Integrated Solar Thermal Systems for renovation of external walls

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Abstract

Until very recently, technical systems such as solar thermal systems, and other HVAC elements have been conceptualized based uniquely in their thermal performance levels, and its integration with other architectural elements (envelopes, slabs,…) limited to mechanical fixation. However, with steadily increasing use of technologies for the reduction of the non-renewable energy needs in buildings, already developed in the last decades, deeper architectural integration is needed, also considering on cost and assembly process optimization to ensure wide market adoption.

In this context, two main trends appear: Integration and hybridation of solar systems in building envelopes. Integrated solutions are created when modular and dimensionally variable glazed collectors are integrated in curtain wall structures or in external cladding systems. Hybrid solutions such as External thermal insulation systems and sandwich panels are generated where unglazed collectors are integrated as part of renders, claddings, etc. to obtain neutral aesthetical impact.

Architectural, constructional and thermal results are discussed, not only based on design assessments, but also on manufacture, assembly and assessment results from experimental data.

Keywords: Solar thermal systems; Building envelopes; Integration; Integrated Solar Collector Envelopes

1. Introduction

Built to facilitate the development of human activities, buildings have developed, and several subsystems have been generated to provide increasing levels of performance. Structural systems; building envelopes; Heating, Ventilation and Air Conditioning (HVAC) systems; etc. are increasingly complex.

Modern envelopes have evolved far beyond their original sheltering functionality, providing also comfortable levels of daylighting, thermal insulation, and even solar energy harvesting. Being part of the human environment, these functions need to be correctly integrated in the overall concept of the building, and with neighbouring systems. Allways keeping within clear cost constraints.

With energy efficiency and an ultimate need to reduce primary energy consumption of buildings towards sustainability, energy systems are increasing its presence in building envelopes. Solar energy systems such as solar thermal and photovoltaic systems are being implemented in buildings, boosted by energy procurement policies and user/owner will to reduce the overall energy costs in buildings.

The increase in use of solar system requires of an increasingly large envelope surface for it implementation, with increasing presence in the overall appearance of the building. The integration of solar systems into architectural systems seeks the reduction of aesthetical and space impact in buildings. However, since a deeper integration is pursued, the interaction of the thermal function with other functions must be understood and placed as a key issue to be solved in the design process. The requirements for highly integrated solar systems if not conveniently achieved, could potentially have a significant reduction in the overall harvesting performance of the system.

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In this paper, several integrated and hybrid envelope technologies are discussed, and its particular benefits and drawbacks identified. Also, research outcomes of several projects are also presented.

These systems commonly are integrated as part of advanced or even new concepts of HVAC systems in which solar systems are connected with thermal storage, heat pumps and low energy delivery systems such as radiant floors, or even thermal mass activation.

2. Integrated vs. Hybrid

The terminology to define integration level of solar thermal systems in building envelopes is still a matter of discussion within the solar thermal industry. To the authors' opinion, three concepts can be defined:

- Building Applied technologies: Solar thermal systems are mechanically assembled over a building envelope. In this case, no architectural consideration is taken regarding its impact on the building. Pipework and connections are not integrated.
- Building integrated technologies: Solar thermal systems are integrated into building envelopes, unless explicitly desired, connections are hidden. Solar technology is integrated into modules with variable dimensions, or with matching "dummy" elements which can provide sufficient flexibility in building design.
- Hybridized envelopes: Envelope systems integrate collector surfaces and all pipeworks. Hybridized envelopes are aesthetically equivalent to common envelope systems. In mixed applications of standard and hybrid envelopes, the layout of these can be defined in such a way that envelopes adapt no nearly any geometrical or other type of constraints.

When related to performance and manufacture costs of the different technologies, Applied and integrated solar thermal technologies provide similar performance ratios, for equivalent solar technologies, however, integrated systems are potentially more expensive, as their dimensions need to be adapted to each particular architectural project. When compared to standardized sizes in Building applied technologies, even with optimal manufacture systems and high production volumes, the handling of the additional engineering and management procedures in building integrated systems implies a cost premium.

In hybrid and applied solar thermal envelopes, part of the costs for incorporating the solar thermal system can be absorbed by cost reduction when compared to traditional envelopes (e.g. compared with a traditional curtain wall, a curtain wall that incorporates a ST collector will already takes benefit of the costs for glazing, profiles….).The cost of hybridized envelope systems is still unclear due to very low adoption of this technology. Regarding its performance, this can be assimilated to unglazed solar thermal collector devices.

3. Case study 1: Glazed air solar collector for integration in envelope retrofitting

Glazed air solar collectors are composed by an absorber, a glazed envelope, framing, ventilation and control elements. Tecnalia has participated in the conceptualization, design and testing of two air solar collectors within projects MeeFS [1] and RETROKIT [2]. Both designs have been based on the same technological framework consisting on an extruded Aluminum frame and a rotating louvre system for the control of ventilation flows in the collector [3].

Although both systems have similarities, their integration framework into a full building envelope retrofitting scheme differs substantially in the following three concepts:

- Façade system
  - RETROKIT integrates within an on-site rendered external energy retrofitting for existing buildings. The glazed collector is anchored directly to the existing façade.
  - MEEFS integrates within a modular dry construction system for external energy retrofitting of existing buildings. The solar system is integrated into a substructure hosting additional retrofitting technologies (i.e. glazed surfaces, insulation,…).
- Energy flows & connection with building HVAC system:
  - MEEFS focuses on a direct use of the collected energy in the indoor space behind the

collector itself. For that purpose, perforations are made in the existing wall.

