

Country Update for the Spanish Geothermal Sector

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ABSTRACT

Spain has relevant geothermal resources potential. An appropriate policy framework to develop geothermal energy in Spain could eventually lead to similar rates of geothermal use as other European countries already have. Lack of specific support measures has meant a low uptake of geothermal in Spain, despite its great potential for both thermal and electrical uses.

Geothermal energy for power generation is in 'stand-by mode' in Spain. The requested exploration permits were kept in some areas, but expired in others, due to the impossibility of promoting projects under the renewable power auction system that has been established in Spain since 2014. The two auctions of renewable power that took place in 2017 have awarded a total of 8,000 MW, none of which will be used to generate geothermal electricity. The auctions were mainly focused on promoting 'traditional' renewables, such as PV and wind, while novel renewables -as geothermal- were arbitrarily wished away.

Regarding the Spanish shallow geothermal sector, geothermal energy for heating and cooling applications and production of domestic hot water enjoys a positive change in the trend. The installation of geo-exchange systems is getting more common in all types of buildings, both in new constructions and in retrofitting applications. Furthermore, public administrations are moving forward at transforming public buildings into sustainable and efficient buildings (even Nearly zero-energy buildings - NZEBs) using geo-exchange systems, single or combined with other renewable technologies (i.e. solar).

It's sure that geothermal energy for heating and cooling applications will play a significant role in the framework of the Integrated National Energy and Climate Plan (NECPs), with the aim of contributing to the achievement of Spain's energy and climate change commitments.

1. INTRODUCTION

Three key pieces of legislation in the Clean Energy for All Europeans package were published in the EU Official Journal (L328) and entered into force as of 24 December 2018:

1. The revised Renewable Energy Directive (EU) 2018/2001 establishes a binding EU target of at least 32% of renewables (consume) for 2030 with a review for increasing this figure
2. The revised Energy Efficiency Directive (EU) 2018/2002 sets a 2030 target of 32.5%, also with a possible revision in 2023
3. The new Governance Regulation (EU) 2018/1999 includes the requirement for Member States to draw up Integrated National Energy and Climate Plans for 2021 to 2030 outlining how to achieve the targets and submit the draft to the European Commission by the end of 2018.

Furthermore, Spain has ambitious climate targets at National level. The main objectives of the Spanish Integrated National Energy and Climate Plan (PNIEC) are summarised in three points:

1. 21% reduction in greenhouse gas emissions from 1990 level (in 2017, in Spain was 18 percentage points above this benchmark)
2. 42% share of renewable energies in the final country mix (which means 74% renewables for electricity generation). The renewables EU target by 2030 is 32%
3. 39.6% improvement in the country's energy efficiency

These scenarios provide great opportunities for geothermal in Spain:

- Environmental and energy commitments: EU Winter package + Conferences of Parties agreements; Nearly zero energy consumption buildings and smart cities; and decarbonization
- Need to transposing and implementing the European Directives
- Increase the penetration of thermal renewable energies in the national mix
- Need to have dispatchable electrical renewables and green base load
- Key technologies for island systems
- Fundamental to meet the requirements of the new Spanish Technical Building Code (more restrictive and demanding)

2. GEOLOGY BACKGROUND

Spain has different types of high potential geothermal resources, which, if harnessed adequately through proper development initiatives, can decrease the gap in the level of use of these resources with respect to other European nations. To enable this development, it is essential and indispensable that the sector undergoes sustained technological evolution.

Spain's geothermal potential can enable the inexhaustible use of this renewable energy source for the production of electricity in the industrial and agricultural sectors as well as for residential use and services. This would also allow us to reduce our foreign energy dependency (the real burden of our domestic economy), reduce the consumption of non-renewable energy sources and contribute to ultimately guarantee a constant supply of energy that is independent of external factors.

