D5.1 - Manufacturing design of the multifunctional façade cladding I

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Deliverable Information Sheet

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Authors	S. García, J. García, A. Llamas, R. Menor, F. Gabaldón, A. Saráchaga (GAR) P. Rodríguez (INDRESMAT)
Contributing Partners	INDRESMAT
Reviewers	F. Leonforte (POLIMI), L. Maestri (ZH)

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1.0	05/05/2023	Final version addressing all further comments	S. García, J. García, A. Llamas, R. Menor, F. Gabaldón, A. Saráchaga, P. Rodríguez

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Disclaimer

1. Executive summary

This document serves as the first deliverable of WP5 and outlines the improvements and enhancements made to the multifunctional precast façade that was previously developed by GAR for the HEART project, in order to meet the requirements of RE-SKIN.

The precast façade has undergone significant changes including the replacement of the conventional sandwich panel insulation with a bio-based alternative, and the utilisation of sustainable steel for the outer shell. Moreover, the mounting structure will be further improved by incorporating recycled materials and optimising the installation process to reduce installation time.

Chapter 2 provides an overview of the façade system and its key components while Chapter 3 includes the design of these components. It should be noted that in the following releases of the current deliverable the detailed aspects related to use, maintenance, end-of-life treatment as well as the manufacturing process and production control. Finally, also the supporting documents and certificates will be included. It should be noted that, even if the framework of the deliverable has been defined in terms of chapters, the part related to use, maintenance, and end-of-life treatment will be filled in the next release.

In fact, the optimisation process will continue throughout the project's development, with constant updates as new information becomes available. Three additional versions of this report are scheduled for release on month 13, month 19 and month 27, respectively. These subsequent deliverables will incorporate further specifications and/or modifications based on the project's progress and testing results.

2. General description

This task aims to assess and enhance the precast façade system designed by GAR for the previous HEART project, with the intention of improving and optimising the system in accordance with the ambitions of RE-SKIN.

The system developed within the HEART project consists of a self-supporting thermal insulation façade that comprises panels and a substructure, which produces an enhanced version of the currently existing commercial solutions.

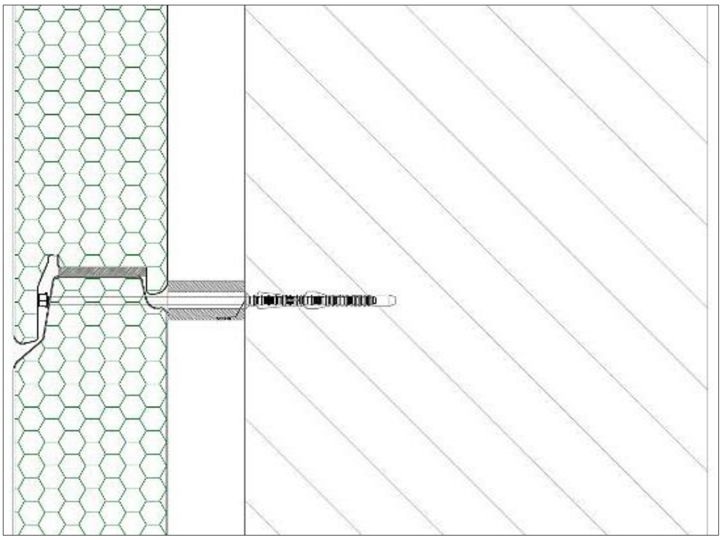

Figure 1. Panel detail (Vertical) [drawing created using AutoCAD]

The panels in the HEART system are composed of a 0.7 mm outer layer of galvanised steel, a polyisocyanurate (PIR) foam core, and a 0.4 mm inner layer, with a total thickness of 100 mm. These panels are joined together with a simple tongue-and-groove joint and then attached to the pre-existing wall through a substructure.

The substructure, which features anti-corrosion properties and galvanic protection, is assembled using supporting brackets that are attached to the pre-existing walls of the façade employing mechanical fixings and plugs. The upright structural profiles are then fixed to the brackets by means of self-drilling screws. The system is entirely sealed, creating an airtight cavity between the panel and the pre-existing wall.

RE-SKIN takes over from the previous H2020 HEART project, considering its outcomes and striving to improve them further. The project focuses on developing multi-technology and low-impact renovation solutions for energy retrofit of buildings in a critical context in order to decrease energy consumption and environmental impact of existing residential, public, and commercial buildings while simultaneously applying the principles of life cycle sustainability and the circular economy.

Therefore, many of the materials and components used in producing the façade system will be recycled, recyclable, reused, repurposed or biosourced.

To develop a sustainable and circular-economy-based façade system, the new sandwich panels will replace the conventional polyurethane (PUR) or Polyisocyanurate (PIR) thermal-insulation foam core with the innovative biosourced PUR (bioPUR) foam produced by INDRESMAT. Moreover, the Greencoat sustainable steel from SSAB, a GAR subcontractor, will replace the former standard metallic sheet outer layer.

The mounting structure will also be improved by using recycled aluminium profiles manufactured by EXLA. Additionally, the assembling process will be optimised to reduce retrofit work time and costs.

The early stages of the project will involve prototyping and testing of the sandwich panel and the façade system as a whole. First, performance and durability tests will be conducted at GAR facilities, and then further testing will be carried out in DTI laboratories in order to conclude product technical assessment and compliance analysis prior to demonstrating the viability of the proposed solution on a large scale, within WP3.

3. System/component design

RE-SKIN project's multifunctional prefabricated thermal insulating façade is a self-supporting system composed primarily of sandwich panels and a substructure, created to increase energy performance and decrease environmental impact. This chapter aims to present a general description of the design procedure and significant characteristics of the system's subcomponents, as well as an examination of the materials and technologies employed to produce a façade that is both sustainable and circular-economy-based. More in detail 3 components have been studied and hereafter described: the sandwich panel, the recycled aluminium mounting structure and the finishing.

3.1. Sandwich panel components

As previously introduced, the multifunctional prefabricated façade system is fundamentally composed of sandwich panels and a substructure. The sandwich panels, being a key component of the system, consist of an outer layer made of Greencoat sustainable steel sourced from SSAB, a novel biosourced polyurethane (bioPUR) foam core, and an inner steel layer. These panels are interconnected by means of a tongue-and-groove joint and subsequently attached to the pre-existing wall through the substructure.

The manufacturing process of sandwich panels can be classified into continuous or discontinuous based on the moulding process employed. In the discontinuous process, a standardised panel is produced using a closed mould of the desired sandwich panel dimensions. In contrast, the continuous process involves the production of larger linear panels that are later cut according to the dimensions of the façade on which they will be installed.

The metal surfaces, in this case steel, are two sheets placed apart by lateral supports to allow for the injection of foam to fill the gap between them and create the insulating core. The use of steel in sandwich panels enhances their durability and strength, surpassing that of other materials.

The finishing phase of sandwich panel production includes processes such as cutting, welding, laminating, and other necessary activities to complete the product. After completing the finishing phase, a protective film is applied to the finished product to prevent scratches and dirt accumulation.

The manufacturable thickness is between 60 and 100 mm. In RESKIN, the determination of the thickness of the panels will be based on the project's calculations for the different demonstrations to be carried out. The typical range for thickness is expected to be between 80 to 100 mm. The panel height has been standardised at 1150 mm to align with the standard width of the steel coil. However, the panel width can be adjusted based on project requirements and is expected to fall within the range of 250 to 4000 mm.

3.1.1. Outer layer

The outer layer steel coating subcomponent is a critical element in building construction that serves to protect and enhance the aesthetic appeal of building façades and roofs. In recent years, the demand for more sustainable and eco-friendly building materials has led to the development of innovative coating technologies that reduce the environmental impact of building construction while maintaining optimal performance. One such technology is the GreenCoat® sustainable steel outer layer, which employs a patented Bio-based Technology (BT).

The GreenCoat® colour coated steel products present a sustainable coating in the building industry. The patented Bio-based Technology (BT) coating launched in 2012 uses a significant amount of Swedish rapeseed oil, which is a natural ingredient, instead of fossil oil. As a result, this coating drastically reduces the environmental footprint of a building. Moreover, it is chromate free, safe to handle, and does not emit harmful substances. This coating provides proven, long-lasting performance for buildings over several decades. In contrast to petroleum-based chemicals commonly used in the building industry, the bio-based solvent in this coating becomes a permanent part of the final product, leading to a healthier environment and reducing the release of harmful substances into the atmosphere. This bio-based coating is suitable for indoor and outdoor use, is compliant with EU REACH (‘registration, evaluation and authorisation of chemicals’) regulations governing the manufacture of chemical substances, and has less impact on the environment compared to other coatings. This patented Bio-based Technology (BT) coating not only offers an environmental advantage but also improved performance for a longer product life.

