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Portugal Country Update 2020

João Carlos Nunes[1*],Luís Coelho[2], José Martins Carvalho[3], Maria do Rosário Carvalho[4] and João Garcia[2]

[1] INOVA- Instituto de Inovação Tecnológica dos Açores, Rua S. Gonçalo s/n, 9504-540 Ponta Delgada, Açores & Universidade dos Açores, Rua Mãe de Deus, 9501-801 Ponta Delgada, Açores, Portugal

[2] Instituto Politécnico de Setúbal (EST/IPS), Escola Superior de Tecnologia de Setúbal, Campus do IPS, Estefanilha, 2910-761 Setúbal & CINEA-IPS, Centro de Investigação em Energia e Ambiente – IPS, Setúbal, Portugal

[3]Laboratório de Cartografia e Geologia Aplicada, Instituto Superior de Engenharia (ISEP), Politécnico do Porto, Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto & GeoBioTec, Universidade de Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal

[4]Departamento de Geologia, Faculdade de Ciências, Universidade de Lisboa & Instituto D. Luiz, Campo Grande, Edifício C6, 3º Piso, 1749-016 Lisboa, Portugal

*jcnunes@inovacores.pt

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ABSTRACT

In Portugal, the presence of high enthalpy geothermal resources is restricted to the volcanic islands of Azores Archipelago, located in the North Atlantic Ocean and which are associated with the triple junction of the North American, Eurasian and African (or Nubian) plates. Power production from geothermal resources in Azores meets about 23% of the total demand of the archipelago, even the geothermal projects being confined to the S. Miguel and Terceira islands.

Present investment projects at the Ribeira Grande Geothermal Field (RGGF) on the island of S. Miguel, implemented by EDA RENOVÁVEIS S.A. (former SOGEO – Sociedade Geotérmica dos Açores S.A.), led the installed generation capacity to a total of 23 MW net, with the contribution of the Ribeira Grande plant (13 MW net), operating since March 1994, and the Pico Vermelho plant (10 MW net), which went into operation in November 2006. Today, power production from geothermal resources in S. Miguel is stabilized since 2013 and meets about 44% of the electrical consumption in the island. On Terceira Island, a 3.5 MW pilot power plant is in operation since November 2017 at the Pico Alto Geothermal Field (PAGF), with a power production that corresponds to about 10% of the electrical consumption of the island.

Geothermal energy is expected to assume an even more impressive role for electric power self-sufficiency of this Autonomous Region of Portugal, particularly in S. Miguel and Terceira Islands. However, its development is now considered in conjunction with other energy sources (particularly wind energy and waste production), energy storage and daily needs/consumptions issues.

Low-temperature geothermal resources in Mainland Portugal are exploited for direct uses in balneotherapy and small heating systems. In the Azores Archipelago low enthalpy resources are also traditionally used in balneotherapy, and pilot/demonstration projects are being developed to take advantage of this resource on domestic water heater (DWH; e.g. hotel) and buildings air conditioning (cf. in the area of Caldeiras da Ribeira Grande/RGGF).

In Portugal, ground source heat pump technology (GSHP) is gaining penetration in the heating and cooling of buildings market. At present, new regulations for shallow geothermal purposes are being prepared to regulate all new GSHP's installations (including its registration), to avoid bad practices and get more realistic statistical data on the new installations. These regulations, financing programs now available, and new data to be incorporated in a Portuguese heat flow density map, will for sure enhance geothermal in Portugal Mainland. It has been noticed in recent times that several brands of AVAC equipment have placed new GSHP models on the Portuguese market, showing that there is an increasing interest in this solution. A large shallow geothermal installation is being built in the Algarve, south of Portugal, for heating, cooling and to produce DWH for a hotel, a club house on a golf course and several individual villas, with about a total pavement area of 14,000 m^2. The total installed capacity is expected to be about 1200 kW for cooling and 2360 kW for heating. The total expected number of boreholes heat exchangers is 244, with a depth between 110 m and 150 m. This large installation will in future increase the visibility of this type of facilities in Portugal.

At Madeira Archipelago, the LNEG - Portuguese National Laboratory for Energy and Geology carried out in 2013 a geothermal survey for the EEM- Empresa Eléctrica da Madeira, including geological, geochemical and geophysical investigations (e.g. magnetotellurics). The available results indicate the existence of geothermal potential within the island with conditions for the development of enhanced geothermal system (EGS).

1. INTRODUCTION

The high enthalpy geothermal resources, in Portugal, is restricted to the volcanic islands of Azores Archipelago (Figure. 1), located in the North Atlantic Ocean and which are associated with the triple junction of the North American, Eurasian and African (or Nubian) plates. The geothermal sources have been used for power production since 1980, at the Ribeira Grande Geothermal Field (RGGF) in S. Miguel island, and since 2017 at the Pico Alto Geothermal Field (PAGF) in Terceira Island.

In spite of some minor environmental impacts, the last years were extremely relevant for geothermal in the Azores (Carvalho et al., 2013, Carvalho et al., 2015, Nunes et al., 2016), as:

- The total generation capacity installed at the RGGF was expanded from the previous 14.8 MW, mainly concentrated at the Ribeira Grande plant, to a total capacity of 27.8 MW, including the Pico Vermelho plant;
- The development of geothermal resources on the island of S. Miguel has been well succeeded, with an annual average contribution of around 42% of the electricity produced in the island since 2013;
- The total generation capacity of the Pico Alto pilot power plant is 4 MW Pico , following the evaluation tests carried out during 2013/2014, but is not still saturated with the existing production wells in the Pico Alto Geothermal Field (PAGF).

