Social Aspects of Geothermal Energy in Greece

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Abstract Greece is a country with high geothermal energy potential; through the research that started over 40 years ago, a significant number of geothermal fields have been identified. Yet, its utilisation is rather limited, as it is exploited solely through direct uses. This means that there is a total absence of power production through geothermal energy, which to a great extent is due to the local societies' opposition created by the bad experience of the Milos Island pilot power plant (1970–80s). Deficiencies and errors made during construction and operation led to environmental pollution, resulting to the strong reactions of the residents. This has affected the attitude of local communities and authorities against the large scale exploitation of high temperature deep geothermal resources (any use of geothermal energy with heat extraction, for resources with temperatures above 90 °C) until today in various areas; on the contrary, low temperature deep geothermal (any use of geothermal energy with heat extraction, for resources with temperatures between 25 and 90 °C) utilization is perceived much more positively. Until now most attempts made for the exploitation of geothermal fields are characterised by the lack of local societies' awareness, involvement and engagement. The conducted literature review shows that public attitudes and awareness are at a rather medium to low level. Exploiting the large potential of geothermal energy requires increase of awareness and improvement of the lost confidence of local societies towards high temperature deep geothermal exploitation.

Keywords Greece · Geothermal energy · Social acceptance · Public awareness

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1 Geographic, Demographic and Economic Information

Greece is a south-eastern European country, located at the southernmost end of the Balkan Peninsula. It has common land boarders, from northwest to northeast, with Albania, FYROM, Bulgaria and Turkey respectively. Greece is strategically located at the crossroads of Europe, Asia, and Africa, at the east part of the Mediterranean Sea. The country is a member of the European Union (1981), Eurozone (2001), NATO (1952) and a founding member of United Nations (1945). It is a developed country with a high per capita income, human development index and quality of life. Administratively, Greece is separated into 7 decentralised administrations, 13 regions and 325 municipalities (Law 3852/2010). The population of Greece is around 10,800,000 (Hellenic Statistical Authority 2011); nation's capital and largest city is Athens.

The Greek terrain is mainly mountainous or hilly; a big part is dry and rocky, with only 20% of the land being arable. Greece is rich in mineral resources; it is a leading country in the European and international market in products such as lignite (EURACOAL 2016), bauxite, alumina, aluminium, nickel, magnesite, caustic magnesia, bentonite, perlite, pumice stone, attapulgite, huntite and marble [Ministry of Environment and Energy n.d. (a)]. Gold, copper (Tsirampidis and Filippidis 2013) and rare earth elements can be also found (Melfos and Voudouris 2012). Oil is extracted from the Kavala-Thassos area (Tsirampidis and Filippidis 2013), while explorations for extraction are being carried out in Western Greece and south of Crete (Ministerial Decree Δ1/A/12892/2014).

The Greek climate can be described as a Mediterranean type temperate climate, characterised by mild wet winters and hot dry summers. The country's climate can be divided into four main categories, namely: wet Mediterranean, dry Mediterranean, continental and mountainous.

Greece can be characterised as a medium power, due to its geostrategic importance, remarkable shipping sector, large tourism industry and unique cultural heritage; it is the largest economy in the Balkans and serves as an important regional investor. Greece has a mixed capitalist economy, which is based on the service sector (80.9%), followed by the industry (15%) and the agriculture sector (4.1%) (GDP 2016 estimates) [Central Intelligence Agency n.d. (b)]. Shipping and tourism are the most important sectors of the Greek economy, while the largest industries are food and tobacco processing, textiles, chemicals, metal products, mining and petroleum [Central Intelligence Agency n.d. (a)].

The Greek economy had an average growth of about 4% per year between 2003 and 2007. Since the end of 2009 Greece has been facing an economic recession, due to the world financial crisis, tightening credit conditions, and failure to address a growing budget deficit. Ever since, the country has signed three bailout agreements with the European Commission (EC), the European Central Bank (ECB), the International Monetary Fund (IMF) and the European Stability Mechanism (ESM). The bailout agreements came along with rigorous austerity, in order to control government spending; this policy has led to economic recession and high levels of

unemployment. By 2013 the economy had contracted 26%, compared with the pre-crisis level of 2007. In 2016 Greece experienced a slight improvement in GDP and unemployment; however, the economy remains in stagnation due to incomplete economic reforms, the massive loan problem and continuing political uncertainty [Central Intelligence Agency n.d. (a)]. Major challenges of the Greek economy are the reduction of unemployment, facing productivity deficiencies, reforming social security, correcting the tax system, tackling tax evasion [some estimates put Greece's shadow economy at 20–25% of GDP (Schneider 2015)] and the minimization of bureaucratic imperfections.

1.1 Energy Statistics

The energy mix of Greece differs from the average of EU28, as there is a much higher use of oil and solid fuels, a lower use of natural gas, while no nuclear plants exist; the share of RES (Renewable Energy Sources) continuously increases during the last years. Primary production of energy in Greece during 2014 was 17.4 Mtoe, i.e. 1.6 toe/inhabitant (EU's average was 1.7 toe/inhabitant). In order to satisfy demand, Greece is reliant on primary energy imports; in 2014 net primary energy imports were 17.4 Mtoe. The energy dependence in 2014 was 66.2% (EU's average was 53.5%), being rather steady during the decade 2005–2014 (between 62.2 and 73.3%). Gross inland energy consumption in Greece in 2014 was 24.4 Mtoe, almost 30% lower than in 2010 and about the same level as 1995. Final energy consumption in Greece in 2014 was 15.6 Mtoe; it had been increasing slowly since 1990, peaked around 2005, and since then has been decreasing. The 2014 value is about 25% lower than the 2005 one. The structure of final energy consumption in 2014 by sector shows that 42% of energy was consumed for transport, 38% by households, trade, services, etc. and 20% by the industry. The impacts of the economic crisis are visible through the energy imports and energy consumption indicators, as the values are lower after 2009, compared to the pre-crisis period (Eurostat 2016).