As described earlier, the patented Bio-based Technology (BT) coating utilised by GreenCoat® incorporates Swedish rapeseed oil as a natural substitute for fossil oil, substantially reducing the environmental impact of buildings. In line with their commitment to sustainability, SSAB (a company specialising in high-performance steel) ensures their products comply with relevant chemical regulations, tracking and anticipating changes in legislation. By adhering to these standards, SSAB demonstrates its commitment to producing environmentally responsible products and promoting sustainable development.

In RESKIN, the thickness of the material to be used is 0.6 mm for the external shape and 0.4 mm for the internal shape.

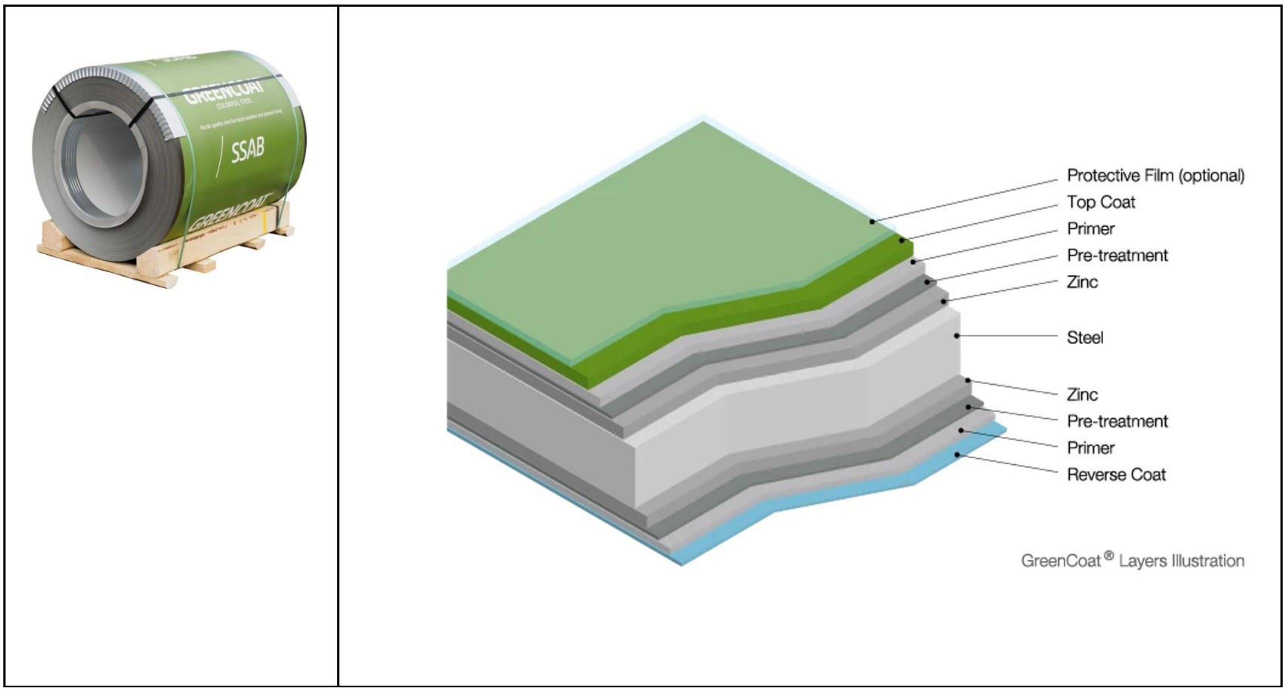

Figure 2. GreenCoat® components

3.1.2. Thermal-insulation

In line with this objective, the project intends to use BioPUR foam as insulation. BioPUR is a foam that can be used for insulation purposes by being sprayed, injected, or used as sheets or sandwich panels.

BioPUR foam is specifically designed for the residential segment, mainly for energy renovation and insulation, as well as waterproofing in renovation activities. To ensure the sustainability of the materials used in the RESKIN project, a life cycle perspective is taken into account, including the product contents, production, and end-of-life options such as recycling or reuse. This approach is essential for achieving complete transparency, and the use of BioPUR foam fits into this framework by being a sustainable and environmentally friendly insulation option.

As previously mentioned, the foams are based on a bioPolyurethane foam at a density of 40-60 kg/m3, which has been shown to have a high insulating capacity having a thermal conductivity value of 0.30-0.40 W/m2K, and the raw materials used are natural oils, making them more environmentally friendly. Furthermore, the end-of-life of these products is approached through a circular use methodology, utilising both mechanical and chemical recycling methods. The utilisation of these products in the RESKIN project is an important step towards achieving a more sustainable and environmentally friendly approach to insulation.

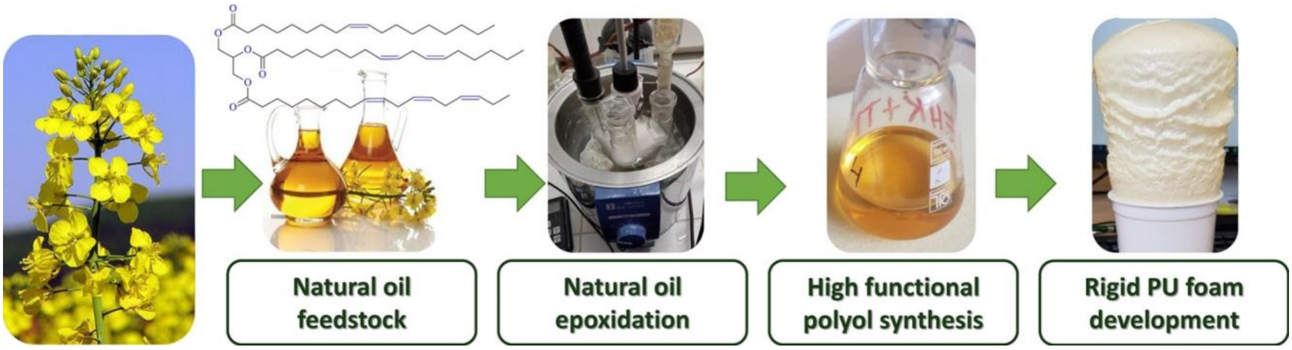

Figure 3. Process for the use of natural oil-derived raw materials in BioPUR foams

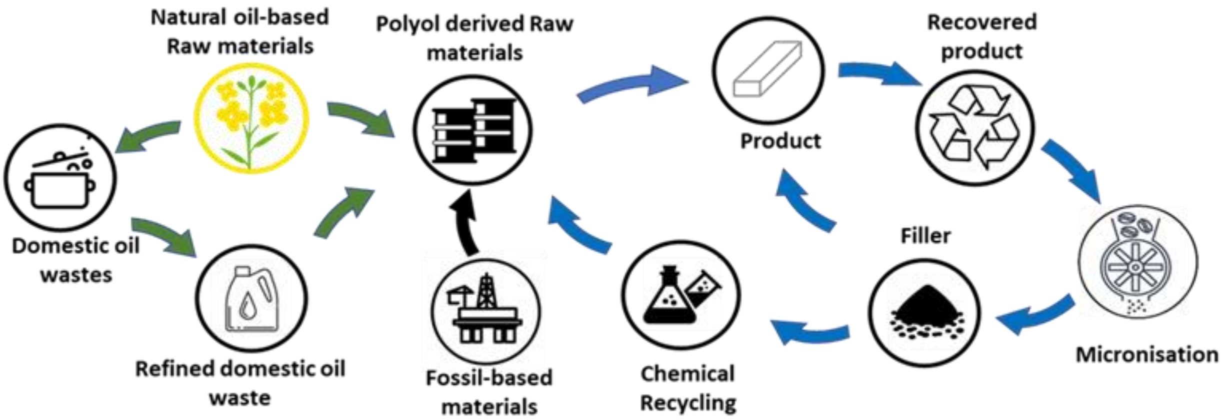

Figure 4. Circular approach of bioPUR material

Figure 5. Mechanical and chemical recycling methods for Polyurethanes

BioPUR technical features for sandwich panels:

BioPUR is a foam at TRL 6-7 that is expected to have similar properties (both mechanical and thermal) than conventional PUR. These properties rely more in the microstructure of the foam (density, homogeneity and distribution of cell size, open/close cell ratio, etc.) rather than in the origin of the raw materials used in their formulations (biobased or fossil based). Related to this, INDRES has achieved a foaming process for BioPUR that is equivalent to conventional PUR, so the microstructure of the foam and properties are suitable for the purpose of insulation in buildings.

