T	19.3*	291.0*
SMART T s	32.7*	681.0*
SMART T UV	18.2*	298.1*
SMART T FT	24.1*	308.2*
SMART T FT s	22.8*	335.1*

Tensile resistance (on membranes)		
Sample name	Breaking strength [N/50mm]	Corresponding elongation [%]
EVO115 T	192.9	80.6
EVO115 T UV	129.7	55.1
EVO115 T FT	203.2	77.5
EVO160 T	203.4	46.1
EVO160 T UV	164.2	30.0
EVO160 T FT	222.9	48.8

Table 1

The sample name is composed of a first part that represents the abbreviation of the product name and 'S' or 'P' which represents the type of test (shear resistance or peel resistance of joints). If there is no additional letters after 'S' or 'P', it means that the test is performed under normal conditions, otherwise 'UV' represents the samples exposed to UV radiation for one year, and 'FT' represents the samples subjected to freeze-thaw cycles.

Peel adhesion on steel 180° (on tapes)	
Sample name	Max. peel adhesion [N/10mm]
FLEXI_P	13.2
FLEXI_P UV	12.6
FLEXI_P FT	20.6
SMART_P	11.1
SMART_P UV	11.3
SMART_P FT	14.9

Table 2

Tearing resistance (on membranes)	
Sample name	Max. tearing force [N]
EVO115_TE	147.9
EVO115_TE UV	90.4
AEVO115_TE_FT	168.2
EVO160_TE	165.5
EVO160_TE UV	99.5
EVO160_TE_FT	181.1

Table 3

Conclusions

It was possible to mechanically characterize the component, specifically defining the shear and the peel resistance of the joint. It is also possible to compare the various types of specimens by evaluating the influence that different conditionings have on the mechanical properties of the component.



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INDRESMAT

Product: KLIMA-PUR Window Profiles

INDRESMAT is an international chemical startup founded in 2017 and based in Barcelona and Geleen, one of the few worldwide companies developing innovative products and technologies for bioPolyurethane (bioPUR) materials. Among such products are the KLIMA-PUR window profiles.



Example of thermal (left) and mechanical (right) tests setup

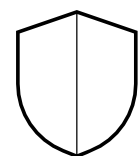
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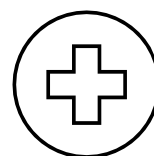


PM&VL6

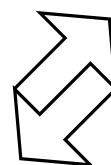
PM&VL6 offers a comprehensive characterization of building envelope components, thanks to its two infrastructures: the Materials & Structures Laboratory (M&S Lab, mechanical characterization) and the BEEpilot (thermal, hygrothermal, air quality and airtightness performances).



SAFETY



HEALTH



EFFICIENCY

Which is the need covered by this service?

Assess the performance and behavior of the window frame in a controlled lab environment and mechanically characterize it.

Design of Experiments

Thermal characterization

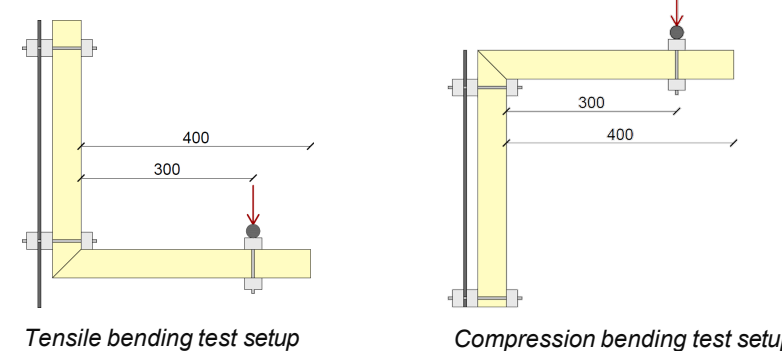
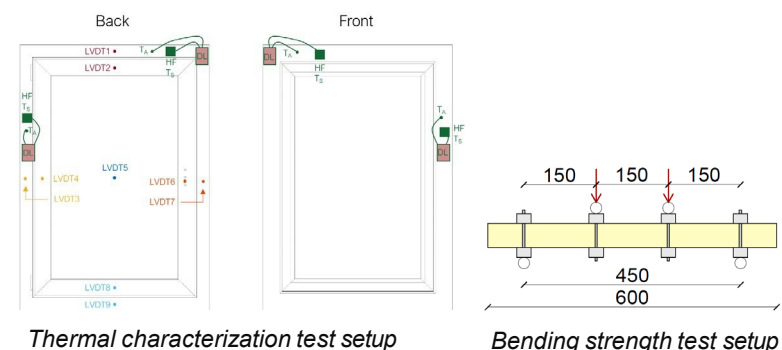
The component was tested under accelerated IR exposure (for 8 hours) generated by two IR-ray radiant panels. Through the entire test, displacements, surface/ambient temperatures and relative humidity were logged.

Bending strength

Linear segments of the frame were tested using a 4-point bending setup, loading the sample up to a limit displacement and then unloading it.

Compression and Tensile bending

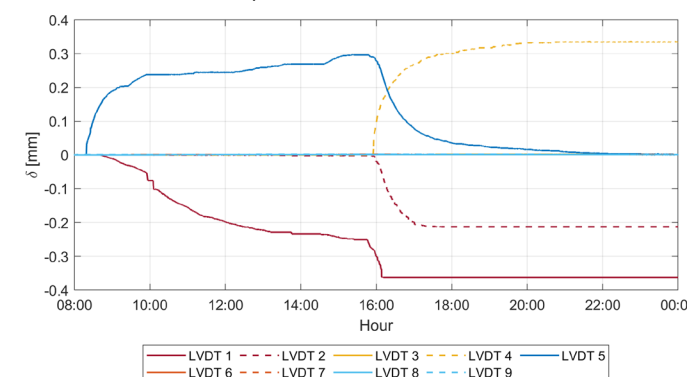
Angles of the frame were tested by applying a load to one end of the specimen, closing (compression test) or opening (tensile test) the corner.



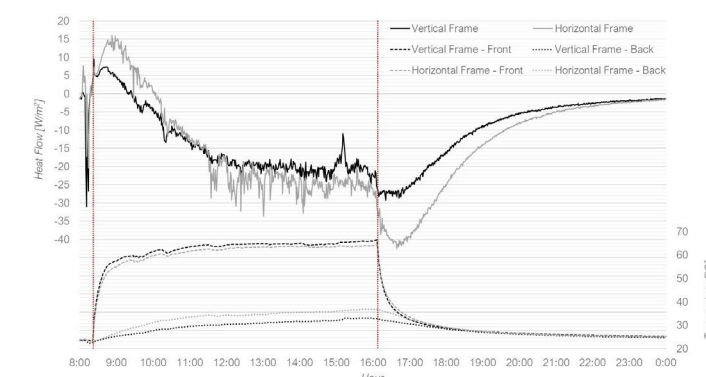
Results

Thermal characterization

- Displacements:** the results show displacements reaching a maximum of about 0.4 mm after 8 hours of irradiation. Given the magnitude of the displacements, it can be inferred that they are negligible.
- Heat flow:** consistency in average values on horizontal and vertical frames (-14 W/m²). The horizontal frame (grey line) shows a broader trend, exceeding peaks recorded on vertical element (black line).
- Surface temperature:** on the front, comparable temperatures on vertical and horizontal frames. On the back, during IR exposure (8:20 am - 4 pm), the vertical element recorded stably lower temperatures (about 4 °C less than the horizontal frame).



Displacement vs. time: comparison between the 9 LVDTs.



Heat flow (W/m²) and surface temperatures (°C): comparison between vertical and horizontal frames behavior.

Bending strength

Table 1 summarizes the average values of the slope of the loading and unloading branch in load vs. vertical displacement curves.

