Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

# Geothermal activities in Greece – Country update 2021-2023

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**Keywords:** resources, exploration, development, direct uses

## ABSTRACT

Geothermal energy is used only for direct utilization in Greece. The total installed capacity is about 266.5 $MW_{th}$, exhibiting a very small increase (2.5 %) since 2020. Direct uses include greenhouse heating, balneotherapy and ground-source heat pumps, the latter constituting the largest geothermal application (180 MWth) in the country. Other, small scale, applications are a couple of spirulina cultivation units, soil heating and a small dehydration plant, that use fluids with temperatures up to 60°C. Moreover, the first geothermal district heating project will be completed and delivered in 2023 in the area of Anthia-Aristino (Thrace, northern Greece). Geothermal power generation is still zero; however, the cooperation of the Public Power Corporation-Renewables (PPC-R) with the private sector (ELECTOR SA), established in 2020, is expected to bear fruit in the near future, with the exploitation of the medium/high enthalpy resources of Milos-Kimolos islands, Lesvos island, Methana peninsula and Nisyros island and the construction of small (5-8 MWe) pilot plants (Project/Subsidiary "Geothermal Objective II"). Due to the covid-19 pandemic and the suspension of all activities, geothermal exploration was limited and concerned the further investigation of low temperature resources in northern Greece and preliminary studies in Methana, Milos and Lesvos.

## 1. INTRODUCTION

Geothermal activities in Greece since 2020 included further surface and drilling exploration in a few known geothermal areas in northern Greece, geophysical, tectonic and geochemical studies in Milos island, Lesvos island and Methana, the completion of the district heating project in Alexandroupolis (Thrace, northern Greece), the installation of monitoring systems in selected low enthalpy fields and thermal springs by the Hellenic Survey of Geology and Mineral Exploration (HSGME), and the creation of the National Registry of Documentation of Geothermal "spots".

Geothermal energy is utilized only for low enthalpy applications, mainly for greenhouse heating and balneotherapy (bathing, drinking & recreation), whereas GSHPs remain the most prevalent sector of the domestic geothermal market. The operation of the first and only geothermal power plant in the country (Milos island, 2MWe) was terminated in the early 1990's, just a couple of years after its start-up. Since then, the share of geothermal energy in the electricity production section is zero. The efforts of the Public Power Corporation - Renewables SA for developing the high enthalpy geothermal areas, do not have tangible results yet, since its joint activities with the private company ELECTOR S.A. ("Geothermal Objective II") for power production in Milos-Kimolos islands, Lesvos island, Methana peninsula and Nisyros island are still in the exploration stage. On the other hand, during the first semester of 2022, the electricity production from other RES and large hydro showed a spectacular increase, contributing, for the first time, more electricity to the interconnected network of the country (9498 GWh) than any energy source (https://thegreentank.gr).

Regarding future prospects, the targets set by the National Energy and Climate Plan (NECP, 2019-Figure 1) for geothermal energy in 2030 are 100MWe in the electricity generation system and 734ktoe in the final energy consumption, ambient heat and GSHPs included. Unfortunately, given the current progress, both goals remain uncertain, if not unrealistic, especially regarding power production.

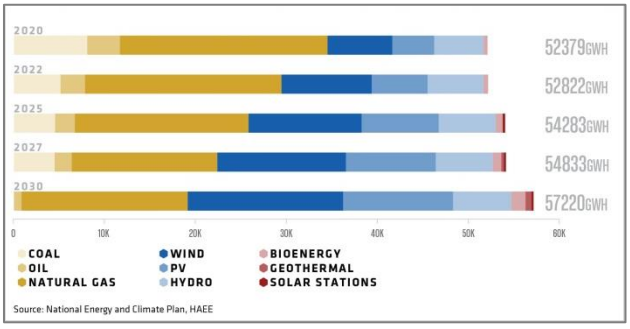


**Figure 1: National Energy and Climate Plan: Forecast (2020-2030) electricity generation by source (www.haee.gr)**

## 2. GEOTHERMAL RESOURCES

As it has been described in previous country update papers (e.g. Andritsos et al., 2015, Papachristou et al., 2020), the extensional tectonics, and, in some areas, the magmatic/volcanic activity has favored the creation of important hydrothermal systems around the country, mostly in some Aegean islands and in northern Greece (Figure 2).