Some of the features of BioPUR are:

- Thermal conductivity (0.03-0.08 W/m.K)
- Biobased content (60-70 %)
- C-Footprint (1.8-3 KgCO2/kg)
- Viscosity (600-3000 cPs)
- Reactivity range (10–50 s)
- Density range (40-60 kg/m3)


Figure 6. Demo sandwich panels made from bioPUR (left). Different varieties of PUR materials from INDRES (right).

SAFE-PUR insulation as disruptive innovation

SAFE-PUR is a new type of PUR foam patented by INDRESMAT with promising properties related to fire safety which use is intended in the RESKIN project. This new foam has a different chemistry behind and the features of this material differ from conventional PUR or BioPUR, mainly increasing the chemical and weathering resistance, as well as a slower reaction with O2 during the combustion of the foam with very positive consequences for fire safety.

When compared to conventional PUR or BioPUR foam, SAFE-PUR foams exhibit significantly better fire safety, which has been the primary obstacle preventing PUR foams from dominating the insulation market.

- Lower flammability (-50%)
- Slower fire propagation (-20%)
- Reduced smoke emission (-70%)
- Decreased fume toxicity (-90%
- Extended shelf life (>60 years)
- Indoor and outdoor applications
- Up to 70-80% biobased
- Easy to separate & recycle

Among the excellent insulation properties of Polyurethane foams, SAFE-PUR has important benefits compared to other insulating material competitors.

INSULATING MATERIAL		Thermal insulation (R-value)	Acoustic insulation	Flam-mability	Smoke Toxicity	Vapour/water permeation
Polymeric	***SAFE-PUR***	7-8	High	Medium	NO	NO
	bioPUR / PUR	7	High	High	YES	NO
	PIR (Polyisocyanurate)	6-7	Medium	Medium	YES	NO
	XPS (Extruded PS)	6	Medium	High	YES	YES
	EPS (Expanded PS)	5	Medium	High	YES	YES
	Phenolic Foam	5	Low	Medium	YES	NO
	Cellulose	4	High	High	NO	YES

Table 1. Benefits of SAFE-PUR compared to competitors

As the development stage of SAFE-PUR is still in its initial phase (TRL 3-4), the foam most likely to be implemented in sandwich panels for demo buildings is bioPUR. However, prototype sandwich panels of SAFE-PUR will be developed and tested within the project, provided that the microstructure of SAFE-PUR attains an equivalence level to that of conventional PUR or BioPUR.

In general, plastic foams have a higher carbon footprint compared to natural and mineral materials. However, the bioPUR insulation material has an estimated carbon footprint value that is lower than many other types of insulation materials.

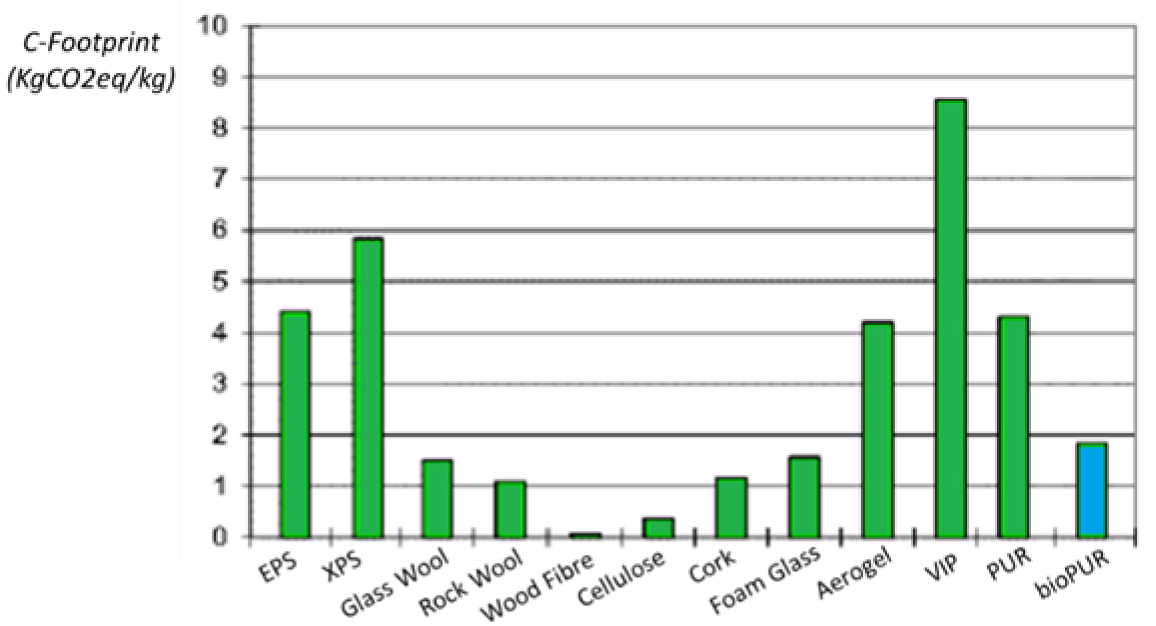

Figure 7. Comparative values of C-Footprint of insulating materials

3.2. Recycled aluminium mounting structure and fixing elements

RESKIN's multifunctional façade utilises a recycled aluminium mounting structure provided by EXLA to attach sandwich panels to the pre-existing façade. The mounting structure is aligned with RESKIN's aim to promote sustainability by using environmentally friendly materials during construction, as it is made from recycled materials and does not generate additional waste. Furthermore, aluminium is a durable material that provides long-lasting support for the panels.

EXLA eco-efficient aluminium

Aluminium is a highly versatile and sustainable material. It can be recycled infinitely without any loss of quality, making it an essential material for sustainable development. EXLA is a company that produces eco-efficient aluminium, which is recycled in their own facilities. Their production process generates a minimal carbon footprint of only 3.67 kg of CO_2 per kilo of aluminium produced, reducing carbon emissions by 79.6% compared to the world average for primary extraction. The use of such recycled aluminium in the production of sandwich panels for building façades supports sustainable construction goals.

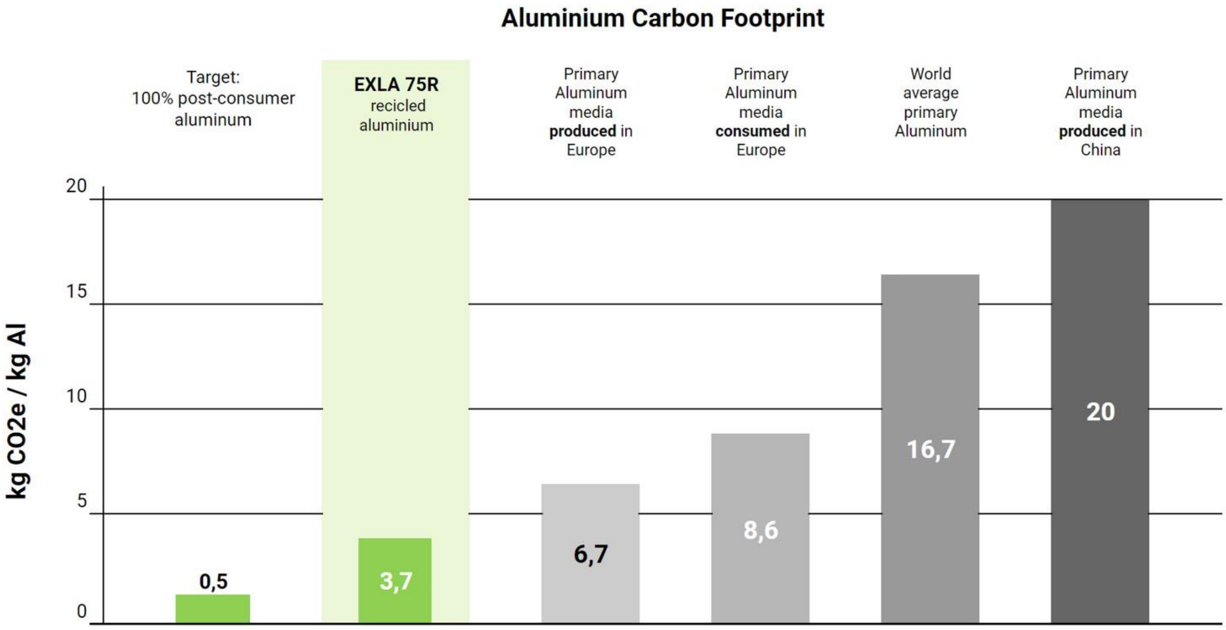

Figure 8. Aluminium Carbon Footprint

Structural Profile properties and composition

AA 6063 is an aluminium alloy containing magnesium and silicon as alloying elements, and its composition is regulated by The Aluminum Association. This alloy has excellent mechanical properties and can be heat treated and welded. It is the most commonly used alloy for aluminium extrusion due to its ability to create complex shapes with smooth surfaces suitable for anodising.

