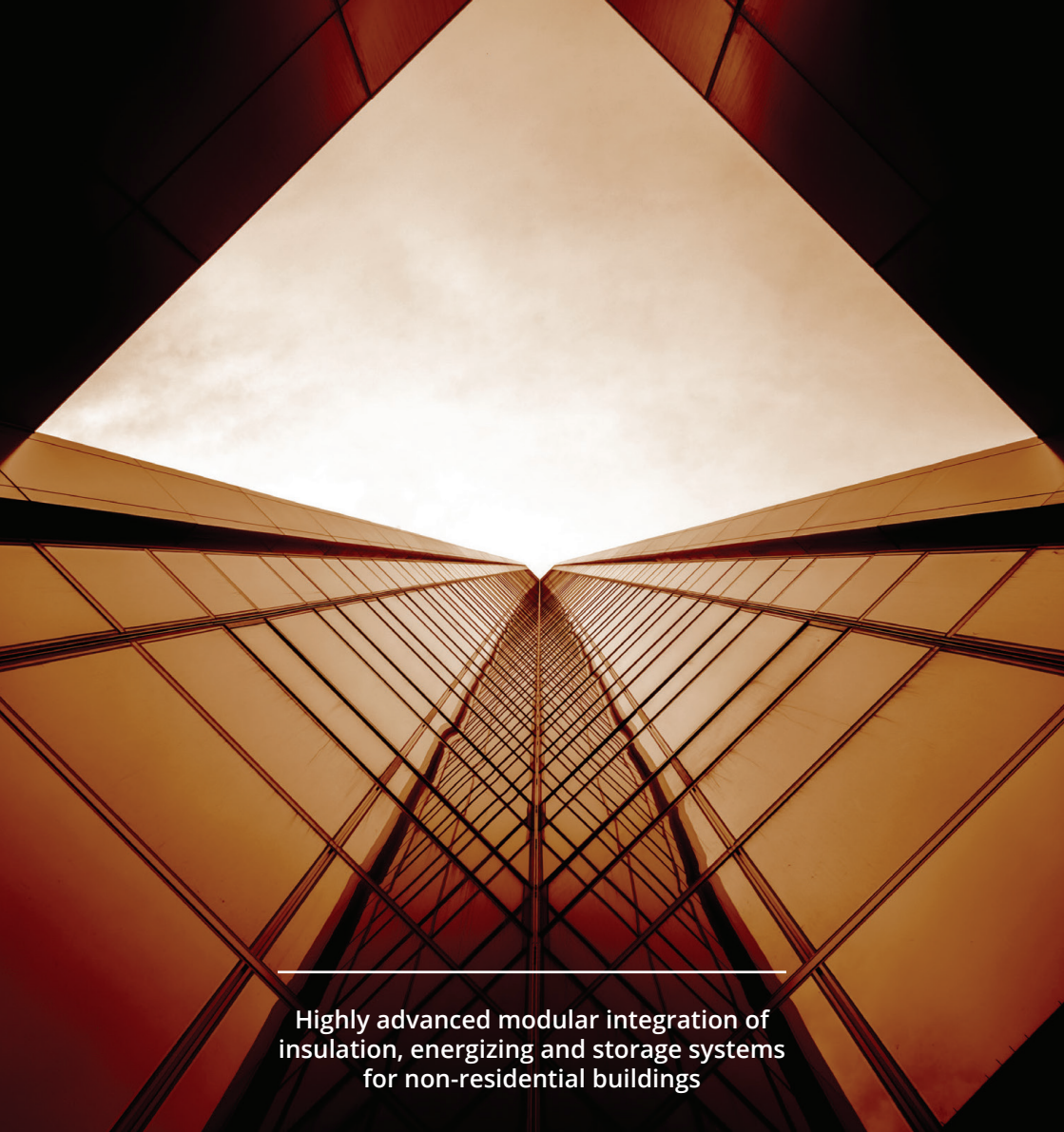




Highly advanced modular integration of
insulation, energizing and storage systems
for non-residential buildings

