Geothermal Energy Use, Country Update for Spain

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ABSTRACT

Spanish geothermal sector is showing an unequal behavior during the last years, while shallow geothermal continues experiencing a steady growth, as it becomes more popular and increasingly applied in the building refurbishment subsector, geothermal for power generation is completely blocked due to the situation of the Spanish electricity sector and the ongoing discussions around a new regulatory framework.

At present, there is no geothermal power generation in Spain. However, Business initiatives have shown a growing interest in developing this type of projects in the short and medium term. Spanish geological setting is very favorable for the development of EGS type projects but projects development is subject to an improvement of the regulatory and market conditions.

With regard to low-temperature geothermal energy, shallow or very low-temperature geothermal energy used for cooling and heating is already a reality in our country. It is estimated that from 2019 onwards, several heating and cooling network projects (geothermal district cooling and heating) may be launched.

1. INTRODUCTION

Spain has a high potential of geothermal resources from different types (high, medium and low temperature). This geothermal potential, if harnessed adequately through proper development initiatives, could decrease the existent gap in the level of use of these resources with respect to other European nations. To enable this development, it is essential that the sector counts on an adequate support framework to undergo a sustained technological evolution.

Spain's geothermal potential could enable the inexhaustible use of this renewable energy source for the production of electricity as well as for residential use and services. This would also allow Spain to reduce its foreign energy dependency (above 75%), one of the biggest among EU countries and shown by many authors to be one of the real burdens to increase the competitiveness of the domestic economy. As well as to reduce the consumption of non-renewable energy sources and contribute to ultimately guarantee a constant supply of indigenous and reliable energy that is independent of external factors.

The following table provides a summary of the assessed geothermal resources in Spain.

Table 1. Geothermal resource potential in Spain. (Source: Evaluation of the geothermal energy potential. 2011-2020 PER technical study).

Type of use	Type of reservoir	Recoverable stored heat (10^5 GWh)	Power (MW)
Thermal	Low temperature (total resources)	15,682	5,710,320 (MWth)
	Low temperature (usable)	160	57,563 (MWth)
Electric	Medium temperature (total resources)	541	17,000 (MWe)
	Medium temperature (studied)	54	1,695 (MWe)
	High temperature (studied)	1.8	227 (MWe)
	Enhanced geothermal systems (known areas)	60	745 (MWe)

2. UPDATE OF CURRENT ACTIVITIES IN THE SPANISH GEOTHERMAL SECTOR

A description of the existing geothermal resources available in the Spanish subsurface is provided next. This description includes the characteristics and potential of each resource, such as zones of interest, geological conditions, depth and temperature of the resource, fluid composition, etc.

The resources have been classified into the following groups to prepare such descriptions:

- Very Low-Temperature Resources (T < 30 ºC).
- Low-Temperature Resources (30 ºC < T < 100 ºC).
- Medium-Temperature Resources (100 ºC < T < 150 ºC).
- High-Temperature Resources (T > 150 ºC).
- Enhanced Geothermal Systems (EGS).

2.1 Very low temperature (<30 ºC) – shallow - geothermal resources

Closed-loop geothermal systems. These resources are available nationwide. There are two main groups depending on the average thermal conductivity and the physical and mechanical characteristics of the ground.

Consolidated formations extending over 60% of the territory area. Formed by sedimentary, igneous or metamorphic rocks ranging from Palaeozoic to Mesozoic age, specific weight greater than 2.0 tm/m^3, the thermal conductivity in saturated conditions is over 2 W/mK and can be drilled without drilling mud or auxiliary casing except for a few starting meters. These formations occupy the entire periphery as well as the central mountain ranges. The conditions for implementing very low-temperature geothermal systems are optimal especially when they go hand in hand with continental type climatic conditions.

Unconsolidated formations occupy broad areas across the two plateaus and the eastern third of the country. Geological conditions are less favorable, increasing the installations cost. However, these areas frequently have continental climatic conditions, with a great and well-equalized heating and cooling demand, improving the attractiveness of shallow geothermal systems in terms of LCE and cost.