More specifically, high temperature (>300°C) reservoirs have been identified and confirmed by drilling in Milos and Nisyros islands, medium to high enthalpy (100-150°C) resources are inferred by surface exploration, thermal gradients and geothermometers in northern Greece's tectonic basins and in some Aegean islands (eg Aristino, Samothrace, Lesvos, Chios etc), whereas low temperature (up to 99°C) resources exist in relatively shallow depths (<500m) all over the country (mainly in Thrace, Macedonia, central Greece, Aegean islands). In addition, more than 750 thermal and mineral springs are recorded, a large number of which can be exploited for therapeutic purposes. The temperature of the thermal springs ranges between 25 and 92°C. The hottest thermal spring in the country and one of the hottest in Europe, is located in Polichnitos (Lesvos island, North Aegean).

According to the Greek legislation (L 4602/2019), the geothermal resources are defined as "*low*" (T=30-90°C) and "*high*" (T>90°C) temperature. Resources with temperature below 30°C, are considered as "shallow geothermal energy" and can be exploited by GSHPs, the use and licensing of which is regulated by different legal procedures and specific ministerial decisions. An area with proven and accessed resources (>30°C) is characterized as "*geothermal field*", whereas a wider region with indications of geothermal resources, is generally described as an "*area of geothermal interest*". The geothermal fields are divided in turn, into "*national*" or "*local*" interest, depending on the temperature of the produced fluids (above or below 90°C, respectively).

There are 32 areas in Greece characterized as "geothermal fields" and several more as "areas of geothermal interest". Two geothermal fields, i.e. in Milos and Nisyros, are classified as "geothermal fields of national interest", while the remaining thirty as "geothermal fields of local interest".


**Figure 2 Main geothermal areas/fields of Greece**

## 3. GEOTHERMAL EXPLORATION

During the past years (2020-2022) exploration activities took place in the following geothermal fields/areas:

- → *Milos island (SAAVA):* PPC-R in collaboration with the National Observatory of Athens (NOA) installed a seismographic network (5 seismographs) for tracing and monitoring the microseismicity within the boundaries of the high enthalpy geothermal field. In addition, a thorough tectonic analysis and study is being currently conducted for the same area, as part of the surface geothermal research in the frame of the "Geothermal Objective II" project.
- → *Methana (SAAVA):* PPC-R is conducting an extensive geophysical survey (gravimetric, magnetic and magnetotelluric methods) in combination with tectonic and petrographic studies, in order to determine the location of the first deep exploratory borehole.
- → *Lesvos island (North Aegean):* The detailed tectonic study has been already completed for the area of the main geothermal interest (Stipsi, central part of the island)
- → *Aristino geothermal field (Alexandroupolis, Thrace)*: During summer/autumn 2021, geophysical research was implemented for the first time in this geothermal area. It was based on the Electrical Resistivity Tomography method, with six geo-electrical lines, each of 2400 m full length, achieving a maximum investigation depth of 450-500m. The geophysical investigation provided valuable information for the geological setting of the area, revealing unknown, buried, tectonic structures that are possibly related to the circulation of geothermal fluids, and indicated the most promising locations for future geothermal drilling exploration.
- → *Sidirokastro geothermal field (Serres, central Macedonia)*: The drilling exploration project held by HSGME was completed, with the construction of (4) geothermal large-diameter exploration wells at the northeast part of the field. The first borehole (Sd18P - October 2021) discovered fluids of 78-79.4°C at depths of 160-190m. Two more wells (Sd17PN and Sd11P), 150-290m deep, were drilled during May-August 2022, recording reservoir temperatures of 53-78ºC. The last well (Sd19P), 213m deep, was drilled during September 2022 identified fluids of 32.5ºC at the depth of 200m. A 48-hour preliminary pumping test at a constant rate of 65 $m^3/h$ was conducted in well Sd17PN, approx. 150m deep, indicating the significant geothermal potential, since the drawdown in the pumping well did not exceed 16m, whereas the temperature of the produced fluids was 77.8-77.9ºC (November 2022). Systematic pumping tests in these new wells will be performed in the first months of 2023
- → The first borehole (October 2021) discovered fluids of 78-79°C at depths of 160-190m. Three more wells, 150-290 deep, were drilled during 2022, recording reservoir temperatures of 53-78ºC.
- → *Myrodato area (Xanthi, Thrace):* The reconnaissance investigation held by HSGME, included collection, review and evaluation of geological, structural and previous exploration data, thermometric survey and hydrogeochemical study. Except for the geothermal well MYR-1, 90m deep, which produces waters of 56.8ºC, the maximum temperature measured at the existing irrigation wells (depth up to 104m) was 25.1ºC, indicating a small geothermal anomaly. In the same area, the temperature measured in a small-diameter exploration borehole (216m deep, constructed in 1990) was 36ºC at the depth of 200m, at the contact between the metamorphic basement and the overlying sediments.

