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Portugal Country Update 2015

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ABSTRACT

In Portugal, the presence of high temperature geothermal resources is restricted to the volcanic islands of Azores Archipelago, which are located at the triple junction of the North American, Eurasian and African (or Nubian) plates.

Present investment projects at the Ribeira Grande Geothermal Field on S. Miguel Island, implemented by EDA RENOVÁVEIS, S.A. (former SOGEO, S.A.), led to the installed generation capacity in Azores to a total of 23 MWe net, with the contribution of two power plants. Thus, power production from geothermal resources in Azores presently meets 42% of the electrical consumption of S. Miguel, and over 22% of the total demand of the archipelago.

On Terceira Island, deep exploratory drilling at the Pico Alto Geothermal Field during 2003-2010 conducted to a maximum reservoir temperature of 312ºC. New short and long term tests were performed in 2013-2014 to evaluate the production capacity of the existing evaluation-production wells. The well tests pointed out the capacity to support a 2.5-3.0 MWe pilot power plant.

Geothermal is expected to assume an even more impressive role for electric power self-sufficiency of this Autonomous Region of Portugal, particularly n S. Miguel and Terceira Islands. However, its development is now considered in conjunction with other renewable energy sources, particularly wind energy.

Low-temperature resources in Mainland Portugal are exploited for direct uses in balneotherapy and small heating systems and shallow geothermal with heat pumps is gaining increasing importance. At present, new regulations for shallow geothermal purposes are being prepared to regulate the new installations and to avoid bad practices. These regulations will also include the obligation to register all new GSHP's installations in order to get more realistic statistical data on the new installations.

After the aborted intention in 2008, when private investors obtained concession rights for exploration of geothermal EGS resources for a total area of 2,655 km^2, no activity is presently reported in this field.

1. INTRODUCTION

In Portugal geothermal resources occur in the Mainland and in the volcanic islands of the Azores and Madeira Archipelagos.

The geothermal energy in Portugal is used for electricity production, direct use in thermal baths/spas and greenhouses, and in ground source heat pumps. The importance of geothermal energy in the Portuguese country for electrical production is negligible (less than 0.4%)

The known high temperature geothermal resources are limited to the Azores Islands, where have been used for power production since 1980, at the Ribeira Grande geothermal field. In spite of some minor environmental impacts, the last years were extremely relevant for geothermal in the Azores, as:

- A total capacity of 23 MWe is installed at the Ribeira Grande geothermal field, concentrated at two power plants owned by EDA RENOVÁVEIS, S.A.;

- The development of geothermal generation projects on the island of S. Miguel has been well succeeded, with an annual average contribution of approximately 42% of the electricity produced in the island.

- A favorable decision regarding the installation of a pilot power plant (2.5 to 3.0 MWe) at the Pico Alto Geothermal Field in Terceira Island, was taken by GEOTERCEIRA - Sociedade Geoeléctrica da Terceira, S.A in April 2014, a first and decisive step towards the development of a successful project in the island.

Based on this scenario, geothermal gained a renovated interest and assumes a leading position in the renewable energy portfolio of the island of S. Miguel. In the scope of renewable energies utilization expansion in Azores, the Regional Government considered geothermal as a main player for the development of new projects for electricity generation. The expansion of the installed capacity at the Ribeira Grande field is under evaluation to increase the geothermal penetration on the market.

The geothermal policy in Azores established by the Azores Government is implemented in the field by the regional electric utility EDA – Electricidade dos Açores, S.A., through its affiliated companies EDA RENOVÁVEIS, S.A. (ex SOGEO) and GEOTERCEIRA - Sociedade Geoeléctrica da Terceira, S.A., which concentrate the local effort in the development of generation projects in the archipelago. Considering the high generation costs using fossil fuels, geothermal is a competitive source of energy, providing significant running savings to EDA, S.A.

In Mainland, at present, there are no new direct use projects running, outside a few existing bath spas, 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.

2. GEOLOGICAL AND GEOTHERMAL BACKGROUND

Mainland Portugal, the Azores Archipelago and Madeira and Porto Santo Islands (Figure 1) are located a few thousand km apart and have different and critical geological, hydrogeological and geothermal settings as described below.