Open-loop geothermal systems. There is a great use of groundwater, especially for urban and agricultural supply, in Spain. Usually, groundwater extraction involves deep aquifers often with high pumping heights, increasing the energy cost over the shallow systems redlines. In addition, complex regulations and hydrological stress in broad areas of the country do not facilitate their use in thermal applications. In practice, the greatest potential can be found in cascade applications, still scarcely developed, or more frequently in alluvial aquifers associated to Spanish main rivers such as the Ebro, Guadalquivir, Guadiana, etc. standing many of the country's main cities (Zaragoza, Seville, etc.). These aquifers, very transmissive (> 10^3 m^2/d), supplies open-loop geothermal systems of several hundreds of kW, just a few meters of drawdown.

In addition, in various coastal areas of Spain (islands and peninsula) are located a significant number of hotels in which the demand for hot water and cooling are being covered by geothermal open loop systems using seawater.

According the methodology provided in other sources (e.g., documents from the US Department of Energy such as "Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. December 2008"), resources are not limited by ground conditions, but rather by demand configuration and our ability to harness the resources in a technically and economically viable way. In this sense Spain has many of the factors that favour geothermal heat pump based systems such as broad climatic areas with important seasonal temperature variations, large numbers of dwellings or buildings in rural or semi-urban areas with sufficient surrounding land and difficult access to gas or other sources and a deeply-rooted heating and cooling industry backed by broad experience

2.2 Low temperature (30 - 100 -ºC) geothermal resources

The Spanish subsurface has been classified into two main groups, for purposes of analyzing this type of resource:

1) large sedimentary basins and peripheral mountain ranges

2) the Iberian Hercynian Massif

The first group includes the Duero, Tajo-Mancha-Júcar, Guadalquivir, Ebro and North-Cantabrian basins. The second group includes the Bética Ranges in addition to the Pyrenees, the Catalan Coastal Ranges and the Iberian Hercynian Massif located in the west of the Iberian Peninsula. Within the areas that are included in the first group, there are numerous Mesozoic and Tertiary permeable formations that fill said basins, as described in studies prepared by IGME (Spanish Geological Survey) in the '80s based on the information obtained from deep hydrocarbon exploration wells. Geothermal energy in the form of recoverable stored heat (geothermal reserves) in such formations has been estimated at a total of 15,126 x 10^5 (GWh). When applying the calculation to zones of influence in key urban centers that have significant thermal demand, this figure increases to 150.3 x 10^5 GW, which is approximately 1% of the total.

The areas included in the second group, which have been studied in detail by IGME from 1975, are characterized by significant regional fracturing coupled with a considerable vertical development of permeable formations that allow the proliferation of zones that host geothermal resources. Geothermal energy in the form of recoverable stored heat (geothermal reserves) in these zones has been estimated at 736 x 10^5 GWh.

When applying the calculation to zones of influence in key urban centers that have significant thermal demand, this figure increases to 9.6 x 10^5 GW, which is approximately 1.3% of the total in these areas.

In summary, low-temperature geothermal energy estimates in the form of recoverable stored heat in Spain's subsurface amount to a total of 15,862 x 10^5 GWh, of which 159.9 x 10^5 GWh are located proximal to areas that have significant demand levels of this energy for direct heat applications.

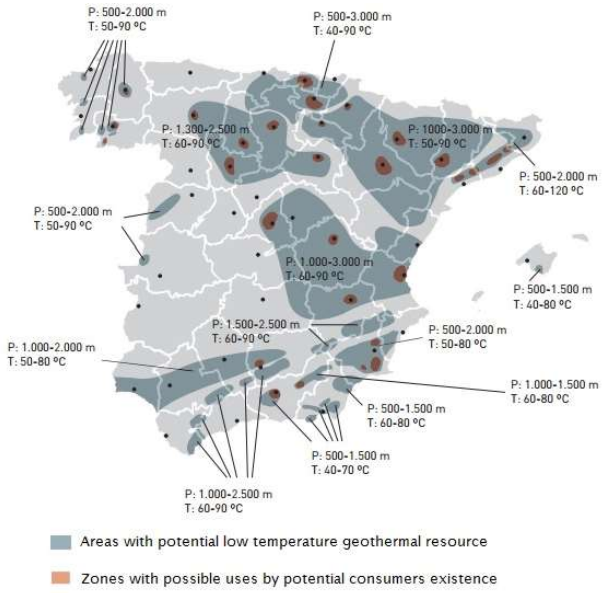

Figure 1. Map of low-temperature geothermal resources and zones with good potential for resource exploitation (Source: PER 2011-2020)