+ SYSTEM BOOKLET



+ MAIN TECHNOLOGIES

A truly integrative smart curtain wall façade solution comprising:



Super-insulative
and energy efficient
elements

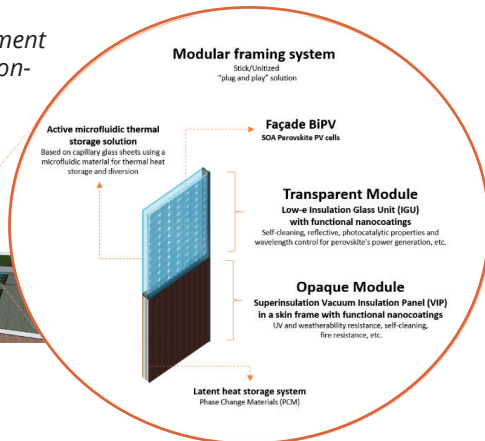
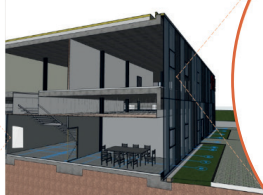


Solar energy
harvesting
components



Energy storage
features

All combined in one single management system, especially address for modern non-residential solutions



New generation of off-site, prefabricated and easy-to-install integrated solutions for curtain wall systems combining a wide number of state-of-the-art high energy-efficient materials, systems and key enabling technologies (KET).



Nano-superinsulation
elements



Multi-functional
nano-enabled
coatings



Solar energy harvesting
components based on
flexible solar cells



Second-life Li-ion
batteries from
electrical vehicles



Active-passive microfluidic thermal diversion
materials and PCM-driven latent heat storage
elements

Both standard (budget) and combined premium solutions.

Different sets of add-ons to match specific needs:



geographical
(climate) conditions



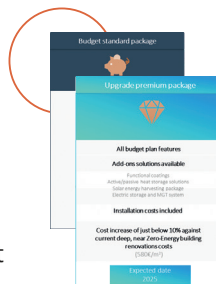
physical
constraints

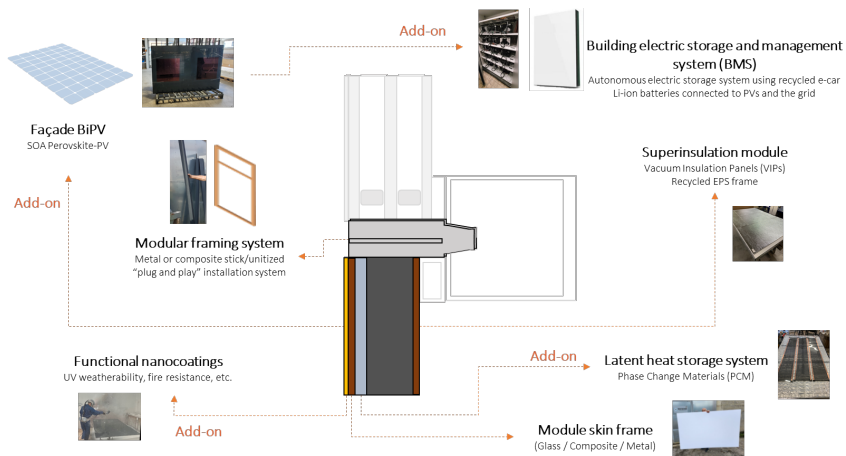
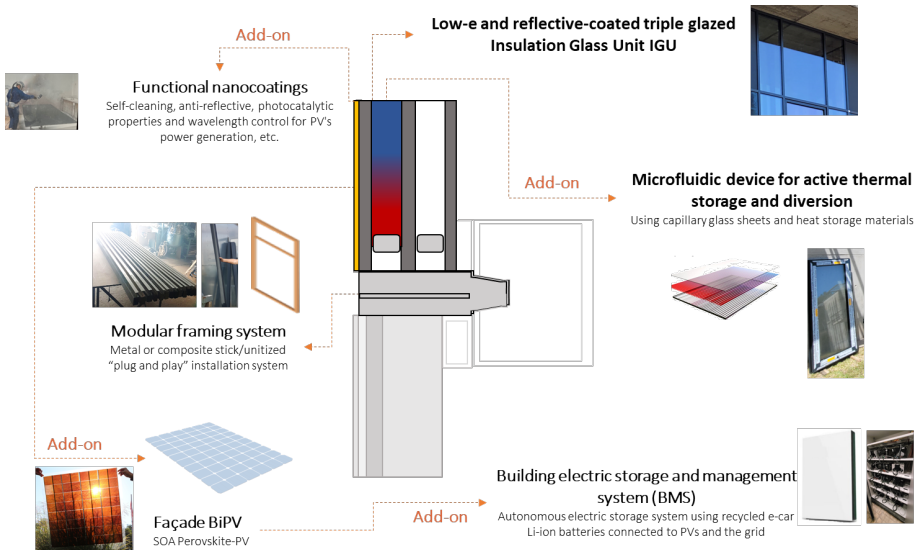