Geothermal gained a renovated interest and assumes a leading position in the renewable energy portfolio of the island of S. Miguel and Terceira. In the scope of renewable energies utilization expansion in Azores, the regional government considers geothermal as a main player for the development of new projects for electricity generation.

The expansion of the installed capacity at the RGGF (S. Miguel island) is already scheduled to increase the geothermal penetration on the market: more wells are to be drilled in 2020, to increase the total running capacity up to 30 MWe. Also, more wells are planned to be drilled in 2020 in the PAGF as back-up wells to the existing power plant, and if possible to increase the installed capacity in Terceira island.

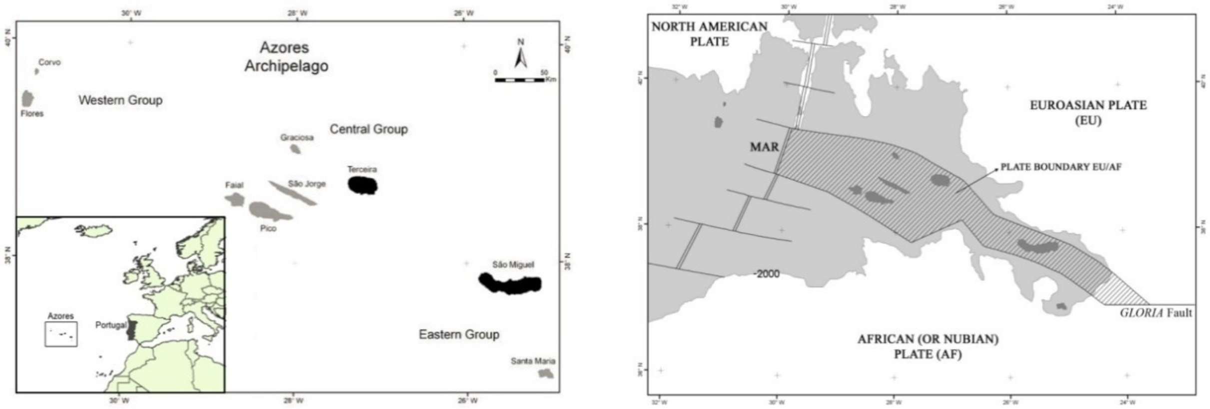

Figure 1: Location of Portugal Mainland, the Azores Archipelago and S. Miguel and Terceira Islands (left) and the Azores Triple Junction area (right). MAR: Mid Atlantic Ridge. Shaded area represents the "Azores Plateau" (adapted from Nunes et al., 2008).

The geothermal policy in Azores issued by the Azores Government is developed in the field by the regional electric utility EDA – Electricidade dos Açores S.A., through its affiliated company EDA RENOVÁVEIS S.A. (a joint of formers SOGEO - Sociedade Geotérmica dos Açores S.A. and GEOTERCEIRA - Sociedade Geoeléctrica da Terceira S.A. companies).

Considering the high generation costs using fossil fuels, geothermal is a competitive source of energy, providing significant running savings to EDA S.A..

The low enthalpy geothermal resources, in Portugal, can be found in the Azores Archipelago, in the dependency of the high enthalpy resources, and in Mainland (Figure 2).

In Mainland, at present, and besides a few district heating operations at existing Bath Spa's, there are no direct use projects of the low enthalpy resources running based in deep wells, and it is not envisaged the oncoming of new operations based in deep wells.

Portugal like the other Mediterranean countries has more leveled heating and cooling needs than Nordic countries. As a consequence, in Portugal GSHP's are usually reversible, producing heat and cooling. The equilibrium between heating and cooling in a dwelling is important in order to maintain the temperature stability of ground along the years.

In the residential sector, heating needs are higher than cooling needs, what can lead to the ground temperature decrease. However that problem is smaller than in northern and central European countries. Commercial buildings can have more cooling needs, function of the activity developed in the building, so special attention has to be paid to geothermal borehole heat exchangers (BHE) design to avoid the ground temperature increase.

The Portuguese government is developing a national plan to demonstrate the feasibility of using natural mineral water in existing spa as geothermal resources for heating purposes. A consortium SYNEGE/ EST (IPS) is running the Project to be carried out in Mainland and Azores.

2. GEOLOGY AND HYDROGEOLOGY BACKGROUND

Geology and hydrogeology controls the occurrence of geothermal resources, so a general description of these conditions is provided below, following a previous update report (e.g. Carvalho et al., 2015).

2.1 Mainland

In Mainland Portugal, classical geothermal resources are generally associated to the following origins: i) thermo-mineral waters related to active faulting and diapirism; and ii) deep circulation in some peculiar structures in the basement and particularly in the sedimentary borders trough permeable formations.

The main geothermal resources occur in the Hesperian (or Iberian) Massif, which is the most extensive segment of the Hercynian basement in Europe (Ribeiro et al., 1979). The Hesperian Massif consists of pre Mesozoic formations, essentially metasediments and plutonic rocks, mainly granites (Figure 2). The majority of the sources are located in the Central Iberian Zone (Julivert et al., 1972), close to the active faults of NNE-SSW trend (Figure 2). Ribeiro & Almeida (1981) pointed out that the occurrence of hot waters is related to zones of uplift during the Quaternary (the vertical movement was about 500m in the northern part and between 100 and 300 m in the south of Portugal) and they propose a mechanism of seismic pumping to explain the ascension of hot fluids to the surface. Although in the field the distance between the sources and the megafractures can sometimes reach many kilometers, detailed hydrogeological studies have revealed the presence of transverse secondary fault, ENE-WSW sub vertical fracture systems intersect (Calado, 1991).