2.3 Medium temperature (150-180 ºC) geothermal resources

The great depths that characterize some geologic basins in Spain that normally host permeable formations at depths greater than 3,500 m, allows for the existence of medium temperature geothermal resources suitable to be used in binary cycles for the combined production of heat and power. At these depths, the temperature of water contained in permeable formations exceeds 100 ºC thanks to the geothermal gradient of the subsurface. In other zones, it is the considerable extent of regional fracturing that facilitates deep circulation of geothermal fluids. Thus, the areas located in the Cantabrian, Pre-Pyrenean, Tagus, Guadalquivir and Betic Range basins host deep permeable formations that contain fluids whose temperature exceeds 100 ºC. In regions where granitic materials predominate, such as Cataluña and the Hercynian Massif (mainly in Galicia, northwestern Spain), regional fracturing favors the existence of these reservoirs thanks to the presence of fluids that circulate at depth. The studies carried out by IGME as well as hydrocarbon exploration conducted by oil companies have allowed recognizing or estimating areas that can potentially host geothermal resources. These areas include La Selva and Vallés depressions in Cataluña, the zone of Jaca- Serrablo in Aragón, the northern zone of the Madrid Basin, Lebrija in the Guadalquivir River Basin, a number of internal depressions in the Bética Ranges such as Lanjarón in Granada or Sierra Alhamilla in Almeria and some disperse areas in Galicia, Salamanca and Cáceres.

The gross potential of these resources in the form of recoverable stored heat in unexplored areas amounts to 541 x 10^5 GWh, which is equal to an installed capacity of 17,000 MW(e). Geothermal resources in the form of recoverable stored heat in the abovementioned known or explored areas have been estimated at 54.23 x 10^5 GWh. Up to 1,695 MW (e) could be installed in binary cycle plants when taking into account performance, renewability and operating load factors.

2.4 High temperature (> 150 ºC) geothermal resources

The conditions that enable the existence of high-temperature geothermal resources associated with active volcanism (a phenomenon which is also known as conventional geothermal energy) have been confirmed in Spain only in the Canary Islands. Previous investigations conducted by IGME and other entities have highlighted the possible existence of steam reservoirs or reservoirs involving a combination of steam and water in several areas of Tenerife (in the NW, E and S of the island). In other islands (Lanzarote and La Palma), several important thermal manifestations at the surface exist which, nonetheless, do not appear to indicate any possible storage of geothermal fluid.

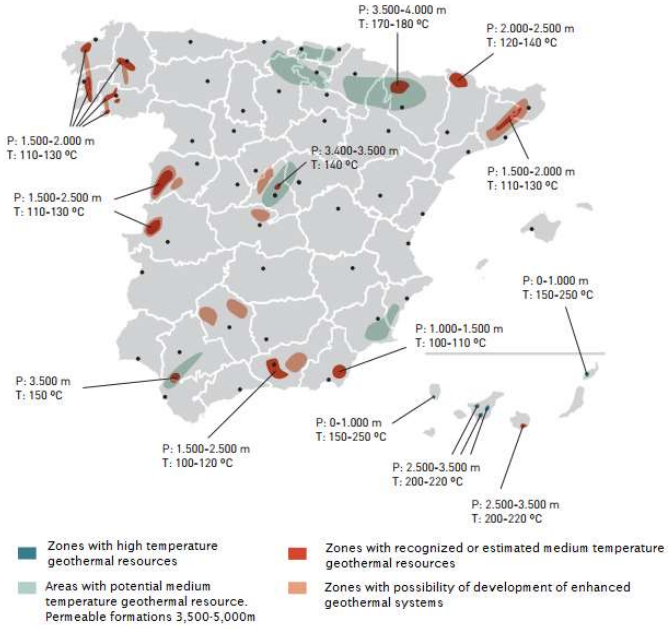

Figure 2. Map of medium and high-temperature geothermal resources and possible enhanced geothermal systems (Source: PER 2011-2020)

