BUILDING INTEGRATION ASPECTS OF SOLAR THERMAL COLLECTORS AND PHOTOVOLTAICS

Yiannis Tripanagnostopoulos
University of Patra, Physics Department, Patra 26500, Greece, e-mail: yiantrip@physics.upatras.gr

Juliane Metzger
Czech Technical University in Prague, Department of Environmental Engineering, 166 07 Prague, Czech Republic, e-mail: Juliane.Metzger@sunwin-energy.com

Summary

Solar thermal collectors and photovoltaics can be widely applied to cover building energy demand and installed properly can adapt building architecture in a harmonic way, improving also thermal insulation and reducing building heating and cooling demand. It is important to integrate solar energy systems of high aesthetics because they are directly visible, as they constitute a large part of the external building surface. The present work gives a figure of the application of solar thermal collectors and photovoltaics to adapt energy demand of buildings. Some innovative solar energy devices are briefly described and aspects regarding aesthetics and performance of them for building integration are discussed. The presented solar energy systems aim to optimise aesthetics, performance and cost with energy saving and solar control of buildings, by replacing conventional energy sources in heating, cooling and electricity therefore contributing to a significant CO_2 reduction.

1 Introduction

Solar energy systems, as thermal collectors and photovoltaics, can be applied in a very harmonic way on buildings. Every building should be designed according to the principles of bioclimatic architecture for the minimization of energy needs and the environmental impact to energy behaviour of it. In this way the installation of solar energy systems is useful and efficient, considering their total energy consumption. Solar thermal collectors (STCs) and photovoltaics (PVs) are installed on buildings to cover hot water and space heating/cooling needs and to provide electricity for lighting and operation of several electric devices. The facades and the horizontal or inclined roofs of buildings are appropriate surfaces for the installation of solar thermal collectors and PV panels, which should adapt building architecture. The energy demand of buildings for electricity and heat corresponds to more than a third of total energy consumption in many countries. Apart from solar energy systems, other renewable energy sources (RES), as small wind turbines, geothermal heat pumps and biomass heat providing systems, can also be used. By these systems a significant part of the energy requirements can be covered, contributing to conventional energy savings and protection of the environment by reducing CO_2 emission. Regarding integration aspects, solar and wind energy systems are directly visible and specific architectural requirements should be met to ensure their aesthetic integration.

The European Solar Thermal Technology Platform (ESTTP) aims towards the standard of the "Active Solar House" for newly built houses, meaning that heating and cooling demand of the building is covered to 100 % by solar thermal energy [1]. For the existing building stock the heating and cooling demand of an actively solar renovated house should be covered to at least 50 % by solar thermal energy ("Solar Active Renovation") [2]. In order to reach these targets of high solar fraction, solar systems for both, domestic hot water production, space heating and cooling of the buildings are required. The average collector area has to be increased to more than 10 m², all building types have to be included (single and multifamily houses and office buildings), roof and façade integrated collectors are fundamental and additionally, a combination of solar thermal and photovoltaic will help to achieve the objectives [3].

Beside the requirement of buildings with very low heating and cooling demand (as a pre-condition) research in the fields of advanced solar thermal components and their integration into the building is needed to come closer to the target "Active Solar Building" ([2], [3], [4]).

Another aspect of the 'solar active house' is the full integration of collectors in roofs and façades under consideration of architectural and economical aspects. For higher acceptance and a higher market introduction of solar systems, architectural aspects have to be taken into consideration. Solar collectors have to become an integral part of the building, ideally becoming standard construction elements. More detailed investigation on the impact of solar thermal systems on the building physics (i.e. façade collectors) is required. Additionally, a differentiation of collector type and shape depending on utilization (domestic hot water preparation, space heating or cooling of the building) is needed and combination of different collector types should be possible. Higher levels of building integration require new rounds of RD & D efforts, in close interaction with architects, construction companies and manufacturers of building envelope.

To achieve the goal of an energy efficient building, technologies should be combined and possible synergy effects used. This is only possible if integrated planning and simulation is available for the whole building and its energy supply (Fig. 1).