Compression and Tensile bending

Table 2 shows the average values of the slope of the loading and unloading branch in load vs. vertical displacement curves of samples subjected to compression bending tests. Table 3 summarizes the average peak load of load vs. vertical displacement curves of samples subjected to tensile bending tests.

Sample name	Slope loading branch [kN/mm]	Slope unloading branch [kN/mm]
KLIMA_f_b	0.415	0.402
KLIMA_m_b	0.439	0.430
KLIMA_f_b_ft	0.469	0.450
KLIMA_m_b_ft	0.386	0.367

Table 1

Suffix 'ft' stands for samples priorly subjected to freeze-thaw cycles.

Sample name	Slope loading branch [kN/mm]	Slope unloading branch [kN/mm]
KLIMA_c	0.0147	0.0134
KLIMA_c_ft	0.0144	0.0131

Table 2

Sample name	Peak load [kN]
KLIMA_t	0.285
KLIMA_t_ft	0.255

Table 3

Conclusions

The thermal characterization under accelerated IR exposure has allowed to understand the frame behavior in excess of its normal service parameters, showing negligible displacements. Linear and angular portions of the frame were also mechanically characterized, specifically defining bending properties and evaluating the influence of different conditioning.



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Research partner:



Main author(s):
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Industrial partner:



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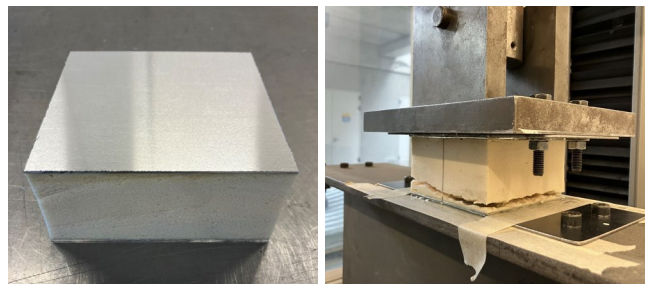
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INDRESMAT

Product: SAFE-PUR (Alifatic based PUR)

INDRESMAT is an international chemical startup founded in 2017 and based in Barcelona and Geleen, one of the few worldwide companies developing innovative products and technologies in biobased Polyurethane (bioPUR) materials. Among such products is the **SAFE-PUR SANDWICH** panel.



Sample before (left) and during the test (right)

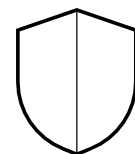
Pilot Measurement & Verification Line 6

Managed by: Politecnico di Milano (POLIMI)

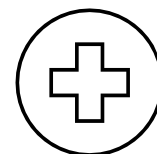


PM&VL6

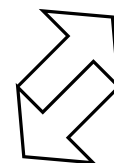
PM&VL6 offers a comprehensive characterization of building envelope components, thanks to its two infrastructures: the Materials & Structures Laboratory (**M&S Lab**, mechanical characterization) and the **BEEpilot** (thermal, hygrothermal, air quality and airtightness performances).



SAFETY



HEALTH



EFFICIENCY

Results

Table 1 provides the output data of each test, the average value and the standard deviation (SD).

The table shows the cross panel tensile strength (f_{ct}) and tensile E-modulus of the core (E_{ct}), calculated with the following formulas:

$$f_{ct} = \frac{F_u}{A}$$

$$E_{ct} = \frac{F_u \cdot d_c}{w_u \cdot A}$$

Where ' F_u ' is the ultimate load; ' A ' is the cross-sectional area of the specimen determined from the measured dimensions (100 x 100 mm²); ' w_u ' is the ideal displacement at ultimate load based on the linear part of the curve; ' d_c ' is the thickness (50 mm).

Figure 1 is a representative example of the load versus displacement experimental curve of sample coded as 'SAFE_1'. The displacement is the vertical displacement of the cross-head machine.

In the graph w_u and F_u are highlighted.

Sample	F_u (N)	w_u (mm)	F_{ct} (MPa)	E_{ct} (MPa)
SAFE_1	1379.29	1.15	0.14	6.00
SAFE_2	1144.45	1.77	0.11	3.23
SAFE_3	990.26	2.04	0.10	2.43
SAFE_4	1326.81	1.85	0.13	3.59
SAFE_5	1012.93	3.02	0.10	1.68
SAFE_6	1427.15	2.02	0.14	3.53
SAFE_7	1153.92	1.34	0.12	4.31
SAFE_8	1172.92	1.21	0.12	4.85
Average	1200.97	1.80	0.12	3.70
SD	162.46	0.61	0.02	1.36

Table 1

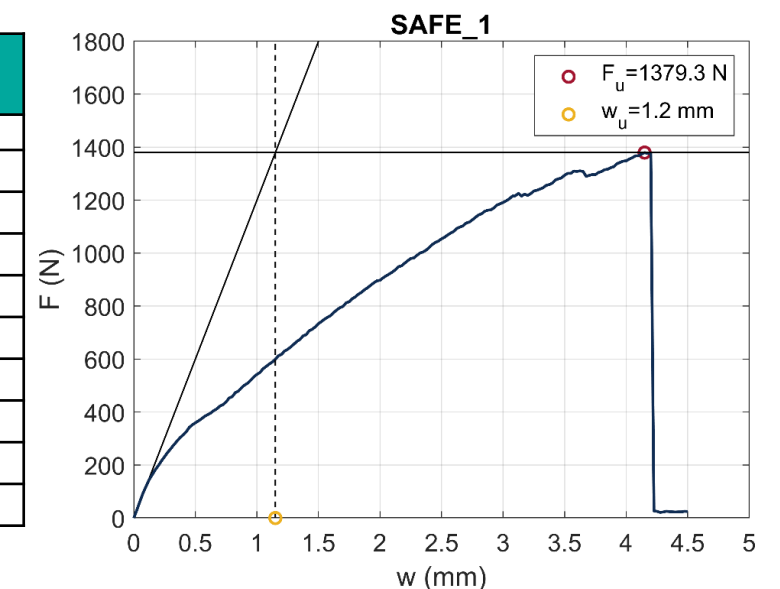


Figure 1

Which is the need covered by this service?

The mechanical characterization of an innovative product, with refer to the cross panel tensile strength and tensile E-modulus.

Design of Experiments

Cross panel tensile strength test

Eight samples, consisting of a portion of the panel and measuring 100 x 100 x 50 mm³ were attached to two stainless steel plates and mounting on an electromechanical tensile machine. The test were carried out according to the standard EN 14509:2013 by loading the specimen continuously with a rate of 2.5x10⁻² mm/s. The test was continued until the ultimate load (F_u) is reached. If the specimen does not exhibit a clearly defined ultimate load the test is discontinued when the relative deformation exceeds 20%.



Cross panel tensile strength test setup

Conclusions

It was possible to mechanically characterize the product, specifically defining the cross panel tensile strength and tensile E-modulus.



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Research partner:



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Industrial partner:



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Dynamic characteristics of Flexbrick façade system in out-of-plane direction

FLEXBRICK

Product: Facade system

Flexbrick is a Spanish company from Catalonia, which created a revolutionary, industrialized system of flexible ceramic sheets used to construct cladding and laminar structures that could easily be adapted to cover all kinds of architectural surfaces.



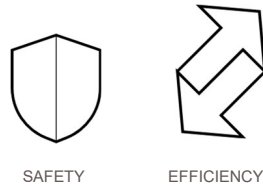
Facade system

Pilot Measurement & Verification Line 7 Managed by: CUT



PM&V L7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrometer) tests are used for ageing diagnosis.



Which is the need covered by this service?

The goal of the test was to determine dynamic characteristics of a façade system in out-of-plane direction and their changes under long lasting vibrations with large deformations. The characteristics allows to design the façade and check its behaviour under the most dangerous scenario when a structure works in resonance during forced harmonic vibrations, simulating extreme cases of strong dynamic loads (wind, earthquake). The obtained results set the path for further research and product development and can also be used during product certification.

