BUILDING INTEGRATION OF SOLAR THERMAL SYSTEMS

S. A. Kalogirou [a]

[a] ***Cyprus University of Technology***
Department of Mechanical Engineering and Materials Science and Engineering
45, Kitiou Kyprianou str., P. O. Box 50329, 3603Limassol, Cyprus
Email: soteris.kalogirou@cut.ac.cy

Abstract

With buildings accounting for 40% of the total primary energy requirements in EU, and the implementation of the Energy Performance of Buildings Directive (EPBD), developing effective energy alternatives is imperative. The EPBD requires that RES are actively promoted in offsetting conventional fossil fuel use. The use of RES in buildings is expected to rise dramatically in the next few years in view of the recast of the Directive, which specifies that the buildings should be nearly zero energy consumption. Meeting building thermal loads will be primarily achieved through an extensive use of solar thermal systems, following standard building energy saving measures. Solar thermal systems (STS) will have a main role as contribute directly to the heating and cooling of buildings and domestic hot water supply. The main problem that STS are facing today is that these are typically mounted on building roofing surfaces, creating aesthetic challenges and space availability issues. The solution to these problems would be the integration of STS into the traditional building envelope. The idea of integration is to replace the traditional building element with a STS one. This would also be a more economically viable solution. The possible problems that this integration could create are related to the rainwater sealing and protection from overheating, thus avoiding increased building cooling loads during summer. This paper aims to give a survey of possible STS integration on the building roofs and façades. The advantages of integration are quantified and suggestions are given to address the possible problems created.

Keywords: *Solar thermal systems; building integration; façade integration; roof integration*

List of Symbols

Abbreviations

BIPV	*: Building integrated photovoltaic*	*STS*	*: Solar thermal system*
BISTS	*: Building integrated solar thermal systems*	*TUD*	*: Transport and urban development*
COST	*: Cooperation is science and technology*		
CPC	*: Compound parabolic collector*		
EPBD	*: Energy performance of buildings directive*		
EU	*: European Union*		
RES	*: Renewable energy system/s*		

1. Introduction

The Renewable Energy Framework Directive sets a 20% target for renewables by 2020. Buildings account for 40% of the total primary energy requirements in the EU [1]. Therefore, developing effective energy alternatives for buildings, used primarily for electricity, heating, cooling and the provision of hot water, is imperative. One way to reduce fossil fuel dependence is the use of renewable energy systems (RES) which are generally environmentally benign. In some countries, RES and in particular solar water heaters are used extensively. The benefits of such systems are well known but one area of concern has been their building integration. Most solar components are mounted on building roofs and they are frequently seen as a foreign element on the building structure. Due to this fact alone and irrespective of the potential benefits, some architects object to this use of renewable energy systems. It is therefore necessary to find ways to better integrate solar systems within the building envelope, which should be done in a way that blends into the aesthetic appearance and form of the building architecture in the most cost effective way.

The Energy Performance of Buildings Directive (EPBD) requires that RES are actively promoted in offsetting conventional fossil fuel use in buildings. A better appreciation of photovoltaics (PV) and solar thermal systems (STS) integration will directly support this objective, leading to an increased uptake in the application of renewables in buildings, which is expected to rise dramatically in the next few years. This is further augmented by the recast of EPBD, which specifies that by the year 2020 the buildings in EU should be nearly zero energy consumption. Meeting building electrical and thermal loads will be primarily achieved through an extensive use of renewables, following standard building energy saving measures. Both PV and STS are expected to take a leading role in providing the electrical and thermal energy needs respectively, as they can contribute directly to the building electricity, heating, cooling and domestic hot water requirements. There are many discussions about the advantages and disadvantages of zero or nearly zero energy buildings. The advantages, with emphasis on STS, are:

1. Offer local generation of heat and so transportation losses are minimized.
2. Usually the generation is done by renewable energy systems, which are friendly to the environment.
3. The building owner can install a high-tech system by taking advantage of the various subsidies that exists.
4. The energy consumption expenditure for the building is minimized or it is not existent (for 100% coverage).
5. The overall value of a property increases tremendously.
6. The building can be of a higher class concerning energy performance certificate.
7. As the energy performance certificate and the class of the building are related to the amount of rent requested, a higher income can result for the owner.
8. There may be substantial income to the building owner by selling the heat produced (if a suitable industry is located nearby).

The disadvantages are also important and are as follows:

1. The initial expenditure for the building is higher.
2. The owner usually has to pay the expenditure for the RES and then apply to get the money back from subsidies.

3. Problems to install the RES on the building structure.
4. Problems with respect to the space availability to install the RES systems required.
5. Most RES systems will require periodic maintenance, which creates extra worries and costs for the building owner.