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

Type of use	Type of reservoir	Recoverable stored heat (10 ⁵ GWh)	Power (MW)
Thermal	Low temperature (total resources)	15,682	7,710.320 (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)

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

3. GEOTHERMAL RESOURCES AND POTENTIAL

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 in order to prepare such descriptions:

- Very Low Temperature Resources ($T < 30\text{ }^{\circ}\text{C}$).
- Low Temperature Resources ($30\text{ }^{\circ}\text{C} < T < 100\text{ }^{\circ}\text{C}$).
- Medium Temperature Resources ($100\text{ }^{\circ}\text{C} < T < 150\text{ }^{\circ}\text{C}$).
- High Temperature Resources ($T > 150\text{ }^{\circ}\text{C}$).
- Enhanced Geothermal Systems (EGS).

3.1 Very low temperature (<30 °C) – shallow - geothermal resources

Closed-loop geothermal systems. These resources are available nationwide. The current installed capacity is estimated at about 60 MWt. 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 Paleozoic to Mesozoic age, specific gravity greater than 2.0 t/m³, thermal conductivity in saturated conditions over 2 W/mK and can be drilled without drilling mud or auxiliary casing except 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 financial ratios of viability reports of these systems.

Open-loop geothermal systems. There is a great use of groundwater, especially for urban and agricultural supply, in Spain. Many times 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 usually in alluvial aquifers of Spanish main rivers such as the Ebro, Guadalquivir, Guadiana, etc., standing many of the country's main cities (Zaragoza, Seville, etc.). These aquifers, very transmissives ($> 103 \text{ m}^2/\text{d}$), supplies open-loop geothermal systems of several hundreds of kW, pumping just a few meters. The actual installed power capacity of these open-loop systems is assessed on 90 MWth.

Following 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”), resource estimates in this case would not be limited by soil conditions, but rather by demand configuration and our ability to harness the resources in a technically and economically viable way. In this sense, there are great areas with potential demand. Spain has many of the factors that favor 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. Also worth noting are the dramatic changes that have taken place in the regulatory sphere (articulated by a diverse range of technical codes and regulations in the case of Spain) which have resulted in the implementation, since 2009, of the European Renewable Energy Directive relative to the promotion of the use of energy from renewable sources (hereinafter Directive 2009/28/CE) in buildings or other previous codes. In the last years, the slowdown of the building sector has resulted in slower uptake of new projects and an increased attention to the possibilities of shallow geothermal in the refurbishment of existing buildings.

3.2 Low temperature (30 - 100 °C) 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 and 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. As described in studies prepared by IGME (Spanish Geological Survey) in the 80's based on the information obtained from deep hydrocarbon exploration wells there are numerous Mesozoic and Tertiary permeable formations that fill the large sedimentary basins included in the first group. Geothermal energy in the form of recoverable stored heat (geothermal reserves) in such formations has been estimated at a total of $15,126 \times 10^5 \text{ GWh}$. When applying the calculation to zones of influence in key urban centers that have significant thermal demand, this figure goes down to $150.3 \times 10^5 \text{ GW}$, which is approximately 1% of the total.

The areas included in the second group are characterized by significant regional fracturing coupled with a considerable development of vertical permeability that allows the circulation of geothermal fluids. Geothermal energy in the form of recoverable stored heat (geothermal reserves) in these zones has been estimated at $736 \times 10^5 \text{ GWh}$. When applying the calculation to zones of influence in key urban centers that have significant thermal demand, this figure gets down to $9.6 \times 10^5 \text{ GW}$, 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 $15,862 \times 10^5 \text{ GWh}$, of which $159.9 \times 10^5 \text{ GWh}$ are located proximal to areas that have a significant direct heat energy demand.

3.3 Medium temperature (150-180 °C) geothermal resources

Some geologic basins in Spain host permeable formations at depths greater than 3,500 m, and those conditions allow the presence 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 °C. 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 containing fluids with temperatures greater than 100 °C. In granitic regions, such as Cataluña and the Hercynian Massif (mainly in Galicia, northwestern Spain), regional fracturing favors the existence of geothermal reservoirs thanks to the deep circulation of fluids. The studies carried out by IGME as well as hydrocarbon exploration conducted by oil companies are showing the most geothermal resource potential areas. 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 Almería 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 $541 \times 10^5 \text{ GWh}$, which is equivalent 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 $54.23 \times 10^5 \text{ GWh}$. Up to 1,695 MW (e) could be installed in binary cycle plants taking into account performance, renewability and operating load factors.