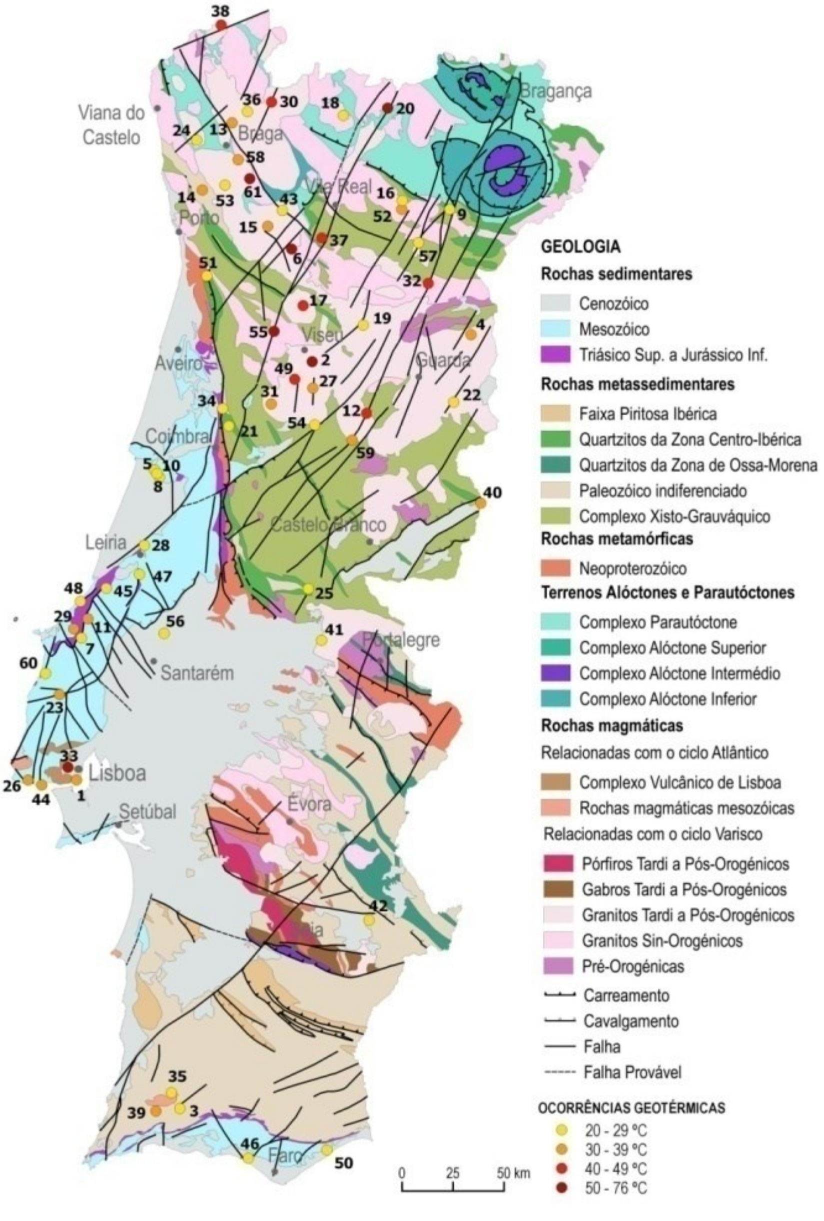

Figure 2: Geological map of Portugal Mainland and thermal occurrences (in: DGEG, 2017).

Naturally available discharging flows from former exploitation systems reached a maximum of 10 L/s. New wells up to 1,000 m depth, drilled after the seventies of the past century, allowed moderate improvements in sustainable production and in temperature (Carvalho, 2006).

Regarding chemistry, the following groups could be considered at the Central Iberian Zone: (i) hypo-saline waters with total dissolved solids (TDS) less than 150 ppm, and frequently under 50 ppm, associated to quartzite reservoirs; (ii) sulphurous waters with up to

1,000 ppm and temperatures up to 62 ºC; and (iii) carbonated sparkling waters with TDS up to 2500 ppm and temperatures up to 76 ºC (Calado 1991, 1995, 2001 and Carvalho 1996a).

In the Mainland sedimentary borders have been identified low enthalpy geothermal sources:

- western border with sediments with thickness up to 4,000 m, present several thermal waters related to deep faulting and diapiric tectonics; water with temperature of 35 ºC, of sodium-chloride type and, some sulfurous, are used for balneotherapy porposes;

- in the Tejo and Sado basins temperatures of 75ºC was estimated for Jurassic limestone, at 2,500 m and with 5,000 ppm TDS water (Carvalho et al., 1990 and ACAVACO 1998);

- in the Lisbon region cretaceous formations are known as reservoir of thermal water, that have been historically exploited (since Romans occupation) for balneological purposes, with springs water up to 40 ºC and a 1,500 m deep well with 53ºC - bottom hole temperature (BHT); the waters show Cl-Na facies and 500 mg/l (Carvalho 1996b and Carvalho et al 2005).

The existing temperatures restrain the utilization to direct uses. Twenty-four springs are officially used in balneotherapy having discharge temperatures between 25 ºC and 76 ºC (Figure 2).The common range of values obtained by the more appropriate geothermometers gives temperatures between 70 °C and 130 °C (Calado, 1991, Calado, 1995). The higher geothermal gradient is about 3.5ºC/100 m (IGM, 1998) or 2.68 ºC/100m according to the on-line information in portal LNEG (Figure 3). Normal gradients are in the range of 2.1ºC/100 m (Ribeiro and Almeida, 1981), that means average BHT of c.a. 50ºC at 1,500 m depth.