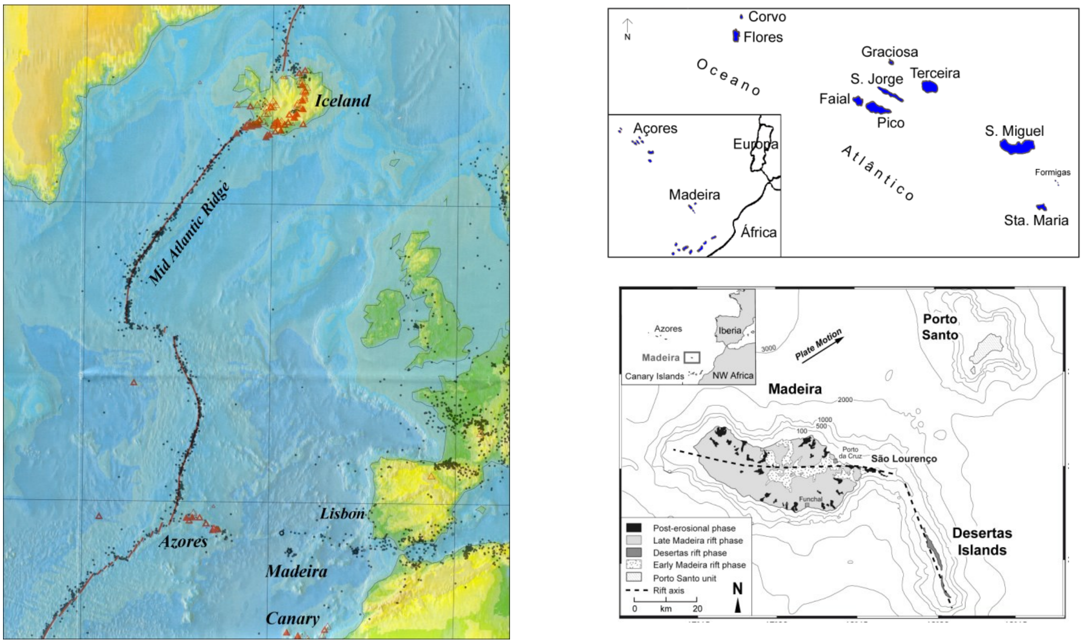

Figure 1: Location of Mainland Portugal, Azores Islands and Madeira and Porto Santo islands in the North Atlantic Ocean.

2.1 Azores Archipelago

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 2), 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, more concentrated in the Central Group and in S. Miguel islands, close to the plate boundary between the Eurasian and African plates.

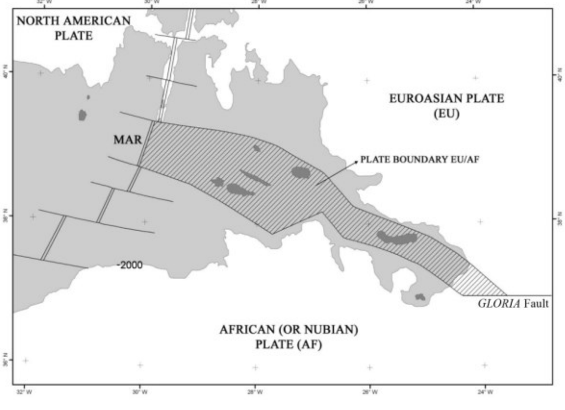

Figure 2: The Azores Triple Junction area. MAR: Mid Atlantic Ridge. Shaded area represents the “Azores Plateau”, defined by the -2000m bathymetric line (adapted from Nunes et al., 2008)

Surface geothermal manifestations are reported in all islands but Corvo and Santa Maria islands. Five thermal baths/spas using geothermal resources are installed in S. Miguel, Faial and Graciosa islands. In addition, the Caldeira Velha and Poça da D. Beija (in S. Miguel Island) are also thermal attractions as well-being facilities.

On the island of S. Miguel, there are three active polygenetic volcanoes with calderas that produced explosive trachytic eruptions: Sete Cidades, Furnas and Fogo/Água de Pau. On the northern slopes of the Fogo volcano is located the Ribeira Grande Geothermal Field. The last event on that central volcano was a plinian eruption that took place in 1563 AD. Surface geothermal manifestations are spread out in all three volcanoes, which are particularly impressive at Furnas with the presence of numerous thermal springs and fumaroles.