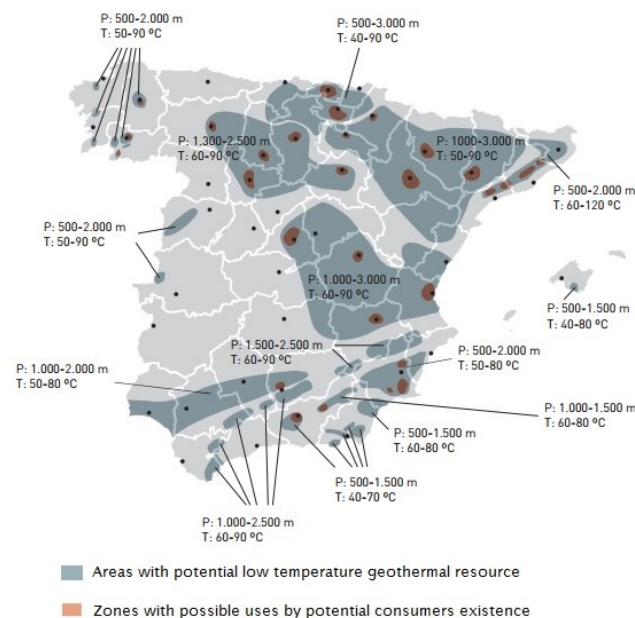


Figure 1: Map of low temperature geothermal resources and zones with good potential for resource exploitation (Source: PER 2011-2020)

3.4 High temperature (> 150 °C) geothermal resources

Active volcanism provides the necessary conditions that enable the existence of high temperature geothermal resources in 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 like Lanzarote and La Palma, geothermal surface manifestations doesn't appear to indicate the presence of geothermal reservoirs at depth.

In the island of Tenerife, the potential existence of geothermal reservoirs has been estimated at depths between 2,500 and 3,500 m and temperatures in the range of 200-220 °C. Geothermal energy in the form of recoverable stored heat in such zone has been estimated at 1.82×10^5 GWh. Up to 227 MW(e) conventional flash type could be installed in taking into account geothermal resource performance, sustainability and operating load factors.

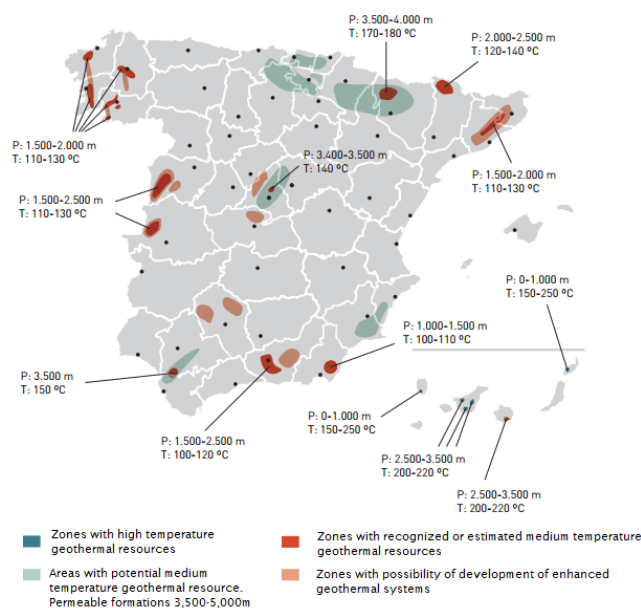


Figure 2: Map of medium and high temperature geothermal resources and possible enhanced geothermal systems (Source: PER 2011-2020)