Design of Experiments



Measurement points

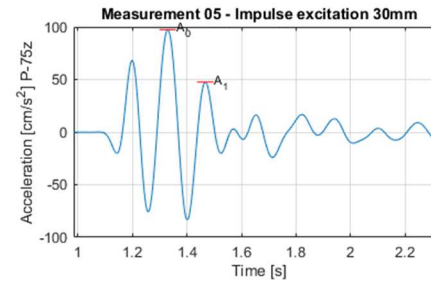
Stage 1:	Impulse excitation with force actuator – determination of the damping coefficient
Stage 2:	Dynamic diagnostics with frequency
Stage 3:	Mode shape analysis with modal hammer
Stage 4:	Diagnostics at resonant frequencies - examining linearity
Stage 5:	Destructive tests - attempts to completely destroy the structure



Dynamic test in out-of-plane direction

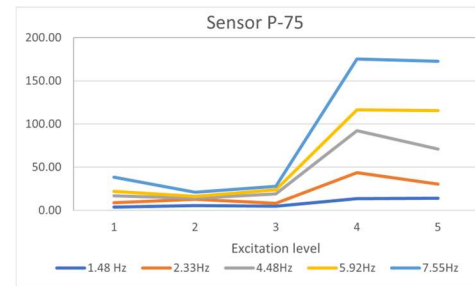
Results

1. Damping factor



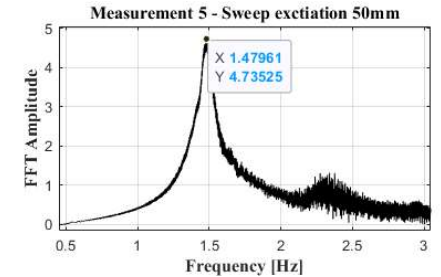
Accelerograms of the sensor P-75

2. Linearity of dynamic characteristics



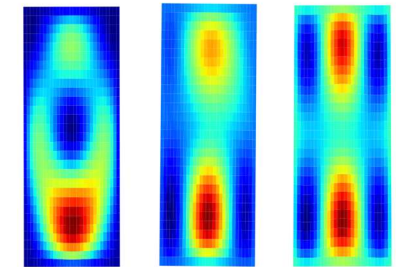
Non-linear dynamic response obtained in acceleration amplitudes

3. Natural frequencies detection from Fast Fourier Transformation analysis



FFT of the sweep with a linear variable frequency

4. Vibration modal shapes of the tested specimen presented in 2D with color maps



Mode shapes of the specimen for resonant frequencies

Open Innovation outcomes

- Construction of a research stand for seismic forcing of the product
- Determination of dynamics characteristics using a modal hammer to calculate the inertance and compliance function.
- Obtaining damping ratio of vibrations with half-power method.

Conclusions

The observed change in resonance frequencies during tests indicates the non-linearity of the characteristics. The modification of the characteristics indicates progressive internal degradation of structures. Tested structure withstood horizontal acceleration of 5m/s^2 of simulated ground excitation.



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Research partner: **Cracow University of Technology**
Faculty of Civil Engineering

Main author:
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Industrial partner: **Flexbrick**
dressing architecture

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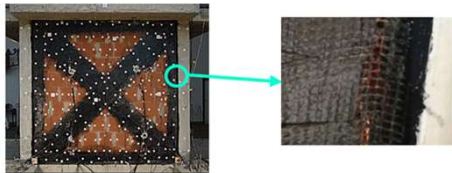
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Flex&Robust

Product: Composite

FlexAndRobust Systems Ltd. is a technology company offering flexible polymer joints developed by scientists from the CUT, which are used to transfer loads with large deformations. Due to the fact that the joints effectively reduce stresses in brittle materials, the strength of the entire structure being renovated increases.



Composite - Polyurethane PS matrix reinforced by glass fiber grid

Pilot Measurement & Verification Line 7

Managed by: CUT



PM&VL7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrometer) tests are used for ageing diagnosis.



SAFETY



EFFICIENCY



HEALTH



INTERACTION

Which is the need covered by this service?

The implemented program of mechanical, durability, acoustic tests and thermal simulations was based on certification requirements for composites with appropriate modifications taking into account polyurethane raw material used to produce the connections and also the designed solutions. The obtained results indicate a path for further research and product development and may also be used during product certification.

Design of Experiments

Mechanical properties:

Dynamic stiffness /modulus of composite, Breaking force of glass fibre grid, Matrix tensile strength and modulus of elasticity of polyurethane PS, Composite tensile strength and modulus of elasticity.

Durability to Xe

- Mechanical and structural properties before ageing
- Exposure to Xe according to EN ISO 4892-2
- Mechanical and structural properties after Xe ageing

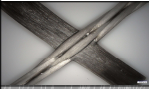



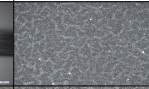
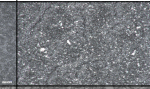
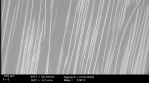
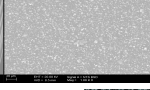
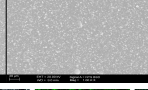
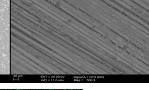
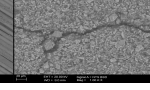
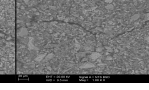
Durability to sea water

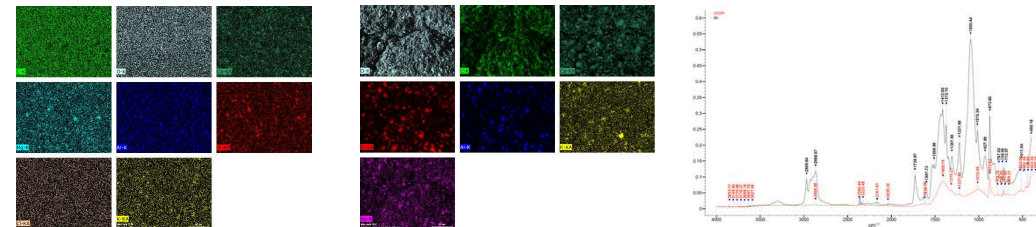
- Mechanical properties before ageing
- Exposure to sea water according to innovative method
- Mechanical properties after sea water ageing

Structural properties: Observation in optical microscope OM, scanning microscope SEM and FTIR analyses.

Acoustic properties: Critical damping ratio [%], Airborne and impact sound insulation measured for prepared solution, Direction-averaged junction velocity level difference for connector or for connection model, Dynamic stiffness (MN/m³).

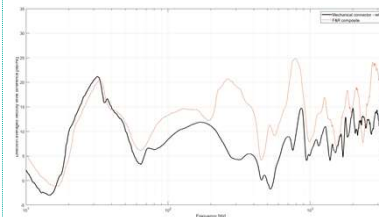
Thermal simulations: Water vapour diffusion (Interstitial water vapor condensation risk and intensity), Internal surface temperature, Linear thermal transmittance.

Results	before ageing			after Xe ageing		
	Grid	Matrix PS	Composite	Grid	Matrix PS	Composite
SEM observation						
OM observation						



Mapping of elements on composite PS surface before and after Xe ageing , mag. 1000x

FTIR analysis before, and after Xe ageing



Velocity level difference for tested solutions



Distribution of isotherms (interval equal to 0.05 K) within the wall, Composite PS

Open Innovation outcomes

The flexible polyurethane Flex&Robust connectors with the intended use as a repair system for connecting and reinforcing structures are innovative construction products that are not covered by harmonized assessment documents. Therefore, the implemented test program was based on standards and technical assessments for similar products and adapted to their intended use.



Conclusions

Artificial ageing through exposure to solar radiation Xe causes changes in polyurethanes.

Flexible structural connectors found to reduce significantly transition of vibration, to be good in providing acoustic tightness of tested element, an also they have influence on resonant frequency of tested system.