## 3. GEOTHERMAL UTILIZATION

### 3.1 Power Production

In 2020/2021, the competent authorities finally ratified and formalized the joint venture of PPC-R and ELECTOR, for the development of the high enthalpy resources of Milos-Kimolos island complex, Nisyros island, Methana peninsula and Lesvos island, where PPC-R holds the geothermal concession rights. This cooperation is realized through the subsidiary "Geothermal Objective II", which is owned by 49% by PPC-R and 51% by ELECTOR. € 120 million will be totally invested for the exploration and exploitation of the aforementioned areas. The timetable for the construction of the production wells and power plants cannot yet be precisely determined; however the first deep wells are expected to be drilled in late 2023 to 2024.

### 3.2 Direct Uses

Geothermal energy is mainly used in the recreational (balneotherapy) and agricultural (greenhouse heating, soil heating, aquaculture) sectors. The total installed capacity from direct uses is approximately 85.1 $MW_{th}$.

#### 3.2.1 Balneotherapy

Thermal water is used in nearly 80 spas and bathing centers (www.ekke.gr), as well as in more than 25 outdoor swimming pools. A traditional bathing town ("Loutropolis", in Greek) usually operates only for a few months a year (June to October). The geothermal fluids are used exclusively for healing and recreation.

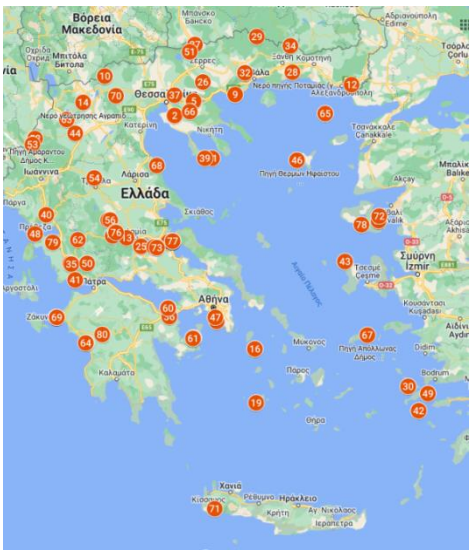


**Figure 3: Thermal springs certified and acknowledged as "curative" (www. mintour.gov.gr)**

According to the Ministry of Tourism (www.mintour.gov.gr), 80 thermal springs have been certified and classified as 'curative', around the country (Figure 3)

Based on a study carried out by the Hellenic Association of Municipalities with Thermal Springs, the spa market in Greece has great prospective with the potential annual turnover reaching €390 million (www.thermalsprings.gr). The bathing and recreational centers attract hundreds of thousands of domestic and foreign visitors each period (www.ekke.gr); however the financial crisis of the previous decade has affected significantly their number (Figure 4). In order to further develop this sector, the Ministry of Tourism set up the company "Thermal Springs of Greece" (L 4875/2021) in order to identify, manage and utilize the country's thermal springs in collaboration with the regional/municipal authorities in whose administrative boundaries curative natural resources exist.