3.5 Enhanced Geothermal Systems (EGS)

The basic criteria used when selecting areas that have the potential for the development of EGS are: 1. the presence of a low permeable granitic or metamorphic formation; 2. significant regional fracturing affecting the rocks; and, 3. a certain degree of geothermal anomaly. In light of these criteria, a detailed review of the peninsular geology has revealed several areas which 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

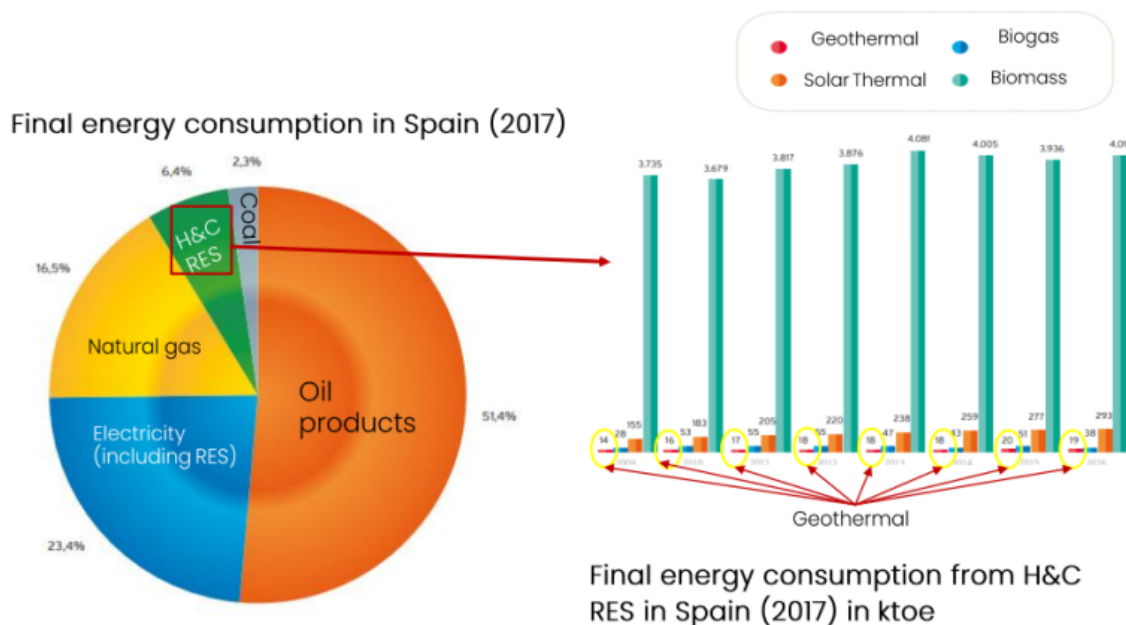
Tormes), fractured areas west of Cáceres, the borders of the Tagus River depression, which are characterized by large-scale fractures that affect the Hercynian basement and finally, areas in Andalucía where the Paleozoic basement is highly fractured, such as Sierra Morena or the the Bética Ranges internal zone 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 60×10^5 GWh, which would allow installing a total power capacity of 745 MW (e) when taking into account the already mentioned performance, sustainability and usage load factors.

4. GEOTHERMAL UTILIZATION

Nowadays renewables constitute 17.5% of the Spanish energy basket. In 2030, the use of renewables in Spain has to reach 42%.

For its part, thermal renewables for heating and cooling constitute just 6.4% of the Spanish energy basket. In Spain, heating and cooling in buildings represents approximately 31% of the final energy demand and is being provided by fossil fuels (mainly natural gas and oil). Spain has a huge energy dependency (over 70%) which means a relevant loss of national wealth (cost of energy 18,000 M€/year). The Integrated National Energy and Climate Plan established thermal renewables have to double its current installed capacity by 2030. It's not an ambitious target, nevertheless it's not a limit, it's just indicative, it could be overpassed.

Geothermal doesn't play a major role in the Spanish energy system. Its presence in the Spanish energy mix is just testimonial.



