Active Solar Facades (PV and solar thermal)

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ABSTRACT

Buildings are responsible for approximately 40% of the CO_2-emissions in the EU. It is therefore urgently necessary to reduce the primary energy demand of the building stock. In last years concepts for reduction of the primary energy demand focused on energy saving measures. Various building concepts were developed among which the passive house concept was the most ambitious one. Recently, a new paradigm is raising increasing attention which goes beyond the passive house concept: the concept of zero-energy buildings. Zero energy buildings are characterized by a net zero-energy balance on an annual level. In order to achieve this goal, local use of renewable energy generation is necessary in addition to a significantly reduced energy demand. Solar energy is the most important energy source for local energy production. High fractions of the energy demand of larger buildings can only be met with renewable energy sources, when the façade is used for solar energy conversion in addition to the roof. This is especially true for net-zero-energy buildings with a small roof area compared to the floor area. It is also true for existing buildings which generally have a higher energy demand than new buildings. Fraunhofer ISE is co-operating with key actors from construction industry and energy research in European and national projects in order to convert facades into multifunctional energy gaining components. One of the projects is the EU-project "cost-effective" (www.cost-effective-renewables.eu) and the national project Solarvalley BIPV (www.solarvalley.org).
In this paper an analysis is made about the necessary building specifications in order to achieve a zero-energy balance and it presents first results on BIPV-facades and on solar thermal façade collectors.

Keywords: zero-energy building, building shell, solar facade, multi-functionality, BIPV

1 INTRODUCTION

In order to reduce the CO_2-footprint of the building sector, the EU has decided in 2009 to change the regulatory framework and the business environment for the construction sector dramatically. The goal is to reduce the primary energy demand of existing and new buildings. It is now officially agreed within Europe that Net-Zero-Energy buildings are the goal for the future. At 18.11.2009 the EU-Parliament and the European Council decided that new buildings have to be net zero-energy buildings after 2020, some public buildings already after 2018. For the renovation of existing buildings a net-zero energy balance is not mandatory, but the reduction of the annual primary energy balance is the target. In order to achieve this goal, we have to do two things:

- increase the efficiency, especially in case of existing buildings
- cover the remaining energy demand with renewable sources.

In case of single family houses and large single- or double-storey factory buildings with flat roofs it might be sufficient to use only the roof of the building for renewable energy conversion. But for many other buildings with relatively small roofs it will be necessary to use also the façade for energy conversion in addition to the roof in order to achieve a net-zero energy balance. This is especially the case for high-rise buildings.

We are co-operating with key actors from construction industry and energy research in European and national projects in order to convert facades into multi-functional energy gaining components. Two important projects are the EU-project »Cost-Effective« (www.cost-effective-renewables.eu) and the national project »Solarvalley BIPV« (www.solarvalley.org). The paper will present first results on BIPV-facades and on solar thermal façade collectors. The target of these projects – converting facades into multi-functional energy gaining components – is exactly in line with these new European framework conditions. The new master conditions will help to create business from the ideas and developments in these projects.

2 HOW TO REACH NET-ZERO ENERGY BALANCE ?

2.1 Simulation case study using example buildings

We assessed for a residential and a non-residential example building how a net-zero energy balance can be reached. It is agreed that the primary energy demand for heating, ventilation, cooling and lighting has to be considered in the energy balance. In this study we also took into account the primary energy demand for the so-called “plug-loads” such as refrigerator, stove, computers etc. This is the reason for a significant “basis-demand” of primary energy in the graphs in figure 1. We are convinced that it is important to consider also the plug-loads since they are significant and since an overall reduction of the primary energy demand should be the target and therefore also the plug-loads have to be reduced. Nevertheless we kept typical average values for the “plug-loads” constant through all the variants since we only want to show the basic principles with this study.

An annual time series of hourly values of the heating and cooling loads and the demand for DHW for each of the buildings, computed using dynamic building simulation, served as basis to assess the impact of application of solar energy systems. Different sizes of a solar thermal system were assessed as well as different sizes of PV systems, assuming a primary resource factor PRF = 2.6 kWhPE per kWh of electricity.