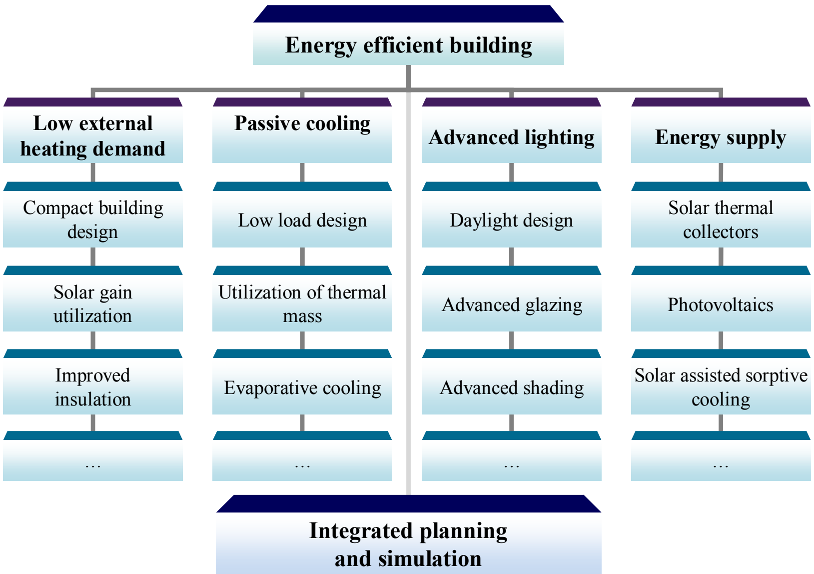

Fig. 1 The energy efficient building.

The present work gives a brief figure of application aspects for solar thermal collectors and photovoltaics to buildings. Some innovative solar energy devices are considered and aspects regarding aesthetics and performance of them are noticed. The presented solar energy systems and the suggested architectural concepts aim to adapt aesthetics, performance and cost with energy saving and solar control of buildings.

2 The term building integration

There are several different meanings of the widely used term building integration of solar collectors: system integration, architectural and constructional integration.

System integration concerns issues on how to include the solar technology into the energy supply system of the building with regard to optimization of energy gains and solar fraction.

A high quality of architectural integration of solar collectors is regarded as key issue to open the way to successful perception of collectors by designers and larger public acceptance of both, solar thermal and electrical systems. Reinberg is one of the architects who regards the solar collector as extremely important and states that collectors are not only part of the architecture but the main influence to define the future architecture [5]. To identify the requirements for the envelope integrated collectors (especially for visually active facades) from the point of architects several surveys by means of questionnaires and a workshop have been carried out [6], [7], [8]. Some architects and researchers ([6], [9], [10], [11]) underline the need for higher architectural quality, such as size, color or shape of the collectors.

Constructional building integration of solar thermal collectors aims towards the replacement of the building envelope through the solar collector. The integration of solar collectors into the building envelope instead of separate installation represents a transition from the concept of the envelope considered as an energy loss to the envelope being an energy source (energy active envelope) which actually means a step further to solar energy active buildings.

For acceptance of solar thermal and PV systems it is important to take all aspects into account: system, architectural and constructional integration. It is important to create an interdisciplinary project and installation cooperation between the architect, builder, solar engineer, plumber etc. to guarantee a working multi-functional building element.

3 Building integration aspects of STCs and PVs

For an aesthetic building integration of both solar energy systems, STCs and PVs, it is important to think about the form and the available surface areas on façade and roof of the building, and to pay attention to their type, performance and colour. The integrated solar energy system should be of high aesthetics because they are directly visible, as they constitute a large part of the external building surface. Several types and forms of STCs and PVs comprise new and interesting materials, which can be easily integrated into buildings, creating new shapes and symbolising the ecological concept. These collectors also appear as a new material in the architect's hands, ready to be shaped to create alternative buildings, improving also their thermal insulation. In an extended use of solar energy, the majority of the exterior surfaces of buildings will be covered with absorbing surfaces of solar thermal collectors and photovoltaics and their form and colour should be taken under consideration, especially in the case of buildings with traditional architecture.