The primary production of renewable energy in Greece for 2014 was 2.4 million toe; the proportion of produced renewable energy increased by 48% between 2004 and 2014. The most important RES was biomass and waste, accounting for 47.1% of primary renewable production in 2014. Solar energy (22.2%) was in the second place, followed by hydropower (16.5%) and wind energy (13.6%); geothermal energy (0.5%) accounted for a very small portion of primary renewable production. RES accounted for 10% of Greece's gross inland energy consumption in 2014 (biomass and renewable wastes, 5%; solar, 2.1%; hydropower, 1.6%; wind 1.3%). The share of renewables in gross final energy consumption was 15.3% for Greece in 2014, with the country's 2020 target being set at 18% (heating & cooling target set at 20%, electricity at 40% and transport at 10%) [Eurostat 2017; Ministry of Environment and Energy n.d. (b)].

Based on the same year's data, electricity generated from RES was 21.9% of the country's gross electricity consumption (EU's average was 27.5%). The increase in the percentage of electricity generated from RES between 2004 and 2014 is over 180%. This is mainly due to the large increase of PV and wind farm installations (Eurostat 2017). The share of RES in heating and cooling in Greece was 26.9% in 2014, with the EU-28 average being 17.7% (Eurostat 2016). The percentage of RES in transport fuel consumption in Greece was 1.3% in 2014, with the EU-28 average being 6.5% (Eurostat 2017).

1.2 Geological Background of Greece

Greece is a natural geological laboratory, which enables the understanding of the current geodynamic process of the Greek arc (including earthquakes, volcanoes, coastal movements, existence of faults and fracturing of rocks and other geological processes). The country presents a complex geological structure with a wide variety of geological formations, as a result of its complex geological history and evolution. Geotectonically, Greece is part of the southern edge of the Euroasiatic plate which has been fragmented due to the process that is taking place in the south Aegean, where the African plate is sliding under the European plate.

The Greek territory is characterized by high levels of heat flow (more than 80 mW/m^2), especially in the internal Hellenides (sedimentary basins of north-eastern Greece) and Aegean Sea, due to active tectonic and volcanic activity. The strong tectonic and volcanic activity has caused the appropriate geological conditions for thermal energy agglomeration, which is characterized as hydrothermal systems of low and high temperature geothermal fields (Fytikas et al. 2005).

High temperature geothermal fields are located along the Southern Aegean volcanic arc (Milos and Nisyros Islands), where low temperature geothermal fields are correlated with grabens (Central Aegean) and post-orogenic sedimentary molassic basins (southern boundaries of the Rhodope and Servo-Macedonian Massifs) (Fytikas et al. 2005). The deep water circulation along the faults in grabens has created a large number of low temperature fields (e.g. Easter Macedonia and Thrace, Chios Island, Euboea, Central Greece) in the whole country (Arvanitis 2011) (Fig. 1).

1.3 Geothermal Fields in Greece

The geological conditions in Greece have generally contributed to the creation of a significant number of geothermal fields, characterizing the country as one of the most favoured ones' in terms of geothermal potential.

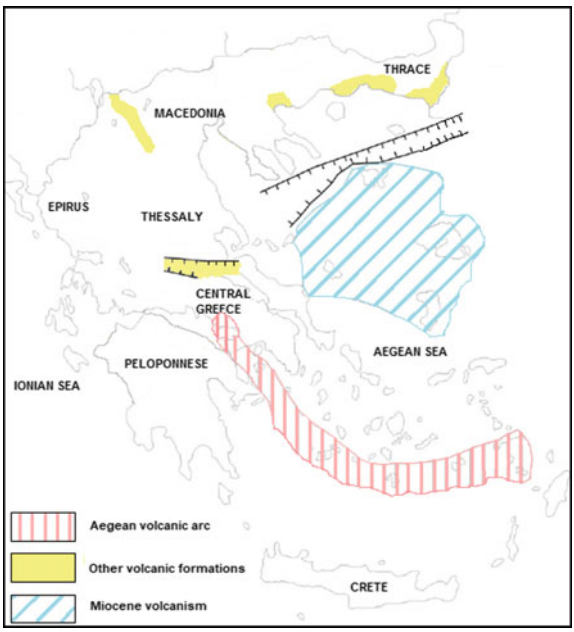

Fig. 1 Main geotectonic structures in Greece

Geothermal energy is distinguished depending on temperature fluids in (a) high temperature (>90 °C), (b) low temperature (25–90 °C) and (c) shallow geothermal (<25 °C), according to Greek Law 3175/2003.

Until now, more than 55 geothermal fields have been identified in total. According to their geographical characteristics, the geothermal fields in Greece are quite scattered and their distribution density differs due to different geological conditions in each region. The large number of geothermal fields in Macedonia, Thrace and the Aegean Islands (Fig. 2) should be noticed. In at least 50 geothermal fields the fluids' temperatures range from 25 to 90 °C, mainly in depths <500 m; their potential has been estimated to 1,000 MWth, although until now only 9% of it is being exploited (Papachristou et al. 2016). In more than 5 of the geothermal fields the fluids' temperatures range from 90 to 125 °C, while in two fields, the temperature is higher than 150 °C; 325 °C in Milos Island and 400 °C in Nisyros Island (Fig. 2), which are the most important high temperature deep geothermal systems in Greece. The proven geothermal potential of Milos and Nisyros Islands is over 30 MWe, while it is estimated that it can reach even a level of 230 MWe (Papachristou et al. 2016).

Geothermal energy is exploited in Greece exclusively through direct uses, in thermal spas, greenhouses, soil heating, fish farming, aquaculture, agricultural products drying and GSHPs (Ground Source Heat Pumps); most geothermal applications, with the exception of thermal spas, are located in northern Greece. The total installed capacity of geothermal applications in mid-2016 was 232 MWth, with GSHPs accounting for 64%, thermal spas for 18% and greenhouse heating for

Fig. 2 Geographical distribution of geothermal fields

14.5% of this capacity. During the last years, the Greek geothermal market has grown mainly due to the increase of GSHP system installations (Papachristou et al. 2016).