On Terceira Island, which has a complex tectonic setting, there are four central volcanoes with calderas (Cinco Picos, Guilherme Moniz, Santa Bárbara and Pico Alto – in chronologic order) 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 and mostly as domes and coulées of trachytic and pantelleritic nature.

The presence of geothermal resources is associated to the active volcanism of the archipelago. Although extensive developments have been made at Pico Alto (Terceira island), the Ribeira Grande field in S. Miguel island is the only high-temperature field under exploitation.

The Ribeira Grande conceptual model has been described by GeothermEx (1996), Cabeças and Henneberger (2001) and later updated by SOGEO and GeothermEx (2008). The Ribeira Grande geothermal field is an extensive water dominated system located on the northern flank of the Fogo polygenetic volcano, and elongated in a northwestern direction, which is related to a major NW-SE trending pattern of faulting originated by the regional tectonic stress regime. However, the field boundaries are not sufficiently delineated considering that drilling has been concentrated mainly in two sectors of the Ribeira Grande field.

The present geothermal model considers that an up flow of geothermal fluid enters in the reservoir in the southern area, at more than 250ºC, and moves to northwest in an extensive zone of several hundred meters thick, in which temperatures exceed 220ºC. The geothermal water is sodium-chloride type, with TDS of about 6-7 g/l. Hydrogeochemical and isotopic studies determined a meteoric origin for the geothermal fluid (Forjaz, 1994, Carvalho, 1999).

On Terceira Island, following the previous exploration studies that included a geoelectric survey and two temperature gradient drilling campaigns, deep exploratory drilling and well testing was carried out at the Pico Alto field during 2009-2010. The results indicated the presence of deep temperatures in the range of 250-300ºC but the occurrence of a geothermal reservoir was not proved at the time. Further, short and long-term well testing (six month) and other exploration and evaluation activities (including detailed geological mapping, CO_2 and Radon surveys, microgravimetric studies and geochemical investigations) were done and concluded in 2014 by GEOTERCEIRA for the resource characterization.

2.2 Madeira Archipelago

The Madeira Archipelago is formed by two inhabited islands (Madeira and Porto Santo) and two sets of uninhabited islets (Desertas and Selvagens).

These volcanic islands are located in the African plate, bounded on the west by the Mid Atlantic Ridge, on the north by the complex structure Azores-Gibraltar and on the southeast by the West African Craton. The islands edification is attributed to the activity of a mantle plume (Mata et al 2013).

Surface geothermal manifestations are not reported but two road tunnels in Madeira Island have intersected fractures filled by groundwater at 30ºC and dissolved CO_2 higher than 2 g/l (Fonseca et al., 2000). These waters can be interpreted as being associated to a possible active volcano-tectonic occurring system, and Fonseca et al (2000) and Forjaz (2001) refers the existence of several strombolian cones southwest of the main town, Funchal, with possible geothermal potential.

In 2013, LNEG, the Portuguese National Laboratory for Energy and Geology carried out for EEM (Empresa Eléctrica da Madeira) a geothermal survey including geological, geochemical and geophysical investigations but the full results are not available so far.

2.3 Mainland

In Mainland Portugal geothermal resources are generally associated to the following origins: i) thermo-mineral waters related to active faulting and diapirism; ii) deep circulation in some peculiar structures in the basement, and, iii) deep circulation in the sedimentary borders trough permeable formations (e.g. Aires-Barros and Marques, 2000; Carvalho, 1995, 1996, 1996a, 1998, 2006; Carvalho and Carvalho, 2004; and Costa and Cruz, 2000).

The existing temperatures restrain the utilization to direct uses. Twenty-four springs are officially used in balneotherapy having discharge temperatures between 25ºC and 76ºC (Figure 3). The installed capacity is of about 20MWt referred to an outlet temperature of 20ºC.