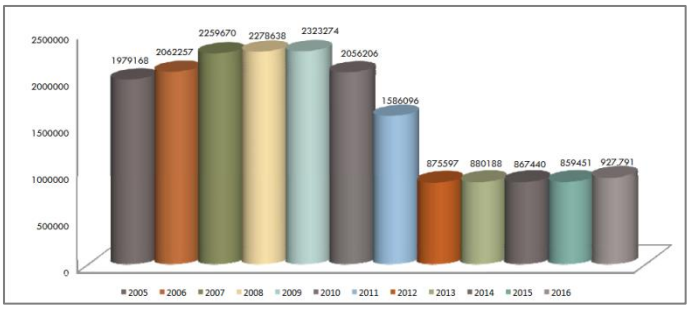


**Figure 4: Number of tickets in the bathing centers of Greece for the period 2005-2016 (www.ekke.gr)**

A conservative estimation of the energy use in the balneotherapy centers in Greece is 260 TJ/y, corresponding to an installed capacity of 43 $MW_{th}$.

3.2.2 Greenhouse Heating

The majority of the geothermal greenhouses of the country (total covered surface approximately 40 ha) are located in Macedonia and Thrace. They produce vegetables (tomatoes, cucumbers, etc) and flowers. Most of the greenhouses are small, family owned enterprises, whereas two are corporate-owned units:

- → THRACE GREENHOUSES (*Neo Erasmio geothermal field):* The unit has reached 18.5 ha in 2021 (Figure 4), after being gradually expanding from 4.2 ha in 2015 (Andritsos et al., 2015). The investment has so far exceeded €20 million, offering 210 job positions to the nearby communities, with an annual turnover of € 8 million. The greenhouses produce 6000 tons of tomatoes and 10000 tons of cucumbers per year, using fluids of 58-70°C from six production wells. The unit is currently growing by another 13 ha, an investment that will reach €15 million, increasing the production by 6000 tons and creating 70 new job positions. The installed capacity and annual thermal energy use in this greenhouse complex are 16.63 $MW_{th}$ and 217.64 TJ, respectively.
- → SELECTA HELLAS *(Eratino-Chrysoupolis geothermal field):* The greenhouses cover 3.5 ha and produce rooted cuttings of ornamental plants, which are exported. The total investment to this point has been €7 million, but, according to the company's investment plan, it will reach €10 million with the construction of additional units (2.5 ha) and a new geothermal doublet (700m deep). For its current heating demands, the unit requires 9$m^3$/h of fluids, which are produced for a 750m deep well owned by the Municipal Water Supply and Sewage Company of Nestos. The temperature of the produced fluids is 75°C; however the temperature of the circulating water inside the greenhouse is 30-50°C, depending on the specific needs of the plants. The installed capacity and the annual thermal energy use are 2.75 $MW_{th}$ and 27.26 TJ, respectively.

**Figure 5: Thrace Greenhouses in Neo Erasmio geothermal field**

Small geothermal greenhouses operate in the geothermal fields of Nea Apollonia, Nigrita and Sidirokastro (central Macedonia, Greece), as well as in the island of Lesvos. The total installed capacity from greenhouse heating is 36.35 $MW_{th}$, while the annual energy use is estimated at 396.40 TJ/y.

