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Geothermal Energy Use, Country Update for Spain

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ABSTRACT

Spain geothermal resources potential is very high. An adequate harnessing through proper development initiatives can take it to similar usage of other European nations. Nonetheless, geothermal energy in Spain still shows a very low penetration despite its great potential.

At present, there are no power generation geothermal plants in Spain. Business initiatives however, have shown a growing interest in developing this type of projects in the short and medium term. It means geothermal energy could show clear opportunities for development in our country according Spain's geological setting, particularly suitable for the development of EGS type projects. Despite this, the development of deep geothermal energy projects in our country clearly lags behind what is taking place in this field in our surroundings as a result of the current situation of the Spanish electricity sector. The indefinite moratorium that was decreed for all types of renewable energy in addition to the 7% tax imposed on the value of electric energy production in all types of power stations, including renewables, are unfortunately slowing down the momentum gained by these types of projects.

With regard to low-temperature geothermal energy, Spain's current installed capacity (built during the 80's) is associated with direct heat applications, mainly for spas and greenhouses. Future estimates indicate that this type of applications will not experience any further increase. In addition, it is estimated that from 2015 onwards, several heating and cooling network projects (known as geothermal district cooling and heating) may be launched. On the other hand, shallow or very low temperature geothermal energy used in cooling and heating is already a reality in our country. Although no definite data are available on the installed capacity of geothermal energy in Spain, estimates of 150 MWt have been reported, allowing the progressive development in parallel of a new industry in this sector.

At present, and despite the contraction experienced by the construction sector, the expected evolution of energy prices in the coming years is continuously fueling the growth in the number of very low temperature geothermal installations both in the residential and institutional fields, as well as in the creation of an emerging market where shallow, or very low temperature geothermal energy, can be used for heating and cooling and DHW. It is worth noting that building (energy efficiency improvement) rehabilitation may play an important role in this respect.

1. INTRODUCTION

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.

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	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)

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 in order 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. 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 weight greater than 2.0 tm/m^3, 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…. standing many of the country's main cities (Zaragoza, Seville, etc.). These aquifers, very transmissives (> 10^3 m^2/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, for 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.

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 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. 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 80's 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 a significant demand levels of this energy for direct heat applications.

