Contract No. 212206

Cost-Effective

Resource- and Cost-effective integration of renewables in existing high-rise buildings

SEVENTH FRAMEWORK PROGRAMME
COOPERATION - THEME 4
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D3.1.2 Prototype for transparent thermal collector for window integration

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Revision [1]

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (incl. the Commission Services)	
CO	Confidential, only for members of the consortium (incl. the Commission Services)	

Introduction

The target is the development of a new transparent solar thermal collector based on low cost window technology. This new façade component will at the same time allow visual contact to the exterior, provide solar and glare control and it will generate heat. In summer the collector will be used as a heat source for solar cooling systems.

The followed approach is based on the integration of apertures with angular selective transmittance into a solar absorber, which is included in the transparent part of a façade.
The solar radiation coming from directions with high solar altitude angles will be selectively shield from the external surface of the absorber, whilst visibility through the collector is retained in direction horizontal or downward, if looking from the inside of the building.

Two opportunities of integration have been investigated:

1. Inside an insulating glazing unit (IGU), air-tight and sealed to the external environment. The main advantage are high efficiency and easy integration into a façade, as simple as installing of standard IGUs. The main disadvantage is the complex assembling into the glazing unit, due to the air-tightness requirements that need to be guaranteed.
2. Inside the cavity of a double skin façade. Due to the lack of complete air-tightness, a pressurized system will be used to flush dry and clean air inside the cavity in order to provide optimum conditions.
   The original plan was to develop it as moving system, only down when sun is shining and therefore the system is capable to collect energy. Due to cost-effectiveness issues and manufacturing challenges the idea was abandoned in favour of the same fixed system to be integrated in the IGU, which is also compliant with the Description of Work.

In order to deliver a successful component, all the relevant challenges have been faced: thermal and optical optimization, aesthetics, cost-effective production and integration of the absorber in façade panels, integration into the main HVAC system and control.

Results

Principles & Design

The transparency of the absorber is based on its angular selective apertures.

A series of optical simulation has been run to optimize the geometry of the apertures for different alternative proposals.
Visual prototypes have been manufactured for an evaluation of the architectural appearance.
Following to a visual examination, to thermal considerations and manufacturing process investigation, solution 3 has been chosen to make a fully functional prototype.

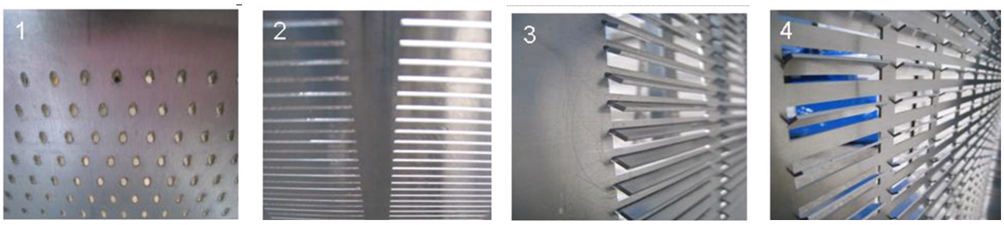

Figure 1. Pictures of the visual prototypes representing the four alternative design investigated.

A new TRNSYS model has been developed to simulate the optical and thermal behaviour of the collector.
The model has been run with different glazing configurations and varying the working conditions (Solar radiation altitude and intensity, mean working temperature of the absorber).
Among the potential solutions, the first one of the following has been selected as best compromise between efficiency and cost-effectiveness.

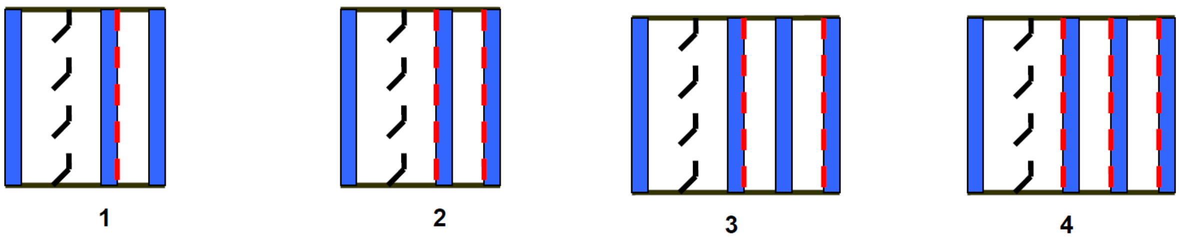

Figure 2. Different glazing configurations simulated.