According to Correia et al. (2002, 2015 and LNEG) the regional heat flow density (HFD) is about 60-90 mW/m^2 in the Central Iberian Zone and 40-90 mW/m^2 in the sedimentary basins (Figure 3).

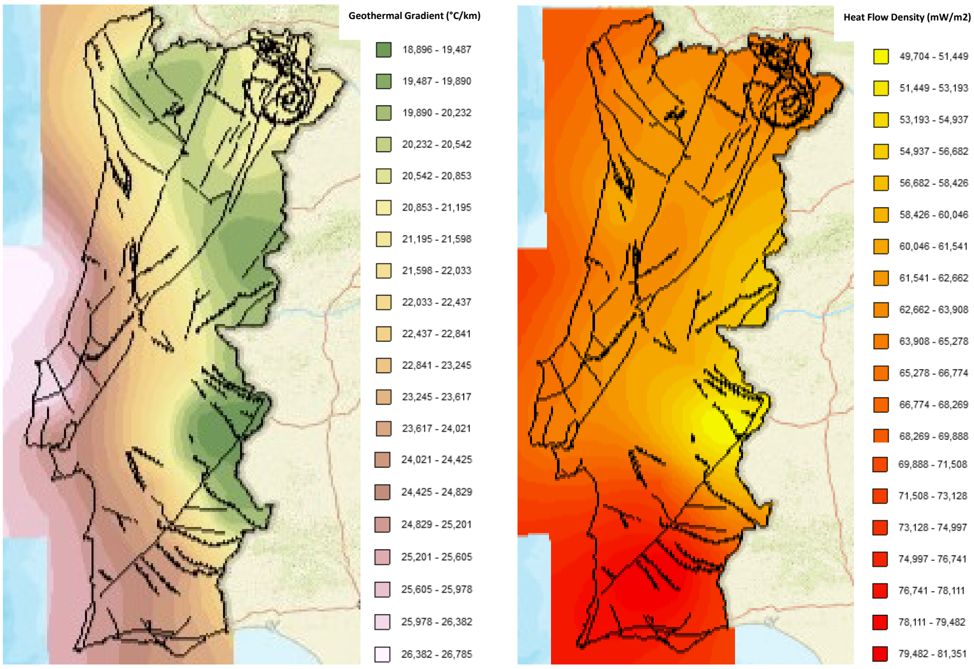

Figure 3: Geothermal gradient and heat flow density in Portugal Mainland (http://geoportal.lneg.pt/).

2.2 Azores Islands

The nine islands that form the archipelago of Azores are spread over 600 km in the Atlantic Ocean, along a WNW-ESE trend and emerge from the designated "Azores Plateau" (Figure 1), which is defined by the bathymetric line of 2,000 m. Being situated at the junction of the North American, Eurasian and African tectonic plates, the Azores display an intense seismic and volcanic activity. Since discovery and settlement of the islands, in early 15th century, 26 eruptions were recorded inland and onshore. Volcanic and seismotectonic activity are more concentrated in the Central Group and in the S. Miguel islands, those at the plate boundary between the Eurasian and African plates (cf. Figure 1).

On the island of S. Miguel, there are three active polygenetic volcanoes with caldera that produced mostly explosive trachytic *s.l.* eruptions in recent times: Sete Cidades, Furnas and Fogo/Água de Pau volcanoes. A fourth silicic polygenetic volcano with caldera (e.g. Povoação volcano) and two Basaltic Fissural Areas (e.g. the Picos and Nordeste Complexes) complete the volcanic systems of S. Miguel island (Figure 4).

The Ribeira Grande Geothermal Field is located on the northern slopes of the Fogo central volcano (Figure 5) and this liquid-dominated high enthalpy system reaches maximum temperatures of about 245ºC in depth.

Surface geothermal manifestations are spread on those three active central volcanoes of S. Miguel Island, which are particularly impressive at Furnas volcano caldera, with the presence of about 30 thermal springs and fumaroles.

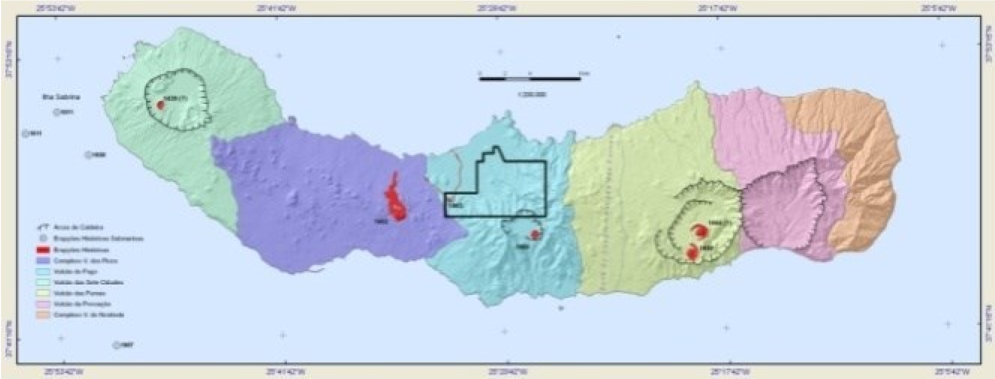

Figure 4: Volcanological map of S. Miguel Island (Nunes, 2004). The RGGF concession area is outlined.