The two analysed example buildings are a multi-family house (3 storeys, 12 flats) and an office building (3 storeys, floor area 960 m^2) – in two different climates, namely Freiburg/Germany and Madrid/Spain. We assessed the impact of different energy standards (annual heating demand of 80 kWh/m^2a, 50 kWh/m^2a, 30 kWh/m^2a and 15 kWh/m^2a). In figure 1 all the results with the same energy standard have the same primary *demand* (horizontal axis). The variants with the same energy standard only differ in the primary energy credits (vertical axis).

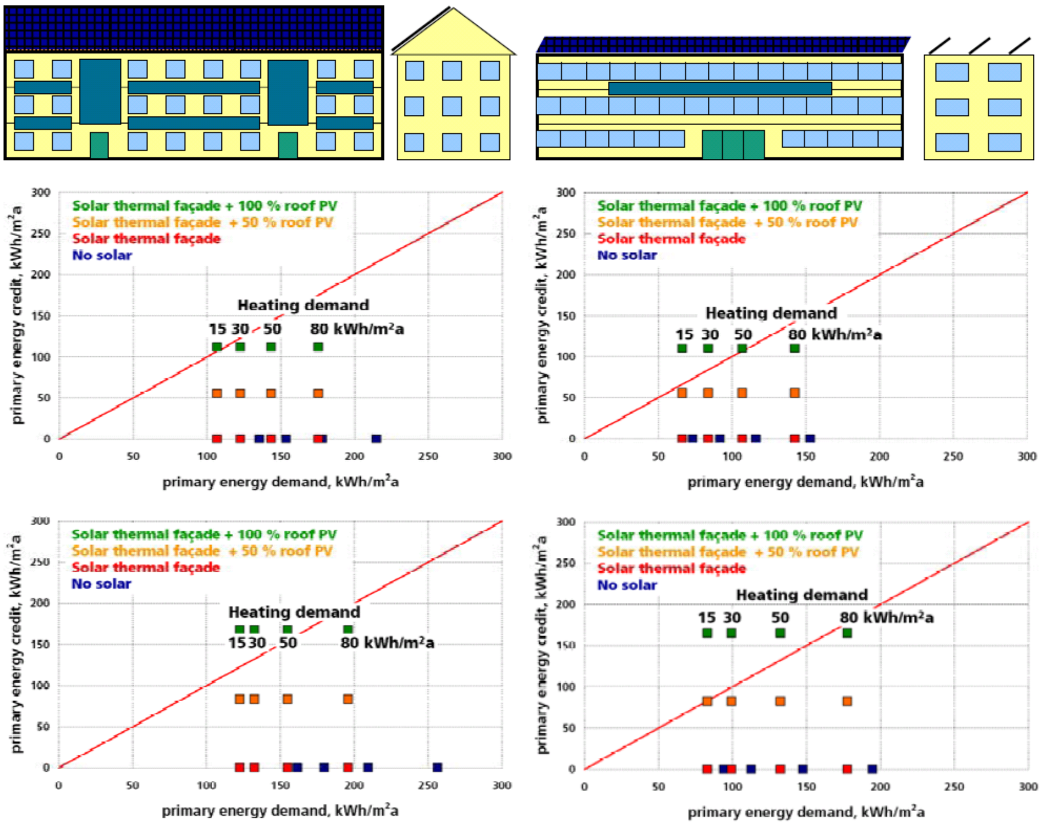

figure 1 Primary energy balance for different examples.
Top, left: multi-family house Freiburg. Top, right: office building Freiburg.
Bottom, left: multi-family house Madrid. Bottom, right: office building, Madrid.
Each dot refers to a certain building type and climate, a certain energy standard and a certain size of solar systems. The x-axis represents the primary energy demand, which can be reduced by application of solar thermal systems and the y-axis represents primary energy credits for application of PV systems.