Constituent element	Minimum (% by weight)	Maximum (% by weight)
Aluminium (Al)	97.5%	99.35%
Magnesium (Mg)	0.45%	0.90%
Silicon (Si)	0.20%	0.60%
Iron (Fe)	0	0.35%

Property	6063-T5
Tensile Strength	186 MPa | 27000 psi
Yield Strength	145 MPa | 21000 psi
Modulus of Elasticity	68.9 GPa | 10000 ksi

Figure 9. Aluminium Composition

The panels are attached to the existing walls via the structural profiles, fastened by self-drilling screws to the supporting brackets that are anchored to the façade walls using mechanical fixings and plugs. Before installation, a dynamometric test (Pull-off Test) is conducted to assess the tensile strength of the walls and load capacity of the fixings.

Façade system

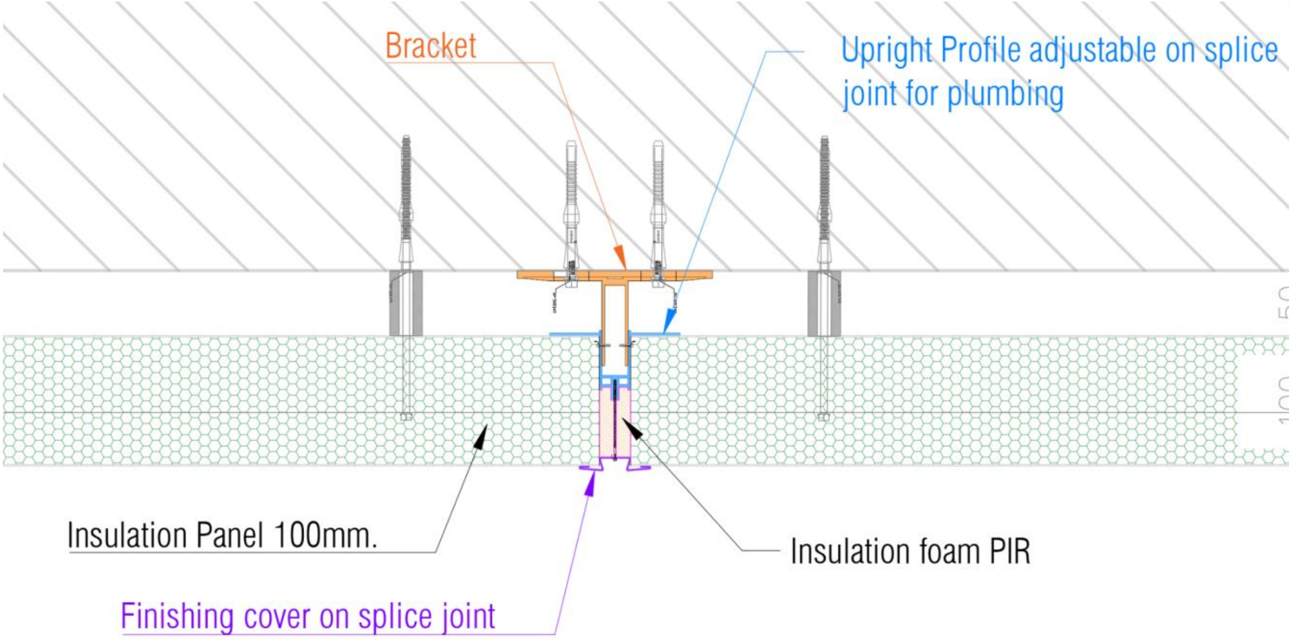

Figure 10. Detail drawing of façade system mounting profile [drawing created using AutoCAD]

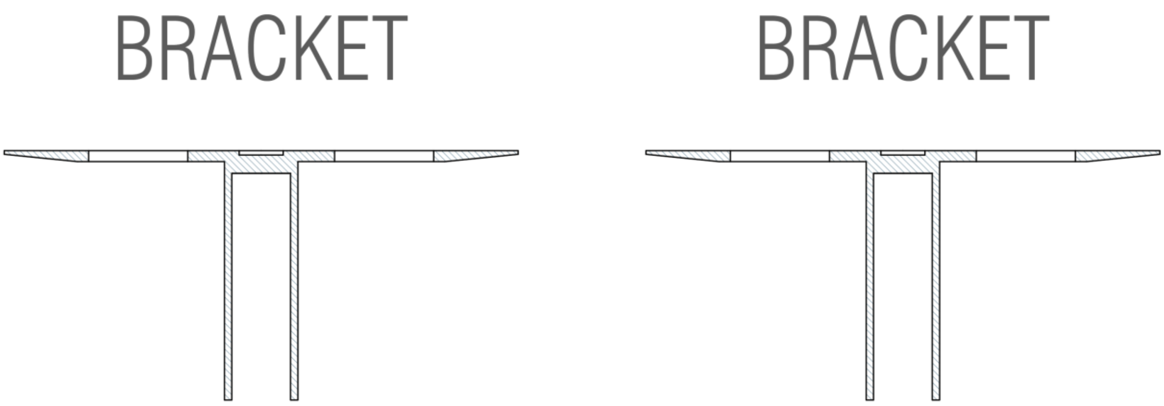

Figure 11. Detail drawing of the façade system's brackets and profiles [drawing created using AutoCAD]

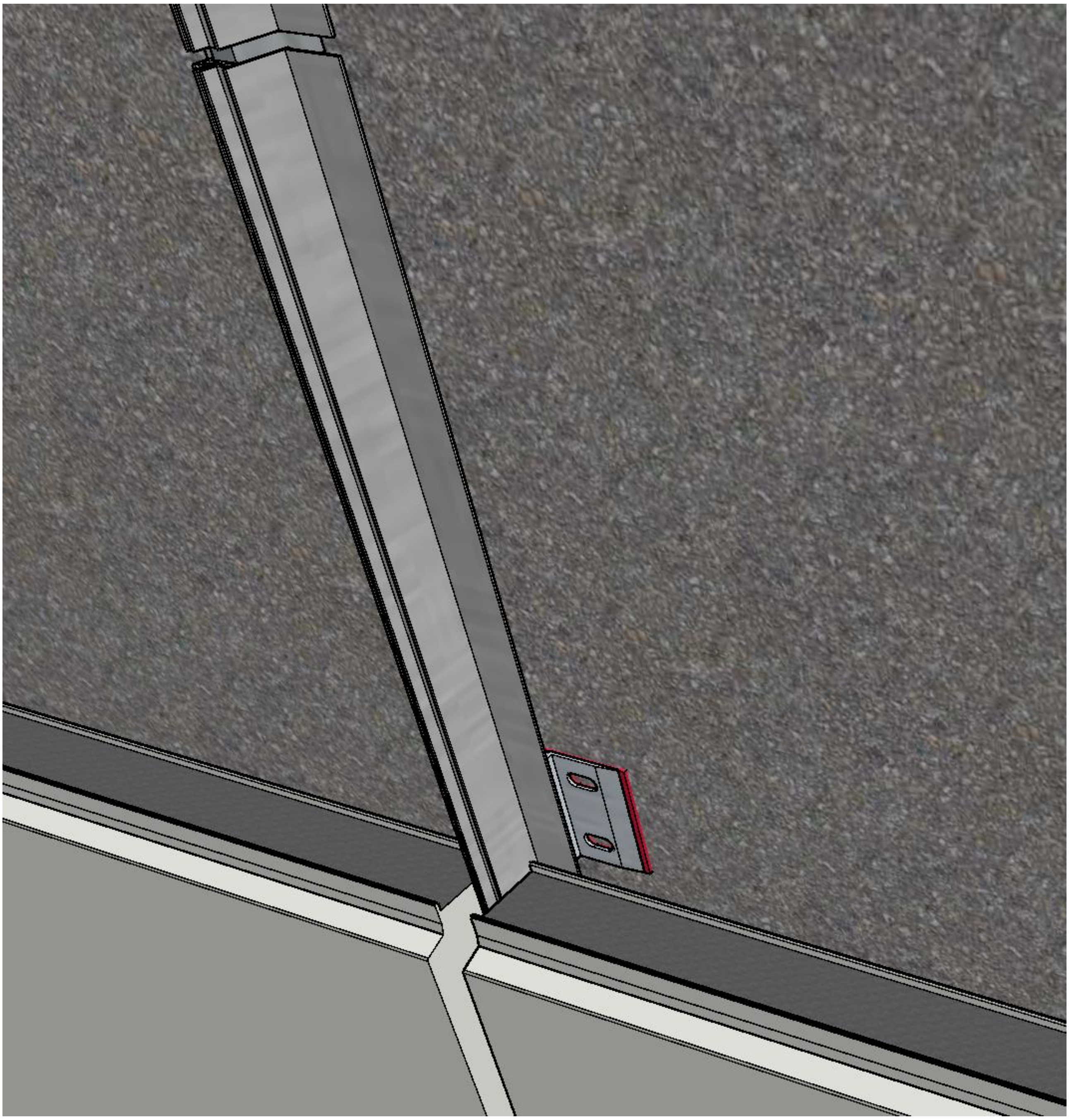

Figure 12. Sandwich panel and substructure [image created using SketchUp]

Figure 13. Substructure elements [image created using SketchUp]

3.3. Finishing elements

The versatility of the machinable and modular façade system enables customisation of the design and configuration to meet the unique needs of a building while integrating with pre-existing elements such as pipes, wiring, vents, or sensors. Additionally, the system is detachable, facilitating installations and services' inspections in designated areas.