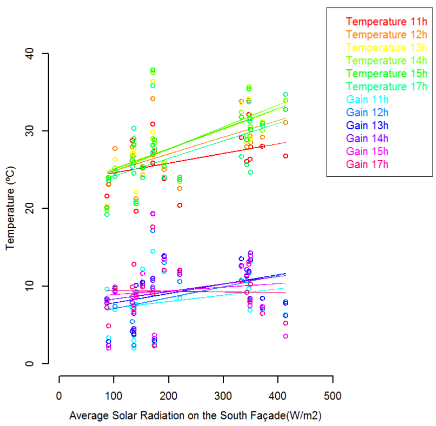
  - RETROKIT integrates into a wider HVAC system. Several RETROKIT modules can be connected in the same system to increase mass flow or output temperature as required by the building HVAC system. Outlet ducts of the system are directed to manifolds in the upper area of the façade.

- Absorber
  - RETROKIT focuses at an instantaneous use of the heat, and the absorber is composed of a single Al sheet painted in black.
  - MEEFS intends to absorb heat and distribute it along the day, and its absorber incorporates black encapsulated Phase Change Materials (PCM) in its absorber.

In both cases, the system is designed with variable height and widths in order to adapt to particular project needs, following design criteria for curtain wall systems. The thermal performance of these systems was tested at the KUBIK $_{\text{by Tecnalia}}$ [4] test facility within 2013, 2014 and 2015. Research output on the MeeFS project is available in [5].

Figure 1: RETROKIT Solar air collector integrated into a curtain wall scheme for testing purposes

Overall, both systems proved their capacity to raise ventilation air temperature within sunny days within the heating season, potentially allowing for a substantial reduction of heating loads in buildings.



4. *Figure 2: Service temperature levels and temperature gain in the air*

*stream in the RETROKIT Solar air collector*Case study 2: Hybridized metal envelope systems

Metal is increasingly common in construction. Originally metal envelopes were limited to industrial buildings, due to the low cost and rapid installation times of sandwich envelope systems. However metal solutions have also developed for commercial buildings and multi-rise residential buildings. With the rise of energy retrofit solutions for envelopes, ventilated façades have been widely adopted in EU due to their capacity to provide high quality cladding in buildings. These ventilated systems are commonly composed by a metal substructure and a cladding material. Common cladding materials are metal, stone, ceramic and phenolic materials. Several projects have investigated in the possibility to use highly conductive cladding materials as the absorber of an unglazed collector.

Research projects SOLABS [6] and BATISOL [7] have investigated in the integration of fluid loops in metal and Aluminum cladding materials. In BASSE [8], steel sandwich panels are used to integrate pipework for an unglazed collector using an additional external steel layer as absorber.

In all these cases, low grade heat is achieved. Very commonly output temperature is well below service levels for space heating and domestic hot water required by modern comfort requirements in buildings. This implies the use of a heat pump where the collector field is connected to the source of the heat pump. Providing that the sizing of the source-side storage is performed correctly, the proposed configuration provides a stable and high-temperature source for the heat pump, thus increasing substantially the performance of the heat pump when compared with benchmark heat pumping technologies.

The advantage of these technologies lies in their seamless integration between envelope and solar thermal collector field. If performed correctly, an observer would not notice any difference between active and non-active sections/elevations of the building envelope.

Figure 3: BASSE Sandwich steel envelope with at its pilot setup in the Kubik by Tecnalia test facility [4].

Numerical and experimental technical assessments have showed that this technological approach reaches the performance level of benchmark unglazed solar collectors.

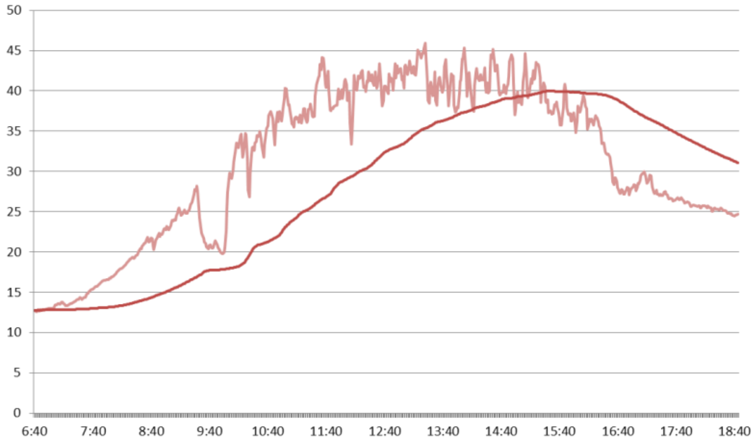


Figure 4: Temperature levels at the absorber and source-side storage tank, for the BASSE test on a representative sunny day.

5. Discussion

Although still under R&D and early deployment scale, the field of envelope integrated and hybrid solar thermal is promising. The underlying approach reaches far beyond the adaptation of solar thermal collectors to sizes and dimensions as required by building projects, and into full envelope systems, designed with parts/sections with solar thermal production capacity. Glazed air collectors are a suitable solution for centralized or de-centralised ventilation systems, which can be integrated as part of retrofitting systems and kits. Hybrid steel envelopes allow for potentially low cost integration of combined solar systems with minimal intrusion in the design of the façade.

In the following years, these technologies should develop into industrially and economically/financially viable solutions with certified performance levels and relevant certifications for its integration as part of an envelope system.

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