From the lithological point of view, main rocks are granites of the Variscan orogeny and metasediments pre and post orogenic. Weathering is quite irregular depending on tectonics and present and past climates. Average reported depths to sound rock ranges from 0 to 60 m but in the vicinity of main tectonic axis it is not infrequent to drill up to 300 m of weathered rock (Carvalho 1996).

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).

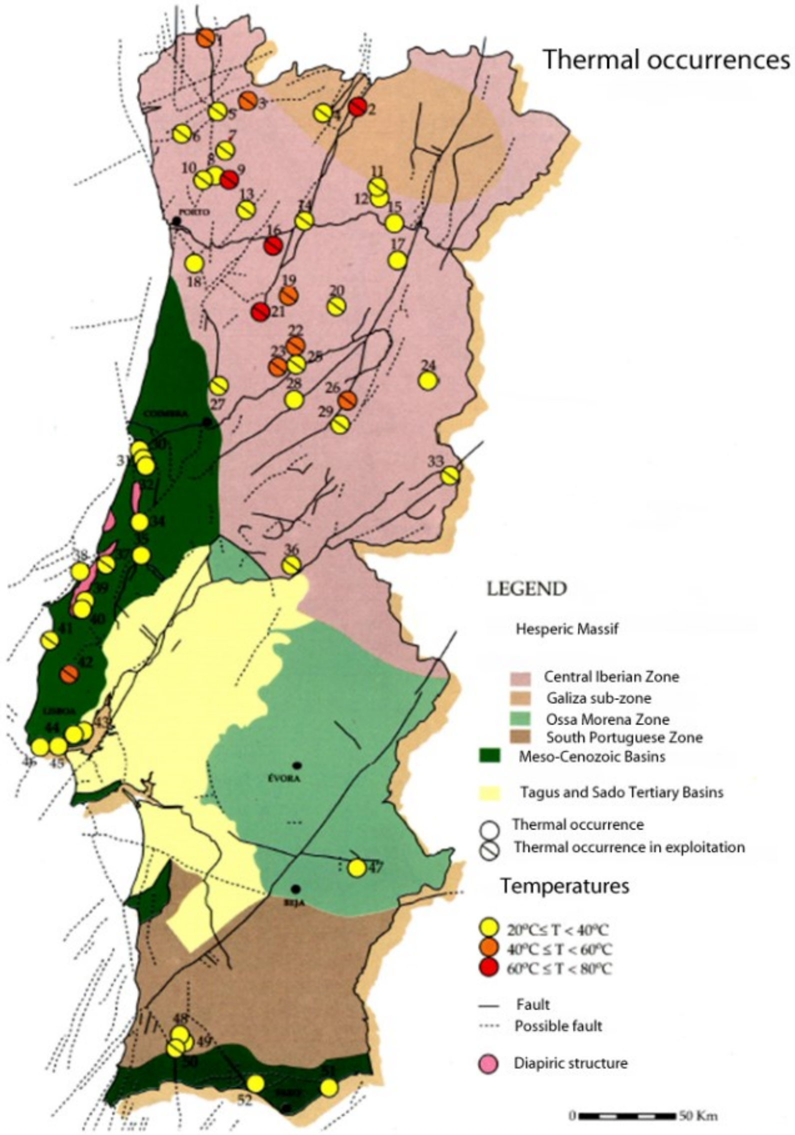

Figure 3: Geological sketch of Portugal Mainland, with thermal occurrences (adapted from IGM, Instituto Geológico e Mineiro 1998)

Regarding chemistry, three main groups could be considered at the Variscan Massif: (i) hypo-saline waters with total dissolved solids (TDS) less than 150 mg/l, frequently under 50 mg/l. This less mineralized group corresponds mainly to water circulating in quartzite reservoirs, (ii) sulphurous waters with up to 1,000 mg/l and temperatures up to 6ºC, and (iii) carbonated sparkling waters with TDS up to 2,500 mg/l (Calado 1991, 1995, 2001 and Carvalho 1996a).

In the sedimentary borders, deep aquifers are known, as in the Lisbon area where a 1,500 m deep well taped Cretaceous sandstone with 53ºC - bottom hole temperature (BHT). This well, with a 500 mg/l TDS and 49ºC water, supplied the Air Force Hospital geothermal project, financed by the VALOREN Program, between 1992 and 2002. (Carvalho 1996 and Carvalho et al 2005.

