Energy and aesthetics of building integrated RES

Y. Tripanagnostopoulos
Department of Physics, University of Patras, Greece

ABSTRACT

New types of solar energy systems and small wind turbines efficient in energy conversion and of advanced aesthetics are presented. These systems have been developed in Physics Department of University of Patras and aim to an improved integration of RES on buildings. New solar water heaters of the Integrated Collector Storage (ICS) type, thermal colored collectors, hybrid photovoltaic/thermal (PV/T) solar systems, Fresnel lenses with linear multifanctional absorbers, and small wind turbines are considered to be applied as satisfactory solutions for the built and urban environment. In this paper energy, cost and aesthetic aspects for the above systems are included and discussed.

1. INTRODUCTION

Significant amount of heat and electricity needs of buildings can be effectively covered by using solar thermal collectors and photovoltaics. In the next years, other renewable energy sources (RES) as wind turbines, biomass and hydrogen (produced only from RES) can be also applied, minimizing the use of the conventional energy sources. RES and nuclear energy can be the considered alternative energy sources to avoid greenhouse effect. Between these two energy sources, only RES are clean and compatible with the environment, are almost uniformly distributed globally, can be easily used from all people with minimum market trust and ownership undertaking and of course are inexhaustible. Based on the above, the consumption of 12% of total energy and of 21% of electricity from RES up to 2010, is for EU member-countries a very critical target.

The bioclimatic design, the energy saving and the integration of several systems of RES on buildings must be considered by the aesthetic view and all the installed energy systems should be adapted to the building architecture. In this paper new solar energy devices and small wind turbines, efficient in energy conversion and of advanced aesthetics are considered. These systems have been developed in Physics Department of University of Patras and aim to an improved integration of RES on buildings.

2. RES AND BUILDINGS

Renewable energy technologies have several benefits such as sustainability and security of energy supply, increased employment, long lifetime of energy systems etc. Even if the cost of solar energy systems remains in high levels it seems to be in compliance with European and international commitments. This is due to the fact that solar technology is a very friendly one in environmental terms for buildings and urban applications. This kind of technology is also highly important for the economy of most countries as they can replace the expensive and imported conventional energy sources (oil, gas, coal and nuclear fuels.

Solar Energy Systems can be applied in a very harmonic way on buildings to cover the heating, cooling, electricity and lighting needs. The facades and the horizontal or inclined roofs of houses, hotels, athletic centers, etc, constitute appropriate surfaces for an expanded use of solar thermal collectors and photovoltaic panels. Buildings can be designed according to the bioclimatic architecture for the minimization of the energy needs and the environmental impact of them, using new heat-insulating materials and special glasses (smart windows), which reduce effectively thermal losses during the winter and energy consumption for cooling during the summer. Under these aspects, the prospective energy savings in the buildings (especially in the new ones) can be more than 50% of the energy consumption of standard buildings and become a regular procedure for the built environment construction.

The installation of devices and active solar energy units is related with their cost increase and their harmonization with buildings' architecture and the environment. Solar energy systems are also preferred for aesthetic reasons, in order to avoid the negative phenomena of diesel engines for heat and electricity (smokes, chimneys, etc). It is also important to apply them if they are harmoniously implemented into the existing, local, natural particularities of the environment through good planning and wise environmental studies. For example solar energy systems can be used effectively in many Greek islands, which are characterized by particular morphological and territorial features, transformed human environment, rich cultural heritage and rich visible resources. This kind of features, transforms these regions into poles of an international ecological and cultural heritage. For sensible ecosystems of this kind, the danger of visible disturbing is very important and needs a balanced handling. In order to avoid the annoying results and due to the fact that these islands are consisted of different local types, one realises that it is essential to indicate the basic morphemes.

The exploitation of Solar Energy Systems towards sustainable development applications, could take the form of the creation of innovative buildings, equipped with bioclimatic features aiming at the saving of energy. As it is known that the sector of buildings is responsible for about 35% of the final energy consumption and for the 40% of the gas emissions, it is estimated that the saving of energy can arrive at 60% when solar energy systems are used for heating and cooling purposes. Besides, a new Directive from EC has been placed into force with regard to the obligation of energy saving in the newly constructed buildings. Thus, RES application to buildings with improved performance and aesthetic integration can result to the rising of the standards of living.