Manufacturing & Assembling

Aluminium has been selected as base material, being light and high-conductive at the same time. Therefore the medium fluid, a water – glycol mixture, needs to be enriched with a proper mix of corrosion inhibitors.
Manufacturing started from the joining of the pipes system to a flat metal sheet by means of a laser welding technique. This is a state-of-the-art technology for the production of most of the commercial existing flat plate collectors, hence it is a consolidate process to start with before integrating in it the most innovative features.

The innovation was achieved with the integration of the angular selective apertures, which was realized by a specifically developed punching tool.
The optical properties of the absorber surface were finally modified to reach the required absorptance by means of a special coating, which was made possible with the processing of the component at the Fraunhofer coater.

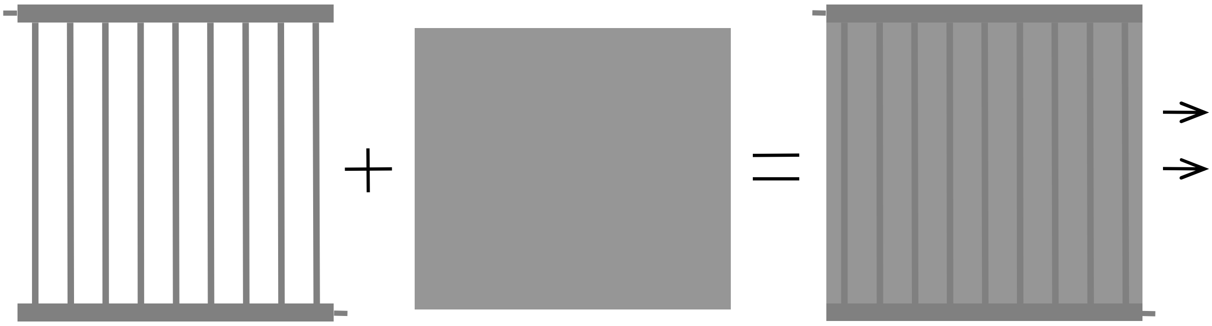

Figure 3. The aluminium pipe system is laser welded to a blank aluminium sheet to form a flat plate absorber.

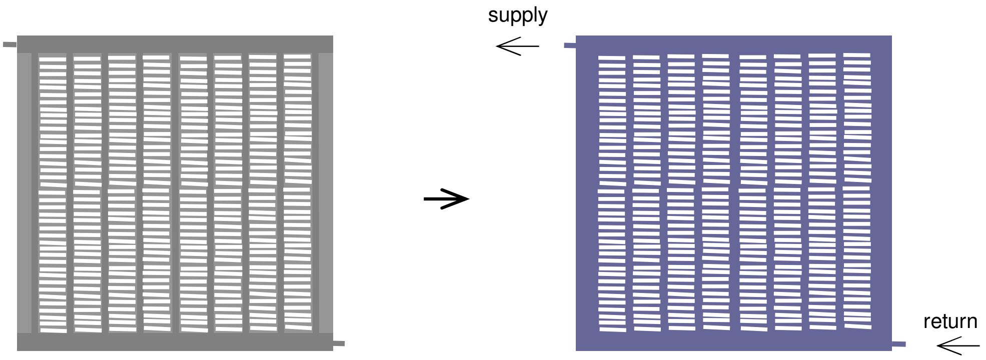

Figure 4. The absorber is first punched, then processed in a magnetron sputtering coater.

Figure 5. Finalized sample of the absorber and close-up picture.

The manufacturing process was finalized with the integration of the absorber in a triple glazing unit.

The procedure is similar to the assembling of a standard IGU. The main difference are the throughputs special connections developed for keeping the cavity air-tight, whilst allowing for the required inlet and outlet supplies of the absorbers to go through the spacer.