In order to ensure the proper installation of façade components, GAR has developed a catalogue of standardised technical details for constructive solutions. This catalogue includes details for the installation of singular points such as windows, doors, corners, air vents, and horizontal and vertical panel connections. These technical details are necessary for the successful implementation of the façade installation system described earlier. By following these standardised details, the installation process can be carried out with greater efficiency and accuracy, reducing the risk of errors and ensuring that the façade functions properly.

Some examples of constructive solutions' technical details regarding façade installation in singular points:

Windows

In order to achieve vertical alignment of window openings and ensure evenness between them, substructure profiles are installed adjacent to the windows along the entire length of the façade.

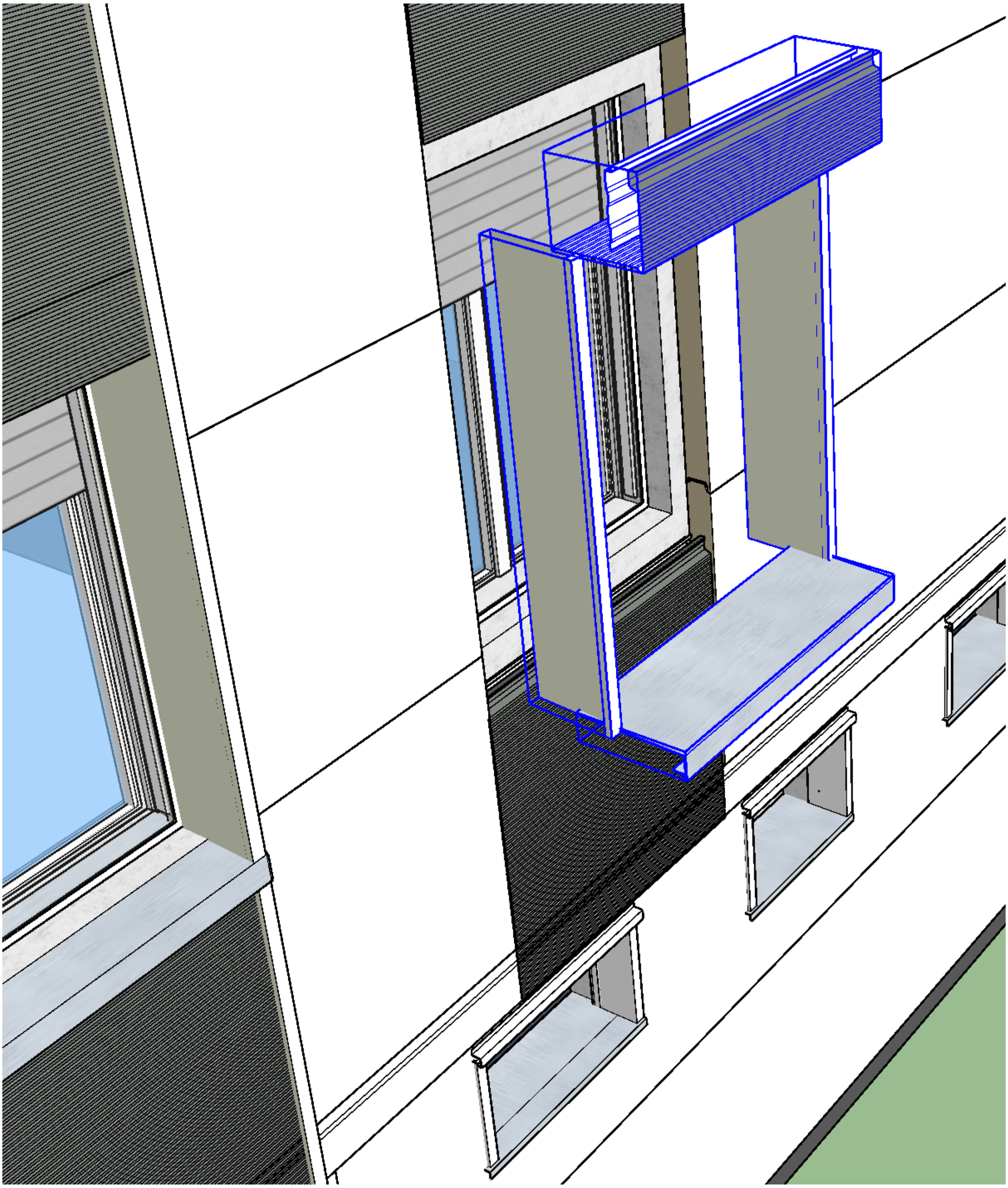

Figure 14. Finishing elements for window frames [image created using SketchUp]

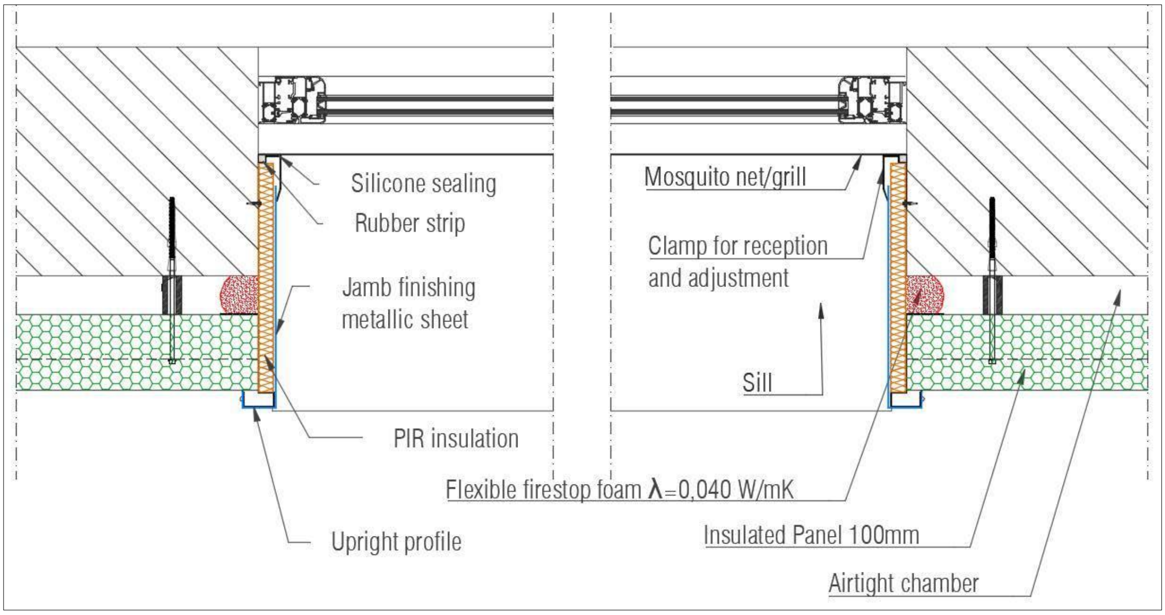

Figure 15. Window detail drawing (horizontal) [drawing created using AutoCAD]

The lintels, jams, and windowsills are sealed using silicone and a rubber strip along the frame to create an airtight cavity. To insulate the jams, biosourced PUR panel insulation is used, while the windowsills are insulated with PUR insulating foam. However, to avoid obstructing the visibility from indoors, it is essential to assess the dimensions of the window frame before determining the thickness of the insulation to be applied to the jambs and lintel.