3. THE INVESTIGATED SOLAR ENERGY SYSTEMS

In Physics Department of University of Patras, several types of solar energy systems, as the ICS systems, the colored collectors, the booster reflectors, the hybrid photovoltaic/thermal solar systems and the Fresnel lenses have been investigated as alternative solar devices to the typical flat plate solar collectors and photovoltaics. In the following we describe briefly the design and performance of them.

3.1 Integrated Collector Storage Systems (ICS)

Flat Plate Thermosiphonic Units (FPTU) and Integrated Collector Storage (ICS) systems are small size solar water heaters, aiming to cover domestic needs of about 100–200 l of hot water per day (Tripanagnostopoulos et al, 2002a, Tripanagnostopoulos and Souliotis, 2004a). ICS solar systems are simpler and have lower cost than FPTU systems, as they consist of solar collector and water storage tank mounted together in the same device (Fig. 1).

The preservation of the temperature level of the hot water is the main problem of ICS systems, as the absorbing surface is part of the external surface of the water storage tank. Extensive study on ICS systems with cylindrical water storage tanks placed properly inside Compound Parabolic Concentrating (CPC) reflector troughs has been performed and several new designs, based on the effective combination of the water storage tanks with symmetric or asymmetric CPC reflectors have been suggested (Fig. 2). These systems can be used as separate

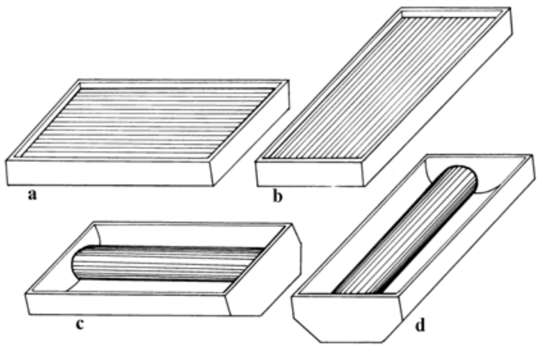

Figure 1: ICS systems with flat and tubular storage tank.

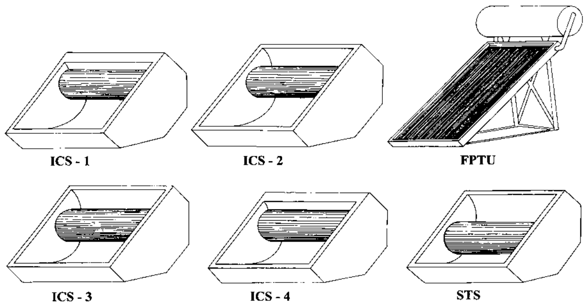

Figure 2: Alternative ICS solar systems.

units for one family houses and also in series connection with an insulated storage tank inside the building, regarding larger size applications.

3.2 Solar collectors with colored absorbers

Considering that the aesthetic view is of priority in most of the existing and the new buildings, solar collectors with absorbers of different color than black could be an interesting solution for the wider application of solar energy systems. These collectors, because of the lower absorptance, have lower thermal efficiency than that of the usual black type collectors but they are more interesting to architects for applications on traditional or modern buildings. We have carried out an extensive study on solar collectors with colored absorber, which has shown that these collectors can be of satisfactory efficiency (Tripanagnostopoulos et al, 2000a). The absorbers of the tested flat plate collector prototypes were painted blue and red-brown and the tests showed that the obtained efficiency can be considered acceptable compared to that of the usual collector type with black absorber. Regarding cost, an additional amount of about 20%, to increase the collector area, can be considered to overcome their lower thermal output compared to the collectors with black absorber of the same type. The application of blue collectors in white buildings in islands, of red brown collectors in buildings with inclined roof and traditional architecture and of other color on modern buildings, could contribute to a wider use of solar thermal collectors (Kalogirou and Tripanagnostopoulos, 2005).

3.3 Solar collectors with booster reflectors

Many buildings have horizontal roof and solar collectors can be installed in parallel rows, placed at a proper distance, in order to avoid collector shading during winter. The space between the parallel rows can be used to provide additional solar radiation on the collector aperture surface by placing booster reflectors from the collector top of the one row to the collector bottom of the next row. These reflectors can contribute to the increase of the thermal energy output by about 20%-50% and from spring to fall this type of installation is suitable for collector operation in higher temperatures, adapting therefore space cooling requirements (Tripanagnostopoulos and Souliotis, 2005a).

