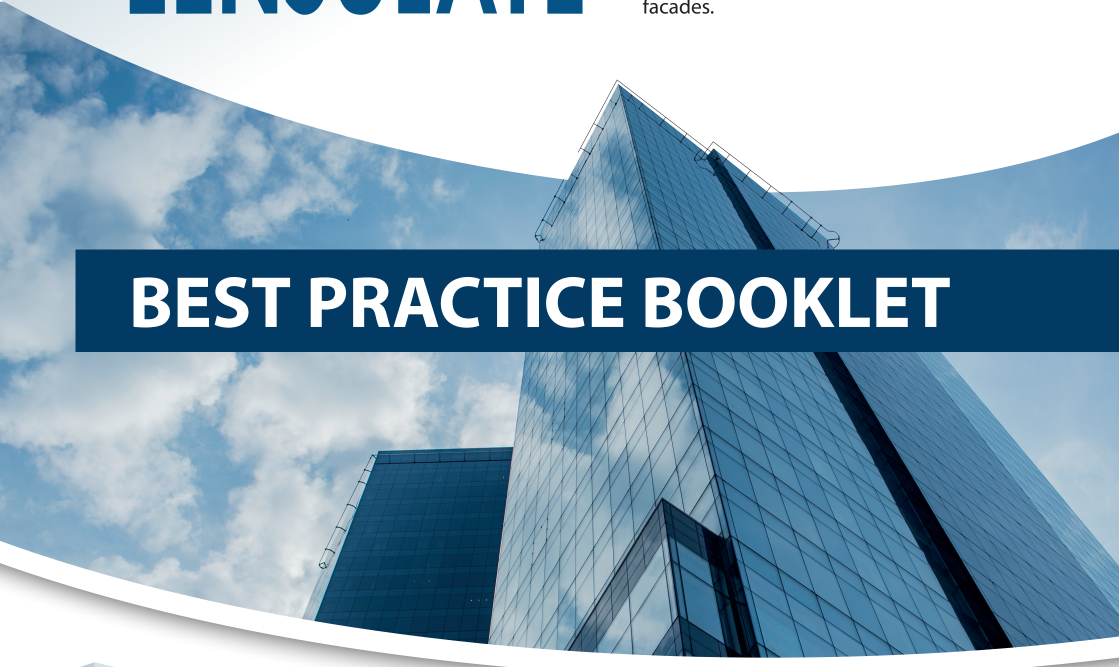
EENSULATE

HIGH END MATERIAL FOR MODERN BUILDINGS

Development of innovative lightweight and highly insulating energy efficient components and associated enabling materials for cost-effective retrofitting and new construction of curtain wall facades.



BEST PRACTICE BOOKLET

PROJECT PARTNERS

This project has received funding from European Union's Horizon H2020 research and innovation programme under grant agreement **No. 723868.**

@Eensulate1 @eensulate @ensulate-project

www.eensulate.eu

MAIN TECHNOLOGIES

1. Lightweight and thin double pane Vacuum Insulated Glass (VIG) for transparent element of façade modules and window applications.
2. Highly insulating and fire retardant foam used for the formulation of two products: a two-component polyisocyanurate foam (TCF) used in the spandrel part and a one-component polyurethane foam (OCF) used as thermal sealant, both enriched with nanoparticles.
3. EENSULATE Sealant
4. EENSULATE Getter
5. Thermochromic coating

VACUUM INSULATED GLASS (VIG)

Vacuum Insulated Glass (VIG) is manufactured by BGTEC using a tailored manufacturing process - implementing innovative sealant and getter strips to ensure the achievement of target properties. The VIG prototypes are manufactured in two sizes:

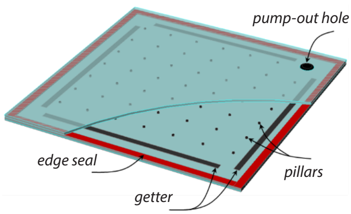
- Small Scale VIG prototypes (500x500mm)
- Large scale VIG prototypes (1000x1000mm)

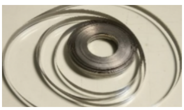
The high effort by project partners ULSTER and SAES during the assembly process for the small-scale VIG prototypes (500mm by 500mm) resulted in the achievement of the project performance goals and the definition of a reliable process protocol ready for technology transfer and for large scale production.