1.4 Stakeholders Involved in the Geothermal Sector

All high and low temperature geothermal fields in Greece belong to the state. The Ministry of Environment and Energy, assisted by the Institute of Geology & Mineral Exploration, is responsible for the exploration of all geothermal fields. Concerning exploitation permissions, the Ministry of Environment and Energy is responsible for the high temperature deep geothermal resources, while the Secretary-General of the corresponding decentralised administration is responsible for the possible and proven low temperature deep geothermal resources. Either public or private bodies can exploit high and low temperature geothermal fields

through a lease for a specific period of time; in order to do so, a tender process is necessary. The tender procedure is initiated either by the state's plans for developing a field, or by the interest of a specific public or private body.

The permission procedures for utilizing shallow geothermal energy are simpler, as long as the application is not located within a proven or possible geothermal field. The permission is provided by the corresponding administrative region. There are several companies active in the GSHPs sector, offering drilling, installation and design services; there are also a small number of heat pump manufacturers.

Most of the proven geothermal fields with temperatures higher than 100 °C have been granted to Public Power Corporation Renewables S.A. for the construction of small (5–8 MWe) power plants; these fields are the ones of Milos-Kimolos-Polyaigos, Nisyros-Kos and Lesvos Islands, as well as Methana.

An international tender process was performed in 2011, for the exploration of high temperatures for the geothermal fields of Chios Island, Samothraki Island, Evros River Delta and Nestos River Delta. The fields were assigned to TERNA ENERGY S.A.—ITA, while the other companies participating in the tender were ENEL S.A., ORMAT, Hellenic Geothermal Holdings Corp., Public Power Corporation Renewables S.A. and Aegean Energy S.A. Until now, no progress has been made regarding the exploration of the fields, as the company withdrew from the project.

Concerning other stakeholders involved in geothermal activities, the Institute of Geology & Mineral Exploration contributes to the research and estimation of geothermal resources and their sustainable management. The Center for Renewable Energy Sources and Saving, which is the national centre for RES, rational use of energy and energy saving, also assists to the development of geothermal energy through research projects, the conduction of workshops, seminars, feasibility studies and other services (e.g. Thermal Response Tests).

2 Public Engagement Activities/Social Acceptance Assessment in Greece

2.1 Review of Social Science Studies on Geothermal and Other Renewable Energies

The literature review on social studies concerning geothermal energy -including public knowledge, acceptance and attitudes- revealed that there is a very small number of social studies focusing exclusively on geothermal energy; these studies are presented in Sect. 2.2. However, individual findings related to social issues of geothermal energy have been identified in studies and reports dealing either with RES in general, or with specific RES such as solar and wind energy—two energy sources rather popular in Greece. Based on the findings of these studies (Table 1), it is clearly indicated that knowledge, awareness and positive attitudes towards

geothermal energy in Greece can be characterised as average to low. People are much more favourable of energy sources such as solar and wind power, with geothermal energy and its applications being one of the least preferred RES.

2.2 Social Studies Focusing on Geothermal Energy

2.2.1 Desalination Plant in Milos Island

A study investigating local residents' views and opinions on the effects of the construction of a desalination plant—basing its operation on geothermal energy—on Milos Island was released in 2004. A survey involving key informants from local government, state agencies, trade unions, social agencies and developmental policy-making agencies was conducted in 2000, leading to the collection of 100 responses. All respondents knew quite well the different geothermal fields that have been recorded on the island. The participants were quite cautious, even negative, regarding the exploitation of geothermal energy—in particular high temperature deep geothermal energy. This is due to the negative experience that Milos had with the geothermal pilot power plant that operated during the 1980s and caused great ecological impact to the local environment, extensive air pollution and soil contamination. According to the respondents, the most preferable energy needs that could be covered by geothermal energy are, in descending order, drinking water, irrigation, heating/cooling of buildings, development of winter tourism and production of electric energy (Manologlou et al. 2004).

2.2.2 Geothermal Development in Milos and Nisyros Islands

A social survey investigating the attitudes of Milos and Nisyros Islands' residents towards geothermal energy was conducted during 2004 (Polyzou 2007; Polyzou and Stamataki 2010); 250 and 90 responses were collected respectively from the two islands. Aim of the survey was to record and analyse the local societies' opinions regarding geothermal energy development, in order to identify the main factors that cause reactions against geothermal energy and to highlight the basic axes of the interventions that should be applied. The majority of Milos (M = 86.8%) and Nisyros (N = 95%) residents knew what geothermal energy is. Main source of information and knowledge was personal experience (M = 79%, N = 72%), while the effect of the imprint and electronic mass media was negligible, confirming the absence of state policy and interest to inform the public and to promote awareness intervention activities.

The vast majority in Milos (82.5%) believed that geothermal energy is a polluting activity. Tourism-related occupation was not found to be related to higher levels of environmental sensitivity. In Nisyros the situation was slightly different, as less (68.2%) respondents believed that exploitation of geothermal energy had an

Table 1 Studies and reports including individual findings related to social issues of geothermal energy in Greece