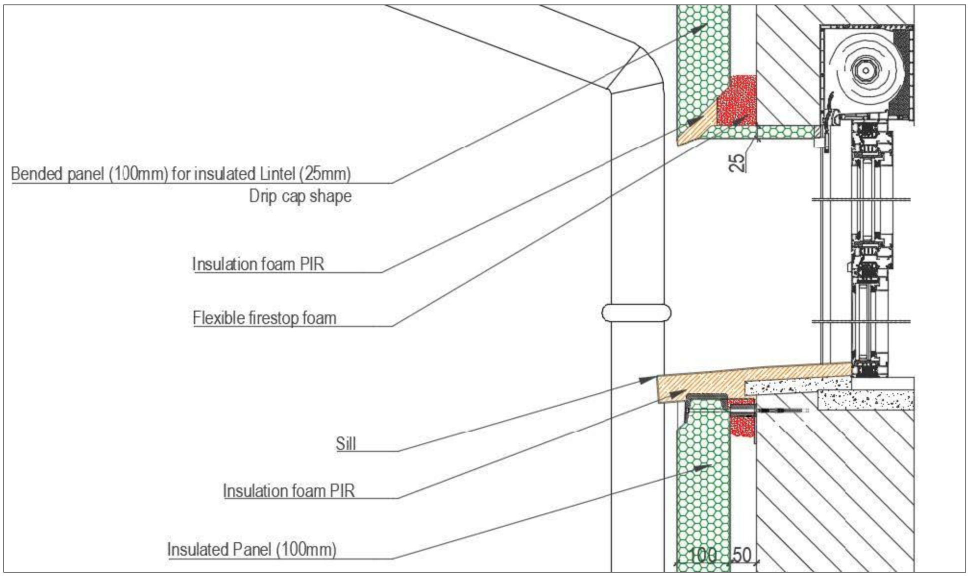

Figure 16. Window detail drawing (Vertical) [drawing created using AutoCAD]

The panel used to cover both the façade and lintel is bent at a 90-degree angle to maintain airtightness and minimise thermal bridging.

Additionally, the finishing covering the windowsill must reach the window frame to avoid water filtration and ensure complete sealing. Finally, when insulating the rain gutter, it is important to determine the dimensions of the window frame as well as the location of the drainage points to avoid covering them.

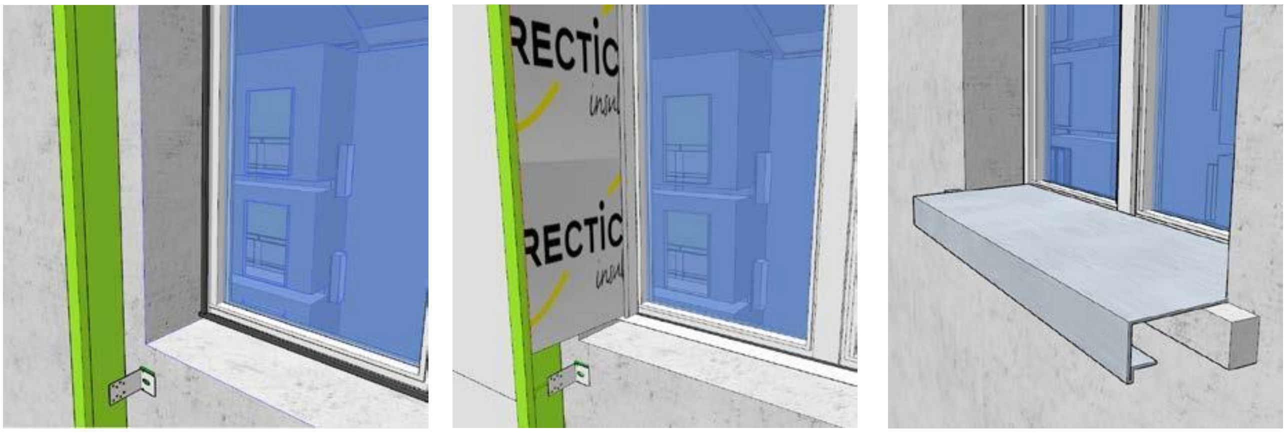

Figure 17. Window elements: rubber strip, insulation in clamp and rain gutter [images created using SketchUp]

<u>Balconies</u>

Residential buildings often have space-constricted areas that need to be insulated. This is the case for balconies, which require a different construction solution than the rest of the building due to the space limitations. The solution for balcony insulation consists of a biosourced PUR foam and a finishing layer of Greencoat sustainable steel, installed using brackets and profiles.

In the areas where it is not possible to install the sandwich panel, an alternative BIO-based material will be used for the 50 mm insulating layer, provided it is available on the market. Otherwise, a PIR insulating foam will be used.

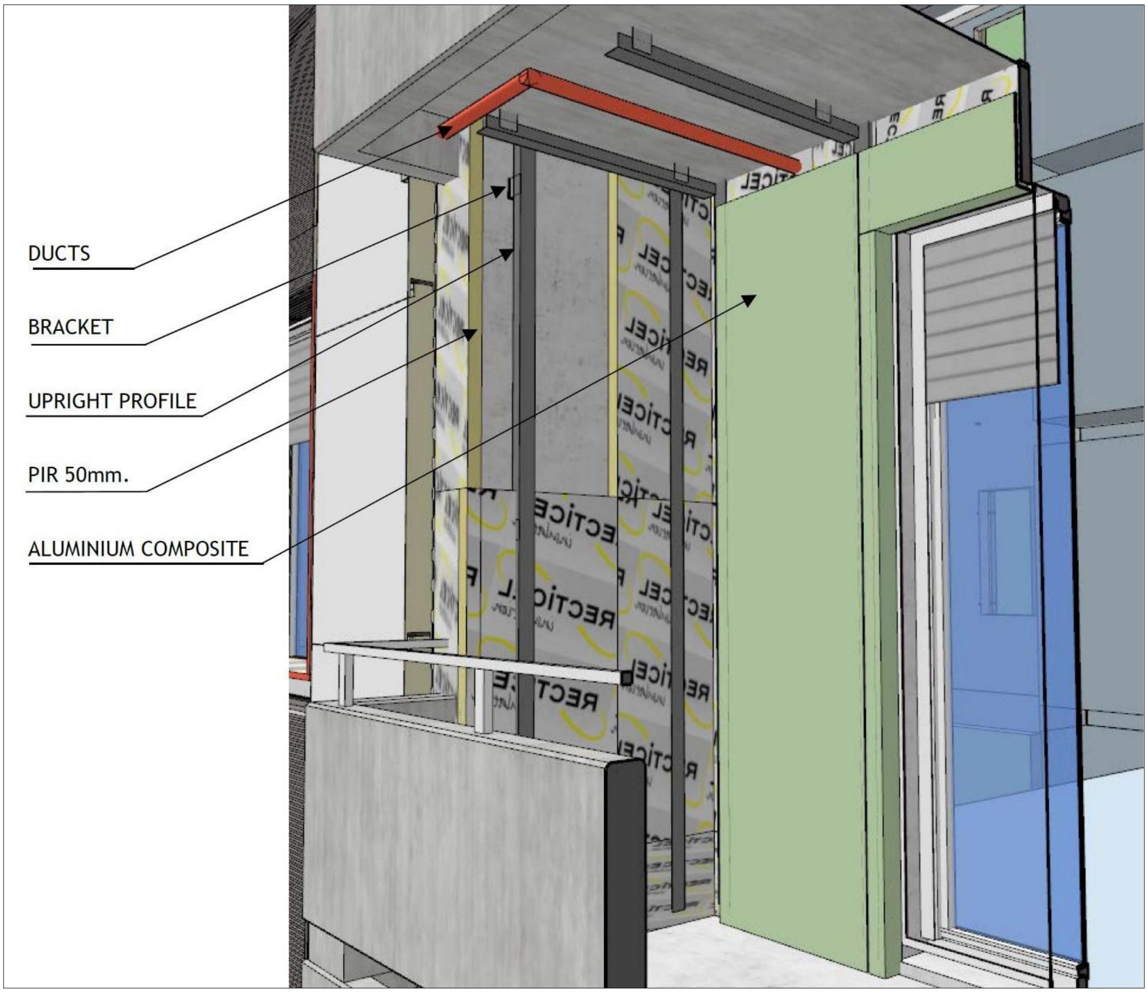

Figure 18. Balcony 3D [image created using SketchUp]

The construction solution for the insulation of balconies aims to reduce thermal bridges while using as little balcony space as possible.

Lintel and jambs are also insulated where possible, similar to window frames. During the insulation installation in these elements, the presence of mosquito nets or window grills in the balcony windows should be considered.