In the three areas mentioned earlier on the island of Tenerife, the potential existence of geothermal storage zones has been estimated at depths between 2,500 and 3,500 m and temperatures in the range of 200-220 ºC. Geothermal energy in the form of recoverable stored heat in such zone has been estimated at 1.82 x 10^5

GWh. Up to 227 MW(e) could be installed in conventional flash type plants when taking into account performance, renewability and operating load factors.

2.5 Enhanced Geothermal Systems (EGS)

The basic criteria used when selecting areas that have the potential for the development of EGS are: 1. the existence of a mass of hard granitic or metamorphic rock with low permeability at its matrix; 2. significant regional fracturing affecting this mass; and, 3. a certain degree of geothermal anomaly.

In light of these criteria, a detailed review of the peninsular geology has revealed a series of areas which, from a geological perspective, can allow the implementation of these enhanced geothermal systems. The areas considered are: the tectonic grabens of La Selva and Vallés in Cataluña, areas of deep fracturing in Galicia, the tectonic grabens in the SW of Salamanca (towns of Ciudad Rodrigo and Tormes), fractured areas west of Cáceres, the borders of the Tagus River depression, which are characterized by large-scale fractures that affect the Hercynian bedrock and lastly, areas in Andalucía where the granitic or Paleozoic bedrock is highly fractured, such as Sierra Morena or the more internal zone of the Bética Ranges in the vicinity of Sierra Nevada.

The geothermal energy that could be found in the form of recoverable stored heat in these areas has been estimated at 60 x 10^5 GWh, which would allow installing a total power capacity of 745 MW(e) when taking into account the already mentioned performance, renewability and usage load factors.

3. SPANISH GEOTHERMAL SECTOR UPDATE

Spain has great potential for geothermal resources. Therefore, an appropriate policy to develop geothermal energy in Spain could eventually lead to similar rates of geothermal use as other European countries already have. The lack of specific support measures means a slow uptake of geothermal in Spain, despite its great potential for both thermal and electrical uses.

Geothermal energy for power generation has been paralyzed since 2012 when a ‘renewables moratorium’ was decreed. About 50 exploration permits were requested. However, just a few of them are being maintained. The majority expired due to the impossibility of promoting projects within the new renewable power auction system that has been established in Spain. The auctions of renewable power that have taken place in 2016 and 2017 awarded more than 8,000 MW, none of which will be used to generate geothermal electricity (the auctions were restricted to biomass, PV and wind).

The geothermal sector has criticized the parameters used in the last renewable power auctions (these parameters could never be assumed by a geothermal 'standard installation'), as well as the lack of guarantees to the profitability of projects. According to the guidelines of the European Commission, the Spanish energy auction held on 17th May 2017 should respect the principle of competitiveness and be technologically neutral. This allows different technologies to compete on equal terms and ensures the incorporation of more efficient projects, resulting in a lower cost for the consumer. However, this principle of impartiality was not complied with. The auction did not consider the principle of competitiveness because of incorporating unsuitable conditions for the state of the art of electricity geothermal technology in Spain. This has prevented the promotion of geothermal power installations in Spain so far.

Only in the Canary Islands has there been a clear movement in favor of geothermal energy. The Island Government has decided to publish a series of official manuals that characterize the existing geothermal resource in the archipelago and analyze the conditions for its exploitation. In addition to the uses of geothermal for heating & cooling used by large hotels in the Canary Islands, geopower production can play a key role in the energy transition of the islands. A massive uptake of interruptible sources such as wind and photovoltaic solar would make it necessary to also use a 100% dispatchable baseload renewable energy, such as geothermal.