Two approaches were investigated for the application of the polymer edge sealant:

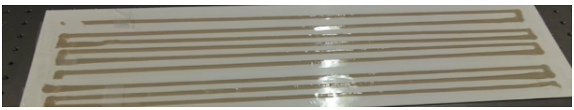
1. Needle dispensing by a semi-automated two-axis machine loaded with sealant syringes kept at a temperature range of 60°C to 80°C;
2. Manual application of a sealant-based preformed solid strips.

VIG sample - key components





Getter strips coil

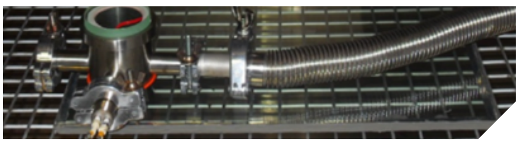


Sealant strips

Sealant and getter

Pairing and clamping glass panes

VIG small scale prototype after sealant curing



Pump down of sealed glazing

Scheme of the EENSULATE glass

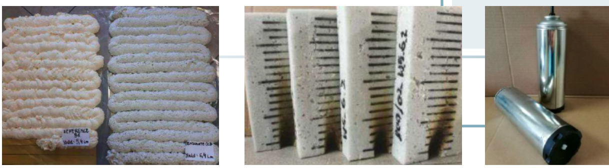
EENSULATE FOAMS

ONE-COMPONENT FOAM (OCF)

The OCF is used as an effective thermal sealant between the curtain wall and sub-structures, containing a bitteri agent that prevents small animals and insects from consuming and destroying the foam in the cavities. The polyurethane foam is packaged in a pressurized can and can be easily used in construction sites.

What are the benefits?

EENSULATE OFC has improved behavior thanks to the use of nanosized inorganic fillers and expandable graphite which ensure high level of resistance. The two-component foam assets were transferred to increase the properties and remove toxic compounds (e.g. halogen molecules).



EENSULATE One-component foam samples

TWO-COMPONENT FOAM (TCF)

TCF is highly insulating polyisocyanurate (PIR) foam based insulating material enhanced with eco-friendly lamellar inorganic fillers, that contributes to energy performance requirements, environmental challenges and cost reduction without compromizing the overall building safety. The TCF is injected as a workable material for the manufacturing of the spandrel replacing cut-to-measure mineral wool panels.

What are the benefits?

The advantages of the TCF system during the production system are increased efficiency of 35 kg/m3 and ease of processing. PIR system with layer fillers also provides protection properties by acting as a reinforced layer. Providing an effective barrier against heat and oxygen, release of non-flammable gases, and at the same time effectively suppressing smoke and gases during a combustion process.

EENSULATE Two-component foam samples

EENSULATE SEALANT

During the sealant development, a number of polymer materials have been analysed. The most promising class was represented by epoxy resins, typically with Ar permeability around 10^{-1} barrer. Through a thorough molecular design of the polymer formulation and the optimization of the active and passive fillers, a sealant formulation with $2.5 \cdot 10^{-3}$ barrer of Ar permeability was obtained. The final formulation also exhibited extremely high barrier performance for N_2 and O_2 (up to two orders of magnitude better than commercial sealants for insulating glass). The sealant also contains an active filler for moisture absorption. The resin has high yield stress and adhesion strength (> 7MPa) on glass surfaces. It can be processed by an automatized system working with precise erogation in the range of 60÷80 °C with final curing at temperature range 150-170 °C.

EENSULATE Sealant

EENSULATE GETTER

In the context of distributed getter development, two getter families were investigated: polymer-based composites and metallic strips/coated films. Metallic strips and coated films exhibited more promising performance. In particular, both St787® coated films and St122®-based high porosity thin films (HPTF) fulfil the sorption targets. However, coating films are not easily scalable to an industrial production while HPTF products exceed the cost targets for VIG technology. Finally, the best getter solution was identified in laminated strips of a Zr-alloy, namely ZAO®02 alloy. This solution meets the sorption capacity requirements for N_2 and O_2 (being also superior to state of the art solutions for VIG), it allows an industrial scale-up at a reasonable cost and it can be easy handled and positioned in air. The getter activation is performed by radio-frequency heating.

EENSULATE Getter

THERMOCROMIC COATING

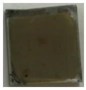
To solve the increasingly urgent need for reduction of energy demand in buildings, EENSULATE proposes a glazed façade system based on VIG technology coupled with a thermochromic coated glass.