Source: Study of the Macroeconomic Impact of Renewable Energies in Spain 2017 (APPA)

Figure 1: (left). Final energy consumption in Spain (2017)

Figure 2: (right). Final energy consumption from H&C RES in Spain (2017) in ktoe

There are no high enthalpy geothermal facilities in Spain. There was great business interest (mainly utilities) in developing projects of geopower. More than 50 exploration permits were submitted in Spain between 2008-2010. However, geothermal energy for power generation is still paralyzed. The requested exploration permits are being maintained or are expiring due to the impossibility of promoting projects in the renewable power auction system that has been established in Spain. The renewable moratorium (2012) and the reform of the electricity sector paralyzed and impeded the initial development of geopower in Spain. The two auctions of renewable power that have taken place in 2017 have awarded a total of 8,000 MW, none of which will be used to generate geothermal electricity.

The geothermal sector has criticized the parameters used to choose the successful tenderers of the last renewable power auctions (these parameters can never be incorporated into 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 have respected 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 unacceptable conditions for the state of the art of electricity geothermal technology in Spain. This has prevented the promotion of geothermal power installations in Spain.

On the other hand, shallow geothermal energy is a reality in Spain. Open systems of geo-exchange with heat pumps have been widely used for many years. Closed systems begin to progressively extend from the year 2000, both in buildings and industries. After the collapse experienced by the construction sector, the installation of geo-exchange systems maintains a growing trend, although slower than desirable given the existing capacities and energy needs. The installation of geothermal exchange systems has intensified in all types of buildings, both in new constructions and in rehabilitations. Furthermore, public administrations are moving more and more 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.

Geothermal energy for heating and cooling applications in buildings should play an important role in the framework of the future Spanish Climate Change and Energy Transition Law, with the aim of contributing to the achievement of Spain's energy and climate change commitments.

A sustained growth of the thermal power installed in Spain (mainly derived from the installation of geothermal exchange systems) (in MWt) has been foreseen by GEOPLAT:

2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
289	326	368	416	470	531	601	679	767	866	979	1.106	1.250

5: DEPLOYMENT OF GEOTHERMAL IN SPAIN

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 are results of the before mentioned analysis, are provisional and based on internal estimations:

5.1 Generation of economic activity

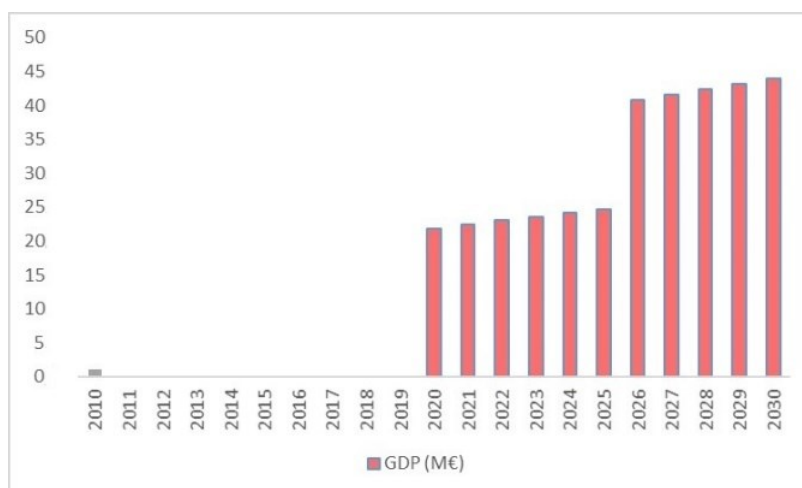


Figure 3: Estimated economic activity generated provided by geothermal energy for power generation sector during the period 2012-2030. Contribution to Spain's GDP (Source: GEOPLAT - provisional data based on internal estimations)