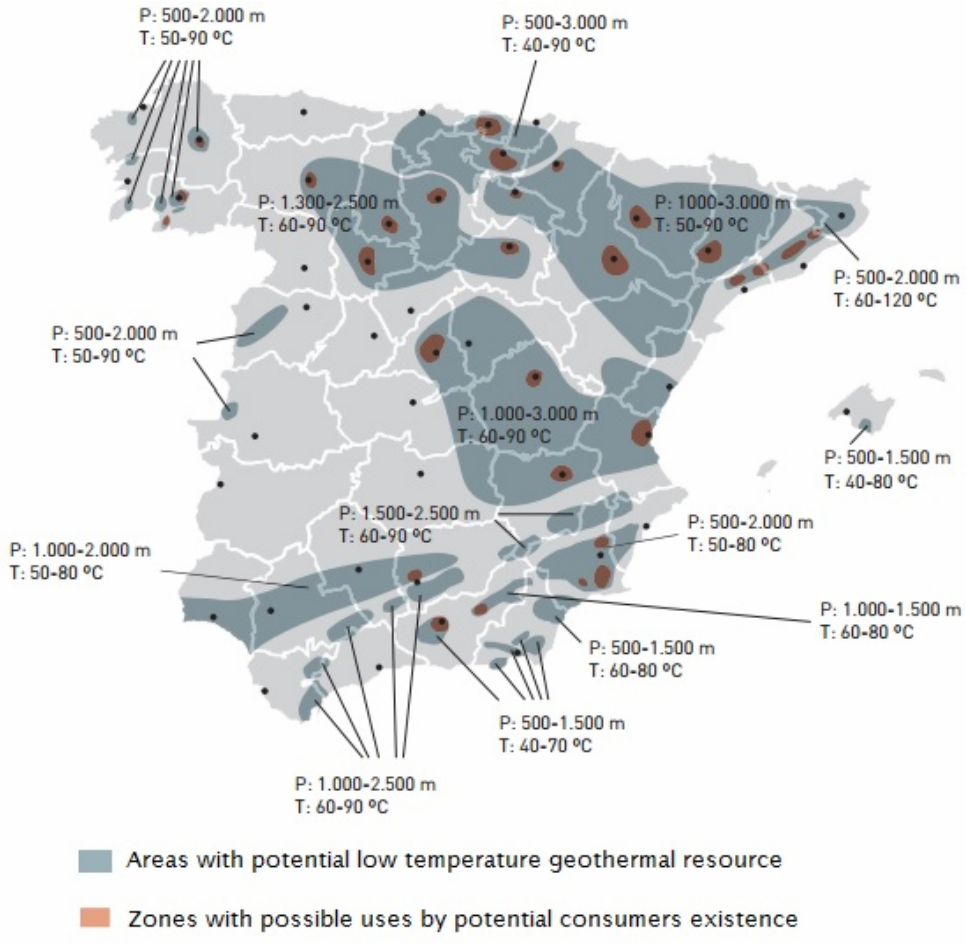

Figure 1. Map of low temperature geothermal resources and zones with good potential for resource exploitation (Source: PER 2011-2020)

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 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.

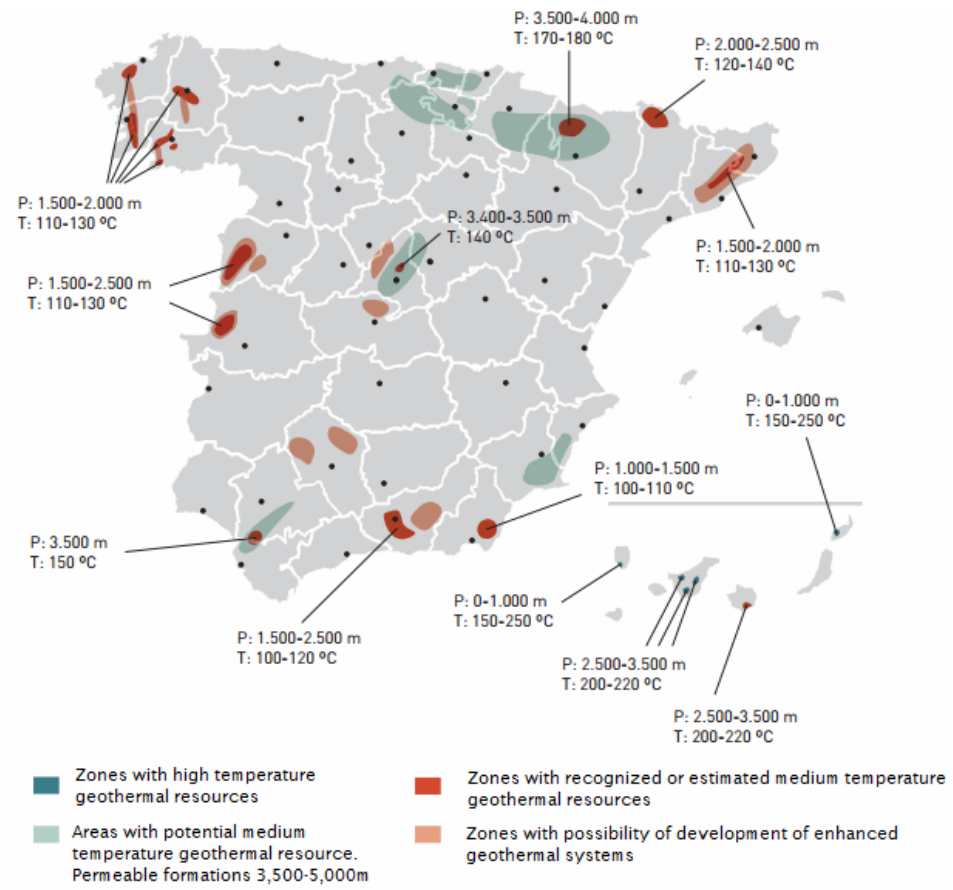

Figure 2. Map of medium and high temperature geothermal resources and possible enhanced geothermal systems (Source: PER 2011-2020)

In the three areas mentioned earlier in 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 are 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. INSTITUTIONAL ACTIVITIES

Originated in Europe, Directive 2009/28/CE brought a clear proposal to the table for the promotion of the use of energy from renewable sources and for implementing efficiency measures aimed at improving the end consumption of energy. A key milestone was established in this respect: the year 2020, in addition to a set of mandatory targets to be achieved in said year that require high levels of competitiveness and excellence during this period.