Oil wells in the Tejo and Sado basins (Carvalho et al., 1990 and ACAVACO 1998) suggest temperatures of 75ºC at 2,500 m in Jurassic limestone, with 5,000 ppm TDS water. The higher geothermal gradient is about 3.5ºC/100 m (IGM, 1998). 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) the regional heat flow density (HFD) is about 60-90 mW/m^2 in the Variscan Massif and 40-90 mW/m^2 in the sedimentary basins.

Potential for EGS projects is not yet scientifically assessed in spite of several attempts carried out in the beginning of this century that vanished with the financial and economical crisis in 2011.

3. GEOTHERMAL UTILIZATION

As previously described geothermal energy in Portugal is used for electricity production, for direct use in thermal baths/spas and greenhouses, and in ground source heat pumps. The Standard Tables 1 to 8 a the end of the paper present a characterization of the geothermal uses in Portugal as of 31 December 2014.

3.1 Electric Power Installation and Generation

Electric power installations and generation facilities are available only in S. Miguel Island, Azores archipelago. At the Ribeira Grande field two geothermal power plants – Ribeira Grande and Pico Vermelho – are in operation with a net combined capacity of 23 MWe. 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 2.5 MWe) installed in March 1994, and Phase B (2 x 4 MWe) completed in November 1998.

The new Pico Vermelho plant started in November 2006 and replaced the former 3 MWe pilot unit, in operation since 1980. This new project at Pico Vermelho included the construction of a 10 MWe power plant and an extensive drilling campaign, to increase the production and re-injection capacity in this sector of the field.

All the geothermal brines resulting from the operation of the two geothermal power plants are re-injected.

The high productivity wells drilled in 2005 in the sector of Pico Vermelho allowed the annual production to attain 196 GWh in 2014, representing approximately 42% of the electric consumption in the island of S. Miguel and about 22% in the Azores archipelago. This production is being regularly maintained from 2007 till now, based in the installed capacity of 23 MWe.

Regarding the Pico Alto Geothermal Field, in Terceira Island, the GEOTERCEIRA consultants ÍSOR (Iceland), GeothermEx (USA) and TARH (Portugal) recommended in April 2014 the installation of a pilot power plant of 2.5-3.0 MWe capacity fed by two wells up to 1,800 m deep (Figure 4). All the geothermal fluid will be re-injected in a single well already tested during an intensive six month program.

No direct uses related with the geothermal brines are in operation: a former INOVA Institute greenhouse operation, financed by the THERMIE Program, has run since 1997 (Rodrigues, 1998) but after 2005 (with the construction of the new Pico Vermelho plant) the installation was no longer nourished with geothermal effluent.

Figure 4: GEOTERCEIRA personnel during the long term well test at the Pico Alto Geothermal field, Terceira Island (September 2013).

3.2 Direct Heat Uses

Direct use application in Mainland and Azores is restricted to small district heating operations, greenhouse heating and mainly balneological applications located nearby some existing thermal baths/spas. The situation was reported by Carvalho et al. (2005), Lourenço (2005), Cabeças et al. (2010) and no significant changes occurred afterwards.

<u>3.2.1 District Heating</u>

Two main operations are running normally:

- Chaves, Northern Portugal: a dedicated well, 100 m deep, 70ºC, TDS of 2,500 mg/l, 5 l/s capacity, in metamorphic slates with quartz veins, is used in a small district heating network (swimming-pool, two hotels and the Thermal Bath). An independent well (150 m deep, 76ºC, TDS of 2,500 mg/l, 5 l/s capacity), taped hot water in metamorphic slates with quartz veins and feeds the Thermal Bath. A geothermal greenhouse, financed by the E.U. Joule Project, is no longer in operation;
- S. Pedro do Sul, central Portugal, the main Portuguese Spa: one inclined well, 500 m deep, 69ºC, 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 E.U. THERMIE Program, in two hotels and inside the Spa.

