Energy 144 (2018) 800–807

Contents lists available at ScienceDirect

Energy

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

Diffusion and adoption of solar energy conversion systems – The case of Greece

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ARTICLE INFO

Article history:

Keywords:
Solar thermal
Photovoltaics
Market diffusion
Energy conservation

ABSTRACT

This article analyses the diffusion and adoption of solar energy conversion systems in Greece during the last forty years. The installed capacity of solar thermal and solar electricity systems and the effects of the policies implemented during this period are analysed. Furthermore, the contribution of solar conversion systems to the energy security of Greece and to the reduction of greenhouse gases and other air pollutant is assessed on an annual base. Different solar technology market penetration, solar system technological changes and demographic changes in association with the climatic conditions in all regions of the country have been taken into account in order to estimate the energy conservation and emissions reduction. The results show that the conserved energy reaches 2% of the gross inland consumption while the abated CO_2 emissions are also substantial.

1. Introduction

During the last years the world's demand on energy is constantly increasing as a result of the constant growth and the ever expanding needs of modern society. Though the conversion of primary energy to work or heat, we have the ability to produce, transform and transport all sort of goods and commodities, along with the achievement of comfort conditions in households and work places, which are the fundamentals of the technological base towards the progress of our civilization.

The constant need for more energy, mostly in the form of fossil fuels, created serious ecological and economic problems while on the other hand increased the fear of energy security for the coming generations.

Another trend that was witnessed, during the last years was the fact that the residential sector gained the lead as the biggest energy consumer, with buildings nowadays consuming more than a third of the total final energy, while in terms of primary energy consumption they represent around 40% in most countries, according to the International Energy Agency [1]. In the European Union (EU) alone, more than 1103.8 million tons of oil equivalent (TOE) where consumed in the building sector [2] in order to cover space heating, water heating and electrical needs.

In order to minimize energy consumption, serious efforts have been made since the 80's from the United Nations, the EU as well as other countries and policies were implemented to reduce greenhouse gas emissions and promote the use of renewable energy sources in general.

During the last decades the EU developed and implemented a series of legislations, regulations and recommendations, in an effort to minimize energy consumption in the built environment. Currently, the Energy Performance of Building Directive (2010/31/EU) [3] and the Energy Efficiency Directive (2012/27/EU) [4] are both aimed at reducing building energy consumption in all EU countries, by employing measures for newly built or renovated buildings. Furthermore, Directive 2009/28/EU [5] implied that member states should increase their use of renewable along with energy efficiency and savings, by 20% until 2020. The target for renewables could be achieved individually by each EU country according to its policy and renewable energy potential distribution. Furthermore, the Energy Performance of Buildings Directive requires that from the year 2020 onwards all new buildings will have to be 'nearly zero energy buildings' (NZEB), which means reducing the energy demand to the cost-optimal level of 2020, while the very low amount of remaining energy demand in a NZEB should be covered to a 'very significant extent' by energy from renewable sources, including energy from renewable sources produced on-site or nearby. For public buildings these standards need to be met by the end of 2018.

At the forefront of the diffusion of renewable energy sources (RES) in the building sector in order to cover energy demand

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https://doi.org/10.1016/j.energy.2017.12.093
0360-5442/

(electrical and thermal loads), solar energy conversion systems are currently the most widely used, mainly in the form of solar thermal and photovoltaic systems. Especially for locations with high annual solar radiation and temperatures, solar energy systems are already a viable alternative to fossil energy systems and are expected to become even more efficient and cost-competitive in the future [6].

Greece is one of the pioneers in the use of solar energy conversion systems. The first solar thermal systems were installed in the late 70's and for more than fifteen years the country enjoyed high sales and exhibited the highest solar thermal collector area per capita in the EU while currently (2016) is placed tenth worldwide [7]. In the form of solar electricity, the first systems were installed in the early 80's and enjoyed the highest capacity increase during the last two years in the EU [8].

Scope of the paper is the review of the diffusion and adoption of solar energy conversion systems in Greece during the last four decades, an overview of how the market reacted to the different policies that were enforced during this period and the estimation of the annual conserved energy and hence the environmental benefits resulting from the use of these systems. The conclusions from the diffusion of solar energy conversion systems in Greece could be used as a guide map for their efficient diffusion in other similar markets as well.

2. Applications of solar energy conversion systems in Greece

Solar energy conversion systems compete with conventional fuels in two distinct markets: electrical power generation (both on- and off-grid) and hot water production and space conditioning. Solar heating and cooling technologies are becoming widespread, with solar space heating and cooling from solar energy conversion systems gaining ground in several countries, although the primary application still remains hot water production for sanitary uses [9,10]. The same can be said for solar electricity from photovoltaics which are seeing a sharp decline of their cost as well as an increase in their conversion efficiency.