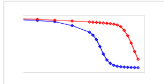
Thermochromic thin film is a recognized solution for the reduction of the solar radiation entering into a glazed system due to its ability to modulate the solar heat gain of the glass. This “intelligent” property of the thermochromic film distinguishes the insulation nature of the windows from any other passive solution, like VIGs that have the same degree of insulation during variable ambient temperature. The thermochromic window has a dynamic behaviour as it allows or prevents the solar radiation from entering through the glazed facade depending on the temperature reached by the thermochromic coating. In fact, below a certain temperature, the coating allows solar radiation to enter the building while above this temperature the solar radiation is reflected outside to prevent indoor overheating.

Energy building simulations have been performed considering the effect of the first thermochromic system developed within the EENSULATE Project and on the energy saving against both clear glass systems and the VIG EENSULATE module. The simulation inputs - the optical properties (visible and solar reflectance and transmittance) of the thermochromic glass were provided by UCL and measured in the UNIVPM laboratory. Those properties have been considered as a baseline from which the simulation start. By changing the switching temperature and minimising the building energy consumption the optimal thermochromic configuration has been retrieved.

EXPERIMENTAL CHARACTERISATION OF THERMOCHROMIC COATED GLASS

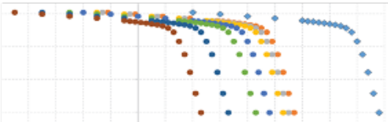
- Solar/visible transmittance/reflectance estimation
- Switching temperature evaluation





VITRUAL TEST BENCH DEVELOPMENT APPLYING THE THERMOCHROMIC GLASS CHARACTERIZED

SWITCHING TEMPERATURE OPTIMIZATION USING THE VIRTUAL TEST BENCH



Switching temperature shift

Minimum consumptions identification for a specific climate and orientation

Optimal switching temperature
LINK TO DESIGN

At UCL, a thermotunable VO2 coating was applied by using a sol-gel process and spin coating on glass. The coating is able to change the transmittance of glass as a function of the ambient temperature. At low temperatures the coating is highly transparent but as temperature rises it becomes more opaque, particularly at the near-infrared part of the spectrum. By using building energy modelling software (EnergyPlus) UNIVPM modelled the performance of the thermochromic coating when applied in real buildings and have identified optimum conditions for different cities in Europe and types of buildings

EENSULATE REAL-SCALE DEMONSTRATION

The performances of the Eensulate insulating solution was assessed in a full scale prototype. Demonstration buildings were located in two different climates (Italy and Poland). The focus was placed on the thermo-acoustic behaviour of the buildings, indoor comfort and different parameters were monitored:

- Weather data
- Internal and external wall temperature
- Heat flux
- Indoor temperature and humidity
- Sound transmission loss

POLISH SCHOOL - DZIERŻONIÓW, POLAND

The Polish school resides in a curtain wall building which the Dzierżoniów municipality aims to refurbish to improve the façade performances. The EENSULATE renovation intervention consisted of introducing glazing curtain walls to enhance the building profile to zero energy in line with EU and national targets for public buildings. After the implementation of EENSULATE solutions, the building was a demo case proving the project results to both national and international stakeholders, and enhancing the image of Dzierżoniów municipality.

Intervention details

The renovation intervention consisted of the full substitution of the curtain wall façade (including frame) of the school building. The selected façade was one of three façades of the building. The refurbished building area is organized as an open-space where students spend their free time during breaks. In order to compare the performances of the project developed solution, two floors of the building façade were partially covered by EENSULATE modules with VIGs and the rest by the same module using standard TGU (Triple Glass Unit) in the frame.

MUZEUM MIEJSKIE DZIERŻONIOWA - DZIERŻONIÓW, POLAND

The Muzeum, built in 1897, originally belonged to Hermann Cohn, Cohn Gebrüder co-founder and was one of the first mechanical weaving mills in Dzierżoniów. The building has undergone many renovations and adaptations in order to adapt the space for museum purposes. Preserved elements of the interior gradually returned to its former state thanks to conservation work. Today the museum hosts permanent exhibitions, including cartographic collections concerning Dzierżoniów and the surrounding area. A large collection of artefacts illustrates the development of the region since the late Paleolithic times.