The balcony ceiling does not require insulation, therefore the gap between the ceiling and composite panel attached to the balcony's façade is used to house the wire-containing ducts.

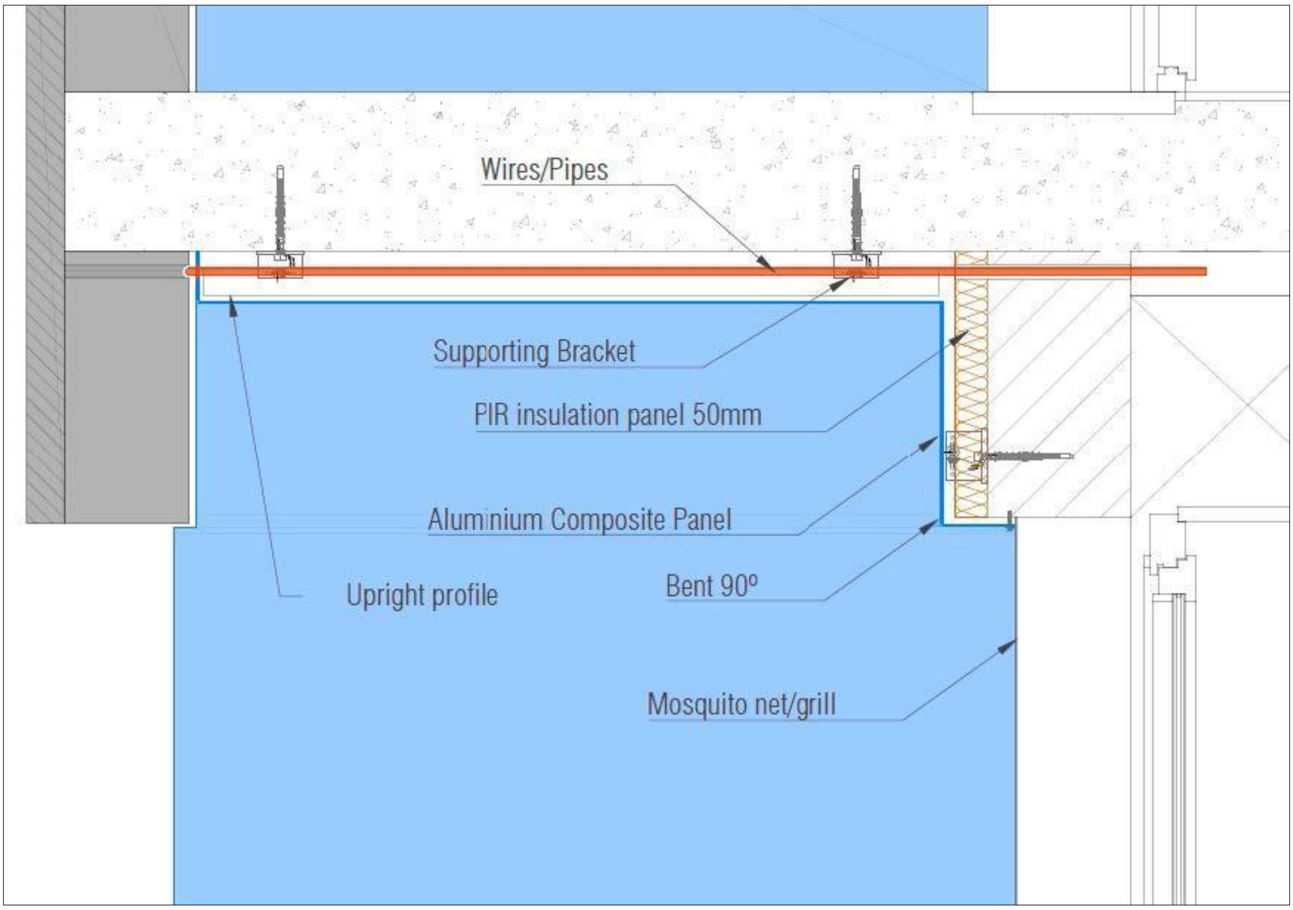

Figure 19. Balcony detail (Vertical) [drawing created using AutoCAD]

Other elements found in pre-existing residential buildings that require specific design solutions to adapt to the new façade system are gas metres, drainpipes, vents, and gas pipes. Drain pipes will remain on the exterior of the new façade, and before the installation of the new façade, they must be dismantled to allow the fitting of the substructure and panels. Once the new building envelope is in place, the drain pipes will be assembled again, readjusting the pipe elbows to adapt to the new façade's width.

Gas pipes and gas metres will be kept in the same location, and the insulation of the façade will be interrupted when its application overlaps with these elements. The composite panels will be adapted to allow for gas metre and gas pipe inspections.

Air vents will also be adapted to the new façade system, with the outside grid removed and a new ventilation duct connected to the former one.

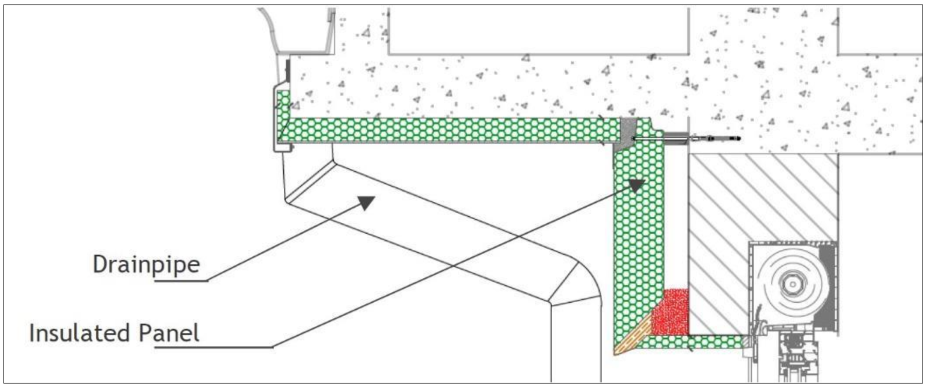

Figure 20. Drainpipe integration [drawing created using AutoCAD]

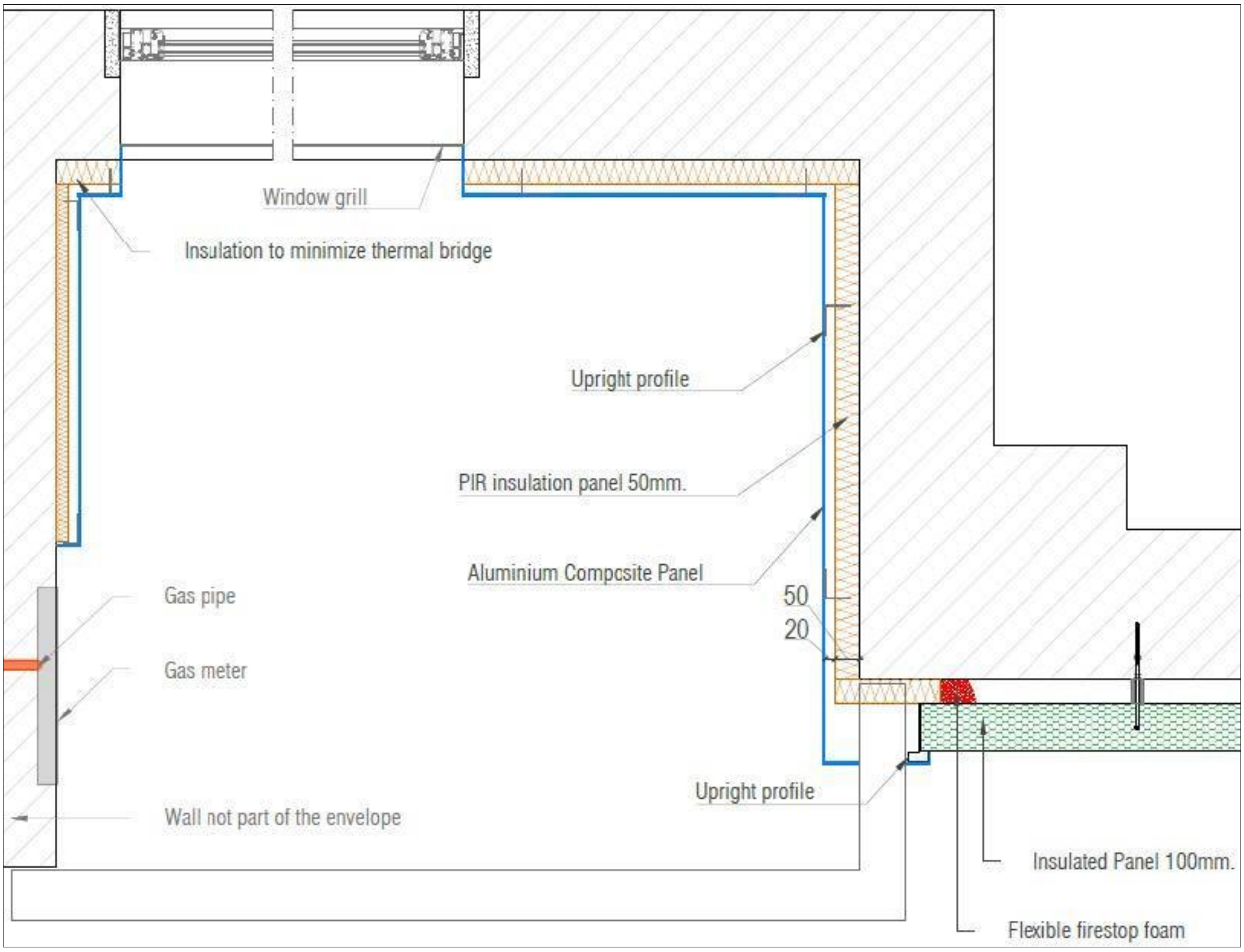

Figure 21. Balcony section (Horizontal) [drawing created using AutoCAD]