3 STATUS OF THE DEVELOPMENT OF NEW COMPONENTS

In the EU-project »cost-effective« (www.cost-effective-renewables.eu) five new multifunctional façade components are being developed. The new components are

being optimised for the high-rise building categories with the highest expected impact on European CO_2-emissions.
The following components are currently developed:

3.1 Glazing integrated solar thermal façade collector

A new transparent solar thermal façade 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 approach is to integrate apertures with angular selective transmittance into the absorber of a solar thermal collector which is integrated in the transparent part of the façade. These apertures will selectively shield the direct irradiation of the sun (coming from directions with higher solar altitude angles) while retaining visibility through the window horizontally or downwards. A virtual image is shown in figure 2.

This façade component is currently developed by Permasteelisa group (coordinator), Interpane, Berchtold Ingenieure and Fraunhofer ISE.

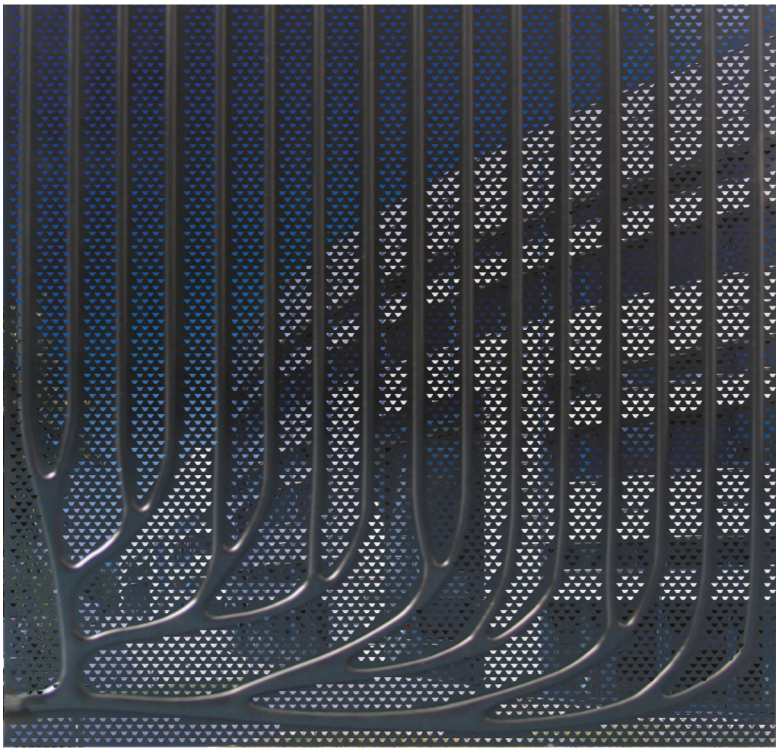

figure 2 Virtual image of a transparent solar thermal collector, © Fraunhofer ISE

3.2 *Façade collector with air-heating vacuum tubes*

A new solar thermal façade collector with air-heating vacuum tubes. The heated air will be used in combination with solar heating and cooling systems. Since the concept is based on air instead of water, no damage due to leakage, no stagnation problems and no frost problems have to be handled, which offers the possibility of reliable, efficient and cost-effective solutions. figure 3 shows a picture of an air-heating vacuum tube collector.

This façade component is currently developed by Kollektorfabrik (co-ordinator), Emmer Pfenninger Partner, Berchtold Ingenieure, Permasteelisa group, D´Appolonia, Labein (Tecnalia) and Fraunhofer ISE