Intervention details

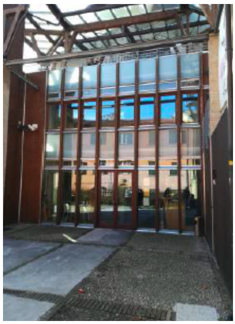
The intervention and the implementation of EENSULATE glass based on VIG (Vacuum Insulated Glass) technology was done in a selected number of museum windows. Being a historical building, renovation works, including the ones related to the windows, are subject to several and severe restrictions to preserve its artistic value. For this reason, the implementation of VIG directly in the original windows minimised the impact of the intervention increasing the insulation capacity with a benefit for the people inside the room. This kind of operation is possible thanks to the low thickness (12.2 mm) and light weight of the VIG, perfectly adapting to the original windows increasing their performances without changing neither the materials (the window frame is the original) nor the aesthetic aspect.

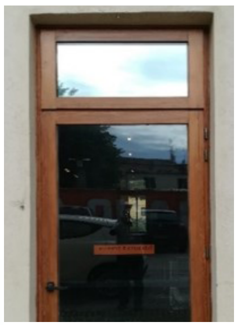
PUBLIC LIBRARY SAN GIOVANNI - PESARO, ITALY

Hosted by the ancient monastery of the Frati Minori Osservanti, once annexed to the church of San Giovanni Battista (one of Pesaro's most beautiful architectural works) and planned by the Della Rovere family's architect Girolamo Genga, the library San Giovanni is an example where the historical (the façade facing the access street) and contemporary architecture elements coexists. Those elements are a large windowed eyelet for the lighting of the public spaces and a curtain walling façade in the building main entrance. The building acted as a demo for testing EENSULATE glass in one window of the historical façade. Although Pesaro municipality is not a project partner, they made this building available as demonstration case of the EENSULATE project.

Intervention details

The intervention was done by implementation of EENSULATE glass based on VIG (Vacuum Insulated Glass) technology in a door-window located in an area of the building organized at an open space hosting a kid-library. The VIG was installed directly in the original frame of the door-window, minimizing the work carried out as well as the waste of material. The simple substitution of the glass part of the door-window with a high insluating VIG increases the thermal insulation of the window system with a consequent benefit for the visitors. The door-window is composed of two parts, the above one is fixed (without the possibility of opening) and the bottom part is an emergency door exit leading directly outside the building.





Peraso Public Library demosite

RETROFIT PROCESS APPLICATION AT THE INDIVIDUAL DEMONSTRATION SITES

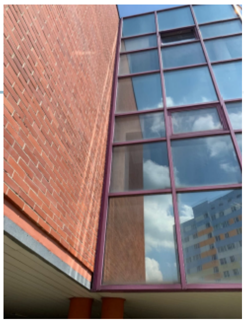
POLISH SCHOOL - DZIERŻONIÓW, POLAND

The school building façade has a curtain wall and represents an ideal example to test and validate the applicability of the EENSULATE module.

Boundary conditions: Architectural and normative requirements

Some boundary conditions emerged during the design phase. key points become evident and have been addressed through the following actions for the retrofitting:

- **Load bearing structure** – the structural components are out of scope of the project, therefore the EENSULATE façade module was installed on the existing load bearing structure of the building. The existing Curtain Wall Façade is a stick system installed on the front of the slab and the installation of EENSULATE module replicates this bearing solution. Once the existing façade is removed, new bracketswere installed to support the EENSULATE modules.
- **Façade interface with existing elements** – the interface between the EENSULATE modules and building elements (walls, ceiling, roof) was a crucial element designed. The concept of manufacturing the EENSULATE modules offsite was chosen to guarantee a "fast installation" solution on-site. Therefore, as many details as possible were designed and solved off-site, reducing the intervention on-site to a minimum. Figure 2, Figure 3 and Figure 4 show the interfaces.



Interface between existing brick wall and façade

Interface between ground floor's ceiling and façade

Interface between roof and façade

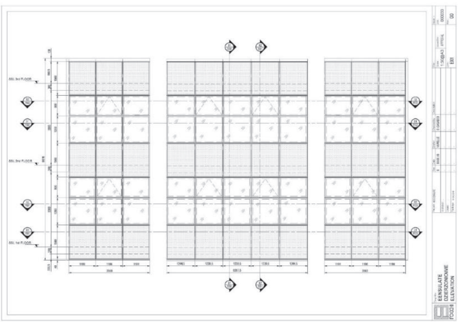
- **Façade colors** – a specific request of the municipality was to preserve the aesthetic homogenity of the retrofitted façade in relation to the other existing façade. For this reason, the application of profile treatment twith similar colors to the ones in the building was done.