Regarding the Spanish shallow geothermal sector, geothermal energy for heating and cooling applications and production of domestic hot water continued to enjoy a positive change in trend. The installation of geo-exchange systems has intensified in all types of buildings, both in new constructions and in refurbishment. Furthermore, public administrations are moving forward to have geothermal exchange systems in public buildings due to the need to make new public buildings fit into the concept ‘Nearly zero-energy buildings (NZEBs)’ promoted by the European Union. This is also favorable for the implementation of this type of geothermal system in Spain.

On the other hand, to achieve an optimal development of the heating & cooling market with geothermal exchange systems in Spain, it is essential to have properly trained professionals. Training in this professional sector is among the fields of earth sciences, heating & cooling engineering, building and renewable energy.

The Spanish Geothermal Technology and Innovation Platform (GEOPLAT) is the entity in charge of carrying out official geothermal training in Spain. Their aim is the certification of training with European recognition in order to promote safe, secure and sustainable development within the Spanish geothermal sector. In 2018, the third course of formal training in Design of Geothermal Exchange Systems was carried out, in collaboration with the International Association of Geo-Education for a Sustainable Geothermal Heating and Cooling Market (GEOTRAINET) and in line with the pursuit of excellence of geothermal energy in Spain, which is the driving force behind all actions of GEOPLAT. The course took place in Bilbao in collaboration with the Energy Agency of the Basque

Government (EVE) with the support of the Spanish Institute for Diversification and Saving of Energy (IDAE), the Spanish Geological Survey (IGME) and the Spanish Centre of Studies and Experimentation in Public Works (CEDEX).

The objective of the course, aimed at professionals, has been to increase the knowledge of the participants, as well as the development of their technical skills to be able to face the design and execution of geothermal exchange systems based on official European criteria.

Also, in 2018 GEOPLAT, jointly with the National Institute of Qualifications of the Spanish Ministry of Education (INCUAL), has worked on the development of the basis for qualification of professionals to manage the installation and maintenance of heat exchange geothermal systems. This qualification will serve to create advanced vocational training courses, as well as vocational training courses for the unemployed. In addition, it will officially accredit experienced installers with the corresponding title. This official qualification will help to advance the professionalization of the sector, which would benefit from an extension of the knowledge to install this type of renewable heating and cooling system, guaranteeing quality standards in the installations.

4. OUTLOOK

In 2018, GEOPLAT has participated in the analysis of the potential of energy technologies in the framework of the Spanish Alliance for Energy Research and Innovation (ALINNE).

ALINNE aims to improve the efficiency and efficacy of the Spanish R+D system, contributes to the consolidation of existent strengths and helps the internationalization of Spanish companies.

In this context, GEOPLAT has developed an analysis of the technological areas of geothermal energy (geothermal for electrical and thermal generation). This analysis provides valuable information on technical, economic and environmental criteria.

Also, GEOPLAT has developed a prospective analysis of the state of geothermal technologies and strategic analysis of the technological coherence and availability of financial instruments and resources.

The following data in figures 3-8 are provisional data based on internal estimations.

- **Generation of economic activity**

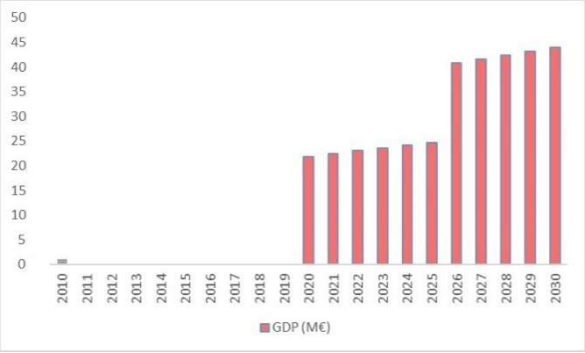

Figure 3. Estimated economic activity generated provided by geothermal energy for power generation sector during the period 2012-2030. Contribution to Spain's GDP (Source: GEOPLAT - provisional data based on internal estimations)