Flat plate collectors are the most widespread collectors but also efficient evacuated tubular collectors and Compound Parabolic Concentrating (CPC) collectors are used. The well known Flat Plate Thermosiphonic Units (FPTU) and the less widely applied Integrated Collector Storage (ICS) systems are solar water heaters, aiming to cover domestic needs of 100–200 l of hot water per day and are mainly suitable for locations with favourable weather conditions. The unglazed solar collectors are cheaper than typical glazed collectors, but the increased absorber thermal losses limit their effective use in low temperature applications, as water preheating for domestic or industrial use, water heating of swimming pools, space heating, etc. In all energy applications, the impact of the used technology to the environment must be considered.

Photovoltaic systems have been installed on many types of buildings in a wide variety of ways. Office blocks have good PV potential because their electricity demand is significant all year round (including summer) and because this demand reaches its highest level during daytime. Residential buildings, even though they are occupied seven days a week, tend to use energy mainly at night. Commercial and industrial buildings with large available roof areas may offer a field of significant interest for the installation of PV systems. Photovoltaics can also be used as elements for building ventilation (solar chimney effect) heated by the solar radiation that is not converted to electricity. Thus, BIPVs may be of triple operation, as building construction material, contributing to building cooling by natural ventilation and of course to provide electricity.

Photovoltaics convert a small percentage (5%-15%) of the incoming solar radiation into electricity, depending on the type of PV, with the greater percentage converted into heat. The solar radiation increases the temperature of PV modules, resulting in a drop of their electrical efficiency, but their installation on horizontal roofs of buildings permits their natural cooling. This undesirable effect can be partially avoided by heat extraction with a fluid circulation which is obtained by hybrid PV/T solar systems. These systems can provide electrical and thermal energy, thus achieving a higher energy conversion rate of the absorbed solar radiation. They consist of PV modules coupled to heat extraction devices, in which air or water of lower temperature than that of PV modules is heated whilst at the same time the PV module temperature is reduced.

Apart from the typical forms of solar thermal collectors (flat plate, vacuum tube, etc) and photovoltaic modules (c-Si, pc-Si, a-Si CIS, etc), several new designs of solar energy systems have recently been developed to address building integration. In addition, new designs based on concentrating systems are already commercially applied. These systems are examples that show the potential for a wider application of novel solar energy systems to the buildings. In addition to STC and PV systems it is equally important to use new heat-insulating materials and special glasses, which reduce thermal losses of buildings during winter and energy consumption for cooling during summer. These products are already considered necessary structural materials for the improvement of energy behavior of buildings, giving at the same time a new visage to them. In new building designs or retrofitting the emphasis is addressed to the effective use of passive and active solar energy systems to partially or entirely cover the demand in natural lighting, space heating and cooling, air ventilating, domestic hot water and electricity.

The emerging concerns for environmental protection and global energy saving have introduced new architectural design rules for buildings, aiming at buildings of reduced energy consumption with effective integration of solar energy systems in combination with satisfactory aesthetics as well. PVs are used as construction materials, which allow innovative architectural designs since there is variety of colours, sizes and shapes of them. Furthermore, they may offer different light transparency, depending on design demands.

4 New solar collector concepts

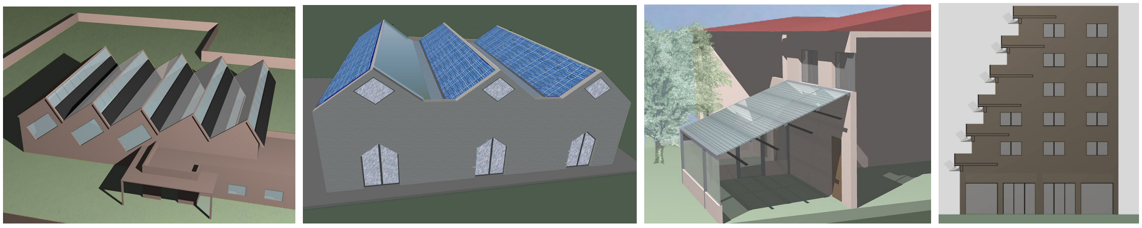

Fig. 2 Architectural designs of building integrated concentrating solar energy systems