3.2.2 Soil Heating

Low temperature geothermal fluids for soil heating are used in two asparagus plantations: in Neo Erasmio since 1998 and in Myrodato since 2005, both located in Xanthi area (Thrace) for early-season production. The heated surface in Neo Erasmio is now only 1.0 ha, exploiting fluids of 58°C. In Myrodato, the cultivated area (3.0 ha) is heated by geothermal fluids of 50°C. The fluids are circulating inside plastic pipes, placed at the base of the soil ridges (Andritsos et al., 2015). The required heating loads range between 100-150 kW/ha, depending on the outdoor temperature and the heating onset. Usually, heating starts in late January or early February and the harvesting period between mid-February and early March. The total installed capacity and annual energy use in these two applications are 0.3 $MW_{th}$ and 2.38 TJ, respectively.

3.2.3 Aquaculture: Spirulina Cultivation

Two spirulina units are located in the low temperature field of Nigrita (Strymon Basin, northern Greece). The total surface of the raceway ponds is 0.9 ha. The average required flow-rate, for maintaining the temperature of the cultivation water at 33-36°C, is 20-21 $m^3/h$, whereas it might reach 35-40 $m^3/h$ during very cold days. The installed capacity of the two units is 3.86 $MW_{th}$. The spirulina production in Nigrita has been suspended since 2020.

3.2.5 Dehydration

Low temperature geothermal fluids (~60°C) are used at one dehydration plant located in the field of Neo Erasmio (Xanthi, Thrace), own by the company "GEOTHERMIKI HELLAS". The geothermal water heats atmospheric air to 55°C, which is then driven to the drying tunnels at a rate of 14.000 $m^3/h$ (Andritsos et al., 2003). Although initially the plant was designed and constructed to dehydrate only tomatoes, in recent years it operates almost all year around to dehydrate several other agricultural products. In 2021 the quantities of dehydrated products were as follows: tomatoes 6 tn (lower quantities than in early 2010s due to unavailability of fresh produce), citrus fruits (lemons, oranges, limes) 9.1 tn, peppers (yellow, green, chili etc.) 9.2 tn, olives 4.2 tn and garlic 1 tn. Smaller quantities of several other products, such as apples, onions, mushrooms, zucchinis, and persimmons have been also dehydrated during 2021. The installed capacity of the unit is 0.24 $MW_{th}$.

3.2.5 Space Heating

The direct use of geothermal energy for space heating is limited (GSHPs excluded) to the offices and process facilities of "THRACE GREENHOUSES", the facilities of the above mentioned dehydration plant and a few dwellings around the country. The installed capacity of such installations is 0.4 $MW_{th}$.

3.2.6 District Heating

The first geothermal district heating project in Greece (Papachristou et al., 2016; 2019; 2020) that started a few years ago in the geothermal field of Aristino (Alexandroupolis, Thrace) has entered its final phase. The ongoing large infrastructure project, comprising pumping and exchanging stations and a dense fluid transport network (12+4 km) is under full development. Moreover, two reinjection wells will be completed by the end of 2022, both drilled at 520m depth, aiming to receive 150-200 $m^3/h$ of used geothermal fluids. Production and injection testing will be completed by the beginning of 2023. End users will receive thermal energy at a maximum distance of 2200 m from the thermal station. The total installed capacity is 10 MWth, 10-20% of which will be used for the heating of public buildings and a local social housing complex, covering a total area of 8000 $m^2$. The rest 8-9 $MW_{th}$, will be available for agricultural uses, mainly for greenhouse heating. The final budget of the project has been finalized at more than €4 million. Pilot tests and startup procedures are expected to be completed by the winter of 2023.