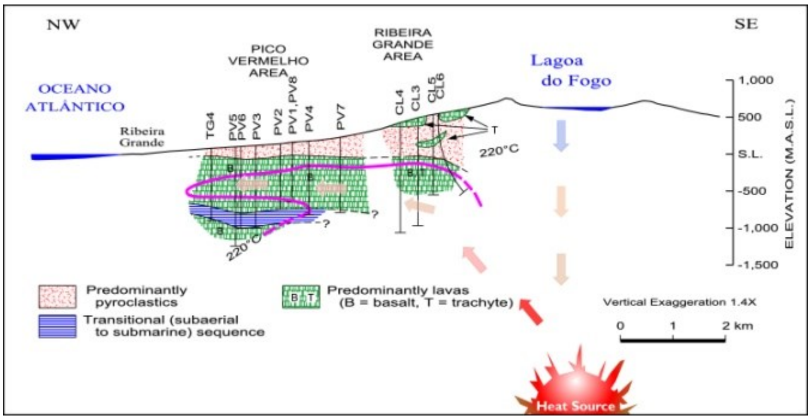

Figure 5: Generalized cross section of the Ribeira Grande geothermal system (adapted from GeothermEx, 2008).

On Terceira Island (Figure 6), which has a complex tectonic setting, there are four central volcanoes with caldera (Cinco Picos, Guilherme Moniz, Santa Bárbara and Pico Alto – in decreasing age sequence) and the Fissural Basaltic Zone, in the central and SE part of the island (Nunes, 2000). The Pico Alto volcano (the younger polygenetic volcano) is dominated by silicious formations of pyroclasts, domes and *coulées* of trachytic and pantelleritic nature.

At surface, the Pico Alto Geothermal Field encompasses mostly Pico Alto volcano and the Fissural Basaltic Zone formations (Figure 5), but the geothermal systems develops on a complex volcanological setting, that encompasses the interference of the Pico Alto (PA), Guilherme Moniz (GM) and even Santa Bárbara central volcanoes formations (Figure 7). This high enthalpy system reaches temperatures of about 300ºC in depth.

Surface geothermal manifestations are reported in all islands but Corvo and Santa Maria islands. Presently four Thermal Baths/Spas using geothermal resources are installed in S. Miguel and Graciosa islands. In addition, the Caldeira Velha, Poça da Dona Beija and Parque Terra Nostra (S. Miguel Island) are also thermal attractions as well-being facilities.

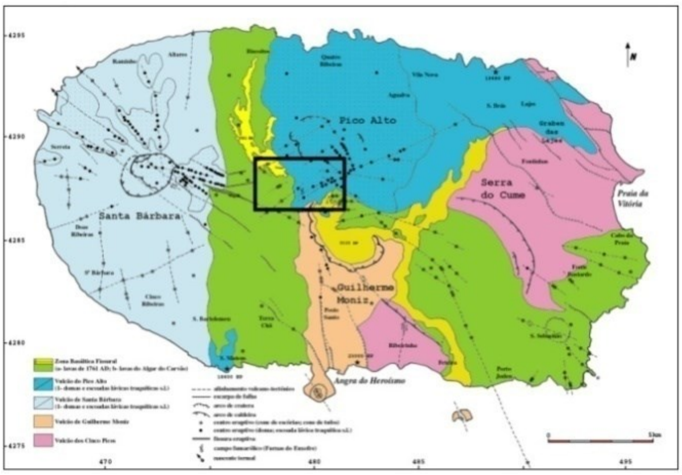

Figure 6: Volcanological map of Terceira Island (Nunes, 2000). The PAGF concession area is outlined.

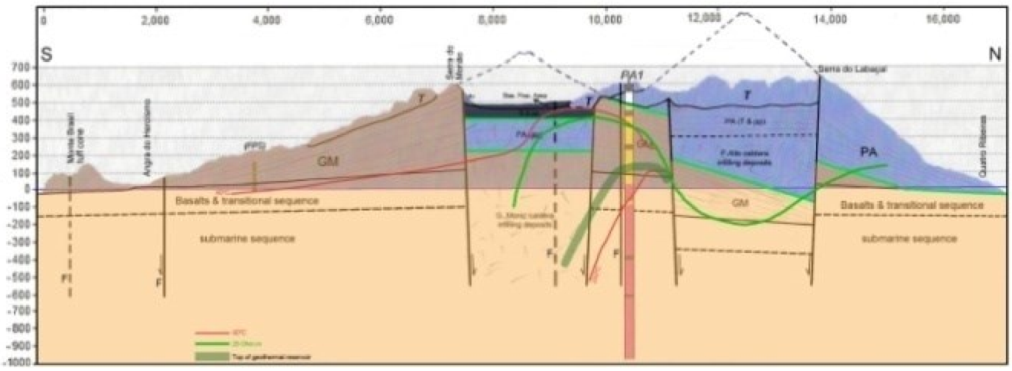

Figure 7: General N-S cross section of Terceira Island, including the Pico Alto Volcano (PA) geothermal area (adapted from TARH & ÍSOR, 2016).

3. GEOTHERMAL UTILIZATION

Geothermal energy in Portugal is used for electricity production, for direct use associated with thermal baths/Spas and in Ground Source Heat Pumps. The Standard Tables 1 to 8 at the end of the paper present a characterization of the geothermal uses in Portugal as of 30 June 2019.

3.1 Electric Power Installation and Generation

At the Ribeira Grande Geothermal Field, S. Miguel Island, two geothermal power plants – Ribeira Grande and Pico Vermelho – are in operation with a net combined installed capacity of 27.8 MW (Table B). Both plants are based on ORC binary systems.

The Ribeira Grande plant consists of four dual turbo-generators developed in two phases: Phase A (2 x 2.9 MW) installed in March 1994, and Phase B (2 x 4.5 MW) completed in November 1998. The 13 MW Pico Vermelho plant started operating in November 2006 and replaced the former 3 MW pilot unit, in operation since 1980. All the geothermal brines resulting from the operation of these two geothermal power plants are re-injected.