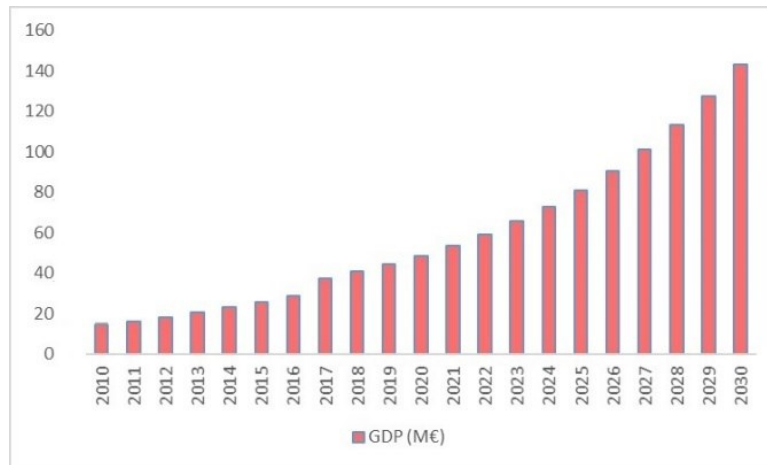


Figure 4: Estimated economic activity generated, provided by geothermal energy for thermal generation sector during the period 2012-2030. (Source: GEOPLAT - provisional data)

5.2 The geothermal energy market in Spain

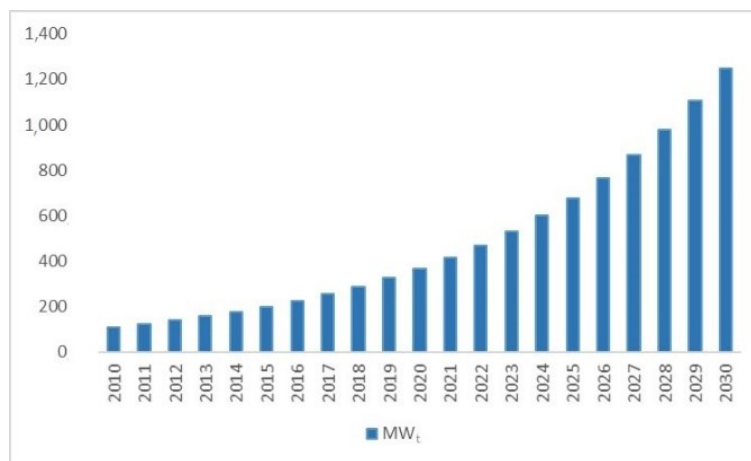


Figure 5: Estimated installed capacity annually by the geothermal energy sector for thermal generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

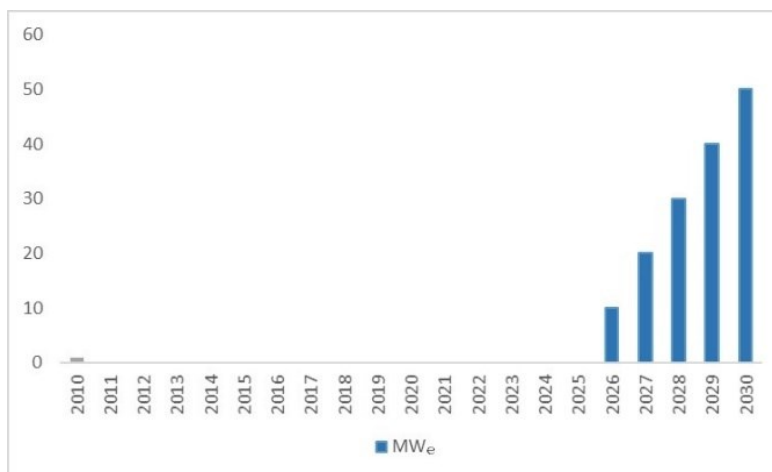


Figure 6: Estimated installed capacity annually by the geothermal energy sector for power generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