New designs of solar energy systems aiming to cost effective and aesthetic integration to buildings have been investigated. Among them, collectors with colored absorbers to avoid the monotony of black color have been introduced [12]. Another type of collector is the improved PV/T system [13] and recently the new designs of stationary and of low concentration photovoltaics, addressed to building integration [14]. Using suitable solar radiation concentrating devices, they can contribute to illumination and temperature control of interior building spaces apart of solar energy conversion [15]. In Fig.2 some of the above mentioned designs give an idea about the view of the suggested systems.

Solar thermal collectors also appear as a new material in the architect's hands, ready to be shaped to create alternative buildings. Due to integration the thermal insulation of both, building envelope and insulation of the solar thermal collector, is improved ([16], [17]).

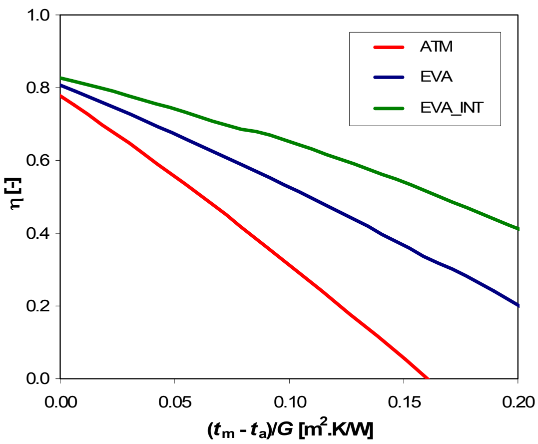

Fig. 3 Efficiency curves for advanced solar collectors (atmospheric, evacuated, envelope integrated evacuated collector) [18]

For advanced solar thermal flat-plate collectors it is obvious that elimination of the back radiation heat transfer is critical to achieve for a good collector performance if the collectors are installed separately from the building envelope. However, integration of advanced solar thermal flat-plate collectors brings high improvement of the collector performance (Fig.3) and a reduction of the heat loss of the building (due to improvement of the envelope insulation). These improved advanced flat-plate collectors could offer new possibilities in combining a good degree of integrability and delivering higher output temperatures that could be used for new solar applications such as thermally driven cooling machines. Another new concept is the so called multifunctional plug and play facade, which is a combination of PV, solar thermal and HVAC prefabricated in one module [19]. The approach of active envelope systems developing unglazed and glazed flat-plate systems has been introduced to meet the needs of energy production and building integration [9].

5 Conclusions

Application aspects for the design, aesthetics and operation of building integration of solar thermal collectors and photovoltaics are briefly given. The suggested systems aim to cost effective solutions in adapting energy demand of buildings and show that new ideas should be applied for a wide application of solar energy to buildings. Synergy effects between the solar collector and the building should not only be taken into consideration but taken as advantage to save costs with replacing the envelope by the collector and improving the insulation of the building. Several technologies that adapt to the architecture are available.

However, to achieve a high quality, harmonic integration of well functioning renewable energy technologies, it is important to create an interdisciplinary project and installation cooperation between all involved persons: architect, builder, solar engineer, roofer and plumber.