<u>3.2.2 Greenhouse Heating</u>

One single operation is running at S. Pedro do Sul (Vau). Two km south of S. Pedro do Sul Spa, two wells up to 216 m in granitic rocks (10 l/s at 68ºC, 350 mg/l TDS) are used in a 2 ha greenhouse producing tropical fruits (mainly pineapple).

The S. Miguel, Azores 6 x 200 m^2 demonstration greenhouses from INOVA Institute formerly heated with the geothermal effluent of Pico Vermelho pilot geothermal power plant (Rodrigues, 1998) is no longer in operation, since after 2006 all effluent is re-injected.

3.2.3 Bathing and Swimming

Balneological activities using thermo-mineral waters are quite popular in Portugal for health, well-being and touristic purposes. About 24 thermal baths/spas are operating within a legal framework. 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. Resulting from these activities, new shallow wells were carried out in Ferraria (S. Miguel), Varadouro (Faial) and Carapacho (Graciosa) – (Nunes et al. 2007).

3.2.4 New developments

In the period 2010-2014 little activity was carried out. Only five "deep" wells were drilled during the last five years at existing spa (Almeida 931 m, Gaeiras 137 m, Granjal 670 m, Monção 250 m and Chaves 200 m). Granjal and Gaeiras are locations not described at Table 3 where the future bath spas are under feasibility studies.

Chaves is probably the most promising geothermal site in Portugal due to the location in the middle of a town with a significant heat demand. The new well CC3 (figures 5 and 6), drilled after a comprehensive hydrogeological and geophysical campaign including electrical and high definition reflexion seismic methods was drilled with a down-the-hole drilling rig and the well was cased with stainless steel AISI 316L. Air flow measurements during the drilling operation reach 100 l/s (in fractured Silurian slates with quartz veins) but the temperature has maintained the existing 74ºC.

Figure 5: Air flow production test, well CC3 with geothermal fluid at 74ºC, Chaves geothermal field (January 2014).

Figure 6: Steam in downtown Chaves when drilling well CC3 (early morning, January 2014).

3.3 Ground Source Heat Pumps

There is no data before 2009, but the number of GSHP's registered installations till 2014 is small. At the end of 2014 there were only 13 installed systems registered in APIRAC, the Portuguese Refrigeration and Air Conditioning Association. It is true that in the residential sector a greater number of small installations are performed each year, but are not registered.

At this moment DGEG is preparing new regulations for shallow geothermal purposes, including the obligation to register all new GSHP's installations. In the near future statistical data of new installations will be more realistic.

Three examples of GSHP's installations, from different types, are presented below (Carvalho et al 2013).

The first example is an installation on the Superior School of Technology of Setúbal (EST Setúbal) from the Polytechnic Institute of Setubal, that was a partner in GROUNDHIT European Project (6th Framework Program), as 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 and 50 places each.

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.

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 (Figure 7). 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 m^2. 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.

This project is currently ongoing but there is no sufficient data to give the final results.

Finally the third example is an installation for heating, cooling and domestic hot water production in Sines Tecnopolo – Business Innovation Centre at Sines city.

This complex has an existing renewed building with 251 m^2, a laboratory building with 534 m^2 and an office building with 1,286 m^2, 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.

Figure 7: GSHP installation at Coimbra demo-site.

The installation in the laboratory building is formed by one GSHP with a heating capacity of 50.8 kWt and cooling capacity of 38.0 kWt, connected to 3 simple U, 150 m vertical borehole heat exchangers. This GSHP also produces domestic hot water.

In the office building two GSHP are installed, with a total heating capacity of 76.0 kWt and a total cooling capacity of 115.5 kWt, connected to 10 simple U, 150 m vertical borehole heat exchangers.

The heating/cooling distribution system is made by two tube fan coils in all buildings.

4. CONCLUSIONS

The below conclusions follow basically those by Cabeças et al. (2010) and Carvalho et al. (2013) as no significant events occurred afterwards.

In the Azores islands, about 30 years after the beginning of the exploitation of geothermal resources for power generation at the Ribeira Grande field, the contribution of this energy source assumes an extremely relevant role. The most outstanding features from the last five years include:

- At Ribeira Grande field, in São Miguel Island, geothermal is now run by EDA RENOVÁVEIS S.A. (formerly SOGEO, S.A.) on an industrial basis. Additional power from additional wells is planned for the next three or four years in order to increase the installed power up to 28.5 MWe.