2. Building integration of RES

Among the renewable energy resources, solar energy is the most essential and prerequisite resource of sustainable energy because of its ubiquity, abundance, and sustainability.

The systems that are usually employed in buildings are photovoltaics and solar thermal collectors. Photovoltaics can supply the electricity required to the building or the generated electricity can be fed/sold to the grid. The latter is usually preferred as the system does not require batteries for energy storage and take advantage of higher electricity rates that can be obtained by selling the electricity produced to the grid. Solar thermal systems can supply thermal energy for space heating, cooling and the provision of hot water for the needs of a house/building. The latter systems, which are the subject of this paper, are further examined in the following sections.

The advantages of building integration of RES are that more space is available on the building for the installation of the required area of the RES systems and that the traditional building component is replaced by the RES one, which increases the economic viability of the systems.

In the case that this concept is employed, coupled with aesthetic and architectural challenges of building integration, many practical issues need to be resolved; such as rainwater sealing and protection from overheating (avoiding increased cooling loads during summer). The extra thermal energy can also be used for the heating of the building in winter. As RES are latitude dependent, with respect to façade application and solar incidence angle effects, these needs to be considered as countries near the equator have high incidence angles (the sun is higher on the sky) but more energy is available compared to higher latitude countries.

The adoption of building integration of RES can fundamentally change the accepted solar installation methodologies that affect residential and commercial buildings throughout the world. Maybe the single most important benefit originating from this idea is the increased adoption of RES in buildings.

A solar thermal system is considered to be building integrated, if for a building component this is a prerequisite for the integrity of the building's functionality. If the building integrated PV or STS is dismounted, dismounting includes or affects the adjacent building component, which will have to be replaced partly or totally by a conventional/appropriate building component. This applies mostly to the case of structurally bonded modules but applies as well to other cases, like in the case of replacing with building integrated solar thermal systems (BISTS) or building integrated photovoltaics (BIPV) on one of the walls in a double wall façade. Therefore, building integration must provide a combination of the following:

1. Mechanical rigidity and structural integrity.
2. Weather impact protection from rain, snow, wind and hail.
3. Energy economy, such as useful thermal energy, but also shading and thermal insulation.
4. Fire protection.
5. Noise protection.

The building integration of renewable energy systems can pose a number of problems that will need to be considered such as:

1. Amount of thermal energy collected and at what temperature range.
2. Resistance to wind-driven rain penetration.
3. If the underlying base layer is transparent, calculation of light and solar energy characteristics.
4. Calculation of thermal resistance and thermal transmittance characteristics of the construction (overall heat transfer coefficient).
5. Fire protection classification and fire protection from hot components in contact with flammable materials.
6. Noise attenuation.

2.1 Solar Thermal Systems

The solar collecting methodologies that can be applied in buildings are the simple thermosiphonic units, forced circulation systems employing flat plate collectors, integrated collector storage units, evacuated tube collector systems and various low concentration compound parabolic units [2]. In some countries, such as Cyprus, renewable energy systems and in particular solar water heating are used extensively, with 93% of all domestic dwellings currently equipped with such a system [3]. Figure 1 shows a number of these systems as applied in various situations. Figure 1(a) shows the typical flat roof installation of a thermosiphon solar water heating system, which is the mostly used system. Cyprus suffers for many years from a water shortage problem, which leads to frequent water supply interruption. For this reason, a cold-water tank is installed (big white circular tank) on top of the collector to supply both the solar system and the house with water. As can be seen this creates even more serious aesthetic problems to the building. Some other designs try to blend the system on the building roof, as shown in Fig. 1(b).

Fig. 1: *Various flat-plate solar water heating systems in Cyprus (a) Typical flat roof; (b) Installation on sloping roof to improve aesthetic appearance; (c) Pressurized system on sloping roof; (d) Forced circulation system on flat roof*

A better way is to use a pressurized water supply system, in which case the cold-water tank can be installed at a lower level but this is more expensive. Such a system on a sloping roof is shown in Fig. 1(c) and the aesthetic improvement is obvious. An even better solution is the use a force circulation system, in which case even the hot water storage tank is also removed from the roof, located indoors, and although this system is even more expensive, the aesthetic appearance of the building is further improved. The solar flat-plate collectors are the only part of the system now installed on the roof but these are not usually integrated to it as shown in Fig. 1(d). A similar situation occurs for other solar water heating system as the ones using evacuated tube collectors, shown in Fig. 2.