national
regulations



refurbishment
budgets





+ PS+ standard transparent modules

PS+ triple-glazed standard IGUs

The glazing device comprises three parallel soda-lime silicate float glass sheets in a standard aluminium frame, separated by aluminium warm-edge spacers and primary sealed at the perimeter employing a butyl string. The cavity in-between the glass sheets is filled with Argon gas to fulfil thermal insulation requirements (U-value below 0.8 W/ m²K). Standard surface-functionalised float glasses with commercial low-emissivity (low-e) coatings are used for the inner pane and centre pane. For the outer pane, clear float glasses are used.

Configurations	Superior thermal insulation (triple glazing IGU)	Thermal storage feature (microfluidic system)	Energy harvesting solution (semi-transparent perovskite PV cells)	Functional coatings
1	✓	-	-	✓
2	✓	✓	-	✓
3	✓	-	✓	✓
4	✓	✓	✓	✓

+ PS+ standard opaque modules

The opaque entrance module comprises a glassfibre core VIP sandwiched by two ultra-light fibre-reinforced plastic protective skin panels enhanced with a fire-resistant coating (PS+ lightweight standard opaque module). In addition, other alternative standard opaque modules are possible mainly comprising optional skin panels, different coatings, inner protective frames and different possible VIP core materials (including recycled and renewable-based ones). This portfolio will be most valuable to secure future exploitation, guaranteeing high flexibility to answer different performance and sustainability requirements, aesthetics aspirations and / or budget constraints.

Configurations	Superior thermal insulation (VIP)	Thermal storage feature (PCM)	Energy harvesting solution (perovskite PV cells)	Functional coatings
1	✓	-	-	✓
2	✓	✓	-	✓
3	✓	-	✓	✓
4	✓	✓	✓	✓

Main components:

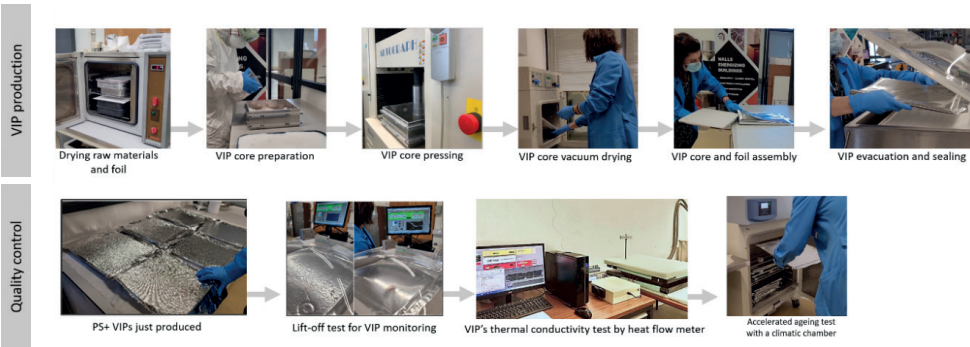
PS+ opaque protective skin sub-module

Thin fibre reinforced polymer skin layer for the lightweight standard panel that could attain the strict weight and thermal performance thresholds of the special applications.