- The contribution of the geothermal source represents today 22% of the power generated in the Azores archipelago;
- Deep drilling in the Pico Alto geothermal area (Terceira Island) was developed and the presence of a productive reservoir is now confirmed, to be exploited in a near future at a pilot scale (2.5-3.0 MWe); plans to extend the exploration and exploitation activities up to 10 MWe are on the move for the next years.

Finally, it should be emphasized that the geothermal generation costs are extremely competitive in the Azores, due to its remote location, the discontinuity between the 9 insular electric production systems, and allowed significant savings.

In the Mainland, the geothermal exploration and exploitation has been quite stable during the period 2010-2015. The main geothermal sources are located nearby existing spas and there are no prospects on new significant direct-use projects. The same applies for new projects in the sedimentary borders tacking profit of the possible existing deep aquifers.

Concerning GSHP's the potential is huge but not exploited. There are a few installations registered until 2014, but this tends to change due to the preparation of new legislation for regulating shallow geothermal operations. That will allow future statistical data to be more realistic and contribute to ameliorate the quality of the operations.

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APPENDIX – STANDARD TABLES

Table 1: Present and planned production of electricity.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind, biomass, 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 2014	23	196	8950	20300	5538	16000	0	0	5833	16500	20350	52995
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	35		7643	20071	7916	13346			6833	16578	22421	50221

(adapted from www.dgeg.pt at 29 May 2014)

Table 2: Utilization of geothermal energy for electric power generation as of 31 December 2014.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status	Type of Unit	Total Installed Capacity (MWe*)	Total Running Capacity (MWe*)	Annual Energy Produced 2013 (GWh/yr)	Total Under Constr. or Planned (MWe)
Ribeira Grande	Ribeira Grande (Phase A)	1994	2		B	6	5		42,5
Ribeira Grande	Ribeira Grande (Phase B)	1998	2		B	9	5		42,5
Ribeira Grande	Pico Vermelho	2006	1		B	13,5	13		100
Total						**28,5**	**23**		

** Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.*

Table 3: Utilization of geothermal energy for direct heat as of 31 December 2014 (other than heat pumps).

Locality	Type	Maximum Utilization					Capacity	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy (kJ/kg)			Ave. Flow	Energy	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor
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 Rib. Grande	B	1,0	90,0	20,0			0,29	1,00	9,2	0,99
Carapacho (Graciosa)	B	2,5	37,6	20,0			0,18	2,50	5,8	0,99
Ferraria (S. Miguel)	B	10,0	62,1	20,0			1,76	10,00	55,5	0,99
TOTAL							**20,2**		**388,2**	**0,5**

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

Table 4: Geothermal (ground-source) heat pumps as of 31 December 2014.

Locality	Ground or Water Temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type	COP	Heating Equivalent Full Load (Hr/Year)	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
		≤ 25kW	8					
		25kW - 50kW	4					
		50kW - 100kW	1					
TOTAL			13					

Table 5: Summary table of geothermal direct heat uses as of 31 December 2014.

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)]	4.9	95.3	
Air Conditioning (Cooling)			
Greenhouse Heating	1	12.4	
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	14.3	280.5	
Other Uses (specify)			
Subtotal	20.2	388.2	
Geothermal Heat Pumps	15	90	
TOTAL	35.2	478.2	

Table 6: Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2010 to December, 31 2014 (excluding heat pump wells).

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration	(all)					
Production	>150 °C	1				1,17 (directional)
	150-100 °C					
	<100 °C		5			2,19
Injection	(all)	1				1,08 (directional)
Total		2	5			4,44

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

Year	Professional Person-Years of Effort: Government	Public Utilities	Universities	Paid Foreign Consultants	Contributed Through Foreign Aid Programs	Private Industry
2010	2	19	9	5		1
2011	3	20	9	3		3
2012	3	20	9	3		3
2013	3	20	9	3		2
2014	3	20	9	3		2
Total	14	99	45	17		11

Table 8: Total investments in geothermal in 2014 (US$).

Period	Research & Development Incl.	Field Development Including	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
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