Figure 6. Sealing of the triple glazing unit (left). The throughput connection (right).

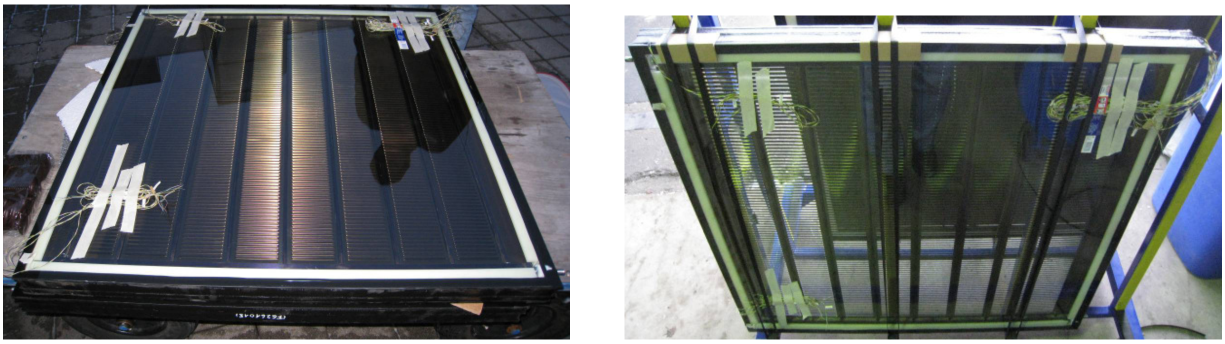

Figure 7. The complete collector ready for the testing. External (left) and internal (right) view.

Testing

The collector has been tested at ISE “TestLab Solar Facades”. All the relevant boundary conditions were reproduced and monitored in a laboratory environment. Solar radiation was reproduced by means of solar lamps.

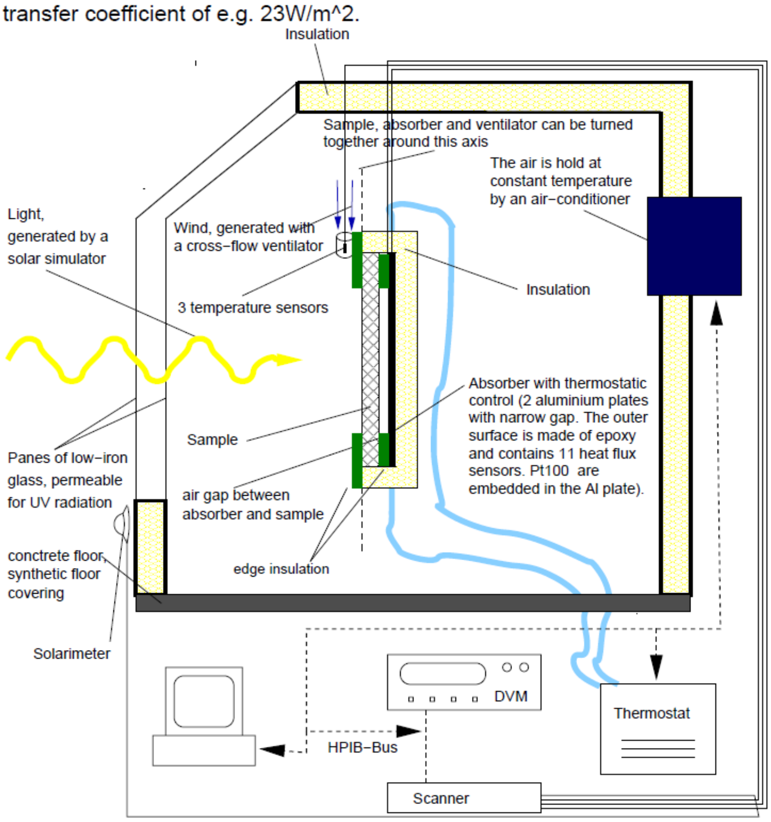

Figure 8. Cross section through the measurement chamber.

The results of the measurements are reported in the following graph.