Crack in the brickwork filled with the tested polymers does not pose any thermal or moisture problems for the tested wall, and also there is no surface or interstitial water vapour condensation risk due to the filling polymers. The presence of the repaired crack is associated with the slight improvement of the brick wall thermal quality.



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Research partner:  **Cracow University of Technology**
Faculty of Civil Engineering

Industrial partner:

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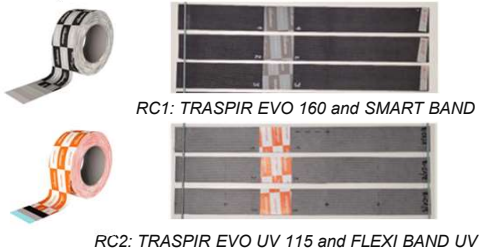
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Rothoblaas

Product: Membranes and tapes connections

Rothoblaas is an Italian multinational company from the Alpine region, leader in the development and supply of high-tech solutions for the areas of beam and post and Mass Timber construction systems, energy efficiency, zero emissions and other building best practices.



Pilot Measurement & Verification Line 7

Managed by: CUT



PM&V L7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrofotometr) tests are used for ageing diagnosis.



SAFETY



EFFICIENCY

Which is the need covered by this service?

The implemented durability program was based on certification requirements for membranes with appropriate modifications taking into account more intense UV exposure than provided for in the standard and their connections with tapes. The obtained results set the path for further research and product development as well as making the construction products comparable.

Design of Experiments



STAGE 1
Shear resistance of joints end lap jointing test before ageing according to EN 12317-2



STAGE 2
UV ageing according to Annex C EN 13859-1 with modification to 5000 h

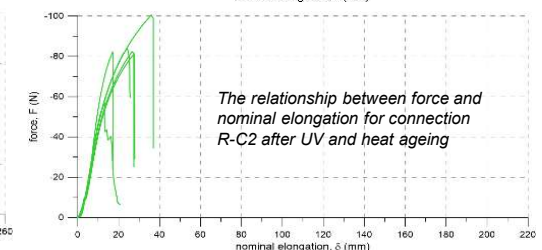
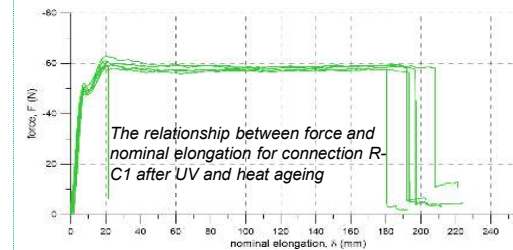
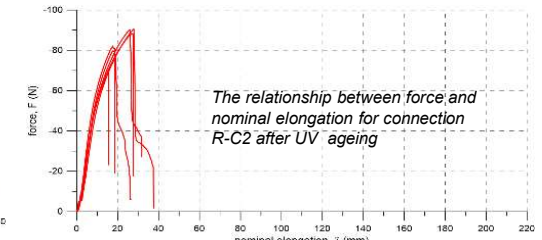
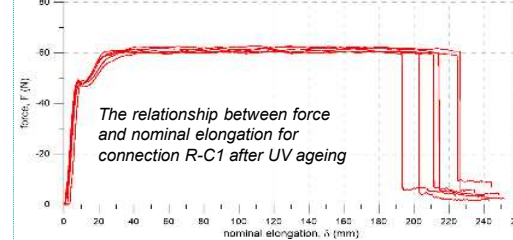
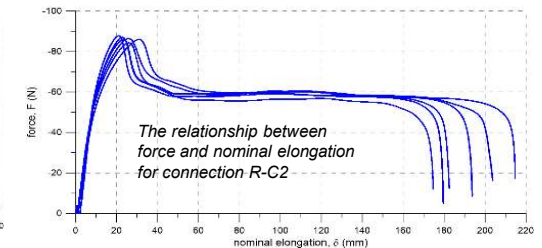
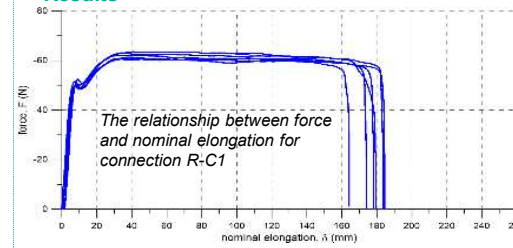


STAGE 3
Heat ageing according to Annex C EN 13859-1



STAGE 4
Shear resistance of joints end lap jointing test after ageing according to EN 12317-2

Results



Open Innovation outcomes

In order to determine the durability of the connections between membrane and tapes and enhance the credibility of product performance information, a non-standard test was carried out involving the ageing of the connected materials. Moreover, a significantly modified UV ageing time was used from 336 to 5000 hours.



Conclusions

The UV ageing did not influence shear resistance of the joint for the connection RC-1, whereas it caused a slight reduction in shear resistance for the connection RC-2.

The UV and heat ageing reduced slightly shear resistance of the joint for both the tested connections.

The both used ageing procedures caused the change in the observed failure mode. All the reference specimens failed due to membrane-tape separation. The aged connections RC-1 failed due to membrane peeling. The aged connections RC-2 failed due to breaking of the tape.



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Industrial partner:



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Rothoblaas

Product: Membrane

Rothoblaas is an Italian multinational company from the Alpine region, leader in the development and supply of high-tech solutions for the areas of beam and post and Mass Timber construction systems, energy efficiency, zero emissions and other building best practices.



Membrane TRASPIR EVO UV 115

Pilot Measurement & Verification Line 7

Managed by: CUT



PM&VL7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrometer) tests are used for ageing diagnosis.



SAFETY



EFFICIENCY

Which is the need covered by this service?

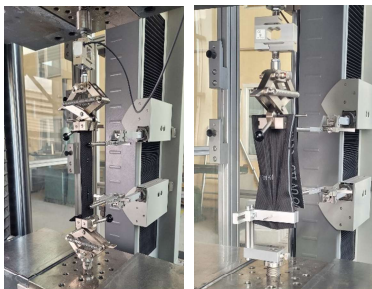
The implemented program of mechanical and durability tests was based on certification requirements for membranes with appropriate modifications taking into account more intense UV exposure than those provided for in the standard. The obtained results set the path for further research and product development as well as making the construction products comparable.

Design of Experiments

Mechanical properties

Structural properties

Durability to UV and heat



Tensile properties according to EN 13859-1 EN 12311-1

Resistance to tearing according to EN 13859-1 EN 12310-1

Observation in optical microscope (OM)

Observation in scanning electron microscope (SEM)

Spectrometric analysis (FTIR)

STAGE 1: Structural properties before ageing

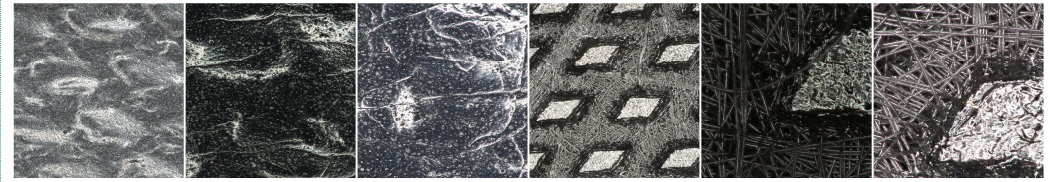
STAGE 2: Exposure to UV according to Annex C EN 13859-1 with modification to 5000h; FTIR after 1000, 2000, 3000, 4000 h