References	Aim of study	Sample type	Sample size	Time period	Findings
Tzanakaki and Mavrogioros (2005)	Public acceptance of various energy saving solutions and RES technologies	Participants of RES and Energy Saving themed open-days in 5 Greek cities	141	2001–2002	Importance of geothermal energy was evaluated with a mean of 3.5 on a 5-point Likert scale, thus ranking it 4th among 5 different RES
Eurobarometer (2006)	Knowledge, attitudes and perceptions of energy issues	General population of Greece	1,000	2006	In the context of energy production, 37% of the respondents had heard of geothermal energy
Spiropoulou et al. (2007)	Perceptions on environmental issues and attitudes	In-service primary school teachers	188	Not available	Most respondents identified geothermal energy as a non-renewable source
Liarakou et al. (2009)	Knowledge and attitudes towards RES, particularly wind and solar energy systems	Secondary school teachers of the town of Rhodes	121	2006	21.5% of the respondents knew that geothermal energy is a RES, thus having the 4th highest percentage among 6 different RES
Koundouri et al. (2009)	Public attitudes towards renewable energy generation and willingness to pay for the construction of a wind farm in Rhodes Island	Adult population of the area of the wind farm construction site in Rhodes Island	200	2007	19% of the respondents were informed on electricity production by geothermal energy (9th among 13 different energy production means), while 36% agreed with the use of geothermal energy in Greece (6th among 13 different energy production means)
Sardianou and Genoudi (2013)	Determinants of consumers' willingness to adopt renewable energies in the residential sector	Greek consumers	200	2009–2010	38% of the respondents were informed about the potential residential use of geothermal energy, thus ranking it 4th among 5 different RES

(continued)

Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
Tampakis et al. (2013)	Satisfaction with the quality and availability of electricity on Andros Island and the installation of wind turbines	Electrical energy consumers of Andros Island	292	2010	Environmental friendliness of geothermal energy scored a mean of 6.71 on a 10-point Likert scale, thus ranking it 4th among 10 different energy sources and 4th among 5 different RES
Tsoutsos et al. (2013)	PV stakeholders' attitudes, perceptions and considerations	PV owners from Greece, Cyprus, Bulgaria, Romania, Croatia and Spain	Not available	2010	24% of PV owners would advise a friend to invest in GSHPs, with the corresponding percentages for PVs and solar thermal collectors being respectively 93 and 27%
Skoupra (2013)	Identification of factors for the acceptance of RES installations by consumers –with emphasis given on wind and solar energy	Population of Larissa, Lasithion and Attica Prefectures	396	2013	51.5% stated that knows geothermal energy, thus ranking it 3rd among 5 different RES, being slightly higher than hydro power (4th) and biofuels (5th)
Dimitriou and Pimenidis (2015)	Local authorities' knowledge and attitudes on energy production, energy management, energy consumption and RES, as well as their energy practices and intentions	Elected representatives of local authorities (municipalities and prefecture) of Rhodes Island	12	2015	In the context of application of RES technologies in public services, facilities and buildings in their area of responsibility, 20% of the respondents believed that geothermal systems can be absolutely applied, 40% that they can be considerably applied and the remaining 40% that they cannot be possibly applied
Ntanos et al. (2016)	Public awareness on various RES	Students and staff members of the Piraeus University of Applied Sciences in Greece	200	2015	Knowledge of geothermal energy was evaluated as rather low (4.5% very good; 14% good; 22% fair; 26.5% poor; 33% very poor), while importance of

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Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
					geothermal energy was ranked 6th among 9 different energy sources (5th between 6 different RES)
Keramitsoglou (2016)	Knowledge, perceptions and attitudes towards RES, in order to detect specific educational needs of high school students	Two high schools of the town of Didimoticho	234	Not available	On a 5 point Likert scale, geothermal energy was evaluated mainly as very environmentally friendly, friendly and less or more friendly; it was ranked 7th among 15 energy sources and 6th among 9 different RES. 18.8% valued geothermal energy as very important, 22.6% as important, 35% as neither important nor unimportant, 16.7% as a little important and 6.8% as not important; thus, it was ranked 5th among 9 RES
Koutroumpi and Saltaoura (2016)	Social acceptance of RES and PVs in particular	Half from Attica Prefecture and remaining half from the rest of Greece	201	Not available	Knowledge of geothermal energy was average (mean of 2.54 on a 5-point Likert scale), ranking it last among 5 different RES; importance of geothermal energy had a mean of 3.16, thus being ranked 5th among 9 different energy sources and 4th among 5 different RES. The importance of geothermal heating and district heating had a mean of 3.02 on a 5-point Likert scale, ranked last among 7 different RES applications

(continued)

Table 1 (continued)

References	Aim of study	Sample type	Sample size	Time period	Findings
Fanourgaki and Mauroudi (2017)	Social acceptance of green investments and evaluation of green investments by consumers	Half from Attica Prefecture and remaining half from the rest of Greece	280	2015–2016	Knowledge of geothermal energy was below average (average of 2.1 on a 5-point Likert scale), thus being ranked last among 5 different RES; the importance of geothermal heating and district heating had a mean of 2.94 on a 5-point Likert scale (ranked 6th among 7 different RES applications)
Petrakopoulou (2017)	Use of renewable energy as part of an energy autonomy plan on Skyros Island	Residents of Skyros Island	183	Not available	Residents tended to be more open to new installations of solar, wind and geothermal energy, while they directly rejected nuclear power and coal plants

environmental impact. Respondents with an occupation related to tourism appeared to be more sensitive in terms of environmental concerns. In both areas, and based on personal experiences, air (M = 81%, N = 98%) and ground/water pollution were considered to create the main environmental impacts. In both islands, the economic activities that seemed to be most affected were those related to agriculture and fishing activities, while tourist activities appeared to be less affected.

In relation to the potential uses of geothermal energy, the public selected as most important those reflecting its everyday needs, i.e. power production and desalination. It should be mentioned that in Nisyros, these two options were the only answers provided. The fact that applications of geothermal energy in agriculture, fishery and tourism were not considered as possible choices may lead to the conclusion that in both local societies there was little knowledge of the multiple and combined uses of geothermal energy, and especially of low temperature deep geothermal energy. In Milos, a high percentage (73%) was in favour of the exploitation of the island's geothermal potential. The speculations about environmental impacts didn't seem to affect the receptivity for the development of the island. On the contrary, in Nisyros the public was divided (positive opinion = 51.1%, negative opinion = 48.9%). Environmental pollution and impact on the residents' health seemed to be the main reasons for the opposition on the implementation of investment plans for the development of geothermal energy in both islands. However, it should be mentioned that a significant part of Nisyros local society was negative without any justification. The majority of the public in both islands believed that a geothermal project would not be properly constructed, reflecting the lack of trust towards the State and its representatives, as well as towards the project operation's monitoring and control means.