2.1. Solar thermal systems

Non concentrating solar thermal collectors can be utilized in a variety of different systems in order to provide:

- Hot water for swimming pools
- Hot water for sanitary uses
- Space heating
- Space cooling
- A combination of the above

The first solar thermal collector for a Domestic Solar Hot Water System (DSHWS) was produced in Greece in 1974 and it was a simple open circuit collector followed a year after by the first closed circuit system. The two oil crisis in the 1970s that first triggered the interest on renewable sources and the price increase of electricity played a key role to the development of the particular market which was rapid. Using available data from the literature [11–15] the overall diffusion of solar thermal conversion systems in Greece is presented in Fig. 1 and can be classified in four periods.

In the first period (1974–1984), sales were relative low as it was the phase of market penetration, almost exclusively in the form of DSHWS. During this period sales were driven mostly due to the high price of oil as the state did not provide any incentives. The second period, in the mid 80's, witnessed a surge of new installations as a result of a state sponsored campaign promoting their installation that coincided with the public's fear that the price would increase due to the introduction of the Value Added Tax (VAT) from 1987 in the Greek economic system.

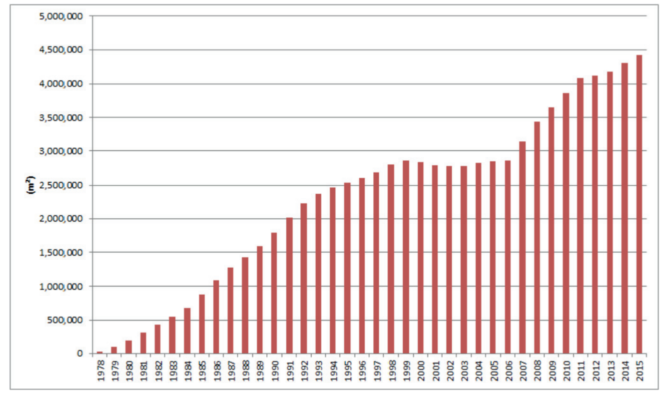

Fig. 1. Evolution of the solar thermal installed capacity in Greece.

From 1987 to 2000 the market saw a continuous increase, due to the economic growth of the mid 1990s along with new financial incentives, like tax reduction which increased sales again, even higher than the peak of the 1980s. Strong positive growth took place from 1992 to 1998.

From 2000 to 2006 the market stagnated, as the penetration had reached more than 30% of the total number of households and there was also a direct competition from the diffusion of natural gas in the large metropolitan areas of Athens and Thessaloniki.

The final phase coincides with the start of the economic crisis in Greece and lasts up to this day in contrast to the overall trend in the EU, where the solar market declined more than 55% [16] during the same time period.

In Greece, despite the economic crisis, the market saw constant increase of sales during this period due to three main reasons. First, a large number of systems that were installed during the second phase reached the end of their life time and were replaced, as the technology had proven to the end users their benefits. Secondly, in 2009 the Greek state passed the first law that permitted the installation of photovoltaics on roofs. In order for the permit to be given the owners were obliged, by the legislation [17] to install a DSHWS as well. Finally from 2010 new legislation incorporating the European Directive for the Energy Performance for Buildings came in to power, dictating the use of DSHWS as obligatory in new or heavily refurbished buildings, while at the same time promoting the use of solar thermal systems for space conditioning as well. At the end of 2015 the total cumulative installed surface had reached 4.4 million m^2 or almost 3500MW_{th} (1 m^2 equals 0.8 kW_{th} [15]).

2.2. Photovoltaic systems

The first photovoltaics were installed in Greece in the 80's by the Public Power Corporation (PPC) mainly in remote islands. Distance from the main grid and lack of noise were the main incentives. Other installation had been installed by the Hellenic Communications Organization for stand-alone antennas and transmitter networks (up to 100 kWp) and by the Hellenic Navy for district lighthouses (up to 70 kWp) [18]. The high initial cost, coupled with the low efficiency that most photovoltaics enjoyed during that period led to a minimal market penetration from the private sector. The status changed during the late 90's when photovoltaic installations started to get support from the state in various national projects. The Operational Programme "Energy" started in 1997 and provided considerable subsidies [19], from 50 to 55% of the investment for PV projects and was followed by the first Operational Programme of Competitiveness (2001–2007) [19], which provided