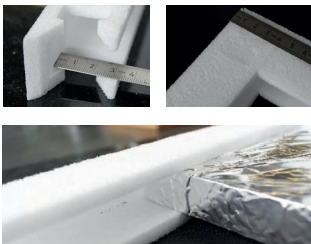
PS+ opaque thermal insulation sub-module (VIP)

Alternative solutions based on hybrid core systems formulated for the VIP inner opaque thermal insulation.



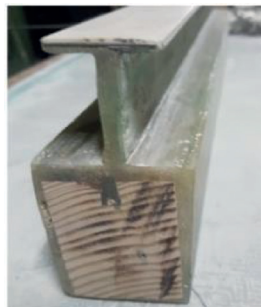
PS+ VIP protective inner frame sub-module

Inner frame to protect mechanically susceptible VIP elements made from extruded XPS foams, incorporating re-compounded granules sourced from recycled EPS packaging materials.



+ PS+ framing system

A novel and disruptive frame design, made of pultruded glass fibre reinforced polymer was developed at prototype level (and mocked-up in small outdoor installations) as a result of more than 50 biocomposite formulations envisaged and tested. While still at a low TRL, the new frame design needs further improvement to comply with strict mechanical performance and fire behavior requirements. At the same time, PS+ modules and their add-ons were designed to be also used with standard aluminum commercial framing systems to improve market their entrance and acceptance.



+ PS+ add-ons

Coatings

Type of POWERSKIN+ multifunctional coatings features

- Self-cleaning properties (Hydrophobic, hydrophilic, photocatalytic)
- Self-healing properties (Scratch and gap sealing)
- IR reflectance controlling
- Transmittance enhancing (in visible by 2-3%)
- Flame retardancy

Multifunctional coatings for both standard semi-transparent and opaque modules were designed, developed, and tested. Their performance in terms of self-cleaning, self-healing capabilities, and increase in optical transmission was prioritised for the semi-transparent modules. At the same time, fire resistance intumescent painting solutions combined with the multifunctional coatings were the main subject addressed for the opaque systems.



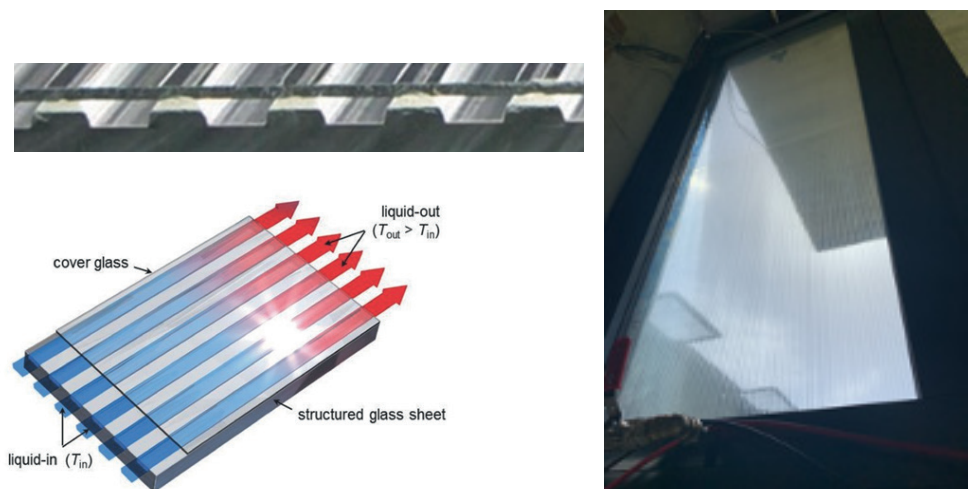
Developed coatings with a positive impact on the efficiency of PV solar modules (total performance increase of around 15% in terms of voltage. Coatings provided self-cleaning activity, with a 61% improvement, self-healing effects that were still good after 52 hours, and anti-fungal activity that reduced fungal growth by about 2% in the inoculated area. Additionally, the coatings had reflective properties that resulted in similar outcomes to commercial reflective paints.



Thermal Storage elements

1. Microfluidic system for the transparent module

The patented glass-glass capillary fluidic device is a flat-panel fabricated through lamination of a microstructured glass sheet and a thin cover glass sheet using a polymeric interlayer. Capillary channels are filled with a liquid providing high optical transparency and enabling efficient via solar-thermal heat harvesting as well as heat exchange at outdoor temperatures upwards 8 °C. Depending on the application, the capillary element can be positioned to face the interior (for heating/cooling) or the exterior (as a heat collector) of a room. The channels in the capillary element are used to circulate the liquid, allowing several plates to be connected in series (or parallel) across a complete façade or building skin.



2. PCM system for the opaque module

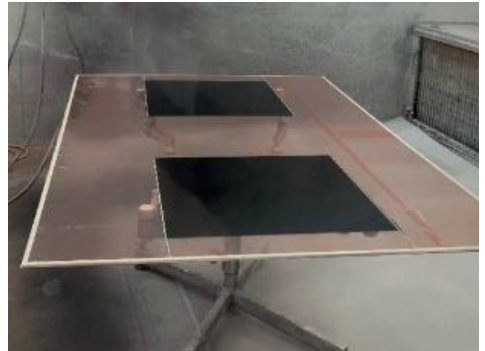
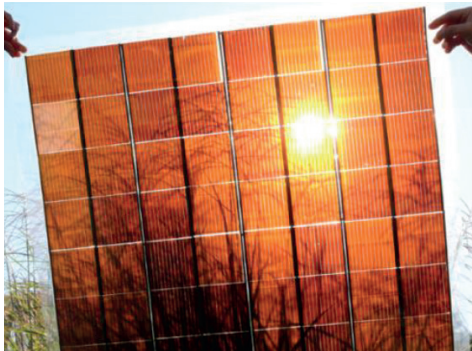
A salt hydrate PCM with a very high heat storage capacity, low weight, good dimensional flexibility and easy integration in the OM combined with an electric heating system that can actively exploit the latent heat storage of the PCM during the winter period, create an additional energy storage system for the excess of energy produced by the PV (primary storage is electric using Li-ion batteries) and provide a secondary heating source (radiant wall system) for the indoor environment. Additionally, using a PCM system can protect the overheating of the opaque PV modules (and their correspondent loss of efficiency).

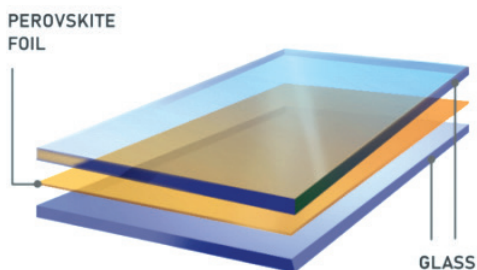


PS+ flexible perovskite PV sub-modules



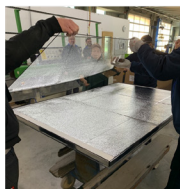
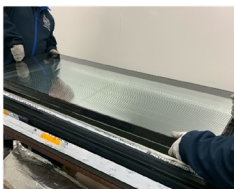
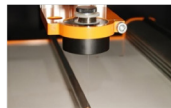
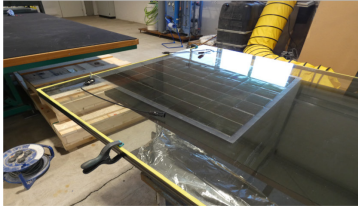
Flexible perovskite solar cells, with power conversion efficiency of 9.5 % and 11,5% for the semi-transparent and opaque perovskite PV sub-modules, respectively. Optimised glass lamination process was attained by integrating flexible perovskite solar cells into the opaque modules (opacified glass skin panel).





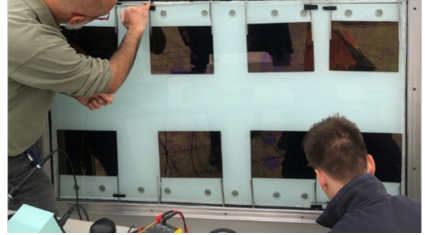
Transparent and opaque standard and premium (add-ons integrated) modules have been manufactured successfully on a custom production line and used in outdoor tests. All developments followed the work plan and the expected performance described in the GA.

+ Pilot production



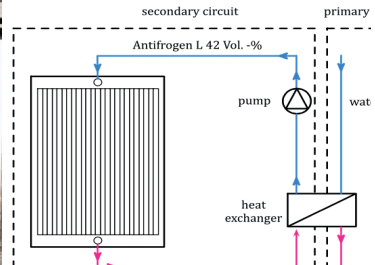
+ Politecnico di Torino, Italy

The first 4 m² mock-up was erected in Politecnico de Torino and includes 2 opaque modules (1 premium with BiPV add-on and 1 standard module), 1 transparent module (premium microfluidic glass thermal storage add-ons) and a small building management system.



+ Friedrich Schiller University Jena, Germany

A performance analysis was also performed in the Laboratory of Glass Science at the Otto Schott Institute of Materials Research to a 3 m² mock-up with 4 transparent modules (2 standard and 2 premium microfluidic glass thermal storage add-ons).



+ Brunel University London, United Kingdom

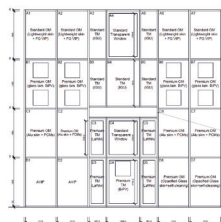
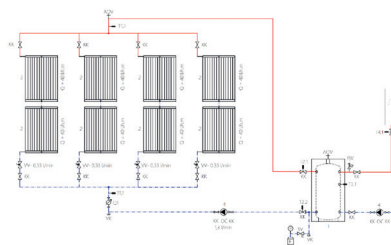
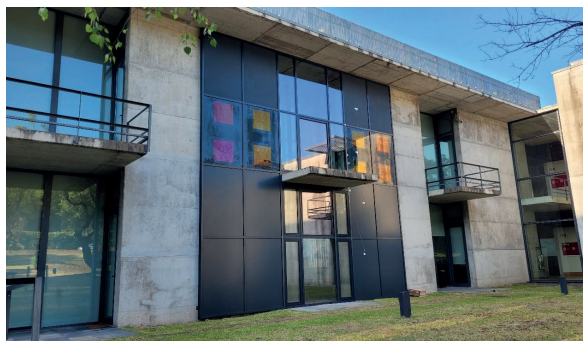
In the UK a 4 m² mock-up with 6 standard opaque modules was compared with the reference cell without VIP insulation, the temperature, heat flux and solar radiation flux density were monitored in different positions of test cell to assess thermal insulation of VIP as the building applications.



+ DEMO SITES

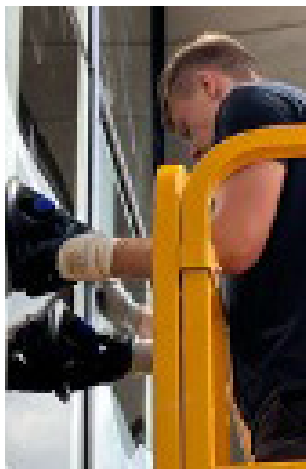
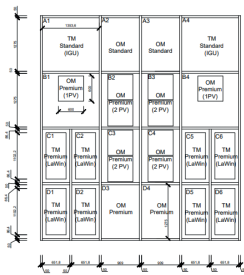
+ Instituto Pedro Nunes, Portugal

Showcasing all the technologies developed and spanning over 60 m², IPN's demonstrator is the largest in the project. The façade includes 16 opaque modules (4 premium with BiPV add-ons, 4 premium with thermal storage add-ons (PCM) and 4 standard lightweight panels), 12 transparent modules (4 premium microfluidic glass thermal storage add-ons, 1 premium semitransparent BiPV add-on and 7 standard panels) and an energy storage, built from post-EV batteries with a usefull capacity of minimum 18 kWh.



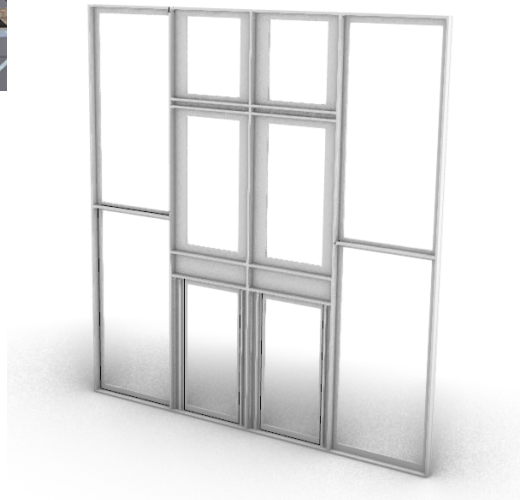
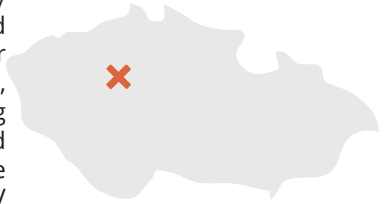
+ Flachglas Sülzfeld, Germany

Flachglas's demonstrator with 26 m² features the biggest microfluidic system installation, while also displaying several other technologies developed in the project. The façade includes 9 opaque modules (6 premium with BiPV add-ons and 4 standard lightweight panels), 10 transparent modules (8 premium with microfluidic glass thermal storage add-ons and 2 standard panels) and an energy storage, built from post-EV batteries with a usefull capacity of 50 kWh.



+ University Centre for Energy Efficient Buildings of CTU, Czech Republic

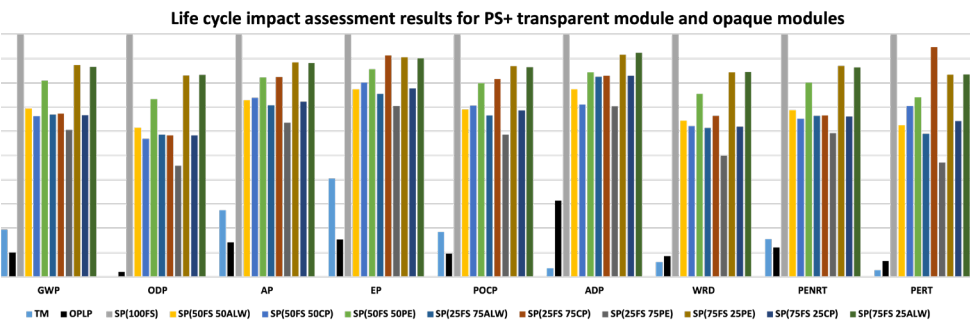
The CVUT demo installation covering an area of 9m² was designed to assess the potential reusability of complete modules in alternative buildings and facades following the removal of existing facades, or in case a module would not be reusable as a whole, the process of material separation for recycling with the main goal to preserve materials that could be reused afterwards. When erected the façade included 6 opaque modules (4 premium with BiPV add-ons and 2 standard panels) and 4 transparent modules (3 premium with microfluidic glass thermal storage add-ons and 1 standard panel).



+ LIFE CYCLE SUSTAINABILITY ASSESSMENT (LCSA)



+ Life Cycle Assessment (LCA)



- The **transparent modules** have a **lower** environmental impact than the **standard opaque module**.
- The standard opaque module using **100% fumed silica** core material in the VIP has the **highest** impact in all the selected impact categories.
- The **lower** the percentage of fused silica the **lower its impact on the environment** of the opaque module.
- The **lightweight modules** which make use of fiberglass VIP have **the lowest overall impact**.

+ Life Cycle Costing (LCC)

Simplified large scale LCC - Cost of Assembled PS+ modules - RESULTS

Originally - cost range between 599 and 629 €/m² for the premium panel PVs + VIP compared to **standard facade 580 €/m²**.

Overall **inflation rate** in Europe was about **22.5%** - gives **710 €/m²**.

Adding **10%** to this gives a value of **781 €/m²** for the insulated photovoltaic envelope of PS+.

RESULT

- | | |
|---|-------------------------|
| 1. Premium panels IPN with the cost of | 809,69 €/m ² |
| 2. Premium panels POLITO with the cost of | 656,17 €/m ² |

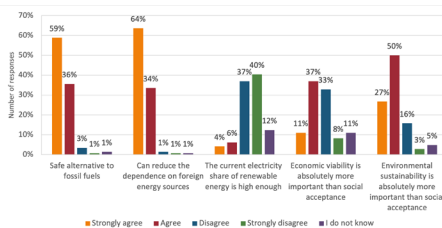
+ Social Life Cycle Assessment (sLCA)

Data was gathered from households across 29 European countries through a survey, with the aim to evaluate both the social acceptance and readiness to adopt the solutions being developed within the project. Analysis showed that there is a strong consensus that renewable energy sources represent a secure and feasible alternative to fossil fuels. Participants advocate for reducing reliance on foreign energy sources and increasing the proportion of renewable energy as the way forward.

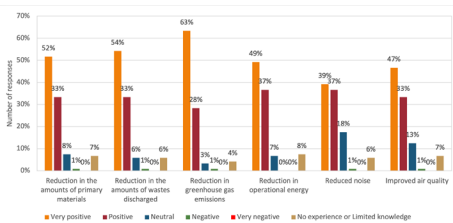
While over a third of the participants prioritize economic viability, another third advocate for the importance of social acceptance. There is widespread approval for efforts to reduce primary materials and limit greenhouse gas emissions, as well as recognition of the potential cost savings in waste disposal and material purchases.

Finally, views on the potential for additional revenue from selling new products somehow varied, and respondents highly valued the potential for new and improved employment opportunities, as well as the health, safety, and overall well-being benefits.

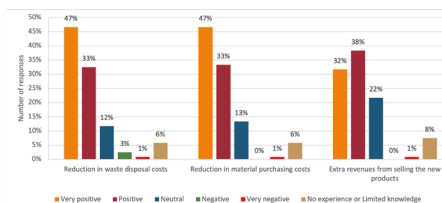
OVERALL ASSESSMENT OF RENEWABLE ENERGY TECHNOLOGIES (N=146)



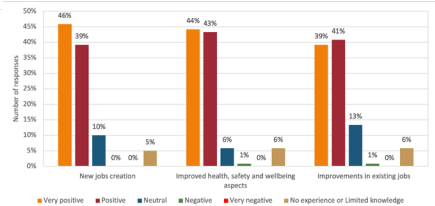
ENVIRONMENTAL IMPACTS IN THE CONTEXT OF CIRCULAR ECONOMY (N=120)



ECONOMIC IMPACTS IN THE CONTEXT OF CIRCULAR ECONOMY (N=120)



SOCIAL IMPACTS IN THE CONTEXT OF CIRCULAR ECONOMY (N=120)



+ Partners



+ Contact



PowerskinPlus



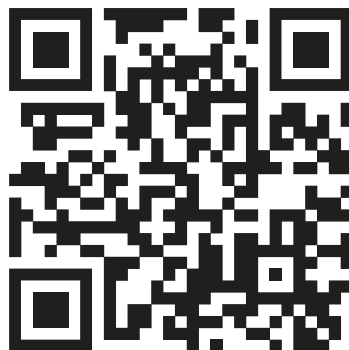
powerskinplus



powerskin-plus



PowerskinPlus project



WWW.POWERSKINPLUS.EU



The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement **No. 869898**.