2.2.3 Power Production in Lesvos Island

Another study that largely concerns geothermal energy was published in 2013, aiming on the investigation of individual preferences and social values towards specific RES technologies in Lesvos Island. Face-to-face personal interviews with permanent households were performed, with 312 responses being collected between July and September 2010. The survey's results indicate that 9% of the respondents selected geothermal energy as the appropriate solution for a 10% substitution of oil-fired electricity production in Lesvos, ranking it last between four different technologies (the alternative three being onshore wind energy, offshore wind energy and PV energy). The percentage in favour of geothermal energy was higher in the area of Polychnitos (33.3%), due to the respondents' knowledge of the existing geothermal potential in the area. Respondents selecting geothermal energy were characterised by high income and their satisfaction with their involvement in the decision-making process. State and municipal companies were preferred for the implementation of geothermal energy projects; the impacts of climate change were not a decisive factor for the selection of geothermal energy. The willingness to pay analysis showed that respondents were willing to pay the highest amount (among

the four technologies) for substituting 10% of the electricity produced by fossil fuels with geothermal energy (Kontogianni et al. 2013).

2.2.4 Knowledge and Attitude Towards GSHPs

A social study including two different surveys was performed during 2011–2012, and concerned knowledge and attitudes on geothermal energy in general, and residential GSHP systems in specific. The first survey involved 203 residents of northeast Attica and was conducted through face-to-face questionnaires; the second survey used an electronically distributed questionnaire and involved consumers in general, with no restrictions in the area of residence; 533 responses were collected in this case. In the first case, 42% stated that knew geothermal energy, 35% knew that geothermal energy can be used for residential heating/cooling, 21% had heard of GSHP systems and 18% that GSHPs can be used for residential heating/cooling; in the second survey the corresponding results were 71% (geothermal energy ranked 3rd among 8 different RES), 56, 35 and 29% respectively. The knowledge levels were higher in the second case, due to the characteristics of the sample (younger, higher education). In both cases, around 7.5% of the respondents had considered installing a GSHP system in their residence. Factors affecting public's knowledge on the issues that were under examination, as well as intention of installing a residential GSHP system, were gender, age, level of education, employment, income, environmentally friendly behaviour, awareness of environmental issues, adoption of new technologies and the relevance of profession or interests with the environment, technology or engineering. In addition, the intention of installing such a system was affected by factors related to dwelling characteristics and factors associated with behaviour and consumer attitudes and preferences towards specific characteristics of heating systems. The study also included a third survey examining the views of people involved in the GSHP sector, regarding existing and future adoption level of residential GSHP systems, dissemination barriers and actions that can contribute to their diffusion; the survey was conducted in 2012, using both face-to-face questionnaires and electronically distributed ones. Among the main findings -based on 181 responses- of this survey was that one of the most important diffusion barriers of residential GSHPs is the lack of public awareness on the GSHP technology and its benefits (Karytsas 2016; Karytsas and Choropanitis 2017; Karytsas and Theodoropoulou 2014a, b).

2.3 Public Engagement Exercises

Until now, only a small number of relevant activities have been performed aiming to raise awareness of the local societies and stakeholders. These activities are limited to the organization of workshops, info days, public's visits to geothermal applications (e.g. greenhouses), etc. These activities aim usually to specific

target-groups (local authorities, installers, manufacturers, engineers, etc.), while it is less common to focus on the local societies. They take place usually in areas of geothermal application interest (e.g. Milos, Nigrita), however it is not unusual to have such events organised in locations where deep geothermal potential does not exist (e.g. Athens) in order to inform a wider group of stakeholders. Talking about awareness activities specifically conducted in Milos Island, a workshop was organised concerning the future geothermal development in the island in 2008, 20 years after the local society reactions against the pilot power production plant.

2.4 Cases of Controversy

2.4.1 Milos Island

Milos is a volcanic island in the Aegean Sea. It is located at the northwest edge of Cyclades complex and is 86 nautical miles away from Piraeus. Milos covers a land area of 151 km^2 and is the fifth in size island of the complex. The total population of the island is 4,966 (National Statistical Service of Greece, 2011). The capital of Milos is Plaka and the largest port is Adamantas. Geologically, it belongs to the Attico-Cycladic massif, along with the entire Cycladic complex. It is located in the "Southern Aegean volcanic arc", where the European and African lithospheric plates converge, thus releasing large amounts of heat into the earth's crust.

Geothermal research in Milos Island started in 1973 as part of the Institute of Geology & Mineral Exploration (IGME) geothermal project. High (325 °C) and low (25–90 °C) temperature deep geothermal resources have been identified in the island. After the identification of the high geothermal potential of Milos Island, the Public Power Corporation (PPC) started the construction of a pilot power plant aiming to the power production for the island and the wider Cyclades complex. The main drillings were carried out in the area of Zephyria in 1982, very close to the largest city of the island, Adamantas, where tourism development had just begun. The negative experience of the residents due to existing industrial facilities (most of the island had already been affected by local mining activity), had as a result the strong reaction of the local society to the pilot power plant, with the simple slogan "no way!" (Polyzou 2007). In addition, mining enterprises based on the island were opposed to geothermal development, believing that it would create problems to their activities (Koutroupis 1992).

Furthermore, deficiencies and errors made during the construction and operation phases of the pilot power plant led to (a) air pollution due to the uncontrolled leakage of hydrogen sulphide and other hazardous gases from the drilling, (b) surface waters pollution (rain water and water reservoirs) with arsenic and sulphate ions and (c) the disposal of large quantities of liquids and solid wastes in the bay of Agia Kyriaki. This situation created additional reactions to the already negative opinion of the local society (Polyzou 2007).

