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An empirical analysis on awareness and intention adoption of residential ground source heat pump systems in Greece

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ABSTRACT

Residential heating, cooling and Domestic Hot Water (DHW) production are responsible for a significant part of the residential energy consumption in Greece, which is currently based on the consumption of fossil fuels. A solution for the reduction of fossil fuel use -and all the negative effects that their use implies- is the application of renewable energy technologies, among which Ground Source Heat Pump (GSHP) systems are included. The present study examined awareness and adoption intention issues concerning this technology in Greece, through the conduction of a questionnaire survey. Specifically, it investigated public's knowledge on issues involving this technology, intention of installing it in households, main information sources and installation barriers. Socioeconomic and residence characteristics, as well as consumers' preferences and attitudes affecting the knowledge and adoption issues were examined. Factors affecting the subjects under investigation are gender, age, education level, environmentally friendly behavior and awareness, as well as having an occupation, studies or interests related to environment, technology or engineering. Additionally, the intention of installing a GSHP system is affected by specific household characteristics, infrastructure and consumers' preferences on characteristics of heating systems. In order to promote GSHPs, suitable financial incentives, regulatory improvements and awareness activities are required.

1. Introduction

On a global level, energy is consumed among the industrial, the transport, the residential and the commercial sectors. The residential sector is responsible for 18% of the total global energy consumption (Isaacs et al., 2006); the corresponding figure on an EU level is 25% (Eurostat, 2013), while for Greece it is 29% (Eurostat, 2013). In addition, the global residential energy consumption is expected to increase between 2010 and 2040 by 57%, mainly due to the increasing demand of non-OECD countries (US Energy Information Administration, 2013b).

Data from Eurostat indicates that in 2011 natural gas accounted for 36% of the total residential energy consumption in the EU, electricity accounted for 25%, renewable energy for 14%, petroleum products for 14%, heat recovery for 7% and solid fuels for 4% (Eurostat, 2013). Data concerning the Greek residential sector shows that households base their energy consumption mainly on oil (44%), electricity (27%), firewood (17%) and natural gas (5%) (Hellenic Statistical Authority, 2013).

Household heating is the activity responsible for the consumption of large amounts of energy; cooling, cooking, lighting, electrical/electronic appliances and domestic hot water (DHW) production are the uses that follow in energy consumption (Department of Energy and Climate Change, 2013; Statistics Austria, 2015; Statistics Finland, 2012; US Energy Information Administration, 2013a). This applies also for the Greek households, with heating (64%) being the main energy consuming activity, followed by cooking (17%), electric/ electronic appliances (10%), DHW production (6%), lighting (2%) and cooling (1%) (Hellenic Statistical Authority, 2013).

According to Frederiks et al. (2015), household energy consumption is an ongoing interaction of multiple individual and situational predictors. The individual predictors are divided between socio-demographic factors (e.g. age, employment status, household characteristics, dwelling characteristics, geographical location) and psychological factors (e.g. knowledge, values, beliefs, attitudes, motives, norms), while the situational predictors include contextual and structural factors (e.g. regulations, policies, pricing, information, broader public norms). Furthermore, the appliance-related factors that affect consumption in households can be grouped as a) total number, b) use and c) power demand (Jones et al., 2015). Concerning the significance of each factor type, Abrahamse and Steg (2011) indicate that residential energy use is strongly related to factors that shape opportunity for use (namely income, household size), with psychological variables also having a contribution. Steemers and Yun (2009) point out the critical role of

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occupant behavioral and socio-economic aspects, while Huebner et al. (2015) found that household energy consumption is affected first of all by building variables, followed by socio-demographic variables, attitudes and behaviors.

Based on the above, it is clear that the residential sector, which is responsible for a large part of global energy consumption, uses mainly fossil fuels in order to cover its needs, with the main one of them being the heating of the household. One of the technologies that can contribute to the reduction of fossil fuel use in the residential sector is ground source heat pump (GSHP) systems. GSHP systems are the key-technology for the utilization of the unlimited resources of shallow geothermal energy; they can be applied almost anywhere, since geothermal resources (hot water or steam) are not required (Karytsas, 2012; Omer, 2008; Sarbu and Sebarchievici, 2014). The technology exploits the fact that the ground and the surface/ground water have a relatively stable temperature around the year, thus offering heating, cooling and DHW production (Florides and Kalogirou, 2007; Younis et al., 2010). In order to offer heating, the system absorbs thermal energy from the ground or the surface/ground water; the process is reversed for cooling, with the system rejecting thermal energy to the ground or the surface/ground water. Detailed description of the technology has been provided in various studies, with those of Ahmadi et al. (2017), Karytsas and Choropanitis (2017), Lucia et al. (2017), Rees (2016) and Sarbu and Sebarchievici (2014) being among the most recent ones.

The benefits of GSHP use can vary based on the climate of each location, and the respective needs for heating and cooling. In hotter climates, primary energy savings are higher, due to the relatively equal distribution between heating and cooling needs. On the contrary, locations with colder climates present better results in the context of emissions reduction and payback period. This is due to the higher number of heating hours, i.e. higher consumption of heating oil or natural gas by the conventional systems, in comparison to electrical energy used by the GSHPs (Karytsas and Choropanitis, 2017). In any case, GSHP systems can be applied either in cold climates, offering mainly heating and DHW, as well as in milder climates, where proportionate energy savings are achieved with heating, DHW production and cooling as well.