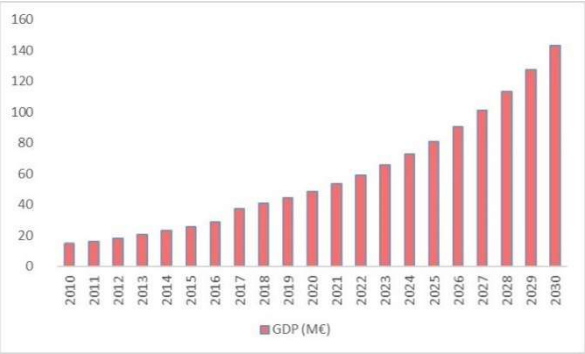

Figure 4. Estimated economic activity generated, provided by geothermal energy for thermal generation sector during the period 2012-2030. (Source: GEOPLAT - provisional data based on internal estimations)

- **The geothermal energy market in Spain**

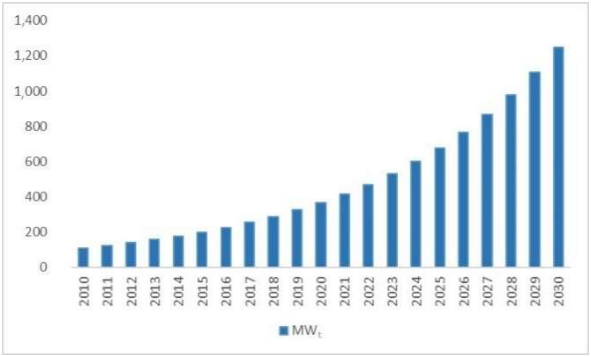

Figure 5. Estimated installed capacity annually by the geothermal energy sector for thermal generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

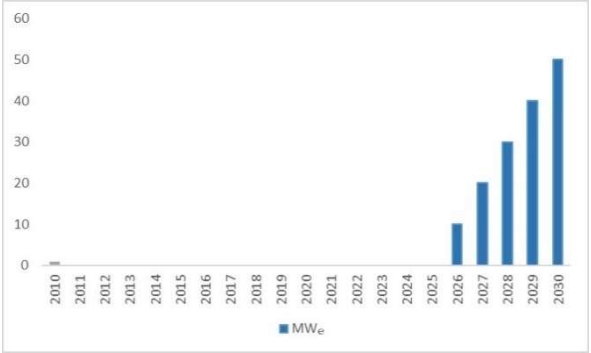

Figure 6. Estimated installed capacity annually by the geothermal energy sector for power generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

- **Potential employment of geothermal energy sector in Spain**

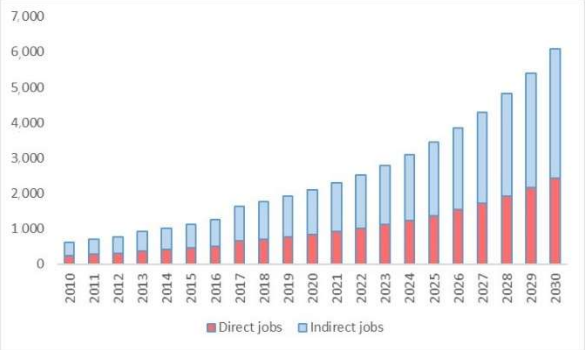

Figure 7. Estimated number of people employed annually by the geothermal energy sector for thermal generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

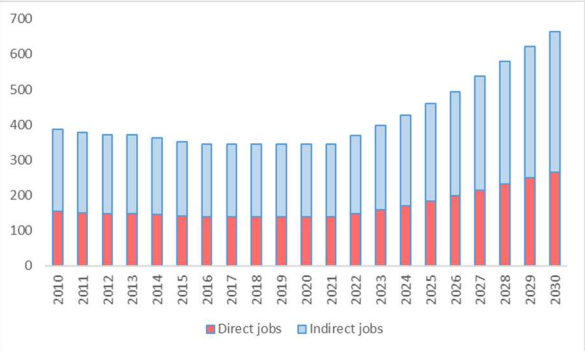

Figure 8. Estimated number of people employed annually by the geothermal energy sector for power generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

3. CONCLUSIONS

The generation of heating, cooling and electricity from geothermal energy can play a crucial role in the future energy mix of Spain based on the existing potential of geothermal resources. Through an appropriate development of the geothermal sector, this potential can bring Spain closer to the exploitation levels of other European countries.