The result of the effects mentioned above was the strong reactions of the local society, with protests and strikes, for about two years (1987–1989) leading to the closure of the pilot plant. In 1993, the walls of one of the geothermal drillings were disrupted leading to the uncontrolled spewing of large quantities of geothermal fluid, where heavy metal compounds, hydrogen sulphide and arsenic compounds were detected. After some months the well was sealed with the assistance of Italian specialists (Polyzou 2007).

Until now, about 40 years later, the negative reactions of the residents have not been resolved. The residents are still against the development of high temperature deep geothermal resources, while they believe that the state will try to overpass the local society's opinion. In addition, they still oppose to the participation of PPC Renewable S.A. in any exploitation of geothermal energy in the island. On the other hand, the island's municipality has made plans for the use of low temperature deep geothermal resources, which has the approval of the majority of the locals.

2.4.2 Nisyros Island

Nisyros is a volcanic island in the south-eastern Aegean Sea. It is part of the Dodecanese group of islands, situated between the islands of Kos and Tilos. Nisyros covers a land area of 42 km^2. The total population of the island is 982 (National Statistical Service of Greece, 2011). The capital of Nisyros is Mandraki, which is also its port. Geologically, it belongs to the Attico-Cycladic massif and is located in the "Southern Aegean volcanic arc". The island is composed of volcanic rock formations, with swelled elevations that were formed by previous volcanic activities.

Geothermal research in Nisyros Island started in 1973 as part of the Institute of Geology & Mineral Exploration geothermal project. High (400 °C) and low (25–90 °C) temperature deep geothermal resources have been identified in the island. In 1982 the PPC proposed the construction of a power plant in order to solve the problems of electricity supply for both Nisyros Island and its neighbouring island, Kos. In 1983, two drillings were constructed in the area of the volcano caldera, which is the main tourist attraction of the island (Polyzou 2007).

The residents reacted to the power plant construction. The aim of all objections and the negative opinion of a large portion of the local society were about the protection of the environment (air and water pollution) in combination with the possibility of seismic and/or volcanic activity by disturbing the balance of the volcano. The experience of the test drilling on the island, in addition to the bad example created by the Milos Island case, led the residents to express their opposition to any thought of exploiting geothermal potential of the island by a referendum held in May 1997 (Polyzou 2007) (Fig. 3).

Until today, there are reactions from the local community and authorities against the development of high temperature deep geothermal energy for power production. On the other hand, they are positive on the utilization of low temperature geothermal fields that would provide drinking and arable water, space heating/

Fig. 3 Protest against geothermal development in Nisyros Island, banner sign: "NO TO THE GEOTHERMAL POWER PLANT". Reproduced by kind permission of Nisyrian Studies' Society (n.d.)

cooling and domestic hot water. Locals believe that they are not informed and their opinion does not matter concerning the exploitation of geothermal energy, they do not trust PPC Renewable for the construction of such a power plant, while the small size of the island and its characterization as a Natura 2000[1] area are other reasons that lead to their negative attitudes. Their reactions are accompanied with actions such as residents' and politicians' awareness, dissemination activities concerning the arguments against the construction of a geothermal power plant and various other activities (meetings, protests, etc.). A phrase showing their position is: "We don't want and we will not allow the construction of any geothermal power plant in Nisyros Island".

Nevertheless, the Municipality of Nisyros has very recently re-examined its policy against the utilization of geothermal energy and is investigating the possibility of low temperature deep geothermal applications in Nisyros covering thermal MED (Multiple-Effect Distillation) seawater desalination, ORC (Organic Rankine Cycle) geothermal power production, greenhouses and public building heating.

2.4.3 Kimolos Island

Kimolos is a volcanic island in the Aegean Sea. It is located at the northwest edge of Cyclades complex, near to Milos and Poliaigos Islands, and is 86 nautical miles away from Piraeus. Kimolos covers a land area of 37 km^2. The total population of the island is 910 (National Statistical Service of Greece, 2011). The capital of

[1]According to the European Commission (n.d.): "Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 28 EU countries, both on land and at sea. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive."

Kimolos is Chorio and its port is Psathi. Geologically, it belongs to the Attico-Cycladic massif, along with the entire Cycladic complex and is located in the "Southern Aegean volcanic arc".

After 1982, PPC carried out a preliminary geothermal survey in Kimolos, drilling eight wells at depths of 100 m. Later on, two geothermal wells were drilled by IGME for the operation of a geothermal seawater desalination plant. During 2009–10 a new Geophysical Research Program was implemented in the island, and new possible locations for drillings were found.

In 2014 PPC Renewables S.A. started planning the construction of a 5 MW power plant in the island. This led to the reaction of the local society and authorities, which were affected by the previous experience of Milos Island. Both residents and local authorities believe that PPC Renewables S.A. wanted to proceed with the development without having informed them and without their agreement.

3 Results and Discussion

Although Greece has a significant number of deep geothermal resources, the utilization of geothermal energy is quite limited; it is exploited exclusively through thermal applications (thermal spas, agricultural sector, GSHPs), meaning that there is no power production at all. Main reasons for the delay of geothermal resources development in Greece are:

- local societies' oppositions, especially against power production;
- inadequate regulatory framework and bureaucratic barriers;
- lack of financial capital;
- absence of financial/investment incentives (e.g. for covering geological risk);
- required infrastructure and installation cost of geothermal projects;
- absence of strategic planning for the rational exploitation of geothermal energy.

One of the main reasons for local societies' opposition against geothermal power production is the bad experience created by the Milos Island pilot power plant case. During the 1980s, deficiencies and errors made during the construction and operation phases of the newly constructed—by PPC—pilot power plant led to air, surface and water pollution, resulting to the strong reactions of the residents. The power plant was closed only two years after its first operation. Until today, the geothermal power generation in Greece is being affected by the negative outcome of the Milos case. There are still reactions from the local communities and authorities of Milos, Nisyros and Kimolos Islands against a large scale exploitation of high temperature deep geothermal resources, while there is no such opposition against low temperature deep geothermal utilization. The locals are sceptical against both the state and the PPC Renewable S.A., as they believe that their opinion does not matter, while they do not feel confident that any issues created by high temperature deep geothermal development will be treated properly.

