Renewable and Sustainable Energy Reviews 47 (2015) 966–982

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The architectural integration of active solar systems. Building applications in the Eastern Mediterranean region

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ARTICLE INFO

Article history:
Received 16 August 2014
Received in revised form
26 November 2014
Accepted 8 March 2015
Available online 1 April 2015

Keywords:
Active solar systems
Architectural integration
Flat roofs
Façades
Urban centres
Traditional settlements

ABSTRACT

This paper investigates the different possibilities of architectural integration of active solar systems on the shell of existing buildings in traditional settlements and in existing urban centres, in Greece and on the island of Cyprus. Insolation conditions in both countries make this integration very advantageous, in terms of energy conservation, environmental protection and financial benefits. In the contemporary urban centres, building façades, under certain conditions, and especially flat roofs could easily be exploited for energy conservation applications. Furthermore, both countries have considerable building stock in traditional settlements. In these settlements, during the summer period significant increase in population is observed as a result of their intense tourism activity, which in turn results in a drastic increase in domestic hot water and power demands.

Based on the above assumptions, the article investigates the different possibilities of architectural integration of active solar systems and analyses the benefits gained and the difficulties caused by the particularities of the contemporary urban fabric, highlighting, at the same time, the restrictions that apply to traditional settlements. As a result, the placement is not always the optimum option in terms of energy efficiency and power generation. Nevertheless, it presents important quantitative advantages in terms of the surfaces that could be utilised and qualitative advantages in terms of educating the general public on issues of energy conservation, renewable energy sources and sustainable development. The economic crisis, that has affected both countries, makes the need to exploit the benefits of active solar systems integration even more pronounced and desired.

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http://dx.doi.org/10.1016/j.rser.2015.03.030
1364-0321/

1. Introduction

Contemporary cities constitute living organisms that "absorb" large quantities of energy, water and resources from their direct and wider environment, while, at the same time, they reject equally large quantities of waste in the air, the soil and the water. According to the "20-20-20" targets the energy consumed in the EU from renewable energy sources should increase to 20% by the year 2020 [1]. Therefore, the need to exploit renewable energy sources in existing cities, not only in the form of passive systems, but also in the form of active solar systems, has become an imperative. The architectural integration of active solar systems on the shell of existing buildings offers an important opportunity to use energy from renewable energy sources and, at the same time, to reduce their energy consumption. These two measures are acknowledged in the *Energy Performance of Buildings Directive* recast (Directive 2010/31/EU) as important for the reduction of the European Union's energy dependency and greenhouse gas emissions and the compliance with the Kyoto Protocol [2].

1.1. Hypothesis/state of the art

The buildings, and especially their roofs, in existing urban centres, cover extensive surfaces to which active solar systems could be integrated. All around the Mediterranean, particularly in the area of the Eastern Mediterranean, the application of solar collectors for Domestic Hot Water (DHW) has been common practice since the 1980's.

Greece and Cyprus are employed as case-studies for a number of reasons which are analysed below. The countries under study are the only two member states of the European Union which are situated in the area of the Eastern Mediterranean and are therefore bound by the Union's legislation, commitments and objectives toward environmental protection and sustainable development. Furthermore, the two countries are situated in areas with significant solar availability and possibilities of exploitation of solar radiation. Cyprus is the southernmost EU member state, whereas Greece is situated at similar latitude with other countries of the Mediterranean Europe, which could allow a more generalised interpretation of the results of the present study.

In terms of electricity demand and consumption, the two countries present many similarities and some differences. Greece and Cyprus have a considerable difference in population, i.e. 11.9 and 0.86 million, respectively, and consequently differ in energy and electricity production, i.e. 10.43 and 0.11 Mtoe, respectively. Nevertheless, the electricity consumption of the population and the subsequent CO_2 emissions for 2012, are fairly close with 5.51 MWh/capita and 6.99 t/capita for Greece and 5.31 MWh/capita and 7.50 t/capita for Cyprus [3] (Table 1).

The peak load for Greece in 2012 was equal to 9735 MW, without the contribution of renewable energy sources, which was 638 MW (total peak load 10,373 MW) [4]. For Cyprus, the peak load in 2012 was 997 MW [5]. During the last decade, the peak load is recorded in July for both countries under study [4,5].

Concerning electricity production, it is important to note that both countries are largely dependent upon fossil fuels (Table 2). This is particularly negative in terms of environmental impact, both globally – primarily with the emission of CO_2 and secondarily with the production of acid rain – and locally with air pollution and the damage caused by mining [6]. Based on 2012 data from the IEA [3], in Greece the dependence on fossil fuels (coal, oil and gas) amounts up to 82.9%, with coal (lignite) accounting for 51% of the total electricity production (oil production accounts for 9.9%, whereas gas accounts for 22%). Based on 2013 data from the Public Power Corporation S.A.-Hellas [7], the coal contribution was reduced to 45.8% and natural gas slightly rose (23.96%). It should be noted that in the last years, there has been a positive steady reduction of the percentage produced in lignite stations, which in 2010 was equal to 58.8% [8]. In Cyprus, the dependence on fossil fuels is even more pronounced, as 94.5% of the total energy is produced by oil [3].

The exploitation of renewable energy sources for the production of electricity is surprisingly different in the two countries under investigation. In Greece, the share of renewable energy sources amounts to 16.9% (i.e. 7.5% hydro, 6.3% wind, 2.8% solar PV and biofuels 0.3%) [3]. On the contrary, renewable energy sources in Cyprus are used in order to produce barely 4.5% of the total electricity [3]. It is nevertheless, important to note that electricity production from wind and photovoltaic parks in 2013 has risen significantly compared to that of 2012 and was equal to 5.4% and 1%, respectively.

Another difference between the two countries is the dependence of Greece on energy imports, which are equal to 9.5% of the domestic supply. The country also exports energy to neighbouring countries, resulting to a net balance of 1785 GWh. On the contrary, Cyprus has no electricity imports or exports [3], probably due to its geographic isolation as an island.

Being situated in the Mediterranean Basin, the two countries have a Mediterranean climate, which in most parts of Greece (Lat. 39°N, Long. 22°E) is characterised by mild, wet winters and warm to hot, arid summers. Cyprus (Lat. 35°N, Long. 33°E) has mild winters and hot and arid summers. In both countries, the sunlight availability (prolonged time of sunshine, low cloud cover, increased sums of incident solar radiation) [9] makes the application of such

Table 1
Selected indicators for 2012 for Greece and Cyprus [source: 3].

Indicators	Greece	Cyprus
Population (millions)	11.9	0.86
Energy production (Mtoe)	10.43	0.11
Net imports (Mtoe)	19.44	2.61
Electricity consumption (TWh) (gross production + imports–exports – losses)	61.33	4.58
CO_2 emissions (Mt)	77.51	6.46
Electricity consumption/population (MWh/capita)	5.51	5.31
CO_2/population (t/capita)	6.99	7.50