After a few years of slowdown, the geothermal sector is reactivating in Spain. It is expected that the next decade will be a decade of expansion of geothermal energy in Spain. There are expectations for a major development on shallow geothermal for HVAC (heating, ventilation and air conditioning) as well as for power generation, given the existing potential and resources.

Given these perspectives, it's necessary to stimulate financing and regulatory instruments to produce energy (power and thermal generation) from geothermal resources. This would provide major economic development opportunities for Spain in the form of taxes and fees, export of technology and jobs.

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Acknowledgments

This work wouldn't have been possible without the collaboration of Spanish geothermal stakeholders and the work of the secretariat of the Spanish Geothermal Technology and Innovation Platform (GEOPLAT).

Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2018 *	0	0	104,122*	248,424*	0	0
Under construction end of 2018	0	0	-	-	0	0
Total projected by 2020	-	-	-	-	-	-
Total expected by 2025	-	-	-	-	-	-
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2018 (indicate exploration/exploitation if applicable):					Under development	
					Under investigation	

* If 2017 numbers need to be used, please identify such numbers using an asterisk

Table B: Existing geothermal power plants, individual sites

No geothermal power plants currently in Spain

Table C: Present and planned geothermal district heating (DH) plants and other uses for heating and cooling, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		Geothermal heat in balneology and other **	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2018 *	>2.9 *See Table D1*	>2.4 *See Table D1*	14,9*	26,2*	-	-	2,6*	14,6*
Under construc-tion end 2018	-	-	-	-	-	-	-	-
Total projected by 2020 **	1,2	3,4						
Total expected by 2025	-	-	-	-	-	-	-	-

* If 2017 numbers need to be used, please identify such numbers using an asterisk

** DH Pozo Fondón (Langreo) - Asturias

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP	Cooling	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2018 produc-tion (GW_{th}/y)	Geoth. share in total prod. (%)
Madrid	DH Aroyo Bodonal			Y	0.9			
Puerto de Pollensa (Balearic Islands)	DH&C Club Pollentia Resort			Y		8.5		
Olot (Girona)	DH Olot		Y *	Y		0.97		
Mieres (Asturias)	DH Pozo Barredo	2019			2	2	2,4	100
Las Palmas (Canary Islands)	DH Hotel Teguise							
Barcelona (Catalonia)	Plaza de Lleó							
Lérida (Catalonia)	DH Camping la Noguera		Y**					
Álava (Basque Country)	DH Neiker – Tecnalia		Y***	Y				
total								

* Trigeneration: geothermal+biomass+natural gas

** Trigeneration: geothermal+biomass+solar thermal

*** Trigeneration: geothermal+biomass

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2018		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2018	-	289*	-	-	-	-
Projected total by 2020	-	368*	-			

* Provisional data based on internal estimations

Table F: Investment and Employment in geothermal energy

	in 2018		Expected in 2020	
	Expenditures (million €)	Personnel (number)	Expenditures (million €)	Personnel (number)
Geothermal electric power		138*		138*
Geothermal direct uses and Shallow geothermal		708*		837*
total		**846**		**975**

* Provisional data based on internal estimations

Table G: Incentives, Information, Education

	Geothermal electricity	Deep Geothermal for heating and cooling	Shallow geothermal
Financial Incentives – R&D	YES	YES	YES
Financial Incentives – Investment	NO	NO	DIS, LIL
Financial Incentives – Operation/Production	NO	NO	DIS, LIL
Information activities – promotion for the public	YES	YES	YES
Information activities – geological information	YES	YES	YES
Education/Training – Academic	YES	YES	YES
Education/Training – Vocational	NO	NO	YES

Key for financial incentives:					
DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)

* GEOPLAT 2018 training course: Design of geothermal systems:
http://www.geoplat.org/wp-content/uploads/2018/09/D%C3%ADptico-informativo-curso-GEOPLAT-Bilbao-24-25-oct.-2018.pdf