**3.3 Ground Source Heat Pumps**

GSHPs constitute the largest segment of the geothermal market in Greece. They are used to provide space heating and cooling and hot water to residential, industrial, commercial and public buildings, individual houses, swimming pools, etc. In addition, GSHPs are installed in a 10 ha asparagus plantation in Chrysoupolis (Kavala, central Macedonia) for soil heating. During recent years, the installation of relatively large units (average ~47 KWth) in public buildings and facilities prevails over the use of small capacity systems in individual residences and small buildings, mainly due to the strong competition from natural gas (up to 2021) and air-source heat pumps. An important turning point for the use of GSHPs, especially in public buildings, has been the enforcement of the national Regulation on the Energy Performance of Buildings (KENAK), which set minimum requirements for the energy performance of buildings.

The overall number of the installed GSHP systems is not available (no exact records are kept), however it is estimated (Mendrinos et al., 2022) that each year nearly 180 units are installed, corresponding to a capacity 6.7 $MW_{th}$. The total GSHPs installed capacity exceeded 180 $MW_{th}$ at the end of 2021.

During the past year, there is an increasing interest for the installation of heat pumps, including GSHPs, due to the soaring increase of natural gas prices for space heating. The price of natural gas for space heating increased from about 45 €/MWh in January 2021 to more than 200 €/MWh in September 2022. In Greece there are no financial incentives (e.g. tax rebates, low interest loans, lower electricity price) for building owners to invest in GSHPs, whereas subsidies were offered recently to replace less efficient appliances (air conditioners, refrigerators or freezers).

## 4. REGULATORY FRAMEWORK

The general obligations and principles for the exploration, exploitation and management of the country's geothermal potential are established by the framework law 4602/2019, a short description of which is included in Papachristou et al. (2020).

In 2021 and 2022, two Ministerial Decrees were additionally issued, in order to regulate:

i. the on-site geothermal works (ΥΠΕΝ/ΔΑΠ/42138/552 published on 21.05.2021)
ii. the terms and procedures for the exploration/exploitation/management concession rights for geothermal resources of national interest (T>90°C) and the exploration rights for unexplored areas (ΥΠΕΝ/ΔΑΠ/25257/126, published on 28.03.2022)

The use of GSHPs is regulated by the Ministerial Decision Δ9Β,Δ/Φ166/οικ13068/ΓΔΦΠ2488 (published on 24.06.2009).

Other relative legislation, briefly discussed in Papachristou et al. (2020), includes:

→ The National Energy and Climate Plan (2019)
→ The Energy Performance of Buildings Regulations (2010)
→ The new RES support scheme (L. 4416/2016)
→ The Energy Communities (L. 4513/2018)

## 5. ON-GOING & FUTURE GEOTHERMAL ACTIVITIES

The most important geothermal activities either in progress or scheduled for the near future are:

- *Geothermal Power Production Project (Geothermal Objective II)*:
  a. Hydrochemical study, pumping tests and additional geophysical investigation (seismic method) in the NNW part of **Lesvos** island (Petra graben)
  b. Geophysical survey and installment of a seismographic network in **Nisyros** (probably in 2023)
  c. Drilling of one exploration well in **Methana** peninsula (2024, by PPC-R)
  d. Drilling of new exploration wells in **Milos** and **Lesvos** island (late 2023, by PPC-R)

- *Eratino-Chrysoupolis and Neo Erasmio fields (Nestos Delta Basin, northern Greece)*: Drilling of one large-diameter exploration well (early 2023, by HSGME)

- *Eratino-Chrysoupolis field*: The Municipality of Nestos will extend the geothermal heating network towards the elementary school of Eratino. In addition, the existing network will be connected to small farm that will comprise demonstration geothermal applications, such a small hydroponic greenhouse for the production of vegetables and under floor heating installations for the cultivation of asparagus, melons and watermelons (Mendrinos et al., 2022). In addition, SELECTA HELLAS has secured the exploration rights for part of the field, in order to construct a new geothermal doublet (depth ~ 700m) and expand the existing greenhouses by 2.1 ha.