Polish Primary School colour study with RAL 4001. Exterior view

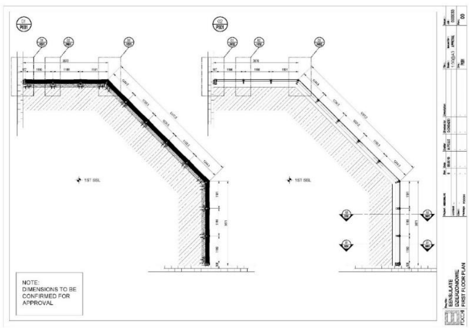
Polish Primary School: cotour study with RAL 4001. Interior view

Retrofitting design

Based on the above-mentioned points and thanks to the building school survey conducted on-site by BGTEC, FOCCHI succesfully carried out the EENSULATE façade retrofitting design.



Elevation curtain wall façade



First floor plan

Monitoring design for validation phase

The School demo was exploited tfor monitoring the EENSULATE VIG system performance in a real installation in comparison to a common low energy triple glass unit (TGU). In order to perform the relative characterization, both systems were monitored with thermal and irradiance sensors. The Polish Primary School façade can be seen on the next image, with the EENSULATE VIG system highlighted in red and the standard glass installed in a frame close to the EENSULATE one in yellow.

The main physical quantities monitored are:

- Internal and external glass surface temperature
- Indoor and outdoor air temperature
- Heat flux through the glass
- Visible external and internal radiation
- Solar external and internal radiation

From this data the thermal and optical transmittance of the glass is calculated for the entire period of the monitoring activity.

VIG

Triple glazing

Polish Primary School façade

Intervention

Before intervention

After intervention

Installation works at the Dzierzoniow Public shool

MUZEUM MIEJSKIE DZIERŻONIOWA - DZIERŻONIÓW, POLAND

Boundary conditions: Architectural and normative requirements

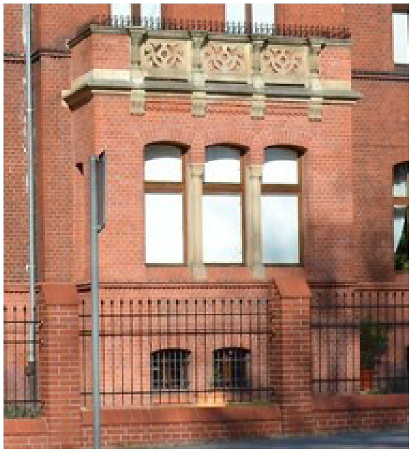
The Museum is a historical building and therefore has restrictions with regards to modification of elements of its construction. It was requested for the appearance of the new window to match the existing ones.

Thanks to the VIG properties, EENSULATE project has foreseen the possibility of substitution of existing poor performing glass with the highly thermally insulating Vacuum Insulating Glazing (VIG) keeping the same construction of the windows thanks to the thickness and the light weight of the new glass. When considering replacement by new windows it is usually challenging and costly to obtain the same details of window construction in terms of shape and hardware.

With the EENSULATE VIG solution the process is easier and faster, eliminating long time normally required for obtaining permissions. According to the construction law, works on monuments require a building permit and consent of the monument conservator which is more complicated to obtain due to several requirements to be respected to allow the renovation .

Retrofitting design

In case of the Polish Museum, renovation of a selected number of the windows in one room on the ground floor was done by EENSULATE. It was important that the intervention did not change visual aspect of the building.



Polish Museum - Side elevation

Existing windows were old box windows with double sash opening to the inside, filled with a single glass pane. As the whole window construction has deteriorated and needed renovation, the frame and sash were repaired by sealing, painting, changing gasket and performing all necessary works required for its proper function.

Old single glass was replaced with EENSULATE VIG of thickness 12,2mm (6+0.2+6mm) and weight 30kg/m2, by dismantling the window sash.

Window sashes were removed carefully in order to perform renovation works, they were sealed and painted, hardware was renewed and new gaskets were attached with the single glass replaced by VIG. The same sash was installed in the refurbished, existing frame. During this intervention, the window opening was protected against damage and weather conditions. Thanks to the thorough assessment of necessary works on site the time of intervention was reduced to a minimum.