STAGE 3: Structural properties after UV ageing

STAGE 4: Exposure to heat according to Annex C EN 13859-1

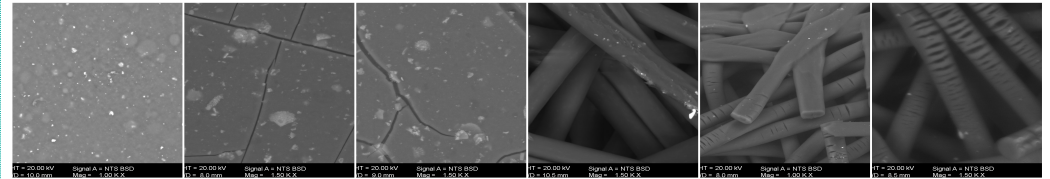
STAGE 5: Structural properties after UV and heat ageing

Results – structural properties



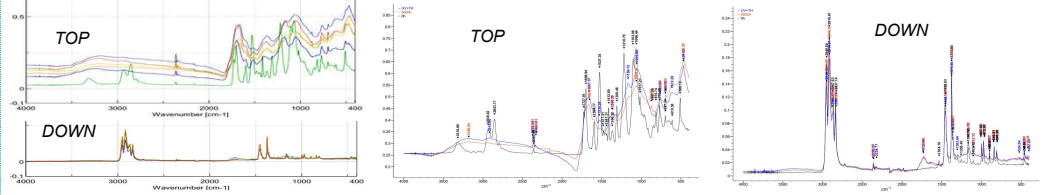
TOP reference TOP after UV TOP after UV+heat DOWN reference DOWN after UV DOWN after UV+heat

OM observation before and after ageing



TOP reference TOP after UV TOP after UV+heat DOWN reference DOWN after UV DOWN after UV+heat

SEM observation before and after ageing



FTIR analysis before, during and after UV, and after UV + heat ageing

Open Innovation outcomes

The standard ageing time under UV rays was significantly modified from 336 to 5000 hours to better reflect real exposure conditions and enhance the credibility of product performance information. In addition, the scope of diagnostics before and after ageing was extended to include the observation of microstructure in an optical and scanning microscope as well as FTIR analyses before, during and after ageing.

Conclusions

Exposure to 5000h UV of membrane causes their degradation (the both side) visible changes include microcracks and defragmentation of fibers PP.
IR spectra after exposure to UV for 1000, 2000 3000, 4000 and 5000 hours allow to monitor changes and determine the beginning of degradation.
IR spectra and SEM images show that exposure to heat intensifies the degradation process. No additional changes were observed.



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Mechanical and Durability tests and Thermal simulations of Indresmat sandwich panel.

INDRESMAT

Product: SAFE-PUR sandwich panel

INDRESMAT is a company founded in 2017 and located in Barcelona (Spain) & Geleen (The Netherlands) that is redefining the thermal envelope of buildings with materials such as biobased Polyurethane window frames and insulation foams.



Pilot Measurement & Verification Line 7

Managed by: CUT



PM&VL7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrometer) tests are used for ageing diagnosis.



SAFETY



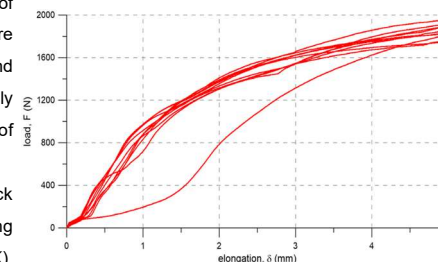
HEALTH



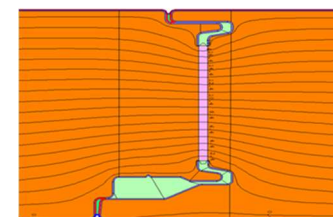
EFFICIENCY

Results

1. Mean value of maximum load obtained in the test of shear resistance of the connection is 1.56 kN. The tests were carried out on the connection of the sandwich panel and aluminum sub-structure of the thickness of 4mm. The only observed failure mode during the tests of shear resistance of the connection was hole elongation of sandwich panel.
2. The average value of thermal conductivity of 50 mm thick samples, consisting of PU foam and metal linings, before aging at the reference temperature of +10°C was 0.036 W/(mK). During aging, the samples underwent significant and uneven deformations, which made it impossible to re-test their thermal conductivity and determine their durability.
3. It was assumed that the metal profiles of the panels do not fit tightly together, and water vapour may penetrate to thermal insulation or expansion tape filling the gap. However, no interstitial condensation will occur.
4. The temperature distribution was calculated as a 2D task. As a result of the analysis, it was found that for typical moderate level of relative air humidity, condensation of water vapor will not occur.
5. The value of additional heat losses, in form of linear thermal transmittance Ψ , caused by the presence of panel joints is for ISOPAR ELEGANT panels equal to 0.015 W/(mK). It must be considered in the standard calculations of heat transfer.



Relationships between load and elongation



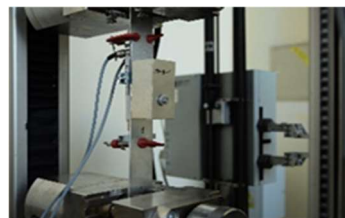
Temperature distribution

Which is the need covered by this service?

The completed program of mechanical and durability tests as well as thermal simulations was based on the certification requirements for sandwich panels with appropriate modifications taking into account the biopolyurethane raw material used as the core and the designed solutions for their connections. The obtained results indicate a path for further research and product development and can also be used during product certification.

Design of Experiments

1. Shear resistance of the connection according to EAD 330047-01-0602.
2. Durability - Change in thermal conductivity over time as a result of ageing according to Annex B of EN 14509 - DUR 1. Diagnostics of durability due to ageing included features not defined in the standard: Thermal test before and after artificial ageing - Thermal conductivity according to EN 12667 with modification.
3. Water vapour diffusion (Interstitial water vapor condensation risk and intensity) according to EN ISO 13788.
4. Internal surface temperature according to EN ISO 13788.
5. Linear thermal transmittance according to EN ISO 10211.



Shear resistance of connection

Conclusions

The only observed failure mode in the tests of shear resistance of the connection was hole elongation of sandwich panel. Mean value of maximum load obtained in the test of shear resistance of the connection is 1.56 kN. The average thermal conductivity of the Indresmat panels after the production stage, equal to 0.036 W/(mK), is high as for polyurethane insulation and corresponds to the properties of standard insulation made of expanded polystyrene or mineral wool. This can be attributed to the manual preparation of samples since 0,022 W/(mK) was the value achieved in the industrial process for continuous manufacturing. As a result of aging, significant geometric deformations of the tested samples have been observed, which made repeated thermal conductivity tests impossible. The joint of the sandwich panels does not pose any thermal or moisture problems, and there is no surface or interstitial water vapour condensation risk. The presence of the panels' joint is associated with the formation of a low intensity thermal bridge and low additional heat losses.



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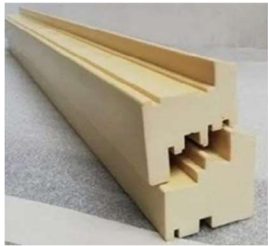


Mechanical, Durability, Acoustic tests and Thermal simulations of Indresmat window frame

INDRESMAT

Product: KLIMA-PUR window frame

INDRESMAT is a company founded in 2017 and located in Barcelona (Spain) & Geleen (The Netherlands) that is redefining the thermal envelope of buildings with materials such as biobased Polyurethane window frames and insulation foams.



Pilot Measurement & Verification Line 7

Managed by: CUT



PM&VL7

Mechanical, durability, vibroacoustic, thermal, and microclimate comfort tests of envelope products and their connectors. Mechanical, vibroacoustic, thermal, and structural (scanning and optical microscope, spectrometer) tests are used for ageing diagnosis.



SAFETY



HEALTH



EFFICIENCY



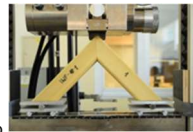
INTERACTION

Which is the need covered by this service?