Local communities' oppositions can derive from (a) lack of awareness, (b) perceptions of negative impacts, (c) absence of benefits, (d) lack of trust and (e) unfair development procedures. In this context, there are two factors affecting the conditions that create oppositions, which are characteristic for the case of Greece: existence of micropolitical interests and population peculiarities of the islands. Concerning micropolitical interest, it is identified that local authorities in many cases form their attitude towards any issue, depending on how they believe this attitude will affect their local power. For example, if the governing local authority supports the installation of a RES project, then the opposing political party will very possibly show great opposition, aiming to retain—or even increase—its power within the local community. In addition, if a local authority identifies a negative predisposition from a part of the locals towards a RES project, it is possible that it will try to benefit from it, by also openly adopting a negative attitude (Maraidonis 2008).

In regards to the population characteristic of the islands, that may affect the level of opposition towards geothermal development, it should be noted that in many cases people don't live all year around on the islands, but mainly reside on them during the summer; also, it is not uncommon for people only having real estate property on the islands, and rarely visiting them. All these people are not permanent residents, but however have a saying concerning the local issues. This can create a challenging condition in terms of acceptance of geothermal developments, since these people usually give much higher importance to the potential negative effects (e.g. aesthetic degradation of the local environment that can negatively affect the quality of their summer destination or their property), compared to possible benefits (e.g. economic development, business opportunities, job creation) that usually have low value for them.

In all attempts of exploitation of geothermal fields there is a gap of local communities' awareness, involvement and engagement. In this context a literature review on social studies is conducted, focusing on the themes of public knowledge, acceptance and attitudes towards geothermal energy. Only a small number of studies focuses exclusively on geothermal energy, while most identified studies aim on RES in general, or on sources such as solar and wind energy (both quite popular in Greece). Based on the findings, it can be concluded that knowledge, awareness and attitudes on geothermal energy in Greece are at a medium to low level. The studies show that people are much more aware and favourable towards solar and wind energy, while geothermal energy is one of the least favourite RES.

In addition, there seems to be a lack of awareness activities as, until now, only a small number of activities have been performed aiming to raise awareness of the local societies and stakeholders. These activities have to do mainly with the organization of workshops, info days and public's visits to geothermal applications (e.g. greenhouses).

However, specific advancements are currently occurring in regard to the exploitation of geothermal energy in Greece. The Municipality of Alexandroupolis (in Thrace) has received a license to exploit the low temperature deep geothermal resources of Aristino-Traianoupolis field, in order to create a district heating system

and greenhouse heating network. This makes the Municipality of Alexandroupolis the first owner of a low temperature geothermal field license in Greece to receive permit from the Regulatory Authority for Energy of Greece (RAE) to distribute geothermal energy as a producer through a district heating system to end-users. Furthermore, the new law on Energy Communities which gives the opportunity to citizens, local authorities and private or public legal entities to produce, distribute and supply energy, can assist the further promotion of geothermal energy in Greece.

In order to increase social acceptance, actions have to be taken both from the part of the state and the developing companies. The state must promote policies and regulations that will ensure the avoidance of any negative impacts (e.g. environmental, health) and the provision of benefits (e.g. economic) for the local societies. In addition, awareness activities should be introduced, focusing specifically on geothermal energy, as well as on RES in general. From the part of the developers, it is important to follow a strategy that will lead to the engagement of the local society, minimization of potential negative impacts and provision of benefits to the locals.

4 Conclusions

Geothermal energy, despite its large potential, is under-utilised in Greece. It is exploited exclusively through direct uses (thermal spas, greenhouses, GSHPs, etc.), while power production is totally absent. One of the main reasons for the delay of deep geothermal resources development for power production is local societies' oppositions, which derives from the bad experience created by the Milos Island power plant during the 1970–80s. This experience affects until today the attitudes of local communities and authorities (Milos, Nisyros and Kimolos Islands) against the large scale exploitation of high temperature deep geothermal resources. On the other hand, there are no such oppositions towards low temperature deep geothermal utilization. In all attempts made for exploitation of the geothermal resources there is a gap of local societies' awareness, involvement and engagement, a fact that contributes to public reactions towards geothermal development, especially concerning high temperature fields. Moreover, the conducted literature review shows that public attitudes and awareness are at a rather medium to low level. In order to achieve future penetration into the energy mix of the country, it is really important to increase awareness on geothermal development and improve the lost confidence of local societies towards high temperature deep geothermal exploitation.

References

Arvanitis A (2011) Geothermal activities in Greece. International Trade Fair Energy 2011, Renewable Energy Industry and Export Forum, Hanover, Germany, 4–8 Apr 2011