Following the 2013/2014 campaign of short and long term tests performed on existing production wells at the Pico Alto Geothermal Field (Terceira Island), a 4 MW geothermal pilot power plant was installed in the central part of the island (Table B), in the Pico Alto volcano and close to the fumarolic field of Furnas do Enxofre. This power plant started in operation in August 2017 and was officially inaugurated in November 2017.

Simultaneously, extensive geological, hydrogeological, geochemical and geophysical exploration campaigns, under the coordination of TARH, Lda., were carried out in 2013/2014 aiming to improve the knowledge on the area and also to allow the delineation of a comprehensive conceptual model for the PAGF. This conceptual model was considered by EDA RENOVÁVEIS S.A. a management tool to reevaluate the geothermal resource and to design and locate new wells (TARH & ISOR, 2016), which will be drilled in 2020.

Nowadays no direct uses related with the geothermal brines are in operation in the Azores Islands.

3.2 Direct Heat Uses

Direct use application in Mainland and Azores is restricted to small district heating operations and mainly balneological applications. The situation was reported recently, namely by Carvalho et al. (2013), Carvalho et al. (2015), Lourenço (2016), Nunes et al. (2015) and DGEG (2017), and no significant changes are to be mentioned.

3.2.1 District Heating

Two main operations are running normally in thermal baths:

- Chaves, Northern Portugal: a dedicated well, 150 m deep, 76 ºC, TDS of 2500 mg/L, 5 L/s capacity, in metamorphic slates with quartz veins, is used in a small district heating network (swimming-pool and hotel). Another well (208 m deep, 74 ºC, TDS of 2500 mg/L, 10 L/s capacity), taped hot water in metamorphic slates with quartz veins and feeds the Thermal Bath as well the district heating network. A third well (100m deep, 68ºC) is maintained as a backup well..

- S. Pedro do Sul, central Portugal, the main Portuguese Spa: one inclined well, 500 m deep, 69 ºC, 350 mg/L TDS, 10 L/s with artesian flow, in fractured granite, supply the Thermal Bath and is in use in a small heating operation, financed by the THERMIE Program, in two hotels and inside the Spa. The total available production (former classical spring and well AC1) is 17 l/s.

Several minor district heating operations are running in Caldas de Monção, Termas da Longroiva and Alcafache in Mainland and at Furnas hotels, in S. Miguel (Azores archipelago).

3.2.2 Bathing and Swimming

Balneological activities using thermo-mineral waters are quite popular in Portugal for cure and touristic purposes. About 30 Thermal Baths are operating within a legal framework (cf. DGEG, 2017). Most are open only in summer, but some of them are operating normally all over the year. All the balneological activity inside the baths is carried out under strict medical control.

Since 2004 the INOVA Institute and the Azores Government undertake several initiatives and studies allowing the exploitation and valuing of the Azorean low temperature geothermal resources for direct use, including touristic activities and balneology (e.g. Nunes et al., 2015). Associated with these activities new shallow wells were carried out in Ferraria (S. Miguel), Varadouro (Faial) and Carapacho (Graciosa).

3.3 Ground Source Heat Pumps

According to the last data recorded by EHPA, European Heat Pump Association, there were no new sales of GSHP in Portugal in 2014. The aggregated sales until 2014 was about 54 units with an installed capacity of 0.65 MW. Considering typical values, the averaged installed capacity was 12 kW, with an operating hours value of 1,340 and a typical Seasonal Performance Factor (SPF) of 3.425. For the years after 2014, it was not possible to obtain data. It is difficult to follow the evolution of new projects concerning GSHP, since Portugal still doesn´t have legislation to oblige the registration of this kind of project, especially concerning the residential sector. It is possible that a greater number of small installations are performed each year, but are not registered.

With a view to increase the knowledge in this area and inherently to promote the dissemination and proper use of GSHP, four national entities (DGEG, LNEG, APG and ADENE) established a collaboration protocol concerning the creation of a baseline study, analysis and dissemination of geothermal use through GSHP. The Portuguese Platform of Shallow Geothermal Energy (PPGS) was created in 2013 with the mission to disseminate the best practices involving GSHP, to promote the dialogue on geothermal community, to collaborate on new legislation, spread knowledge of technical standards and procedures, contributing to the training of the agents involved and to promote the development of new projects. However due to the weak interest in the application of shallow geothermal energy in Portugal, this platform ended its activity in 2017.

One of the gaps in Portugal for the development of shallow geothermal energy is the lack of a legal framework.

A new legislative framework concerning shallow geothermal purposes began to be prepared about 5 years ago and only at the end of last year did it pass to the Portuguese parliament to be approved. It is expected that during the year 2019 this legislative framework to enter in force. This legislative framework imposes the obligation to register the installed GSHPs. So, it is expected to have statistical data of new installations in the near future.