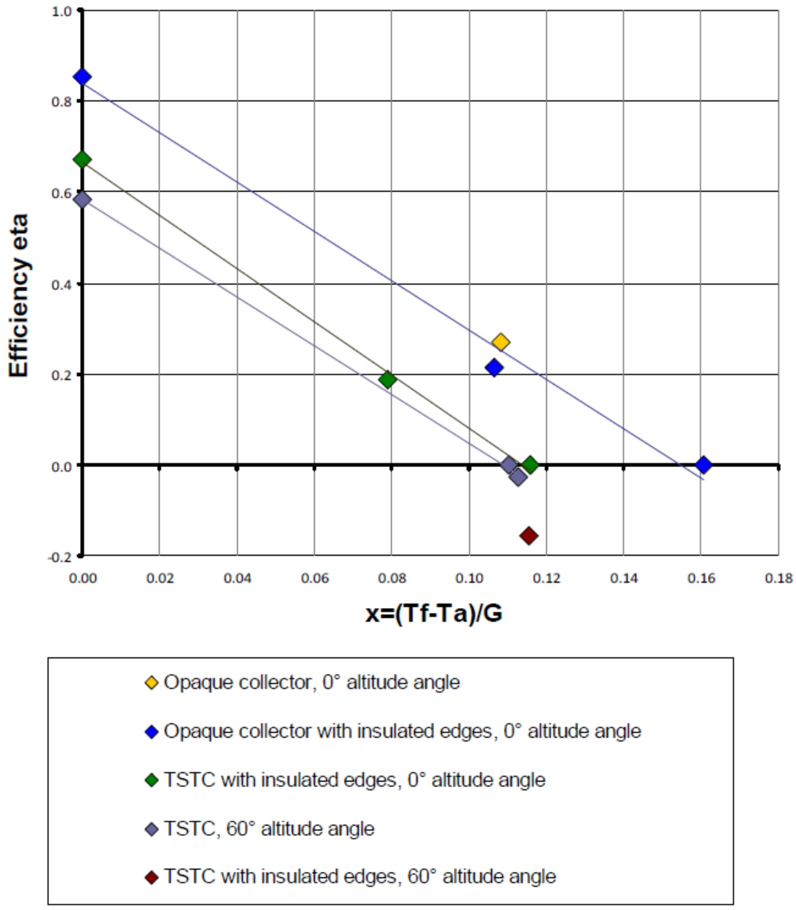

Figure 9. Collector efficiency curves.

In the table below the measured efficiency eta0 – with the fluid temperature equaling the ambient temperature - and g values are reported with reference to the target values. For the g values, the value for the fluid temperature Tf equaling the ambient temperature Ta is provided as well as the value for zero fluid flow.

Solar altitude	**Measured efficiency eta0**	**Targeted efficiency eta0**	**Measured** g value, Tf=Ta	**Measured g value, zero fluid flow**	**Targeted g value**
0°	0.67	≥ 0.7	0.03	0.09	≤ 0.2
60°	0.58*		0.02	0.1	

*At 60° of solar altitude the efficiency is lower than at 0° due to the higher reflection at the external pane (even if the absorption of the unglazed absorber at 60° is higher).

The efficiency of an opaque flat plate collector (the same but without apertures) is 0.85.

For the transparent collector the efficiency is limited due to thermal losses along the edges of the collector and restricted contact areas between the pipes and the metal sheet.
Enlarging these contact areas as well as increasing the insulation at the edge should boost up the performance of the collector.

Further integration

Being the TSTC useless as a standalone component, the integration with the building skin and with the HVAC system has been considered.

Integration in the façade

The transparent solar thermal collector has been designed to be included both in an air-tight tripled glazing unit than in a pressurized double skin façade.
For both the options, the suggested position is at the lower part of the glazed area. This is to exploit the angular selective properties of the component (the transparency is higher when looking downward from the internal of the building).