5.3 Potential employment of geothermal energy sector in Spain

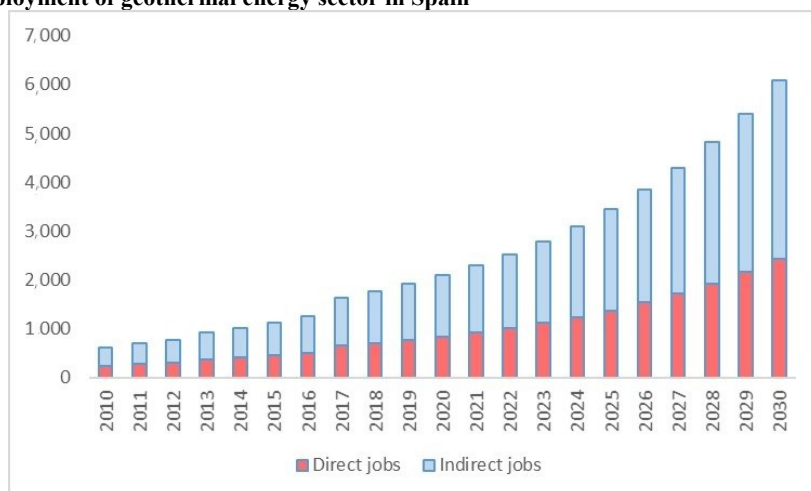


Figure 7: Estimated number of people employed annually by the geothermal energy sector for thermal generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

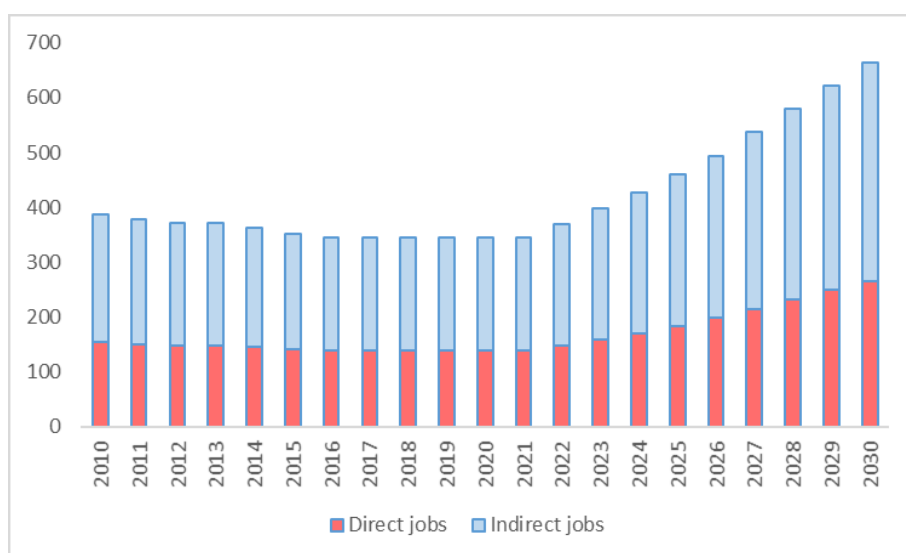


Figure 8: Estimated number of people employed annually by the geothermal energy sector for power generation in Spain until 2030. (Source: GEOPLAT - provisional data based on internal estimations)

6. DISCUSSION

The 2020-2030 decade is presented as a very hopeful period to achieve an implementation of geothermal energy in Spain. An opportunity to value the capabilities of geothermal energy and contribute to the objectives of future Spanish standards that are yet to be approved, such as the Law on Climate Change and Energy Transition and the National Integrated Energy and Climate Plan. Geothermal energy added value will be strategic for Spain due to:

- Production of renewable thermal energy (heating and cooling) that can be used in buildings as well as in industries and the tertiary sector (hotels, shopping centers, etc.)
- Production of renewable dispatchable energy able to provide green base load
- Buildings in which this type of renewable HVAC systems can be installed range from individual buildings to community buildings and sets of buildings (using district heating and cooling systems). Both in new construction and in refurbishment
- Possibility of generating heating and cooling in the same system, 24 hours a day, 365 days a year. In addition to being soundproof systems, without external visual impact and without condensation towers (avoid sanitary problems due to legionella)
- The geothermal resource of very low enthalpy and the storage capacity of the land is found everywhere, so there are no restrictions of use associated with the existence of the resource