In spite of the lack of registration, there is some information about GSHP projects developed in Portugal that are presented below (see also Carvalho et al., 2013, Edifícios e Energia, 2013, Cardoso & Lapa, 2015a; 2015b, Ferreira, 2019):

- Brigantia Ecopark in Bragança: it is equipped with three GSHP, one just for domestic hot water (DHW) heating and two for the building acclimatization. To dissipate the heat generated by the GSHP 45 boreholes, with a depth of 120 m, were performed. Regarding GSHP for DHW, only heat is produced and the system is interconnected with DHW reservoir. Concerning the other two GSHP, for acclimatization, heat and cool is produced and the system is connected to a buffer tank of 9,000 L. When the tanks are full, the excess of heated/cooled water is dissipated into the boreholes heat exchangers. Under this building there is a set of tubes to serve as an air inflow pre-heating to reduce energy consumption, thereby improving the system efficiency;

- Aveiro University (ECORR, ESAN, CCI, CICFANO and ESSUA buildings): Aveiro university has 5 buildings acclimatized with GSHP. Table 1 resumes the main properties of the installation;

- Superior School of Technology of Setúbal (EST Setúbal): the Polytechnic Institute of Setubal, that was a partner in GROUNDHIT European Project (6th Framework Program), has a demonstration site for high energy efficiency GSHP's. Two GSHP's of 15 KWt for heating and 12 KWt for cooling, each, were installed in the thermodynamics laboratory, to acclimatize 7 office rooms with areas between 13 and 17 m^2 and 2 classrooms with 63 and 65 m^2. The project aimed at monitoring the prototype of improved energy efficiency heat pumps (COP higher than 5.5) in real conditions in a Mediterranean climate, and test two different Boreholes Heat Exchangers (BHE) types: double-U pipes and coaxial pipes. The demo site results showed that the GSHP's COP is according to the expected ones during the design phase (COP of 5.19 for cooling and 6.05 for heating in real conditions), with a good performance in the terminal units (fan-coils, secondary circuit), boreholes (primary circuit) and GSHP;

- Regional authority administration building in Coimbra: the second example is another European project (7th Framework Program) called GROUNDMED, that aims at verifying sustainability of heat pump technology for heating and cooling of buildings in a Mediterranean climate. The Portuguese GROUNDMED installation is set on a regional authority administration building with offices and laboratories, located in Coimbra city. One GSHP with a heating capacity of 56 kWt and cooling capacity of 61 kWt (Eurovent conditions) serves the building 3rd floor offices. The GSHP is coupled to seven double U, 125 m vertical borehole heat exchangers. The heating/cooling distribution system consists of 33 ceiling Coanda effect fan coil units with high efficiency permanent magnet EC motors, installed in 22 offices, with a total area of 600 m2. Since all systems were designed to function with moderated temperatures the real cooling capacity is 63.5 kWt and the real heating capacity is 70.4 kWt, resulting in an increased performance. The results showed good results with a GSHP COP of 5.65 and an EER of 6.19;

- Sines Tecnopolo: this complex, that includes heating, cooling and domestic hot water production, has an existing renewed building with 251 m2, a laboratory building with 534 m2 and an office building with 1,286 m2, all served by GSHP's. The existing renewed building is served by one GSHP with a heating capacity of 24.5 kWt and cooling capacity of 18.4 kWt, coupled to 2 simple U, 150 m vertical borehole heat exchangers;

- Aveiro University has been also collaborating with "Chama Energia" company in other projects as listed in Table 2;

- Ombria Resort, Algarve: This resort includes one golf course, the club house, one hotel, one Spa and some villas. This is the largest installation of shallow geothermal energy in Portugal. At the moment it is in the final phase of the installation, being completed this year. The total needed capacity based in GSHP is about 2370 kW of heating and 1100 kW of cooling. The club house has an area of 1,260 m2 and the hotel, spa and villas have an area of 15,940 m2. For the club house were installed 40 BHE with 100 m depth each, for the hotel were installed 60 BHE with 125 m depth each and for the spa and villas, 144 BHE with 115 m depth each. Solar collectors (vacuum type) for DHW, hot water for the swimming pools and also to inject heat in the ground trough the BHE to equilibrate the balance of energy injected and extracted by the GSHP along the year, were installed. A total of 108 solar collectors were installed for the club house, and 48 solar collectors for the hotel.

4. CONCLUSIONS

In Portugal, the presence of high temperature geothermal resources and the production of electricity from geothermal resources are restricted to the volcanic islands of Azores Archipelago.

Presently EDA RENOVÁVEIS S.A. has a total installed generation capacity in S. Miguel Island Azores of 27.8 MW net in two geothermal power plants. Those power plants ensured the production in 2018 of 183.6 GWh_e in S. Miguel Island, that represents 42% of the electrical consumption of the island, and 23.1% of the total demand of the archipelago. Power production is stabilized since 2013 and new wells are expected to be drilled in 2020 to increase the total running capacity of the Ribeira Grande and Pico Vermelho power plants up to 30 MW.

On Terceira Island, the 4 MW Pico Alto pilot power plant (that started operating in August 2017) ensured the production in 2018 of 20.6 GWh_e, that represents 10.8% of the electrical consumption of the island, and 2.6% of the total demand of the archipelago.

Low-temperature geothermal resources in Mainland Portugal are exploited for direct uses in balneotherapy and small district heating systems.

Concerning GSHP's the potential is huge and is starting to be exploited, with new projects ongoing and new regulations is expected to be approved this year 2019. There are a few installations registered until 2014, but the registration data of the installations are scarce and do not represent the totality of what is installed in Portugal. However this tends to change due to the preparation of new legislation for regulating shallow geothermal operations.

The Ombria Resort installation, the largest shallow geothermal energy in Portugal will be completed during 2019 and could be an interesting case study about the use of this renewable energy source to promote and disseminate this technology in Portugal

In fact, a new legislation draft on GSHP's was already prepared by the Directorate General for Energy and Geology (DGEG) – the Portuguese authority for geological resources – that will contribute not only to ameliorate the quality of the operations, but also to allow future statistical data to be more realistic.