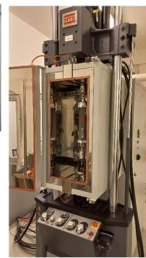
The completed program of mechanical, durability and vibroacoustic tests as well as thermal simulations were based on the certification requirements for window frames with appropriate modifications taking into account the biopolyurethane raw material used to produce the frames and the designed solutions for their connections. The obtained results indicate a path for further research and product development and may also be used during product certification.

Design of Experiments

- Low temperature cracking according to EN 12697-46 with modifications.
- Durability:
 - Resistance to artificial ageing by exposure to freeze-thaw according to EN 13165 with modification.
 - Resistance to accelerated ageing by exposure to temperature in accordance with the requirements of EN 13165.



Strength of corner



Low temperature cracking

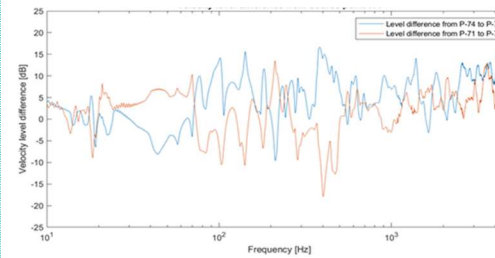
- Diagnostics of durability due to ageing included features not defined in the standard:
- Mechanical test before and after artificial ageing - Strength of corners according to EN 514.
 - Direction-averaged junction velocity level difference for connector or for connection model according to our own procedure based on EN ISO 12354-1 and EN ISO 12354-2.
 - Internal surface temperature according to EN ISO 13788.



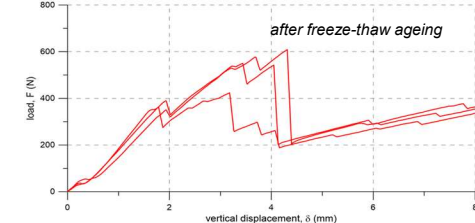
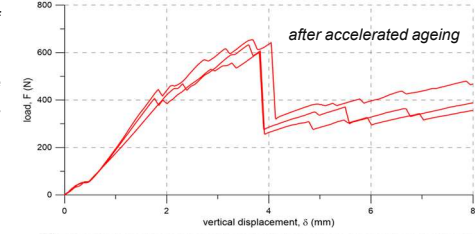
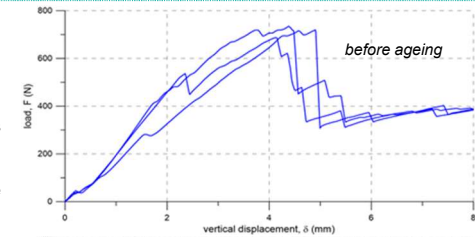
Velocity level difference

Results

- Strength of the tested window frame corners is 3.3 N/mm², 2.5 N/mm² and 2.9 N/mm² for reference specimens, specimens after freeze-thaw ageing and specimens after accelerated ageing, respectively. Relationships between load and vertical displacement of corners before and after ageing.
- In the low temperature cracking test, the average value of maximum cryogenic stress was equal to 1.36 MPa.
- Foamed (bio)polyurethane frame connections found to be acoustically stiff. Average transmission of vibration velocity in frequency domain is below 6 dB.

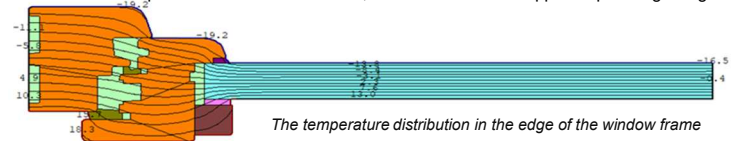


Velocity level difference from source point W1



Relationships between load and vertical displacement of corners

- The purpose of the test was to check whether condensation and mold may occur on the inner surface of the window frame. The temperature distribution in the edge and middle element of the window frame was calculated as a 2D task. As a result of the analysis, it was found that in typical residential and office spaces with a moderate level of relative air humidity, condensation of water vapor will not occur. However, an influence of the applied specific glazing should also be checked.



The temperature distribution in the edge of the window frame

Conclusions

Both types of the used ageing procedure caused reduction in strength of the tested window frame corners. In the low temperature cracking test, the specimens met the required evaluation criterion. Biopolyurethane frame connections found to be acoustically stiff.



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Industrial partner:



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TECNAN

Product: Heat barrier coating

TECNAN produces and commercializes new raw materials (high performance nanoparticles) for various industrial applications

TECNADIS HEATSHIELD is a nanotechnology-based heat barrier treatment for glass surfaces, which blocks infrared solar radiation (IR) by more than 40%.



Glazed façades

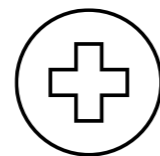
Pilot Measurement & Verification Line 8

Managed by: University of Innsbruck

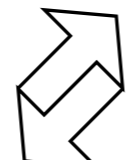


PM&VL8

PM&VL8 operates measurement facilities to measure the thermal and visual performance of semi-transparent and opaque envelope products. The in-situ g-value device allows as a novelty to evaluate the solar heat gain under installed conditions.



HEALTH



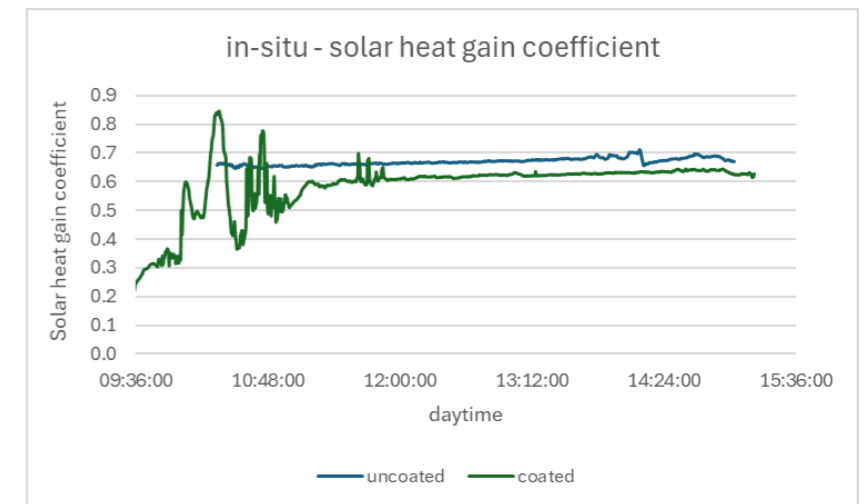
EFFICIENCY

Results

Under static (laborious) conditions, the visual transmittance of the coated glazing show a relative reduction about 25%, when comparing to an uncoated. The reduction in the effective g-value was about 20% for the normal incident direction and 23% for the incidence angle of 30°.

The in-situ measurement for a south orientated probe (location: Innsbruck, 2nd of November) shows a dynamic behaviour with lower heat gains in the morning hours and higher heat gains in the afternoon through absorption effects. The coated glazing shows lower g-values throughout the day.

Single pane	uncoated		coated	
	SHGC	Tau_sol	SHGC	Tau_sol
AI				
0°	0.69	0.89	0.56	0.67
30°	0.67	0.84	0.52	0.63

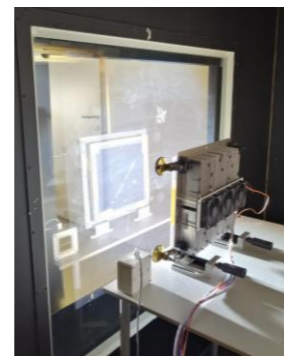


Which is the need covered by this service?

The analysis aimed to determine the effect on the resulting solar heat gain transmission by comparative measurements on a coated and an uncoated glazing. In this test campaign, an installed glazing will be used to evaluate the effect under real outdoor conditions. With the in-situ g-value device, the instantaneous value of the solar heat gain and the solar transmission will be evaluated. Also, the performance was tested under laborious conditions to get static values for solar heat gain coefficient and solar transmittance.