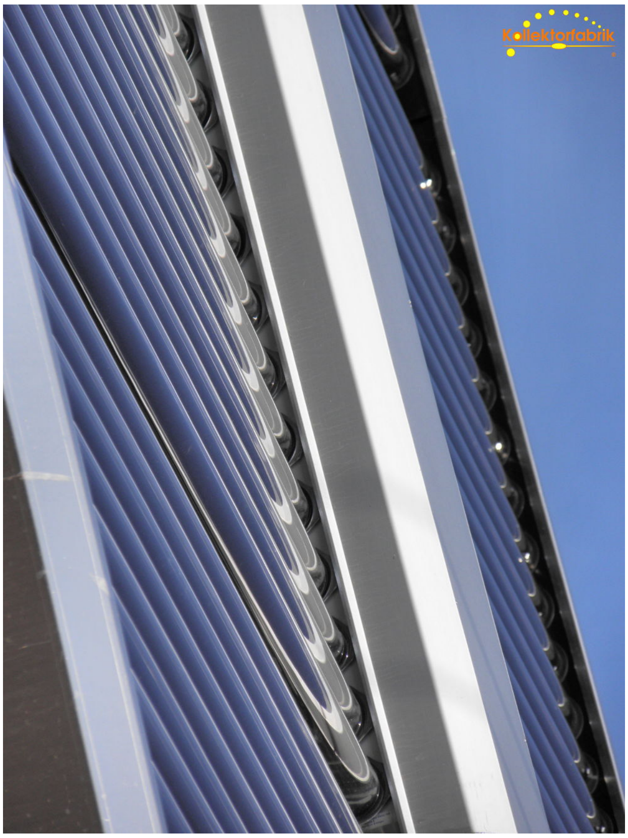

figure 3 Air-heating vacuum tube collector. © Kollektorfabrik.

3.3 *Building integrated PV-component with improved glare protection, solar control and electrical efficiency*

A new transparent building integrated PV (BIPV) component. It will simultaneously provide solar control, glare protection and electricity and it will allow visual contact to the exterior. It is possible to see outwards horizontally and downwards through the new angle-selective PV configurations while direct irradiation by the sun is blocked. It will be possible to reach very low total solar energy transmittances ($g < 0.10$). A visual mock-up (without PV-functionality) is shown in figure 4.

This façade component is currently developed by Fraunhofer ISE (co-ordinator) and Signet Solar.