3.4 Unglazed solar collectors

The optical annoyance from reflected light, the use of glass coatings that diffuse reflected light is the most appropriate solution. More often and to avoid the problems from the glare, it is considered worthy to use uncovered (unglazed) solar collectors for low temperature applications (swimming pools, preheating of water, etc). The unglazed solar collectors can be alternative to typical collectors with glazing, for water heating up to about 35°C (Fig. 3). In this perspective, uncovered collectors can be combined with colored surface for an even more interesting integration of solar collectors in facades and inclined roofs of buildings. From May to September, the ambient temperature is higher than water temperature from mains and the unglazed solar collectors perform better than glazed collectors for operation in lower than ambient temperatures (Tripanagnostopoulos et al, 2000b).

The results from our research show that the thermal energy output can be increased, by using booster reflectors between the parallel rows of the unglazed collectors. Finally, in the horizontal roof applications, it is effective to use flat booster reflectors between the rows of collectors with colored absorbers and increase the thermal output of them.

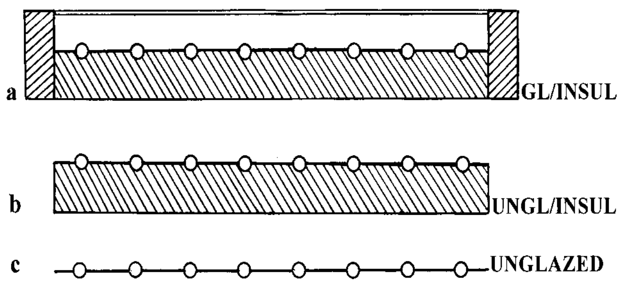

Figure 3: The glazed and the unglazed collector types.

3.5 Hybrid photovoltaic/thermal (PV/T) systems

The solar energy systems that provide electricity and heat simultaneously are the Hybrid Photovoltaic/Thermal (PV/T) systems, which are consisted of PV modules coupled to water or air heat extraction devices achieving a higher energy conversion efficiency of the absorbed solar radiation (Tripanagnostopoulos et al, 2002b). Design and performance improvements of hybrid PV/T systems, with water or air as heat removal fluid, have been carried out to improve the total energy output of the PV/T system. In low latitude applications the water type PV/T systems can be effectively used all seasons, as water from mains is under 20^{o}C. In the case of PV/T systems with air heat extraction (Fig. 4), they can be used as building integrated PV/T systems, like the BIPV systems, but with improved performance (Tripanagnostopoulos et al, 2000b).

The air-cooled PV/T systems are considered cost effective for application in medium and high latitudes, where ambient air is most of the year kept at a low temperature level. These devices are not yet applied enough and their applications until now are mostly for demonstration and mainly have to do with air hybrid PV/T on the facades of buildings. Such installations can contribute to building natural ventilation, operating as solar chimneys on building façade and inclined roof. Considering PV/T solar systems installed on horizontal building roof, the parallel rows keep a distance from one to the other in order to avoid PV module shading. We have investigated the use of stationary flat diffuse reflectors placed between the rows of PV modules.

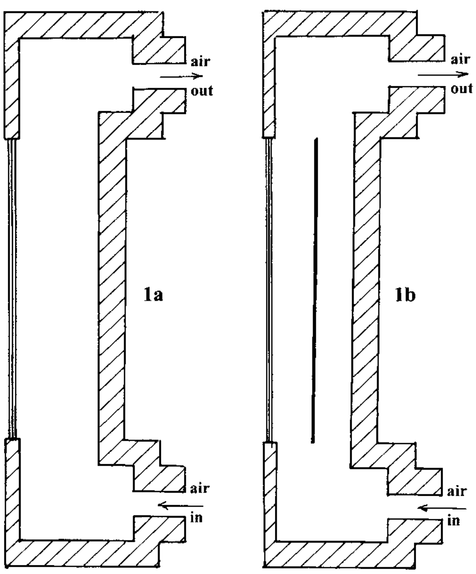

Figure 4: Air-cooled PV/T solar systems.