- *Nea Kessani geothermal field:* THRACE GREENHOUSES S.A. acquired the exploitation rights for the northern part of the field. The company's plan is to use fluids of 73°C from 400-450 m deep wells for the heating of 13 ha greenhouses that will produce 10 thousand tons of vegetables (tomatoes and cucumber). The corresponding investment amounts at 12.6 million euro and will generate 90 job positions. The expected installed capacity is 12 $MW_{th}$.

- *Akropotamos geothermal field (central Macedonia)*: The project of the Paggaio Municipality to exploit the local low temperature resources for district heating/cooling of semi-urban settlements, greenhouses and spa resorts, is still in the early implementation phase (prefeasibility studies)

- *Nigrita geothermal field (Strymon Basin, central Macedonia)*: The Municipality of Visaltia is implementing a new project for the distribution of 2MWth of geothermal heat to local farmers for greenhouse and soil heating

- *Aristino geothermal field (Alexandroupolis, Thrace):* Further exploration in this geothermal area is planned by the company "THRACIAN ENERGY", which was awarded the exploration rights for in June 2022. The exploration project includes geologic, tectonic and geophysical studies, as well as drilling of two exploration wells (500-600m deep), seeking fluids of 90°C and 200 $m^3/h$. Furthermore, "EVROS TOURISTIC THERMALISTIC SINGLE MEMBER PRIVATE COMPANY" secured in May 2021 the exploitation rights for a small part of the field, which includes an existing geothermal productive well.

- *Polichnitos geothermal field (Lesvos island):* The local Municipality has renewed its interest in exploiting the significant low temperature potential of the area (30-90°C at depths of 50-200m) and has submitted the relative proposal to acquire the concession rights (exploitation and management) to the Decentralized Administration of Aegean. For this purpose, the Municipality has already secured €60 thousand for technical support, in the frame of the Project "European Islands Facility-New energy Solutions Optimized for Islands**"**.

- *Monitoring of selected geothermal fields and hot springs for their optimal use and ensuring their sustainability:* Based on the new geothermal law (4602/2019, article 21), the monitoring of the country's geothermal fields is carried out by HSGME. For this purpose, geothermal telemetry stations for monitoring, recording and data transmission have been installed since July 2020 in the following geothermal areas: Neo Erasmio-Magana geothermal field (wells), Nisyros island (fumaroles and springs), Santorini island (Nea Kameni, fumaroles), Nea Apollonia geothermal field (wells), Agkistro geothermal field (well) and Milos island (Agia Kiriaki, fumaroles). Each geothermal telemetry station consists of the following main components: (a) temperature and hydraulic pressure sensors installed at specific depths in monitoring boreholes and contact thermometers at wellheads of production wells for water temperature measurements (in cases of monitoring of fumaroles, springs and hot soils, temperature sensors are installed only), (b) a box for collecting, recording and transmitting data containing the necessary equipment (data logger unit, radio modem, battery, charge controller) and (c) protected cables connecting sensors to the box. A telemetry station can be supplied either by photovoltaic panel or electricity grid. The installed telemetry stations use the "LoggerNet" support software for real-time access to data. All data is transmitted to the server of HSGME.

- *Management Plans of Low Temperature Geothermal Fields in Greece (HSGME):* This project started in February 2020 and is funded by the Operational Program "Competitiveness, Entrepreneurship & Innovation" (EPAnEK), in the frame of NSRF 2014-2020. The aim of the project is the creation of a pilot and synthetic study of management plans for geothermal fields of local interest and its pilot application in two selected geothermal fields (Neo Erasmio-Magana and Nea Apollonia). The first two technical reports entitled "Management plan specifications of low temperature geothermal field" and "Standard pilot implementation of a management plan in the Neo Erasmio-Magana geothermal field, Xanthi area" were completed and submitted to the Hellenic Ministry of Environment and Energy in November 2020 and August 2021 respectively.