Although still at incipient stages of development but with an enormous potential to contribute to these targets, geothermal energy must not lag behind and must face the challenge of becoming an additional, real and accessible option in the energy market up to the year 2020.

In Spain, the 2011-2020 Renewable Energy Plan (PER) constitutes the strategic roadmap that was prepared by the Government with the purpose of providing the necessary instruments that would allow integrating the particularities of our situation with the energy potential of our country for developing a sustainable national energy model. In this sense, the 2011-2020 PER represents a milestone in the Spanish geothermal sector since, after decades of absence, geothermal energy, our energy, once again becomes part of national energy planning and its potential contribution thereto is taken into account.

A gross potential of 3,000 MW has been estimated according to the 2011-2020 PER, which can be harnessed through conventional or enhanced geothermal systems for the generation of electricity. It has been stated that the challenge that must be overcome to develop this sector would be to find the manner in which geothermal resources can be tapped in a technically and economically viable way. In this respect, the 2011-2020 PER states that new drilling methods must be developed. Furthermore, the 2020 50 MW target still remains, and the 2011-2020 PER indicates that plants will begin to be developed starting in 2017, linking their pace of development to potential drilling risks and the development of new enhanced geothermal systems technology. In addition, it is stated that Spain has an installed thermal capacity greater than 100 MWt and that the geothermal energy potential for thermal uses can exceed 50,000 MWt. Some of the challenges that must be overcome to promote further the development of the sector include the reduction of thermal energy generation costs and the increase in heat pump efficiency.

Moreover, the 2011-2020 PER specifies the targets that this technology must achieve by 2020, both in terms of electricity and heat (table 1).

It is estimated that the production of thermal energy from geothermal sources will occur through the use of heat pumps, to which a partial target of 40.5 ktoe has been assigned (representing about 471 GWh) and direct heat uses. In the latter case, a partial target of 9.5 ktoe has been assigned (about 110.5 GWh).

Based on analyses of the sector (which were eventually used as a source of information for the preparation of the 2011-2020 PER), the latter is expected to grow based on two scenarios (figure 3). Both suggest that the penetration ratios of shallow geothermal energy through the use of heat pumps will converge toward the 2010 levels of two of our neighboring countries that were chosen as a reference (France, with similar climate and market configuration) and Austria, with maximum levels of penetration of GSHP in terms of installed capacity per capita. Convergence to such rates is shown in the following chart and is perhaps the most reliable market potential indicator at present. It is worth noting that the values that were used for its preparation are quite less ambitious than those reflected in said market potential charts.

Table 1: 2011-2020 targets for renewable technologies in PER 2011-2020)

- Electricity production targets. The 2020 target in the use of geothermal energy for the production of electricity is set to 50 MW.

	2010		2015		2020	
	MW	GWh	MW	GWh	MW	GWh
Hydro (w/o pumping)	13,226	42,215	13,548	32,538	13,681	33,140
<1 MW (w/o pumping)	242	802	253	772	268	843
1-10 MW (w/o pumping)	1,680	5,432	1,764	4,982	1,917	5,749
>10 MW (w/o pumping)	11,304	35,981	11,531	26,784	11,676	26,548
With pumping	5,347	3,106	6,312	6,592	8,811	8,457
Geothermal	0	0	0	0	50	300

- Heat production targets.

ktoe	2010	2011	2015	2020
Geothermal energy (excluding low temperature geothermal heat in heat pumps applications)	3.8	3.8	5.2	9.5
Thermal solar energy	183	190	308	644
Biomass	3,729	3,779	4,060	4,653
Solid (includes waste)	3,695	3,740	3,997	4,553
Biogas	34	39	63	100
Renewable energy from heat pumps	17.4	19.7	30.8	50.8
Of which, aerothermal represents	5.4	5.7	7.4	10.3
Of which, geothermal represents	12.0	14.0	23.4	40.5
Total	3,933	3,992	4,404	5,357