In addition, in 2018 it was released a call for geothermal projects, sponsored by the FAI – "Fundo de Apoio à Inovação", to promote the use of geothermal resources in Portugal, namely the low enthalpy resources associated with Thermal Baths/Spas facilities. For the time being, two district heating networks for hotels and public buildings were retained for funding: (i) S. Pedro do Sul (67ºC, 17 L/s) with a proposed 5 km network, and (ii) Chaves (74ºC, 15 L/s) with 3 km extension; field work will be performed in 2019/2020.

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APPENDIX – STANDARD TABLES

Table 1: Present and planned production of electricity.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind and photovoltaic)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2017	26	217		38 344		7 632	0	0		13 240		59 432
Under construction in December 2019	0	0					0	0				
Funds committed, but not yet under construction in December 2019	10		not available	not available	not available	not available	0	0	not available	not available	not available	not available
Estimated total projected use by 2020	26	217	not available	not available	not available	not available	0	0	not available	not available		not available

Table 2: Utilization of geothermal energy for electric power generation as of 31 December 2019.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe[3)]	Total Running Capacity MWe[4)]	Annual Energy Produced 2018 GWh/yr	Total under Constr. or Planned MWe
Ribeira Grande S Miguel Island	Ribeira Grande (Phase A)	1994	2		B	6	5	15.7	3
Ribeira Grande S. Miguel Island	Ribeira Grande (Phase B)	1998	2		B	9	5	78.3	3
Ribeira Grande S Miguel Island	Pico Vermelho	2006	1		B	13.5	13	101.4	0
Pico Alto Terceira Island	Pico Alto	2017	1		B	4.5	3	21	3
Total						**33**	**26**	**216**	**9**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.
2) B = Binary (Rankine Cycle)
3) Electrical installed capacity in 2019
4) Electrical capacity actually up and running in 2019

Table 3: Utilization of geothermal energy for direct heat as of 31 December 2019 (other than heat pumps).

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Monção	B +D	12,5	49,0	20,0			1,52	8,00	30,6	0,64
Chaves	B+D	15,0	74,0	20,0			3,39	10,00	71,2	0,66
Caldelas	B	7,5	30,3	20,0			0,32	4,50	6,1	0,60
Gerês	B	0,9	47,0	20,0			0,10	0,80	2,8	0,88
Taipas	B	2,0	29,0	20,0			0,08	2,00	2,4	0,99
Caldas da Saúde	B	4,0	30,0	20,0			0,17	3,00	4,0	0,75
Carlão	B	0,4	27,5	20,0			0,01	0,37	0,4	0,99
Aregos	B	4,0	63,0	20,0			0,72	4,00	22,7	0,99
Carvalhal	B	6,9	60,0	20,0			1,15	0,30	1,6	0,04
Cavaca	B	5,0	29,0	20,0			0,19	1,00	1,2	0,20
São Pedro do Sul	B+D+G	19,4	67,0	20,0			3,81	15,40	95,5	0,79
Alcafache	B+D	6,0	51,0	20,0			0,78	4,00	16,4	0,66
Sangemil	B	6,5	40,0	20,0			0,54	4,00	10,6	0,61
Felgueira	B	9,2	36,0	20,0			0,62	4,00	8,4	0,43
Luso	B	10,5	24,9	20,0			0,22	2,00	1,3	0,19
Manteigas	B	4,0	47,0	20,0			0,45	3,00	10,7	0,75
Unhais da Serra	B	7,2	37,0	20,0			0,51	5,00	11,2	0,69
Monfortinho	B	36,0	31,0	20,0			1,66	4,00	5,8	0,11
Vimeiro	B	29,0	24,5	20,0			0,55	2,00	1,2	0,07
Monchique	B	10,4	32,0	20,0			0,52	3,00	4,7	0,29
Longroiva	B+D	6,3	47,0	20,0			0,71	2,50	8,9	0,39
Azores Islands										
Caldeiras R.Grande	B	1,0	90,0	20,0			0,29	1,00	9,2	0,99
(Graciosa)	B	2,5	37,6	20,0			0,18	2,50	5,8	0,99
Ferraria	B	10,0	62,1	20,0			1,76	10,00	55,5	0,99
TOTAL							20,2		388,2	0,5

1) B = Bathing and swimming (including balneology); D = District heating (other than heat pumps); G = Greenhouse and soil heating

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171

Table 4: Geothermal (ground-source) heat pumps as of 31 December 2019.

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used[5)] (TJ/yr)	Cooling Energy[6)] (TJ/yr)
not available								
TOTAL	12 to 18	18	90	V/H		1340	0,0022	0,0007

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

Table 5: Summary table of geothermal direct heat uses as of 31 December 2019.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]		95,300	
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	20,20	292,900	
Other Uses (specify)			
Subtotal	20,20	388,200	
Geothermal Heat Pumps	1,62	0,003	
TOTAL	21,82	388,203	0,5

4) Other than heat pumps
7) Includes balneology

Table 6: Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2015 to December, 31 2019 (excluding heat pump wells).

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total		0	0	0	0	0

Table 7: Allocation of professional personnel to geothermal activities (restricted to personnel with University degrees).

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	2	19	9	5		1
2016	3	20	9	3		3
2017	3	20	9	3		3
2018	3	20	9	3		2
2019	3	20	9	3		2
Total	**14**	**99**	**45**	**17**		**11**

Table 8: Total investments in geothermal in 2019 (US$).

Period	Research & Development Incl. Million US$	Field Development Including Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1995-1999						
2000-2004	2.5	6.4	0.25	8.5	50	50
2005-2009	8.5	71.4			90	10
2010-2014	1	6.9			50	50
2015-2019	1	7.0		4.5	50	50