- *Creation of a National Register for the Registration and Monitoring of Geothermal Points:* This project started in January 2022 and is included in the Act entitled "Reinforcing Entrepreneurship in the Domain of the Hellenic Survey of Geology and Mineral Exploration (H.S.G.M.E.)". The implementation of the National Register for the Registration and Monitoring of Geothermal Points is provided for by article 17 of the Law 4602/2019. This project is accompanied by Legal Implementation Support and Publicity of the Act.

- *Compilation and publication of a Guide on Geothermal Energy, in Greek and English - A Guide on Geothermal Energy:* The aim of the Project, funded by the Public Investment Program (National Funding) and carried out by HSGME, is to compile an investment guide for the geothermal energy use in Greece, which will provide useful information on the geothermal situation, fields and potential, the existing legal framework and the available financial tools for investment projects.

- *Long-term monitoring, supervision and restoration of geothermal wells drilled by IGME (now HSGME) which have not been assigned to third parties:* A large number of geothermal wells have been drilled by IGME (now HSGME) for exploration, identification and evaluation of the country's low temperature fields. The afore mentioned project, funded by the Public Investment Program (National Funding) includes the following activities, performed by HSGME: (a) inventory and registration (location, history, lithology, geothermal and construction characteristics, current status) of existing geothermal wells that have not been assigned to third parties, (b) systematic in situ supervision and monitoring, (c) preparation of emergency response plans in case of leak detection, well-construction failures etc and (d) problem management in collaboration with the Decentralized Administrations of Greece. At the end of this project, the operational wells will be assigned to the Decentralized Administrations.

## 5. DISCUSSION - CONCLUSIONS

One of the main axes of the energy reformation in Greece is to move towards low-carbon-intensity energy systems. By the end of this decade, the country will need to double the national installed capacity from RES to reach the target of 20 GW (35% share in the energy mix) and reduce greenhouse gas emissions by more than 50%, compared to 2005 levels.

While these targets are feasible for some RES (e.g. wind and solar), they remain very ambitious for geothermal energy. Despite the revived interest in **geothermal electricity generation** and the encouraging initiation of the "Geothermal Target II" activities, it is still unknown when power production will begin. Thus far, these activities pertain to surface exploration and installment of seismiv monitoring systems in the high temperature fields where power plants will be constructed.

The utilization of geothermal energy for **direct uses** mainly regards agriculture and balneotherapy. The largest investments have been made for greenhouse heating, with two large corporate units operating since the middle of the previous decade in Xanthi and Kavala areas (northern Greece) and a few small family-owned greenhouses also in northern Greece, as well as in Milos and Lesvos islands. The thermal spa market remains unchanged for many years; however, if the existing investment plans will be materialized, this sector could have a great potential for significant growth. Except for one case, the thermal water is not used in the spa facilities as a source of energy, but only for its therapeutic properties.

The **GSHP** market grows slowly but steadily, with approximately 4000 units installed in the country. This sector has been particularly favored by simple licensing procedures and the implementation of targeted measures and regulations for the full decarbonization of the heating sector.

Regarding the near future, the first geothermal district heating project of the country in the area of Aristino (Alexandroupolis, Thrace), is going through its final phase and is expected to operate in 2023. In addition, the surface and drilling exploration of geothermal resources continues in several geothermal areas, and, hopefully, it will be followed by exploitation.

The new regulatory and legislative framework for geothermal energy established in the past 3 years created new environmental safeguards and economic standards for geothermal exploration and exploitation, seeking to accelerate the bureaucratic licensing procedures and to attract new investments.

Greece has abundant, available, but also largely untapped geothermal resources. However, the transformation of the domestic energy sector, in combination to the current volatile global energy market and the skyrocketing prices of fossil fuels, could constitute a "golden" opportunity for the, long-anticipated, geothermal development. Some of the main challenges to be faced remain the institutional capacity to speed up the pace especially for power production, the perception by the society of geothermal as a stable, reliable, round-the-clock and safe source of energy, and the lack of financial support/incentives.

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