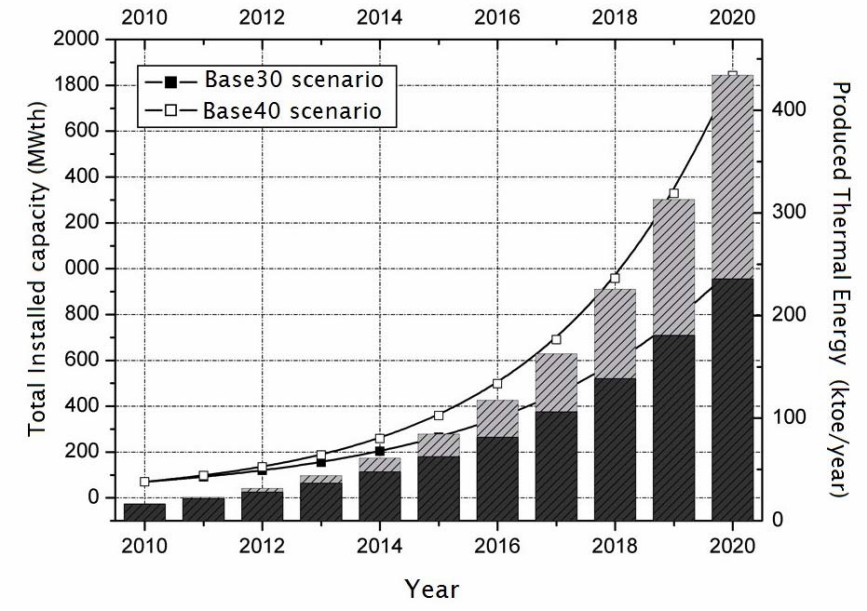

Figure 3: trend chart showing the potential growth of GSHP in the Spanish market based on two scenarios (see text).

Although the targets that were established in the 2011-2020 PER are quite far from the actual generation potential displayed by both high enthalpy geothermal systems for electricity production and low enthalpy geothermal systems for heat production, the sector values strongly that one of the youngest renewable energy sources in Spain has been taken into consideration at last, and that a series of specific measures have finally been proposed to promote their development in the coming years.

In addition, the sector is working jointly in the preparation of the AENOR (The Spanish Association for Standardization and Certification) standard that will cover the design, execution and monitoring of vertical, closed-circuit shallow geothermal installations. The purpose is for this standard to be one of the first of a series of standards that will cover the same phases for all types of geothermal exchanger based installations: closed loop horizontal, open loop, etc. The lack of specific regulations in Spain for this type of installations represents a significant hurdle, since not enough mechanisms exist to guarantee the operation and quality of installed geothermal exchanger systems.

4. POLICY UPDATES

The situation of the Spanish electricity sector in 2012 makes the development of deep geothermal energy systems or the production of electricity in Spain difficult to a large extent. The indefinite moratorium that was decreed for all types of renewable energy in addition to the 7% tax imposed on the value of electric energy production in all types of power stations, including renewables, are unfortunately slowing down the momentum that many Spanish energy companies had gained with the purpose of developing projects in Spain. This will continue to maintain Spain's anonymity, despite the country's unique capacities such as the ability to replace large conventional installations, which are suitable for delivering a manageable base load to the system.

There are over 50 geothermal exploration-investigation permits in Spain, representing a commitment of about 10 million euro. Significant employment opportunities are linked to the development of these permits, which will be truncated as a result of the regulatory changes approved during 2012.

In turn, shallow geothermal energy for heating and cooling and ACS have enjoyed a few years of relative expansion in Spain, thriving on the success of the construction sector. The development of shallow geothermal energy (or low enthalpy) in our country will come from the savings and the improvements in energy efficiency that it brings. The breakthrough of this technology in the market is quick, although the crisis that affects the construction sector in our country hinders its development. Nonetheless, the possibility to generate heat and cold using the same system, coupled with high performance, a progressive reduction of technology costs and the upward trend of fossil energy source prices with which it competes make this technology more attractive every day, not only in the case of new buildings but also when improving the energy efficiency of existing ones.