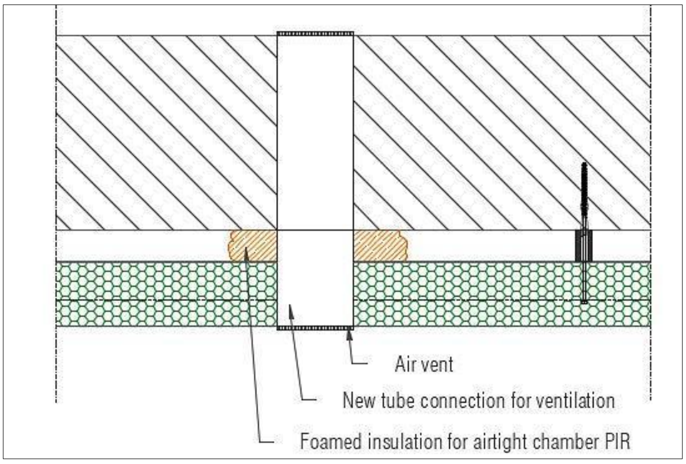

Figure 22. Air vent detail [drawing created using AutoCAD]

4. Installation mode

4.1. Selection of auxiliary equipment

The selection of an installation system by the installer is reliant on the complexity of the façade and the current accessibility conditions. For instance, when the façade is excessively intricate, the installer may prefer to use general scaffolding systems, while crane platform installation systems may be employed in less complicated situations.

Figure 23. Crane platform and scaffolding installation system

4.2. Preparation of walls that will support the new façade

To ensure the strength and endurance of the pre-existing wall structure that will support the façade system, multiple test samples using a dynamometer are necessary. GAR has developed a Pull-Off Test Guide with detailed instructions and indications to determine the required type of anchoring. The test aims to establish whether mechanical anchoring is sufficient, or whether chemical anchoring is necessary in cases where the façade walls are weak, deteriorated or poorly constructed. This process ensures the stability and safety of the façade system.

Figure 24. Wall testing

4.3. Substructure installation

The installation of the façade structure requires at least two operators to work simultaneously. The workers are responsible for laying out and distributing the components with the assistance of laser measuring and guiding equipment. The installation process begins by fixing the brackets, followed by the lower base profiles. Finally, the remaining substructure is installed, using the appropriate fixings depending on the condition of the wall that will support the façade envelope.

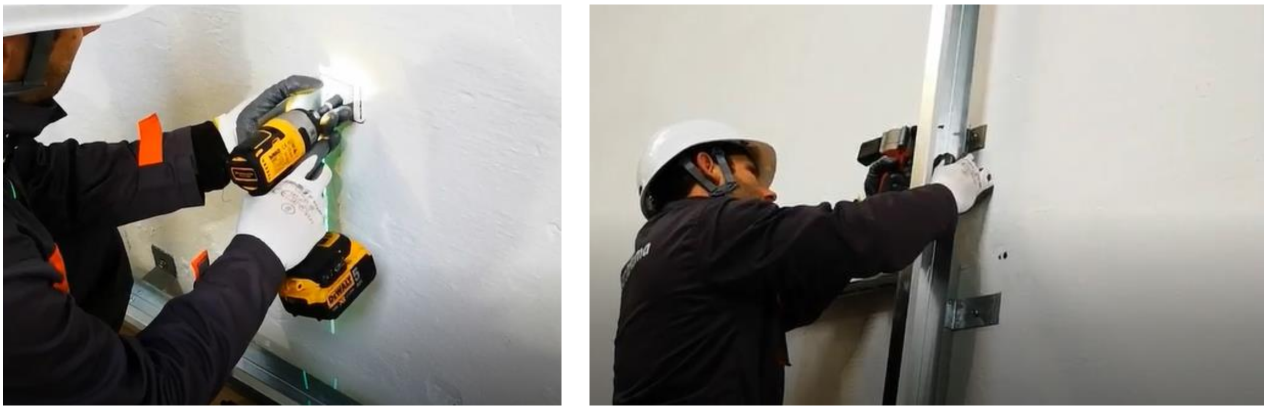

Figure 25. Demonstration of substructure installation

4.4. Insulating panel installation

The façade panel is affixed to the substructure and subsequently to the wall using screws, which remain concealed as a result of the tongue-and-groove system.

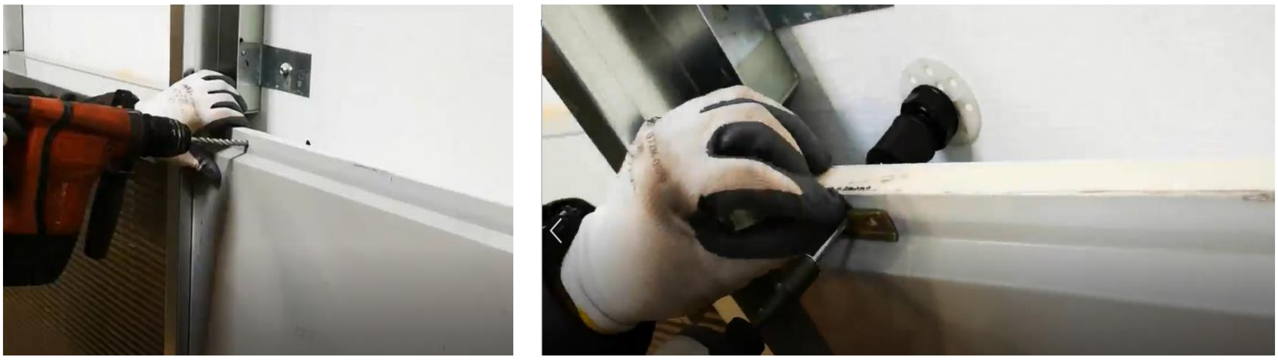

Figure 26. Demonstration of insulating panel installation

4.5. Installation of finishing elements

As with other façade cladding systems such as ETICS (External Thermal Insulation Composite System) or ventilated façades, finishing elements are required to complete singular elements such as window frames, jambs, rain gutters, and gables. It is recommended to use aluminium sheet components for this purpose. In the case of window frames, an insulating sheet should be placed on the inner layer to prevent thermal bridging.

Figure 27. Images of the façade fully installed

5. Operation mode

The aim of the installation system in the RESKIN project would be to include an adaptive sealed chamber. GAR is studying the possibility of developing such a system, which could potentially be implemented in the future. This chamber would be separated from the existing façade by a sufficient distance to enable the placement of installation components. The internal chamber would be designed to serve as a thermal resistance and could be created by sealing an airtight gap. Such a system, if developed in the future, could provide an effective insulation solution in cold seasons. The transmissivity of the chamber could be adjustable, and it could be opened to enable ventilation in warm seasons. This would ensure energy efficiency and reduce energy costs while allowing for easy adjustments according to seasonal changes. The airtight seal in the cold seasons would ensure that the internal temperature of the building is maintained, while in warmer seasons the cavity would allow air to circulate and prevent the accumulation of moisture and heat. If ventilation grilles are placed strategically, fresh air could enter the cavity and stale air could be exhausted, creating a continuous flow. In this preliminary design stage of the system, the grilles are positioned at the base and top of the façade, allowing for the intake and exhaust of air. The grilles would be designed to prevent the ingress of water or other debris and could be made of materials such as stainless steel or aluminium. This design solution could thus contribute to creating a comfortable living environment for the building occupants.