References

[1] ESTTP – European Solar Thermal Technology Platform. *Solar heating and cooling for a sustainable energy future in Europe. Vision, Potential, Deployment Roadmap, Strategic Research Agenda*. Revised version, ESTTP, Renewable Energy House, Brussels, Belgium

[2] DRÜCK, H. *Status and perspectives of solar thermal technologies in buildings*. Presentation at the European Sustainable Energy Week EUSEW, 2nd February (2007)

[3] SPARBER, W. *New buildings with high solar fraction*. Presentation at ESTEC-ESTTP Workshop in Freiburg, 19th June 2007, Germany (2007)

[4] EUROPEAN RENEWABLE ENERGY CENTRES AGENCY. *FP7 Research priorities for the renewable energy sector*. Consolidated Input from European Renewable Energy Research and Industry to the European Commission Stakeholder Consultation on Research Themes of the 7th Research and Development Framework Programme, EUREC Agency, March (2005)

[5] REINBERG, G. W. Kollektoren sind moderne Architektur. Fastvortrag at 19. OTTI Symposium Thermische Solarenergie, Bad Staffelstein, Germany, May 06. – 08, (2009)

[6] BERGMANN, I., WEISS, W. *Fassadenintegration von thermischen Sonnenkollektoren ohne Hinterlüftung*. Berichte aus Energie- und Umweltforschung, 13/2002, Austria (2002)

[7] MUNARI-PROBST, M., ROECKER, CH., SCHUELER, A. *Architectural integration of solar thermal collectors: Results of a European survey*, Proceedings of the ISES Solar World Congress 2005, Orlando, Florida, USA (2005)

[8] WEISS, W., STADLER, I. *Façade integration - a new promising opportunity for thermal solar collectors*. Proceedings of the Industry Workshop of the IEA Solar Heating and Cooling Programme, Task 26 in Delft, The Netherlands (2001)

[9] MUNARI-PROBST, M. *Architectural integration and design of solar thermal systems*. Thesis no. 4258 (2008), École Polytechnique Fédérale de Lausanne, Suisse (2009)

[10] PROBST MUNARI, M., ROECKER, C. *Towards an improved architectural quality of building integrated solar thermal systems (BIST)*. Solar Energy 81 (2007) 1104-1116, ScienceDirect (2007)

[11] HESTNES, A.G. *Building integration of solar energy systems*. Faculty of Architecture, Planning and Fine Arts, Norwegian University of Science and Technology, Solar Energy vol. 67, no 4-6 (165 p.), (1999)

[12] TRIPANAGNOSTOPOULOS Y. SOULIOTIS M., NOUSIA TH. *Solar Collectors with Colored Absorbers.* Solar Energy 68, No 4, pp 343–356 (2000).

[13] TRIPANAGNOSTOPOULOS Y., NOUSIA TH., SOULIOTIS M, YIANOULIS P. *Hybrid Photovoltaic / Thermal Solar Systems* Solar Energy 72, 2002, pp 217-234

[14] TRIPANAGNOSTOPOULOS Y. (2008). *Building Integrated Concentrating PV and PV/T systems.* Int Conf Eurosun 2008, Lisbon Portugal 7-10 Oct 2008.

[15] TRIPANAGNOSTOPOULOS Y., SIABEKOU CH, TONUI J.K. *The Fresnel lens concept for solar control of buildings.* Solar Energy 81, 661-675, (2007).

[16] METZGER J., MATUSKA T., SOUREK B. *Solar combisystems with building integrated evacuated solar flat-plate collectors*. ISES Solar World Congress 2007, Beijing, China (2007).

[17] METZGER J., MATUSKA T, SCHRANZHOFER H. *A comparative simulation study of solar flat-plate collectors directly an indirectly integrated into the building envelope.* Building Simulation 2009, 27th – 30th July 2009, University of Strathclyde, Glasgow, Scotland (2009)

[18] MATUSKA T., ZMRHAL V., METZGER J. *Detailed modelling of solar flat-plate collectors with design tool KOLEKTOR 2.2*. Building Simulation 2009, 27th – 30th July 2009, University of Strathclyde, Glasgow, Scotland (2009)

[19] SCHRANZHOFER H., STREICHER W., MACH T., MÜLLER M. *Multifunctional plug & play facade (MPPF)*. 19th Symposium Thermische Solarenergie, 6th – 8th May 2009, Kloster Banz, Bad Staffelstein, Germany (2009)