Design of Experiments

- For in-situ testing on an installed facade, a measurement period with stable (sunny) weather conditions was chosen. An uncoated part of the same glazing type was used to get a performance baseline and to be comparable with the coated one.
- For the lab measurement, a small-scale sample of a single-glass pane was used to measure solar heat flux as well as the solar transmission.



Lab installation



In-situ installation

Conclusions

The tests performed under laborious conditions show a **minimum effect on the visual transmittance**, which is also desirable. On the solar heat gain, a reduction of g-value of 20% (normal incidence) and 23% (Incident angle of 30°) has been observed. Regarding in-situ measurements, treated glazing's show a lower g-value throughout the day. To proof this effect, further variants on glazing types should be tested, especially in the solar spectral range above 1,5µm.

Finally, regarding incorporation of treated 2-pane glazing's in the PM&VL8 demonstrative for testing the coating performance under real conditions, liquid formulation supplied by TECNAN is being employed to conduce, properly, the application procedure to obtain desired aesthetic.



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Product: Heat barrier coating

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Glazed façades

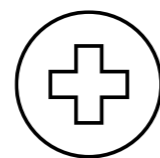
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PM&VL8

PM&VL8 operates measurement facilities to measure the thermal and visual performance of semi-transparent and opaque envelope products. The in-situ g-value device allows as a novelty to evaluate the solar heat gain under installed conditions.



HEALTH



EFFICIENCY

Results

Based on a single pane clear glass, the visual transmittance of the coated glazing shows an absolute reduction at normal incident direction of about 25% compared to the uncoated glazing. This result corresponds directly to the solar transmittance determined in the in-situ g-value analysis.

The scattering effect is not significant. The results on the different angular directions show a similar result. The transmittance drops continuously with a higher angle of incidence.

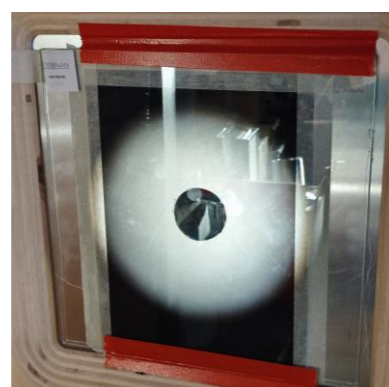
Single pane	Uncoated	Coated
AI	tau_vis	tau_vis
0°	88.59 %	66.45 %
10°	85.15 %	64.10 %
20°	83.58 %	62.30 %
30°	84.85 %	61.55 %
40°	84.24 %	61.28 %
50°	81.90 %	57.01 %
60°	76.11 %	49.79 %
70°	50.53 %	39.17 %
82,5°	19.91 %	6.31 %

Which is the need covered by this service?

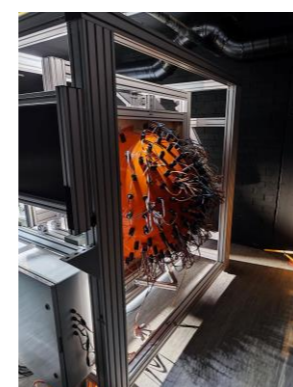
The analysis aimed to determine the angular-resolved visual transmittance (BTDF) to get information about a possible influence of the IR-coating on the visual characteristics. As an overall result, also the integral value for the visual transmission is determined. Although the information gained by an angular-resolved BTDF is very limited in case of a clear glass, the measurement can show possible scattering effects on the glazing due to the coating. The analysis is also coupled with the g-value analysis done on the same sample probes.

Design of Experiments

- Initially, the measurement of the full BTDF (145 patches) are performed for the normal incident direction (0°)
- For variations in the angle of incidence are measured (10/20/30/40/50/60/70/82,5°)
- Integral values have been obtained by summing up all 145 outgoing directions.



Coated glazing sample by TECNAN



Measurement device

Open Innovation outcomes

The aim is, firstly, to evaluate the characteristic of the product behaviour in terms of optical transmission/reflection, and secondly, to do a visual performance characterization in order to be able to define the model in an optical simulation environment (e.g. lighting simulations in Radiance).

Conclusions

The measurement results of the visual transmittance of the coating glazing show a comparable characteristic to an uncoated float glazing. Thus, the visual effect and the "look-through" should not be influenced significantly. Anyhow, the absolute reduction in the visual transmission is evaluated with 25% absolute, which will have a slight effect on the daylight availability, especially for deeper spaces. Nevertheless, this reduction is minimum when compared with other commercial alternatives to block infrared component of the light, based on dark schotchtint films for solar control.



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INDRESMAT

Product: SAFE-PUR sandwich panel

INDRESMAT is a startup founded in 2017 and headquartered in Barcelona (Spain), having international presence in Geleen (The Netherlands) that is redefining the thermal envelope of buildings with biobased Polyurethane (bioPUR) materials in products such as window frames and insulation foams.



High-density window frames and low-density insulation panels

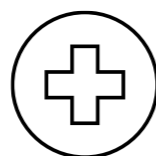
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PM&VL8

PM&VL8 operates measurement facilities to measure the thermal conductance of solid materials like insulation material or other opaque construction elements. The heat plate apparatus from Taurus allows to perform conductivity measurements according to DIN 52616.



HEALTH



EFFICIENCY

Results: Following measurements results are achieved, considering a temperature difference of 10K for three different base temperatures (10°C/15°C/20°C):

Probe	Thickness [mm]	Density [kg/m ³]	HF meas [W/m ²]	Conductivity [W/(mK)]
I	48	68.3	7.480	0.0345
II	48	70.1	7.456	0.0343
III	48	65.8	7.574	0.0349
IV	48	66.4	7.489	0.0345
V	48	66.4	7.559	0.0348
X	48	509.3	15.161	0.0703
Y	48	463.0	14.243	0.0660
Z	48	451.4	13.832	0.0641
B-X	48	497.7	17.796	0.0828
B-Y	48	474.5	16.754	0.0778
B-Z	48	474.5	16.301	0.0757
A	26	367.8	48.104	0.0619
B	26	380.0	49.444	0.0622
C	26	382.2	49.415	0.0617
D	26	394.5	51.079	0.0654
E	26	357.3	47.794	0.0615



Probes I-V:
Low density bioPUR foam probes



Probes X - Z / BX - BZ: High density PUR and bioPUR foam probes



Probe A - E: High density bioPUR foam probes (2nd Gen.)

Which is the need covered by this service?

The objective of this measurement is to determine the thermal conductivity $W/(m^*K)$ of the various INDRESMAT bioPUR materials to determine their insulation capacity. Prototypes will be assessed as a basis for continuous development of the products in their portfolio. By the conductivity tests, the newly invented bioPUR materials should be benchmarked against the already existing products made from conventional PUR (fossil based) and demonstrate similar or superior performance at the material level. The measurement results are also used to continuously improve the manufacturing process – therefore, several generations of insulating material products have been tested.

Design of Experiments

The mean values of the heat flow measurements are determined according to different top/bottom plate temperatures at the sample probes, which defines the boundary temperatures forcing a heat flux. By automatic detection of the sample thickness the resulting in a thermal conductivity value in $W/(m^*K)$.



Sample measurement process with the Taurus TCA-300 device

Open Innovation outcomes

The aim is to advance the technical development of biobased PUR foams to further reduce CO₂ emissions by improving the thermal insulation performance, but also with a focus on reducing the carbon footprint of the materials used. The research activity has been performed between University of Innsbruck and INDRESMAT, without specifically aiming to an Open Innovation approach. Results will be shared with the PassivHaus Institute for certification purposes.