The benefits of solar water heating systems are well known but one area of concern has been their building integration. Most solar collecting components are mounted on building roofs with no attempt to incorporate them into the building envelope, as shown in Figs 1 and 2. In many instances, they are actually seen as a foreign element on the building roof. Many architects, irrespective of the potential benefits, object to this use of renewable energy systems due to this fact alone. The problem will be even more serious, when solar space heating and cooling systems are used, as they required much more solar collectors. It is therefore necessary to find ways to better integrate solar collectors on the building envelope and/or structures, which should be done in a way that blends into the aesthetic appearance and form of the building architecture in the most cost effective way.

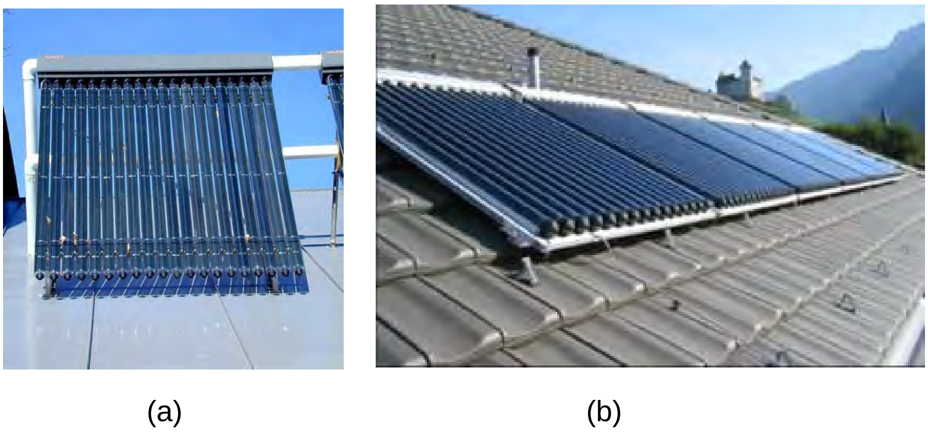


Fig. 2: *Evacuated tube solar collector on building roofs (a) Flat roof; (b) Sloping roof*

As was seen above various solar heating systems can be installed in buildings and each one of them has to be considered by itself when building integration is considered. For example, it is not yet investigated if a thermosiphon system installed vertical on the façade of a building can work effectively. Evacuated tube collectors can lead to serious rain penetration problems when integrated in buildings unless a special construction is done behind the collector to keep rain out of the building structure. Two solutions of building integrated flat plate collectors are shown in Fig. 3. The collector consists of the usual parts found in stand-alone systems without the casing and the whole construction is set up in front of the brick of the normal wall. The collector can be installed by leaving an air gap between the insulation and the brick according to the prevailing conditions that exist in the area of installation and the necessity to avoid migration of moisture into the building. In both cases, good insulation is used to avoid transferring unwanted heat into the building, especially during the summer months. The same construction can be used for sloping roof applications in which case the brick is replaced by concrete slab.

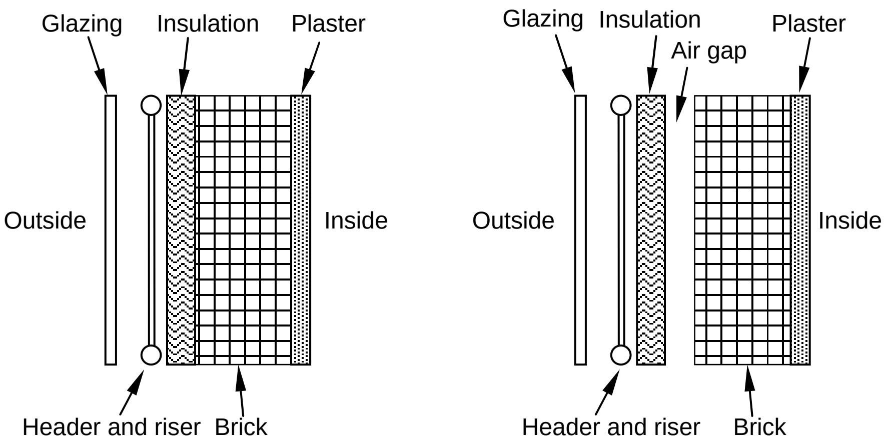
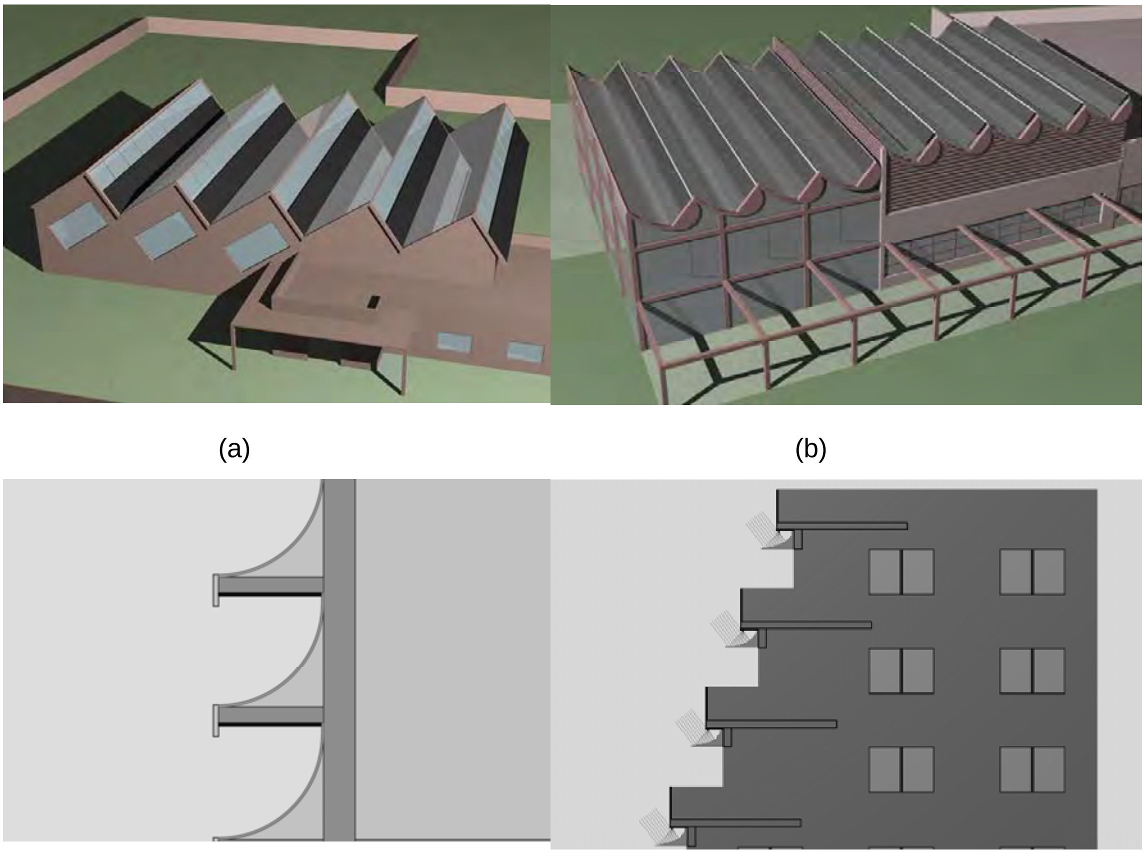


Fig. 3: *Two solutions of façade building integrated flat plate collectors*

Integrated collector storage and compound parabolic collector (CPC) designs can be used in a variety of applications. Various solutions to integrate these collectors on the building structure are proposed by Tripanagnostopoulos [4, 5]. These concern flat reflectors to increase the solar radiation falling on solar receiving surfaces, CPC type designs and Fresnel type reflectors. All of them can be used for solar thermal applications and/or photovoltaic systems and some of the proposed solutions are shown in Fig. 4. The designs which show building integration of CPC solar systems concern static concentrators with linear absorbers on building roofs, facades or under the balconies. CPC systems can also be used effectively in central and northern Europe where the sun is at low altitude angle for many months of the year.



(a) (b) (c) (d)

Fig. 4: *Building integration to flat and CPC type of reflectors (a) Flat reflectors on sloping roofs; (b) CPC reflectors on roof of a building; (c) CPC reflectors on building façade; (d) CPC reflectors under balconies [4, 5]*

Recently a new COST Action is approved to investigate the building integration of solar thermal systems (BISTS). The COST identification number of the Action is TU1205 and the Action belongs to the Transport and Urban Development (TUD) Domain.

3. Conclusion

The Energy Performance of Buildings Directive (EPBD) requires that RES are actively promoted in offsetting conventional fossil fuel use in buildings. A better appreciation of PV and STS integration will directly support this objective, leading to an increased uptake in the application of renewables in buildings. This uptake of RES in buildings is expected to rise dramatically in the next few years. This is further augmented by a recast of the Directive, which specifies that the buildings in EU should be nearly zero energy consumption (residential and commercial buildings by the year 2020 and public buildings by 2018). Meeting building thermal loads will be primarily achieved through an extensive use of renewables, following standard building energy saving measures, such as good insulation or advanced glazing systems. Solar thermal systems are expected to take a leading role in providing the thermal energy needs, as they can contribute directly to the building heating, cooling and domestic hot water requirements.

As can be seen from the solutions presented in this paper a number of ideas have been tried and others are just at the concept stage and generally more R&D effort is needed. It is believed that in the coming years more and more of these solutions/ideas will find their way in the market in view of the implementation of the directives imposed by the EU.

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