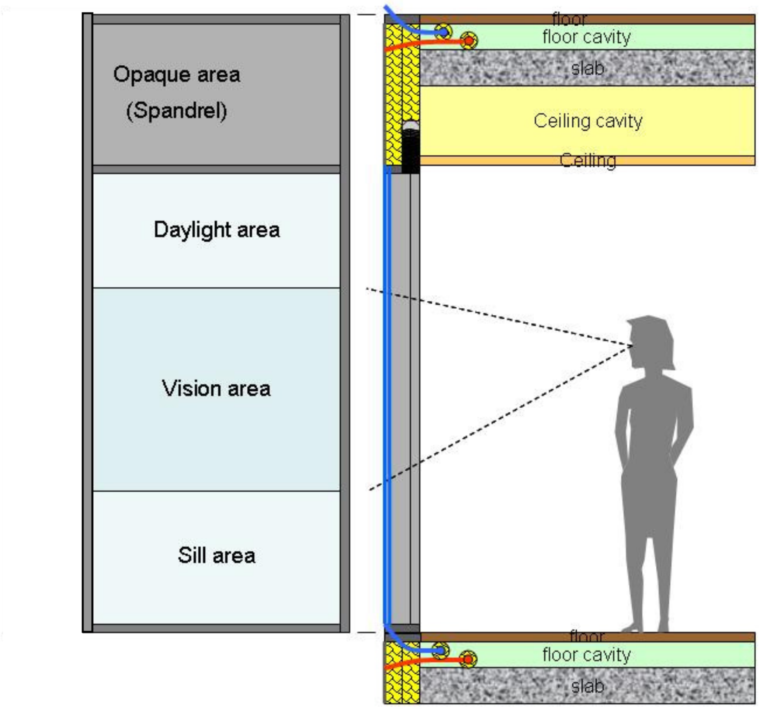

Figure 10. The different functional parts of the glazed area.

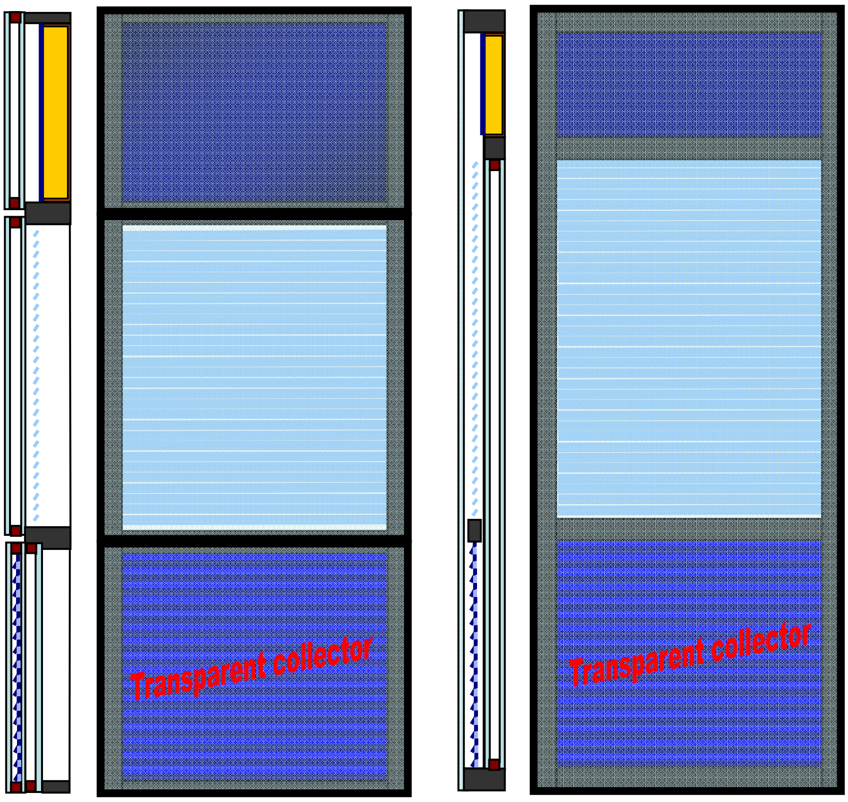

Figure 11. Collector may be integrated in the sill area of a single skin façade (left) or of a double skin façade (right).

For each one of the two options a detailed design proposal has been prepared.