The article structure of the European Energy Efficiency in Buildings Directive approved in 2010 must be transposed in the next RITE (Regulations on Building Heating Installations) and CTE (Technical Building Code) updates. The drafts of the Royal Decree project that modify certain articles and technical instructions of the RITE and the Draft Order that updates the DB HE Basic Document 'Energy Savings' of the Technical Building Code were published during 2012. Unfortunately, none of them capture the essence of such Directive, to the point where this renewable technology has been outright ignored along with its prioritization in the use in building construction with the rest of renewable energy options, particularly in public buildings. On the contrary, the partial contribution of renewables is maintained, but only for domestic hot water needs (DHW) of buildings, when in fact geothermal energy has the capacity to satisfy the full needs of a building, including heating and cooling.

The timely adoption of this European Directive is of paramount strategic importance since it would allow steering the industrial sector in the direction indicated by the objectives contained therein (smart cities and zero emission buildings) by 2020. This would kick-start the national production machine, triggering also the creation of jobs in the field of energy efficiency improvement in buildings.

From a technology perspective, in 2012 the Spanish Geothermal Technology Platform (GEOPLAT) agreed to the creation of an entity dedicated to formalize official training in the field of geothermal energy in Spain. The fundamental purpose of this newly created entity will be to satisfy the requirements established in article 14 of the European Directive on the promotion in the use of energy from renewable sources, which establishes that member States must have certification or qualification systems for renewable energy based heating system installers. The Directive will also be used to certify official geothermal energy training programs (to be recognized across Europe), which would favor the safe and reliable evolution of the Spanish geothermal sector.

To conclude, a great challenge still remains in the field of shallow geothermal energy with regard to the creation of reliable databases that capture the number of existing installations and their characteristics. The absence of such information is largely due to disperse regulations and the lack of coordination at the national level in terms of the amount and type of the information that should be submitted in addition to how the latter should be handled by housing or geothermal system project developers. In this sense, we the authors consider that the development of criteria that can contribute to stiffen the requirements

in terms of the quantity, quality and homogeneity of statistical information on thermal use in member states is of paramount importance.

CONCLUSIONS

Traditionally ignored in Spain due to scarce information and knowledge, geothermal energy has experienced a certain come-back in recent years as a result of the emergence of new applications such as the use of heat pumps or the growth of renewable energy over the past few years, which has once again displayed the significant potential that this resource has in our country.

In the context of Directive 2009/28/CE and European efficiency criteria running up to 2011, a new range of laws and national directives (particularly the 2011-2020 PER) have set objectives and figures for the sector, given both its potential and the interest it has generated.

Nevertheless, the current crisis in the construction sector coupled with the introduction of a strong set of legislative measures that do not discriminate between sources and technologies and which show a tendency to reduce the system costs that other renewable technologies have generated pose, at present, a serious threat to our sector's ultimate takeoff.

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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	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2012	0	0	108,296	283,773	0	0
Under construction end of 2012	0	0	N/A	N/A	0	0
Total projected by 2015	0	0	N/A	N/A	0	0

Table B: Existing geothermal power plants, individual sites*

*Geothermal power plants are not available in the country.

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

*Geothermal district heating plants are not yet available in the country.

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

*Geothermal district heating plants are not yet available in the country.

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

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2012	3,300	150	210	450	18	<1
Projected by 2015	4,600	210	285			

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power		212	N/A	N/A
Geothermal direct uses		0	N/A	N/A
Shallow geothermal		126	N/A	N/A
total		**338**	N/A	N/A

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	LIL	LIL	LIL
Financial Incentives – Investment	-	-	-
Financial Incentives – Operation/Production	FIT (now under moratorium since January 2012)	-	DIS; LIL
Information activities – promotion for the public	-	-	YES
Information activities – geological information	NO	NO	NO
Education/Training – Academic	NOT YET	NOT YET	NOT YET
Education/Training – Vocational	-	-	YES

Key for financial incentives:					
DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota