

Technology Position Paper

Building Integrated Solar Envelope Systems for HVAC and Lighting

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This position paper explains the relevance, potential and present status of development and market of building solar envelope systems contributing to HVAC and lighting of buildings, leading to actions needed to best exploit their integration into building design practices. It addresses policy and decision-makers as well as influencers and aims to present high-level information as a basis for uptake and further development.

1 Introduction and Relevance

The decarbonization of the heating and cooling sector in buildings is one of the main challenges towards reducing greenhouse gas emissions and achieving the Paris Agreement objectives. The transformation of the current building stock into net-zero or positive energy buildings requires investing in energy efficiency to lower buildings' overall energy demand and to replace fossil fuel energy sources with renewables.

As of today, power to heat seems to be the designated technology to achieve this goal. Nonetheless, the high primary energy content of the electricity mix in most countries does not allow for significant reductions in the overall equivalent emissions by only exploiting heat pumps. Moreover, electric grids are not yet prepared to bear the loads potentially introduced due to a massive use of electric appliances for heating and cooling purposes.

From this perspective, the exploitation of locally available renewable energy source (RES), such as solar energy is not only desirable to reduce the import of high primary energy carriers on site; it also is needed for the reliable and resilient operation of the grids - mostly the electric grid – by means of a wise integration with local storage and building energy management.



Figure 1. Examples of solar envelope systems described in Task 56 Deliverable DA1+2. From the top to bottom, Kromatix BIPV panels (photovoltaics), Lumiduct (photovoltaics and shading system), Okalux Okasolar 3D (shading system), Kindow (shading system) and SunRise façade (solar thermal system).

On the one hand, building electric and thermal energy needs can be reduced by improving daylighting and managing solar gains. On the other, a share of the energy demand can be covered by harvesting, storing, and distributing the solar radiation reaching the envelope, according to the demand patterns.

The sector of building-integrated solar envelopes embraces a rather broad range of technologies – building-integrated photovoltaics, solar thermal collectors, and photovoltaic-thermal (or PVT) collectors – that actively harvest solar radiation to generate electricity or usable heat. Shading systems instead control incoming radiation to lower the energy demand for air conditioning, enhance daylighting, and improve visual comfort.

2 Current Status

Solar envelope systems may not be a consolidated practice in the construction sector. Still, a progressively increasing number of concepts and solutions are being developed and several innovative products have reached the market.

The sector of solar envelope systems can be split into two main segments. The first relates to solutions controlling solar radiation. Innovative solutions, such as motorized shadings or electrochromic glass have a place, beside traditional shading devices, such as shutters, blinds, and curtains, which already have a well-established market in the residential and tertiary buildings sectors.

The second segment relates to building-integrated solar harvesting technologies. Here the market is structured around small-size enterprises that offer their solutions primarily targeting architects and energy planners. These systems represent a niche market, even though the large number of building integrated photovoltaic products reaching the market in the last years speaks of rapid growth.

Several challenges hinder a higher level of market penetration of innovative building-integrated solar envelope systems. Their design, manufacture and installation are usually more complex and time-consuming activities compared to conventional solutions adopted in the construction sector and require the collaborative involvement of a range of professionals. Roles and responsibilities in the building construction process, information and material fluxes, legal liability for the correct installation and operation, warranties and maintenance are the relevant multi-faceted questions that must be cleared and planned before installation.

Moreover, solar envelope systems must comply with both construction codes and energy industry norms. This adds to the lack of adequate design tools adapted to estimate energy performance and architectural impact during initial concept design. The resulting regulatory gaps and the lack of consolidated international standards create an unfavorable environment that may hinder planners, investors and clients from adopting these technologies.

In addition, solar envelope systems, due to their level of innovation, have higher upfront costs compared to conventional construction materials. However, they offer several co-benefits - higher energy efficiency and user comfort, higher property

value, and reduced impact on power grids – that can be properly valued once the building is assessed from a system perspective.

3 Potential

Challenges in delivering on-site RES include accommodating spatial constraints, adapting to the surrounding built environment, providing enough energy storage, and effectively managing a building's systems. ***For optimal performance, it is essential to integrate solutions across technologies. Industry and research are developing solar envelope systems as multifunctional solutions dealing with this requirement.***

New materials entering the market are driving product innovation. For example, high-efficiency polymers used to produce absorbers of solar thermal collectors and new light shifting species for semi-transparent photovoltaic solutions. ***The progress in solar envelope technologies is pushing advances in manufacturing and assembling existing materials, resulting in new concepts, improvement of existing technologies, and design of new applications from conventional concepts.***

The main research and development trend is towards achieving industrialized multifunctional solutions to move as much as possible of the building plants (i.e., space heating, cooling, and ventilation) into the envelope, thus speeding up the construction process. From the building construction perspective, the envelope assumes higher value since it can replace to some extent central services, such as the artificial lighting or entire parts of the HVAC system. In addition, ***prefabrication offers a huge opportunity to components manufacturers who can evolve and place higher added-value solutions on the market.***

As interdisciplinarity is more frequently requested by solar envelope systems, prefabrication is necessary, but so is collaboration among planners and installers from different specialties. If taking the conventional approach, the planning process can be more complex than usual. In contrast, ***a collaborative approach might offer new opportunities and selling points to companies that adopt a systemic approach to designing the building and organizing the construction site. Once more, new skills and high added-values services are stimulated in the construction market.***

Constructed floor space in buildings worldwide has increased by 65% since 2000, reaching nearly 240 billion square meters in 2018. Yet, average energy use per square meter has declined by only 25%, meaning progress did not offset floor area growth. Final energy use in buildings grew from 2,820 Mtoe in 2010 to around 3,060 Mtoe in 2018, while the share of fossil fuels decreased only slightly, from 38% in 2010 to 36% in 2018. As a result, direct emissions from buildings increased to just over 3 GtCO₂ in 2018 ¹.

While more and more countries worldwide are adopting mandatory building energy codes to transform their stocks into net-zero- or plus-energy buildings in the short- to

¹ source IEA, Tracking buildings report, 2019

medium-term, ***packages of technologies are needed in which integrated operation is proven in a range of climate, social and economic conditions, and that cover energy demands based on locally available RES and reduces energy carriers import on site (hence reducing the loads on the networks and grids).***

Building integrated solar envelope systems can be game changers under this perspective since they allow to both reduce the energy intensity of the sector by cutting energy demand for space heating and cooling and increasing the exploitation of local RES. By maximizing the utilization of the envelope surfaces and by prompting the synergic operation with storage and building, solar thermal and photovoltaic solutions have the chance to effectively complement the renewable energy exploitation performed through technologies - such as heat pumps - towards the n-ZEB standard.

As an example, if we imagine that only 10% of the buildings globally will have solar envelope systems and that these systems will be able to cover the missing 30%-40% of renewable energy, which is not provided by a heat pump, huge savings could be achieved in the range of 90-100 Mtoe of final energy and 90-100 MtCO₂ a year.

4 Actions Needed

Actions needed to foster the sector of the building-integrated solar envelope systems and promote better use of solar energy in buildings are:

Manufacturers – To offer systemic design and construction packages. Solar envelope technologies are intrinsically systemic solutions designed for multifunctional performance, which require the collaboration of many stakeholders in the design, manufacturing, and construction processes of buildings. A systemic approach eases this challenge and generates new opportunities based on innovative links among companies, business models and financing.

Manufacturers – To elaborate on new value propositions promoting solar envelope systems. As economic assessments are key to any decision-making process, solar envelope solutions manufacturers should be able to provide life-cycle cost and risk assessments that are adapted to their customer needs and account for commodities prices, incentives, norms, and legal frameworks.

Manufacturers should not promote solar envelope systems based on a single selling point (e.g., energy savings guaranteed); instead they should adopt a broader perspective and be able providing information on the impact of their solutions have on sustainability protocols – such as LEED or BREEAM – and on user comfort and healthiness, hence on better productivity and wellbeing in general.

User and human-centric solutions can be a strong “go to market” strategy.

Manufacturers – To offer customizable architectural appearance. There is no general rule as of what is preferred by architects, public authorities, building owners,

or occupants; thus, manufacturers should offer aesthetically flexible solar envelope systems to comply with specific architect requirements.

Manufacturers and associations – To promote professionals training.

Manufacturers and industry associations should stimulate targeted training and dissemination activities devoted to raising planners’ awareness of the range of opportunities offered by market available and near-to-market solar envelope systems and endorsing a collaborative design approach.

Decision-makers – To harmonize regulations and promote energy sharing economy. Building-integrated are subject to a higher level of country-specific legal approvals, since they need to comply with both construction products regulations and with industrial norms addressing compliance and performance. As this creates a significant market-entry barrier for manufacturers, policymakers should address this obstacle by defining and enforcing a regulatory framework that is as uniform and international as possible and that facilitates dealing with both construction and industrial regulations.

At the same time, current regulations can be a barrier to sharing locally produced energy among neighboring buildings. Devising legal frameworks to allow for the practical implementation of energy communities can make a difference, by creating a playground suited to solar envelope systems.

Decision-makers – To support solar envelope systems. Decision-makers should support building integration of solar envelope systems: this should not be limited to the mere deployment of incentives supporting specific technologies; rather, it should be considered to elaborate a whole framework of measures allowing a level playing field with conventional solutions.

This could include developing practical tools like 3D solar cadasters facilitating the evaluation of the solar source availability on the buildings’ façades, devising pre-commercial-procurement demonstration projects and elaborating administrative and legal procedures to promote private-public investment initiatives.

Challenge	Action needed
A large number of actors are involved in manufacturing, planning and installing solar envelope systems	To offer systemic design and construction packages
The construction market is often unaware of the potential of solar envelope systems	To promote professionals training To elaborate on new “user-centric” value propositions: <ul style="list-style-type: none"> ● to provide LCC and risk assessment ● to provide information for sustainability protocols ● to provide information on user comfort and wellbeing

Architectural integration is not easy, but it is key for acceptance	To offer customizable architectural appearance
The regulatory framework is often unclear with respect to building integrated technologies.	To implement a normative framework facilitating the integration of solar technologies in the construction sector, as uniform and international as possible
Current regulations can be a barrier to the foundation of energy-sharing economies	Improve the regulations to ease the implementation of energy communities
Early-stage assessment of solar envelope technologies is crucial, but there is a lack of tools	To support the development of tools such as 3D solar cadasters allowing the evaluation of solar availability on façades
The construction sector is conservative and innovative solutions can hardly penetrate the market unless a proven record of installations is available	To promote pre-commercial-procurement demonstration projects in public buildings To devise administrative and legal procedures promoting private-public investment initiatives