Conclusions

The measurement results achieved for the bio-based insulation foam material as well as the probes based on conventional based foams showed a good thermal performance, being with $0,06 W/m^*K$ in the same range as conventional insulation materials (e.g. XPS, EPS). Also foams with higher densities have been measured, which show conductivity values $>0,08 W/m^*K$



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RIKO Hiše

Product: Sustainable prefab wooden external cladding components

The wooden prefabricated buildings by RIKO HIŠE combine quality living, economy, and environmental friendliness, following sustainable construction guidelines.



An example of RIKO Hiše wood based structure

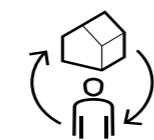
Pilot Measurement & Verification Line 9

Managed by: ZAG

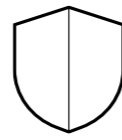


PM&VL9

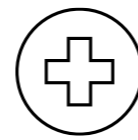
The PM&VL9 is built on a deep understanding of the performance of wood-based envelope elements and structures. It focuses on specific issues, properties, and performances of wooden structures, addressing essential requirements—from fire reaction to sustainability, including environmental footprint considerations.



INTERACTION



SAFETY



HEALTH

Which is the need covered by this service?

The sustainable prefab wooden external cladding components by RIKO Hiše underwent testing, including exposure to accelerated aging. Visual inspections assessed potential deterioration, particularly moisture-related damage around fasteners. Additionally, tests compared the hail resistance and impact resistance of aged versus unaged elements to evaluate durability under different conditions. Most of the methods used are based on existing standards and procedures described in EOTA TRs and EADs but can be adjusted to specific needs and in most cases adapted and further developed to fit to the purpose of the testing for the specific tested product. These comprehensive analyses ensure the high performance and resilience of the cladding components over time.

Design of Experiments

1. Hygrothermal behaviour acc. EAD 040083-00-0404 Paragraph 2.2.6.
2. Impact resistance acc. EAD 040083-00-0404 Paragraph 2.2.8 on aged and on as delivered samples.
3. Hail resistance acc. FM Approvals 4473 on aged and on as delivered samples.



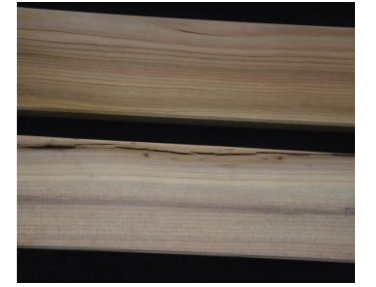
Tested specimens: Tongue and Groove Boards (left) and Wooden Slats with Dilatation (right) by RIKO Hiše

Results

1. Visual inspection after artificial ageing: The wood showed minor colour changes, slight chipping, and raised knots on less than 0.01% of the surface. Traces of water retention were noted at cladding joints, with more moisture observed in the configuration without gaps. No serious wood deterioration was found.
2. Impact resistance: The damage caused by steel ball impacts depends mainly on impact energy, but also on wood quality, and density. Artificial aging has little effect. Edges are most vulnerable, possibly disadvantaging wooden slats with dilatation compared to tongue and groove boards.
3. Hail resistance: The damage caused by ice ball impacts of varying sizes and masses depends more on the wood's quality and density at the impact point than on the ice ball's size or mass. Artificial aging appears to have little effect on the degree of damage. The edges of the wooden claddings are the most vulnerable areas, potentially putting wooden slats with dilatation at a disadvantage compared to tongue and groove boards in terms of hail resistance.



Minor discolorations and chipping after artificial ageing.



Minor dent and discoloration at the point of impact of the steel ball.



Minor dent and edge chipping at the point of impact of the ice ball.

Open Innovation outcomes

The research activity was conducted exclusively between ZAG and RIKO Hiše. The results will be shared in the RIKO Hiše catalogue and on their website, primarily for marketing purposes, rather than with a focus on an Open Innovation approach.

Conclusions

All tests, simulations, and calculations confirmed the tested product's suitability for its intended use. The only unexpected finding was that, during impact and hail resistance testing, the extent of damage was influenced more by the wood's density at the point of impact than by the impact energy.



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FlexAndRobust Systems

Product: Flexible structural connectors

FlexAndRobust line of products is developed from polyurethane flexible joints which are dedicated to structural and non-structural bonding of elements made of various materials (concrete, masonry, timber or steel).



Cross-section of timber elements with flexible structural joints

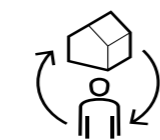
Pilot Measurement & Verification Line 9

Managed by: ZAG

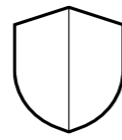


PM&VL9

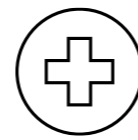
The PM&VL9 is built on a deep understanding of the performance of wood-based envelope elements and structures. It focuses on specific issues, properties, and performances of wooden structures, addressing essential requirements — from fire reaction to sustainability, including environmental footprint considerations.



INTERACTION



SAFETY



HEALTH

Which is the need covered by this service?

The flexible structural joints produced by FlexAndRobust underwent reaction to fire testing as well as fire resistance testing to determine its fire properties. Within the reaction to fire testing Cone calorimeter according to EN ISO 5660-1 and small flame tests according to SIST EN ISO 11925-2 were performed on small scale samples, namely 100 x 100 mm and 90 x 240 mm respectively for two different materials of flexible joints – PST_I and PM_P. For the resistance to fire test two different materials in two different thicknesses (80 mm and 160 mm) were tested in bending and in tension during exposure to standard fire curve as in ISO 834. During the fire resistance test the temperature development in timber elements and flexible structural joints was measured. At fire resistance testing of flexible structural joints the conditions in the furnace and temperature measuring method were performed according to standard SIST EN 1363-1.

Design of Experiments

1. Cone calorimeter test according to ISO 5660-1.
2. Small flame test according to SIST EN ISO 11925-2.
3. Fire resistance test of joints with furnace conditions and temperature measuring method according to SIST EN 1363-1.



Tested specimens: PST_I (left) and PM_P (right) type of flexible structural joint by FlexAndRobust.

Results

1. Cone calorimeter tests: Flexible joint between two timber members was tested with constant incident heat flux of 50 kW/m². Three conditions have been considered; with joint in line with structural surface, and with joint 20 mm and 40 mm withdrawn from the surface to simulate reduction of the material inside the joint. In the first case the joint material ignited before the surrounding wood, otherwise it ignites when the wood burning front reached the joint surface.
2. Small flame test: Flexible joint was exposed to a small flame for 30 seconds at the edge and the surface of the joint. Flexible joint material PST_I and PM_P ignited and in case of PM_P flaming droplets ignited filter paper under the test specimen as well. Flaming of the material did not stop after the pilot flame removal.
3. Fire resistance test: fire resistance test of mechanically loaded samples was performed on 500 x 500 mm samples including one (loaded in tension) and second (loaded in shear) in two thicknesses: 80 and 160 mm. Fire resistance test was performed for 43 minutes. The collapses that occurred were due to exceeded shear strength of the timber and not of the flexible joint. Most of the flexible joints withstood simultaneous mechanical and fire loading and assured tightness.



Cone calorimeter test of flexible joint – simulation of reduction of material.



Small flame edge exposure for 30 s results in ignition of the flexible joint and dropping of flaming material.



Flexible joint in tension after fire resistance test: unexposed side (left), exposed side (right).



Open Innovation outcomes

The research activity was conducted exclusively between ZAG and FlexAndRobust. Fire resistance test design was custom made for this specific product since it is a mix of sealant and kit material. The results will be shared in a scientific paper that will be jointly written by both partners.

Conclusions

Cone calorimeter tests indicated that when polyurethane material is exposed to direct heat flux, it ignites before the surrounding timber. The small flame test show that polyurethane material did not stop burning after the pilot flame was removed. In the fire resistance test it was noticed that timber specimens (with one or two polyurethan joints) in case of collapse, collapsed through timber. The results are of research interest and show that timber elements of stronger mechanical properties should be used to obtain collapse through the flexible joints in case of fire resistance test.



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