- Being inertial heating and cooling systems that maintain the temperature throughout the year, make them perfect for rolling the consumptions peaks of electricity that occur in heat and cold peaks
- Thermal storage capacity in the field
- Creation of a sustainable industrial sector of difficult or impossible offshoring. Small and medium-sized companies linked to the installation and larger companies linked to the manufacture of equipment
- Reduction of the energy dependence of fossil fuels in the generation of thermal energy, a real energy sink for both Spain and the EU due to its high dependence. The implementation of geothermal exchange systems for heating and cooling is strategic for energy transition
- Hybrid technology with other renewable thermal technologies and also with renewable systems of electrical self-consumption (photovoltaic)
- Reduction of greenhouse gas (GHG) emissions
- Improvement of the National balance of payments
- Lamination the effect of Urban Heat Island in cities

But it is necessary the adoption of an adequacy of the legal framework to implement geo-exchange massively in Spain. This would give an increase knowledge among public administrations and other decision-makers (developers, architects, property managers, etc.); and an improvement / optimization of the processing of the facilities: simple, coherent and homogeneous instrumentalization between Autonomous Communities of administrative and environmental procedures.

In addition, it will be key training of qualified professionals to guarantee the quality of the geothermal installations and appropriate promotion instruments such as:

- Auctions for new technologies in Spain, not only driven by price, also driven by strategic qualities: Dispatchability, green base load, etc.
- Support mechanisms to mitigate/share geological risks in the first phases of geopower projects
- Deductions / Tax incentives (not the 'polluter pays principle', the other way round)
- Innovation windows and public green purchase

ACKNOWLEDGEMENTS

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REFERENCES

- ALINNE – Alianza por la Investigación y la Innovación Energéticas (www.alinne.es)
- APPA – Spanish Renewable Energy Association (www.appa.es)
- European Commission - Clean energy for all Europeans (<https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans>)
- GEOPLAT – Spanish Geothermal Technology Platform (www.geoplat.org)
- IGME - Estudio de las posibilidades de explotación de energía geotérmica en almacenes profundos de baja y media entalpía del territorio nacional. 1981
- IGME – Seguimiento de sondeos de hidrocarburos. 1984
- TRT – Sánchez Guzmán. Yacimientos Geotérmicos Estimulados. Potencial en España. GeoEner 2010
- IDAE - The Spanish Institute for Energy Diversification and Saving (www.idae.es)
- IDAE – Instituto para la Diversificación y Ahorro de Energía: Evaluación del potencial de energía geotérmica. Estudio técnico PER 2011-2020)
- MITECO – Spanish Ministry for the Ecological Transition
- REE - Informe del Sistema Eléctrico Español 2018 (www.ree.es)

TABLE 1: PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		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 2019	0	0	2,490*	6,683*	17,049*	34,106*	7,117*	53,198*	31,564*(1)	66,208*	104,094*	260,974*
Under construction in December 2019	-	-	-	-	-	-	-	-	-	-	-	-
Funds committed, but not yet under construction in December 2019	-	-	-	-	-	-	-	-	-	-	-	-
Estimated total projected use by 2020	-	-	-	-	-	-	-	-	-	-	-	-

*31 Dec 2018. National electricity system

(1) Hydro-wind, wind, solar thermal, photovoltaic, biomass, biogas and hydraulic marine energy

TABLE 5: SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (oC) - outlet temp. (oC)] x 0.1319 (TJ = 1012 J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 106 W)

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity ¹⁾ (MWt)	Annual Energy Use ²⁾ (TJ/yr = 10 ¹² J/yr)	Capacity Factor ³⁾
Individual Space Heating ⁴⁾			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying ⁵⁾			
Industrial Process Heat ⁶⁾			
Snow Melting			
Bathing and Swimming ⁷⁾			
Other Uses (specify)			
Subtotal	31*	391	
Geothermal Heat Pumps	513	3,542	21.9
TOTAL	544		

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

* Includes Individual Space Heating, Greenhouse Heating, Bathing and Swimming.