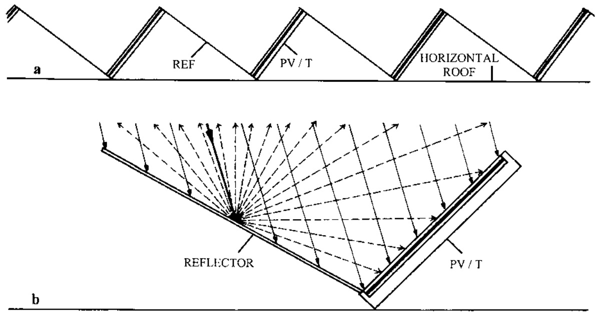

Figure 5: The PV/T - booster reflector concept.

The reflectors can provide an almost uniform distribution of reflected solar radiation on PV module surface, resulting to increase solar input on PV modules and improve the electrical and thermal output of the PV/T systems (Fig. 5).

An extensive study on the performance improvement of hybrid PVT systems has been done in Physics Department at University of Patras with new designs and results on PVT systems.

3.6 Fresnel lenses for building atria

Fresnel lenses are optical devices for solar radiation concentration and are of lower volume and weight, smaller focal length and lower cost, compared to the thick ordinary lenses. The advantage to separate the direct from the diffuse solar radiation makes Fresnel lenses suitable for illumination control of building interior space, providing light of suitable intensity level and without sharp contrasts. The Fresnel lens concept has been suggested for solar control of the buildings to keep the illumination and the interior temperature at the comfort level (Tripanagnostopoulos et al, 2005b).

Laboratory scale experimental results give an idea about the application of this new optical system. The collection of 60%-80% of the transmitted solar radiation through the Fresnel lenses on linear absorbers leaves the rest amount to be distributed in the interior space for the illumination and thermal building needs. In low intensity solar radiation, the absorber can be out of focus, leaving all light to come in the interior space and to keep the illumination at an acceptable level.

The Fresnel lenses can be combined with thermal, photovoltaic, or hybrid type photovoltaic/thermal absorbers to collect and extract the concentrated solar radiation in the form of heat, electricity or both. By using thermal absorbers and for low operating temperature, efficiency of about 50% can be achieved, while considering photovoltaics, satisfactory electrical output can be obtained. Regarding the effect of the suggested system to building space cooling, a satisfactory temperature reduction, exceeding 10 ^{o}C for cold water circulation through the absorber, has been achieved.

3.7 Building integration of solar/wind systems

Another interesting subject that has been studied is the building integration of solar and wind energy systems. Both of these devices appear to be the most interesting among renewable energy sources for the built environment. The facades and the horizontal or inclined roofs of houses, hotels, athletic centers and buildings of other types are appropriate surfaces for the application of solar energy conversion systems as they are the photovoltaic panels and the thermal collectors, for the electricity and heat demand respectively. Apart of them small wind turbines (WTs) can be mounted on building roofs, mainly at locations with satisfactory wind velocity potential. The use of small WTs to typical grid connected residential buildings, hotels, etc, is recently suggested to provide electricity supply and they are suitable mainly for decentralized applications. In addition, they can be effectively combined in complementary operation with photovoltaics and solar thermal collectors. (Tripanagnostopoulos and Tselepis, 2003). To this direction there are various systems developed, such as wind turbines of horizontal (HAWT) or vertical (VAWT) axis, wind concentrators, etc.

Hybrid photovoltaic-wind and/or Diesel systems can offer great abilities in the production of energy based on solar and wind energy. In regions where sunshine and wind conditions are good, like the Greek islands, the combined use of photovoltaics and wind turbines has great results for most of the day-night period and also for a very large period of a year, with the thermal collectors covering thermal needs all year round. We must also mention that in most Greek houses, water heating is usually covered by electricity and it could be covered by the use of the surplus energy from the small wind turbines.

The combination of PVT and WT systems has been suggested as a new concept and the multiple energy conversion systems are the hybrid wind (electric)/solar (electric and thermal) systems or WT/PVT. They are considered suitable in rural and remote areas with electricity supply from stand-alone units or mini-grid connection. WT/PVT systems can also be used in typical grid connected applications. (Tripanagnostopoulos et al, 2004b). For stand-alone WT and PV systems, diesel generators are used in case that solar and wind energies are not sufficient to cover the electrical load.