Integration with the HVAC system

From a façade integration point of view, each collector is individually integrated in one single panel. But then they are required to be connected together to form the overall collector field, which is connected to the main HVAC system.
A detailed schematic of the collectors' connections to the main system has been designed for a specific reference building.

The HVAC system working architecture has also been investigated and designed, in order to optimize the exploitation of the components whether the system is used for heating or cooling.

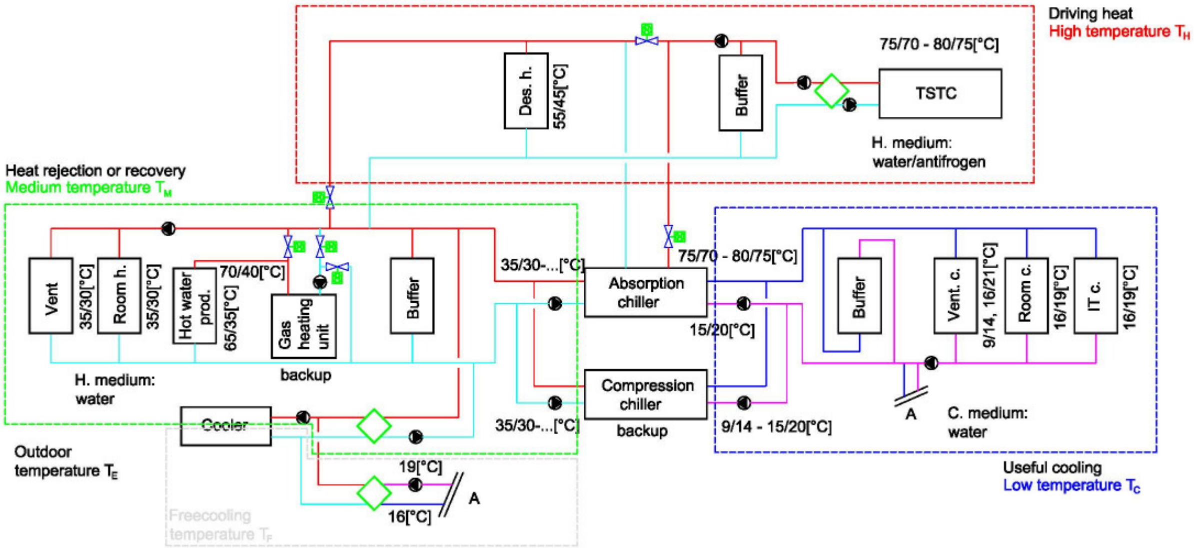

Figure 12. Scheme of the integration of the TSTC with the HVAC system.

An appropriate control and operation strategy for the solar thermal collector has been defined, which will be examined in deliverable 4.1.6.

Overall building energy analysis

The new component has been developed to exploit a renewable source in an effective way. Its effectiveness should be examined when applied to a real building.
In order to assess the collectors advantage in terms of overall energy savings for the building, simulations has been run.
A realistic building has been defined, with its geometry and size. A specific type of cladding has been considered (with the collectors integrated), together with the specific HVAC system developed to work with the collectors.

The performance data of the TSTC (simulated and then measured) are input for the analysis, which has been run taking into account different climatic boundary conditions.

The output is a complete content of information on the renewable energy production, the cooling and heating load of the building and the percentage of renewable energy consumed on the whole amount.

Conclusions

A new transparent solar thermal collector has been first investigated, then designed and manufactured. Two options for integrating it in a façade have been considered and one working prototype has been manufactured for one of them.
The short term testing proved the effectiveness of the concept and provided the necessary measurements for the validation of the software model.
The measured performance of the first test model almost meet the target values, while the g values clearly fulfil the expectations even if there is no fluid flow. In order to increase the efficiency up to exceed the target values, improvements may be easily done on the manufacturing side, by applying a joining solution between the pipes and the metal sheets with enhanced thermal contact.

Together with the development of the component, efforts have been done also in its integration with the building.
Detailed design research has been done to optimize the HVAC system and the façade to work properly with the collectors. The contribution in terms of energy to the whole building energy consumptions has been assessed.
Still the analysis may be improved on the simulation side, introducing a detailed model that describes more accurately the interaction between the collectors and the internal building environment.