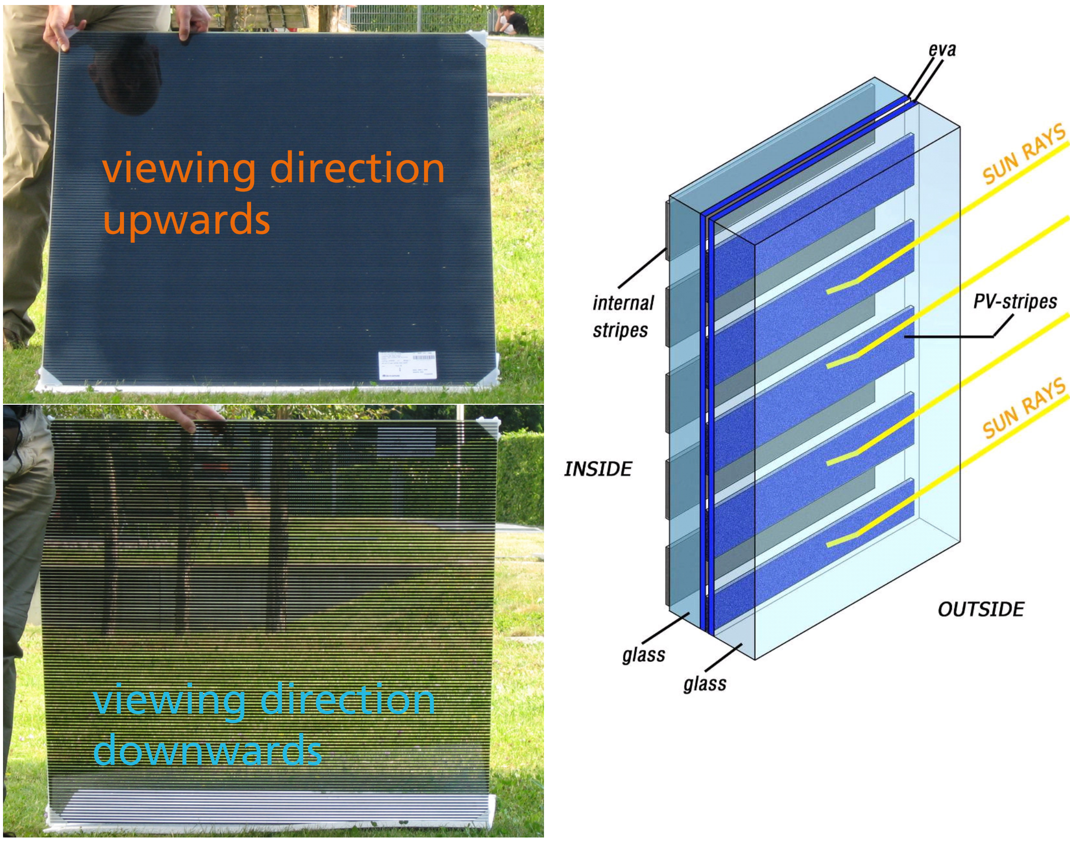

figure 4 Visual mock-up for new BIPV component. © Fraunhofer ISE

3.4 Façade-integrated ventilation with de-centralized heat recovery

A new façade-integrated ventilation with de-centralized heat recovery. Since no ducts for the supply air are required, it is especially well suited for cost-effective retrofitting of high-rise buildings without pre-existing mechanical ventilation systems. Since no fans are used in the individual rooms, the system is also a very low-noise system. A schematic diagram is provided in figure 5.

This façade component is currently developed by TNO (co-ordinator), Alusta and Permasteelisa group.

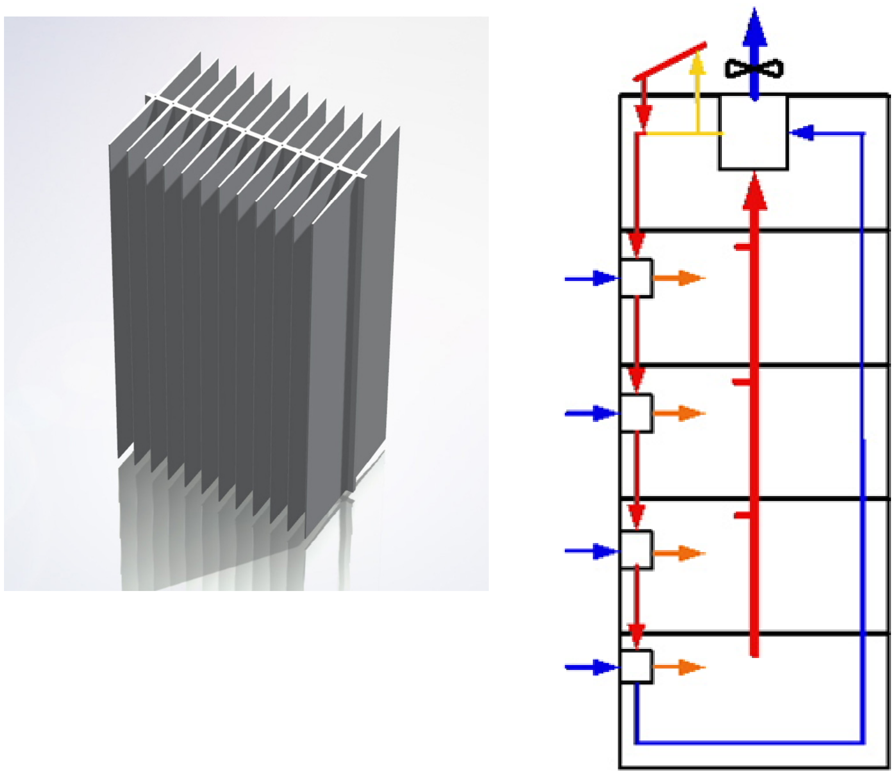

figure 5 Heat exchanger and schematic diagram of the new ventilation system

3.5 New unglazed façade collector coupled with a new heat pump

A new active solar system consisting of a new unglazed façade collector and a new heat pump. In this concept a new façade element is coupled to a heat pump for the distributed supply of heat and cold to existing high-rise buildings where space restrictions dictate system implementation.