A very important issue that makes hybrid systems interesting solution for the production of energy is the complementary function of the photovoltaic panels and the wind turbine. PV panels can be useful only in daytime and under a certain solar radiation. On the other hand, WTs can produce energy only when the wind velocity is above a certain rate. So, PV and WT systems can effectively be combined with PVs for sunny days and WTs for windy nights or for the cloudy days. Also, during winter, where the solar radiation is generally at a low rate, PV systems cannot reach a sufficient performance while WTs can offer a lot to energy supply. During summer months, PV systems have fascinating results, which could compensate the unsteady performance of the WTs.

4. CONCLUSIONS

New solar energy systems of better view than the usual types, such as the Integrated Collector Storage solar water heaters and the thermal collectors with colored absorbers are suggested for a wider and more aesthetic application of solar energy to buildings. The horizontal roofs of buildings can be effectively used for the conversion of the incoming solar radiation if booster reflectors are mounted between the parallel rows of the collectors. Lighting and temperature control of atria or other interior building spaces can be achieved with Fresnel lenses combined with linear multifanctional absorbers. Alternatively to the building integrated photovoltaics, new solar devices, the hybrid photovoltaic/thermal (PV/T) systems, can be used to provide electricity and heat. The wind energy systems, such as the small wind turbines with horizontal or vertical axis can be considered interesting RES devices for the buildings, which can be effectively combined with PV or PV/T solar systems.

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REFERENCES

Kalogirou S., Tripanagnostopoulos Y. and Souliotis M., 2005 Performance of solar systems employing collectors with colored absorber, Energy and Building 37, pp 824–835.

Tripanagnostopoulos Y. and Yianoulis P., 1992. Integrated collector-storage systems with suppressed thermal losses. Solar Energy 48, pp 31-43.

Tripanagnostopoulos Y. and Yiannoulis P., 1994. Solar water heaters with booster mirrors. Proc. Int. Conf. WREC III, pp. 1908-1910, Reading, U.K., 11-16 Sep.

Tripanagnostopoulos Y., Souliotis M. and Th. Nousia, 2000a. Solar collectors with colored absorbers. Solar Energy 68, pp 343-356.

Tripanagnostopoulos Y., Nousia Th. and Souliotis M., 2000b. Low cost improvements to building integrated air cooled hybrid PV-Thermal systems Proc. 16th European PV Solar Energy Conf. pp. 1874-1877, Glasgow, U.K. 1-5 May.

Tripanagnostopoulos Y., M. Souliotis and Th. Nousia, 2002a. CPC type integrated collector storage systems. Solar Energy 72, pp 327-350.

Tripanagnostopoulos Y., Nousia Th., Souliotis M. and Yianoulis P., 2002b. Hybrid Photovoltaic/ Thermal solar systems. Solar Energy 72, pp. 217-234.

Tripanagnostopoulos Y., Tselepis S., 2003. Hybrid solar/wind PVT/WT building integrated systems. In Proc. 2nd Int Europ. PV-Hybrid and Mini-Grid Conf.; Kassel, Germany, 25/26 Sep, 329-333.

Tripanagnostopoulos Y., Souliotis M., 2004a. ICS solar systems with horizontal E-W and vertical N-S cylindrical water storage tank. Renewable Energy 29, pp. 73-96.

Tripanagnostopoulos Y., Tselepis S., Souliotis M., Tonui J. K. and Christodoulou A., 2004b. Practical aspects for small wind turbine applications. Proc. in Int. EWEC 2004 Conf., Track 7; Autonomous and/or Hybrid Systems, London, UK, 22–25 Nov.

Tripanagnostopoulos Y. and Souliotis M., 2005a. Booster Reflector Contribution to Performance Improvement of Solar Collectors. Proc. in CD, Int. Conf. WREC 2005, pp. 63–68, Aberdeen, UK, 22–27 May.

Tripanagnostopoulos Y., Siabekou Ch. and Tonui J.K., 2005b. The fresnel lens concept for solar control of buildings. In Proc. Int. Conf. PALENC2005, Santorini, Greece, 977-982.