Central Intelligence Agency [n.d. (a)] The world factbook—Europe: Greece. https://www.cia.gov/library/publications/the-world-factbook/geos/print_gr.html. Accessed June 2017
Central Intelligence Agency [n.d. (b)] The world factbook –GDP—Composition, by sector of origin. https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html. Accessed June 2017
Dimitriou A, Pimenidis D (2015) Local authorities' views and attitudes on sustainable energy policy: the case of mayors of Rhodes Island, Greece (2010–2014). Int J Env Protect Pol 3 (2):20–30
European Association for Coal and Lignite aisbl (EURACOAL) (2016) EURACOAL Statistics—Coal in Europe 2016. https://euracoal.eu/info/euracoal-eu-statistics/. Accessed June 2017
Eurobarometer (2006) Energy technologies: knowledge, perception, measures
European Commission (n.d.) Environment. Natura 2000. http://ec.europa.eu/environment/nature/natura2000/index_en.htm. Accessed Feb 2018
Eurostat (2016) Statistical books—energy, transport and environment indicators. Publication Office of the European Union, Luxembourg
Eurostat (2017) Renewable energy statistics. http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics. Accessed June 2017
Fanourgaki I, Mauroudi IM (2017) Green investments/evaluation from the consumer's side. Bachelor's thesis, Technological Education Institute of Piraeus (in Greek)
Fytikas M, Andritsos N, Dalabakis P, Kolios N (2005) Greek geothermal update 2000–2004. In: Proceedings world geothermal congress 2005, Antalya, Turkey, 24–29 Apr 2005
Hellenic Statistical Authority (2011) 2011 population—housing census. http://www.statistics.gr/2011-census-pop-hous. Accessed June 2017
Karytsas S (2016) Heating and cooling of buildings with the use of renewable energy sources: socioeconomic factors that contribute to the diffusion of ground source heat pumps (GSHP) in the residential sector. Doctoral dissertation, Harokopeio University (in Greek)
Karytsas S, Choropanitis I (2017) Barriers against and actions towards renewable energy technologies diffusion: a principal component analysis for residential ground source heat pump (GSHP) systems. Renew Sust Energ Rev 78:252–271
Karytsas S, Theodoropoulou H (2014a) Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling. Renew Sust Energ Rev 34:49–57
Karytsas S, Theodoropoulou H (2014b) Socioeconomic and demographic factors that influence publics' awareness on the different forms of renewable energy sources. Renew Energ 71:480–485
Keramitsoglou KM (2016) Exploring adolescents' knowledge, perceptions and attitudes towards renewable energy sources: a colour choice approach. Renew Sust Energ Rev 59:1159–1169
Kontogianni A, Tourkolias C, Skourtos M (2013) Renewables portfolio, individual preferences and social values towards RES technologies. Energ Pol 55:467–476
Koundouri P, Kountouris Y, Remoundou K (2009) Valuing a wind farm construction: a contingent valuation study in Greece. Energ Pol 37(5):1939–1944
Koutroumpi M, Saltaoura I (2016) Renewable energy sources—photovoltaics. Bachelor's thesis, Technological Education Institute of Piraeus (in Greek)
Koutroupis N (1992) Update of geothermal energy development in Greece. Geothermics 21 (5–6):881–890
Law 3175/2003 (Government Gazette 207A)
Law 3852/2010 (Government Gazette 87A)
Liarakou G, Gavrilakis C, Flouri E (2009) Secondary school teachers' knowledge and attitudes towards renewable energy sources. J Sci Ed Tech 18(2):120–129
Manologlou E, Tsartas P, Markou A (2004) Geothermal energy sources for water production—socio-economic effects and people's wishes on Milos island: a case study. Energ Pol 32 (5):623–633
Maraidonis T (2008) Social acceptance and renewable energy sources: the case of south Euboea. Final thesis, National School of Local Governance (in Greek)

Melfos V, Voudouris PC (2012) Geological, mineralogical and geochemical aspects for critical and rare metals in Greece. Minerals 2(4):300–317
Ministerial Decree Δ1/A/12892/2014 (Government Gazette 2186B)
Ministry of Environment and Energy [n.d. (a)] Mineral resources. http://www.ypeka.gr/Default.aspx?tabid = 294&language = el-GR. Accessed June 2017
Ministry of Environment and Energy [n.d. (b)] National renewable energy action plan. http://www.ypeka.gr/LinkClick.aspx?fileticket=vBWJVY3FdTk%3D. Accessed June 2017
Nisyrian Studies' Society (n.d.) Reaction of Nisyros people. http://www.nisyriakesmeletes.gr/antidraseis.html. Accessed June 2017
Ntanos S, Ntanos A, Salmon I, Ziatas T (2016) Public awareness on renewable energy sources: a case study for the Piraeus University of applied sciences. Presented at the 5th international symposium and 27th national conference on operational research, Athens, Greece, 9–11 June 2016
Papachristou M, Mendrinos D, Dalampakis P et al. (2016) Geothermal energy use, country update for Greece. Paper presented at the European geothermal congress, Strasbourg, France, 19–24 Sept 2016
Petrakopoulou F (2017) The social perspective on the renewable energy autonomy of geographically isolated communities: evidence from a Mediterranean island. Sustainability 9 (3):327
Polyzou O (2007) Geothermal energy—sustainable development and local societies. Doctoral dissertation, National Technical University of Athens (in Greek)
Polyzou O, Stamataki S (2010) Geothermal energy and local societies—a NIMBY syndrome contradiction? In: Proceedings world geothermal congress 2010, Bali, Indonesia, 25–29 Apr 2010
Sardianou E, Genoudi P (2013) Which factors affect the willingness of consumers to adopt renewable energies? Renew Energ 57:1–4
Schneider F (2015) Tax evasion, shadow economy and corruption in Greece and other OECD countries: some empirical facts. http://www.amcham.gr/wp-content/uploads/2015/taxspeeches/friedrich%20schneider.pdf. Accessed June 2017
Skoupra M (2013) Social acceptance of renewable energy sources installations by consumers. Master's thesis, Harokopeio University (in Greek)
Spiropoulou D, Antonakaki T, Kontaxaki S, Bouras S (2007) Primary teachers' literacy and attitudes on education for sustainable development. J Sci Ed Tech 16(5):443–450
Tampakis S, Tsantopoulos G, Arabatzis G, Rerras I (2013) Citizens' views on various forms of energy and their contribution to the environment. Renew Sust Energ Rev 20:473–482
Tsirampidis A, Filippidis A (2013) Mineral resources of Greece: reserves and value. Department of Mineralogy-Petrology-Economic Geology, Department of Geology, Aristotle University of Thessaloniki (in Greek)
Tsoutsos T, Tournaki S, Gkouskos Z et al. (2013) Training and certification of PV installers in Europe: a transnational need for PV industry's competitive growth. Energ Pol 55:593–601
Tzanakaki E, Mavrogioros D (2005) Public acceptance of renewable energy sources and energy conservation. Paper presented at Heleco'05, TEE, Athens, 3–6 Feb 2005