A GSHP system can be combined with other RES technologies such as solar PVs or solar thermal, or even with both, leading to the minimization of heating/cooling and DHW costs, zero-emission and zero-power consumption buildings. When coupled with solar PVs, the electrical energy required by the GSHP system is produced by the solar PV system. In the case of combining GSHPs with solar thermal, the total efficiency of the system is improved, thus reducing its electrical energy needs. A solution incorporating all three technologies can lead to a system with maximum energy savings offering heating/cooling and DHW production with zero electrical energy needs and zero CO_2 emissions (Karytsas and Choropanitis, 2017).

The use of GSHP systems can offer technological, environmental and socioeconomic benefits; based on the literature review performed by Karytsas and Choropanitis (2017), main benefits of the system are energy efficiency, absence of outdoor unit (thus offering aesthetic, acoustic and lifespan benefits), safety (due to the absence of combustion, flammable materials and fuel storage units), environmental friendliness and low operation & maintenance cost. On the other hand, the main barriers that can hinder the diffusion of GSHP systems are a) high initial investment cost, b) lack of qualified personnel to install and promote systems, c) regulatory barriers and unsuitable regulatory frameworks, d) lack of certification, guidelines and standards for the design, installation and reference data, and e) low awareness level of consumers, industry, government agencies and policy/legislation makers on GSHP systems and/or their benefits.

The first GHSP systems were installed in the United States more than 60 years ago (Fridleifsson, 1998; Sanner et al., 2003), while in Europe the first countries adopting the technology were Switzerland, Sweden, Germany and Austria (Fridleifsson, 1998; Rybach and Sanner, 2000). The largest markets, taking into account the last 15 years, are the United States and Canada in America (Lund and Boyd, 2015; Thompson, 2010); Germany, Switzerland, Austria, France, Finland and the Scandinavian countries in Europe (Angelino et al., 2014; Curtis et al., 2005; Sanner et al., 2003); and China, Japan, South Korea and Turkey in Asia (Curtis et al., 2005; Lee, 2009; Lund and Boyd, 2015).

Concerning specifically the Greek GSHP sector, it should be noted that significant growth took place in the mid-2000s, with a peak in around 2010. Among the factors that had a positive effect to the sector's growth were the increase of heating oil prices compared to electricity prices, public's and installers' awareness, and the improvement of the licensing process (Andritsos et al., 2007, 2010). During the last years, the sector's growth rates are stable, mainly due to the financial recession, the stagnation of the construction sector, as well as the competition from natural gas systems and air-cooled heat pumps (Andritsos et al., 2013, 2015). In 2015, the installed capacity of GSHP systems in Greece was 148 MWth (Papachristou et al., 2016). According to the most recent available data, 61% of the installations are open systems, 30% vertical closed loop systems and 9% horizontal closed loop systems (Andritsos et al., 2015). The simple payback period of GSHP systems' installation in new buildings in Greece has been estimated between 1.7 and 10.7 years, depending on different types (open/closed loop), conventional systems to be compared with (heating oil/natural gas) and climate zones (Zones A to D) (Karytsas and Choropanitis, 2017).

Available financial incentives that have been offered in the past for GSHP installation in Greece included small tax exemptions (200€), reduced VAT for GSHP equipment compared to natural gas systems (Andritsos et al., 2007) and direct subsidies and interest-free or subsidized loan rates (Andritsos et al., 2013). However, financial incentives for GSHP installation are not always available (Andritsos et al., 2010; Fytikas et al., 2005). During the last years the "Energy efficiency at household buildings" program was presented (Andritsos et al., 2015). Very few systems were installed through this initiative due to two main reasons: a) the program could not cover the whole installation cost of a GSHP (there was an upper limit of 15,000 €) and b) the program concerned renovations/improvements only in existing buildings, where the installation of GSHPs is relatively complex. Additional factors hindering the use of the program for GSHP installation were the requirement of permission for the drilling, and the fact that it is difficult to install such a system in a building's apartment, since consensus is required from the buildings assembly. It should be noted that during 2018 a new "Energy efficiency at household buildings" program has been planned to be launched, with the limit of the subsidized loan being 25,000 €.

Although the installation of GSHP systems can offer several advantages, they have a low diffusion level in the Greek heating/cooling residential market, with one of the main diffusion barriers being the low level of awareness. The present study aims to offer further evidence concerning the factors that affect awareness and installation intention of residential RES heating systems –and especially GSHP systems- thus contributing to the diffusion of the GSHP technology on a policy level. The study intends to achieve this through the examination of the factors that affect Greek households knowing about: a) geothermal energy and that it can be used for residential heating and cooling, b) GSHPs and that they can be used for residential heating and cooling, c) the procedures required for the installation of a GSHP system, as well as factors affecting d) the intention to install a residential GSHP system. In addition, information sources on GSHP systems, as well as barriers hindering their installation in the Greek residential sector are examined.

2. Theoretical framework

2.1. Factors affecting knowledge of renewable energy sources

Awareness and sufficient information about RES are critical factors