This façade component is currently developed by EDF (co-ordinator), Nibe, Sto, D´Appolonia, Labein(Tecnalia) and Fraunhofer ISE.

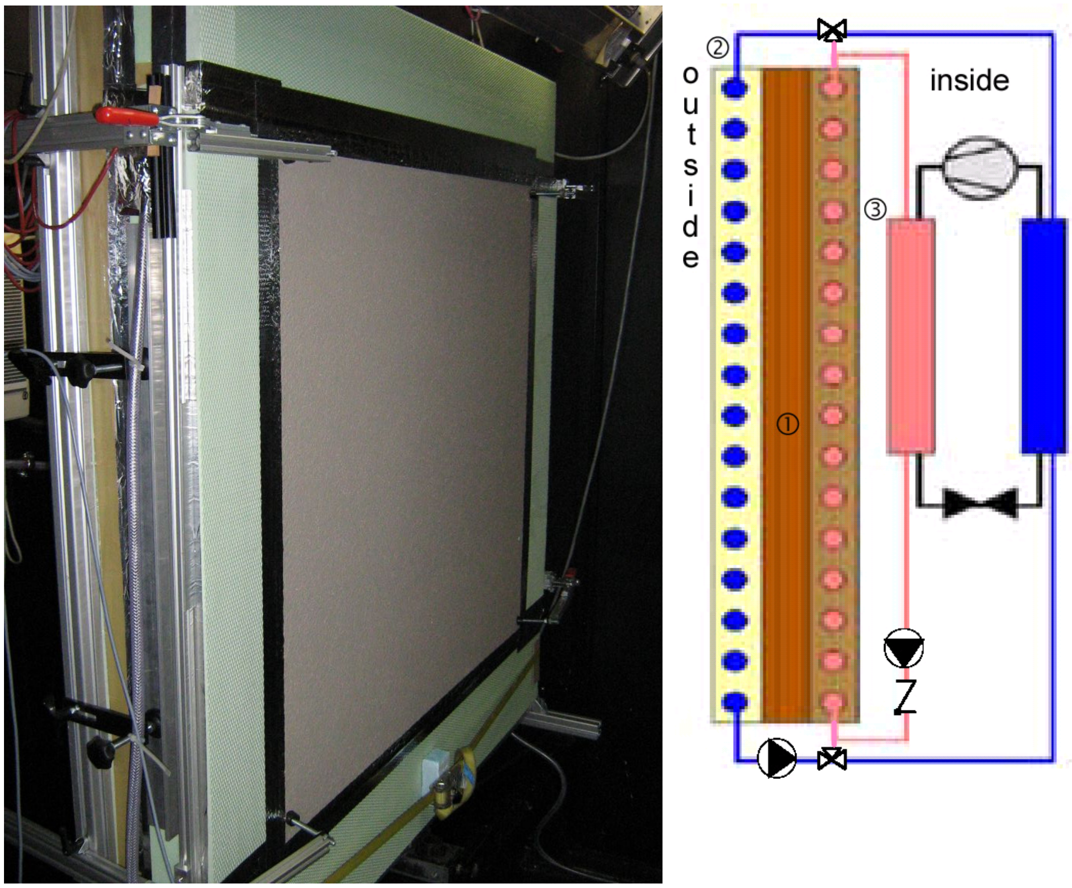

figure 6 Testing of a prototype unglazed solar thermal façade collector and schematic drawing of a possible system. Photo © Fraunhofer ISE

4 OUTLOOK

In the future building concepts will become more important which not only show a significantly reduced energy consumption but which include the production of energy using locally available renewable energy resources, mainly solar energy. A true integration of systems which convert solar radiation into useful energy – electricity, heat or cold – into the building envelope are needed for this purpose. Different appropriate solutions are required for existing houses and for new buildings. First examples are entering the market. However, there is still a large potential for new solutions and both, enhanced performance and cost reduction is necessary in order to allow for a broad market deployment.