Polish Museum - Internal view of the windows

Polish Museum - Window view with old roller shutter boxes

Monitoring design for validation phase

The Polish Museum was monitored to estimate relative glass transmittance performances, therefore two glass systems were monitored: the one that includes the EENSULATE system (dashed red line in the image below) and the traditional one (solid yellow line in the same image). In addition, in the Dzierżoniowie Museum, the thermal comfort was monitored. To realise this aim the following quantities were measured:

- room mean radiant temperature
- relative humidity
- velocity of the air in the room

Polish Museum front and zoom on the window to be monitored

SAN GIOVANNI PUBLIC LIBRARY – PESARO, ITALY

Boundary conditions: Architectural and normative requirements

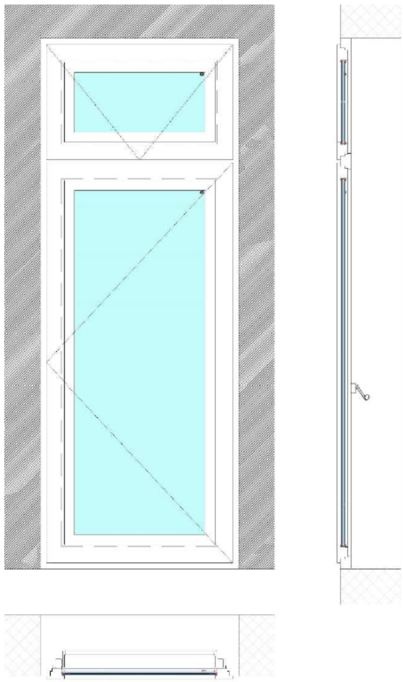
San Giovanni Public Library is a complex building owned by Pesaro Municipality, protected by the regimentation of Architectural Superintendence. Therefore, the possible intervention for the application of EENSULATE solutions was evaluated to comply with the existing architectural configuration of the building, to decrease the approval process and check its suitability. For this reason, the demo has been considered not suitable for validating the retrofitting with the EENSULATE modules. Along the main corridor of the Library, there is a long interior with door-windows with wooden frame and DGU. The intervention has been conducted by replacing the existing DGU with the VIG. The main objective of this demo was not to affectthe aesthetic of the building.

San Giovanni Public Library: internal view

San Giovanni Public Library: door-window

Retrofitting design

The retrofitting of the door-window preserves the overall window frame and replaces only the DGU (28 mm) with the VIG (18 mm). The intervention were conducted by removing the internal aluminium frame which restrains the DGU, cleaning the area from the existing sealant, placing the VIG, sealing the edge to create air and water tightness performance and repositioning the aluminium restrain to their initial position.



San Giovanni Public Library: VIG door window technical drawing

Monitoring design for validation phase

The San Giovanni Public Library was monitored in terms of glass transmittance and room comfort as for the Polish Museum. In addition, in this historical building, the wall transmittance was measured by heat flux meter and thermocouples installed on the internal and external surface of the wall itself. The same quantities as for Demo 2 were measured with the same sensors with an exception: the comfort was monitored by a unique system - Comfort Eye patented by UNIVPM. The monitoring has started in Demo 3 in October 2019 for the assessment the transmittance of the glass installed and the indoor comfort. The data registered was used for monitoring the glass performances and room conditions in the as-is configuration and for assessing the improvement that was obtained with the replacement of the window with the EENSULATE system.

San Giovanni library and window chosen for monitoring

Intervention

Installation at the Pesaro demo site

CONCLUSION

The design of the EENSULATE solutions for retrofitting scenarios demonstrates the wide applicability of EENSULATE components in different types of buildings with various objectives of retrofitting. Application guidelines are defined supporting the retrofitting market with EENSULATE components, as summarised below:

Retrofitting of Curtain Wall Façade:

1. **Façade replacement** – the EENSULATE module is applicable for the replacement of existing Curtain Wall Façades – The School building. The EENSULATE module is a lightweight solution which does not add weight on the load bearing structure of the building and is able to increase the energy performance. The profile color of the EENSULATE module can be customized to meet specific architectural needs.
2. **Existing glass replacement** – the EENSULATE VIG is applicable for the replacement of other glazed elements in Curtain Wall Façade – Focchi Headquarters. The adoption of the EENSULATE VIG is possible with minor changes in Curtain Wall system and with the adoption of a curved profile to mitigate thermal bridging. Moving from Triple-glazed Units and Vacuum Insulated Glass (VIG) – and vice-versa (the School replacement strategy) proves easy application of EENSULATE VIG.

Retrofitting of Windows

1. **Historical window** – the EENSULATE VIG is applicable for the replacement of historical glass with an improvement in energy performance without affecting the overall configuration of the windows.
2. **Contemporary window** – the EENSULATE VIG is applicable for the replacement of Double-glazed Units / Triple-glazed Units in existing windows with improvement of energy transmittance without affecting the overall configuration of the window.