geoplat

SPANISH GEOTHERMAL TECHNOLOGY PLATFORM

Vision for 2030

UNION EUROPEA
FONDO EUROPEO DE DESARROLLO REGIONAL

GOBIERNO DE ESPAÑA

MINISTERIO DE CIENCIA E INNOVACIÓN

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Executive
Summary

The endorsement in June 2009 of the European Directive on Renewable Energy *(Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of the use of energy from renewable sources)* by the European Parliament constitutes a solid backing for the development of thermal energy from renewable sources in general and for geothermal energy in particular. The reason is the inclusion, for the first time, of energy from renewable sources that is destined to heating and cooling in the calculation of the share of renewable energy that each Member State is to attain by the year 2020, which is currently set to 20% of the total energy consumption.

The importance of the use of thermal energy, which represents 48% of the final energy consumed in Europe in 2007, has been traditionally overlooked with respect to electricity generation based on renewable sources. In our country, where thermal demands for heating are slightly lower to the European average, this phenomenon has been stressed despite the threat that a ceaseless increment of the cooling demand poses to the electricity generation and distribution system in particular.

It is precisely within the context of this Spanish generation system – where renewable energy is gradually acquiring more importance – where high-enthalpy geothermal energy offers an enormous potential for continuous electricity generation, adding thus reliability and stability to the grid. The development and implementation of new techniques to harness the energy stored in deep formations – together with its ease of dispatchability – can clear the road for the take-off of this type of energy in the coming years.

Until recently, geothermal energy has remained outside of the national energy outlook. After the experiences at the end of the 80's, a period of over ten years followed in which, due to a number of reasons geothermal energy remained marginal to Spanish energy planning. The introduction of geothermal exchange technology for harnessing low-temperature geothermal resources and the advent of enhanced deposit type projects developed in several parts of the world have reactivated the interest about this type of energy.

Some of the characteristics of geothermal energy that have once again allowed their upturn in the global context must be highlighted:

ESTIMATES CONDUCTED FOR SHALLOW GEOTHERMAL PREDICT THAT INSTALLED CAPACITY CAN EVOLVE IN THE COMING YEARS FROM THE CURRENT 80 MW TO ABOUT 1,000 MW IN THE YEAR 2020 AND UP TO 3,000 MW IN 2030.

- It is a renewable energy linked to the subsurface of the Earth at variable depths, which can and must be harnessed in a sustained manner.
- It is an energy whose production can be maintained without suffering variations in neither supply nor limitations at any time.
- It is an environmentally-friendly type of energy that does not generate contaminant emissions.
- It is compatible with other natural resources whose research and use thereof can be surely conducted with minimal interference with any existing and future use of other resources.
- It is a type of energy that requires significant initial economic investment but with very low maintenance and operation costs, which allows moderately short return on investment periods.
- It can contribute efficiently toward the approaches and requirements, from an energy standpoint, of new buildings with respect to climatization, hot sanitary water and aeration.
- On top of its use for climatization of spaces and hot sanitary water, there are important industrial sectors who demand this type of energy to improve their energy supply systems including greenhouses, fish farms, drying facilities, desalination plants, public works, etc.

Shallow geothermal energy can contribute significantly toward the achievement of national renewable energy generation targets set forth both in the new European Directive on Renewable Energy and in the 2008-2012 Spanish Energy Saving and Efficiency Action Plan (PAEE). It entails a distributed type of generation that has no incidence on the tariff deficit, does not cause land occupation, has a net positive environmental impact, is impossible to delocalize and has average costs of around 5 million €/ktoe.

Estimates conducted predict that installed capacity can evolve in the coming years from the current 80 MW to about 1,000 MW in the year 2020 and up to 3,000 MW in 2030.

Deep geothermal energy has a strong potential in Spain. Estimates conducted show that, in the presence of a favourable regulatory and financial framework, an installed capacity of 1,000 MW electric and 300 MW thermal can be reached. 2030 forecasts raise these figures up to 3,000 MW electric and 1,000 MW thermal.

The key aspects that will enable the development of geothermal energy in our country in the scenarios considered are:

- Promotion of geothermal energy through its inclusion in the new 2011-2020 Spanish Renewable Energy Plan (PER) and National Action Plan with the adoption of precise regulatory measures and the definition of pilot programs.

- Updating and permanent management of the knowledge pertaining to the Spanish geothermal potential.

- Development of R&D&i programs that are adapted to the particularities of the sector in Spain, aimed at strengthening the innovation capacity through facilitating significant reductions in generation costs and increasing system efficiencies.

- Development of a training and certification model that covers the different spheres of geothermal energy.

ESTIMATES CONDUCTED FOR DEEP GEOTHERMAL SHOW THAT, IN THE PRESENCE OF A FAVOURABLE REGULATORY AND FINANCIAL FRAMEWORK, AN INSTALLED CAPACITY OF 1,000 MW ELECTRIC AND 300 MW THERMAL CAN BE REACHED. 2030 FORECASTS RAISE THESE FIGURES UP TO 3,000 MW ELECTRIC AND 1,000 MW THERMAL.

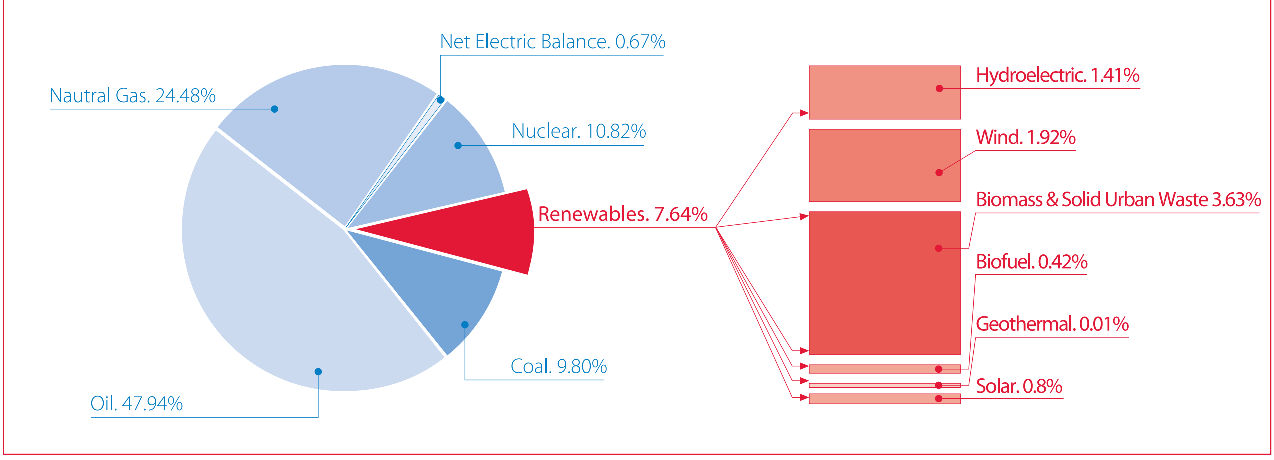
2 Introduction

BENEFITS OF RENEWABLE ENERGY

In the current energetic context –which is characterized by a pressing need to reduce foreign energy dependence and improve the use of existing resources, coupled with society's growing environmental sensibility – renewable energy, together with energy saving and energy efficiency have become the strategic answers to the key problems that have been raised.

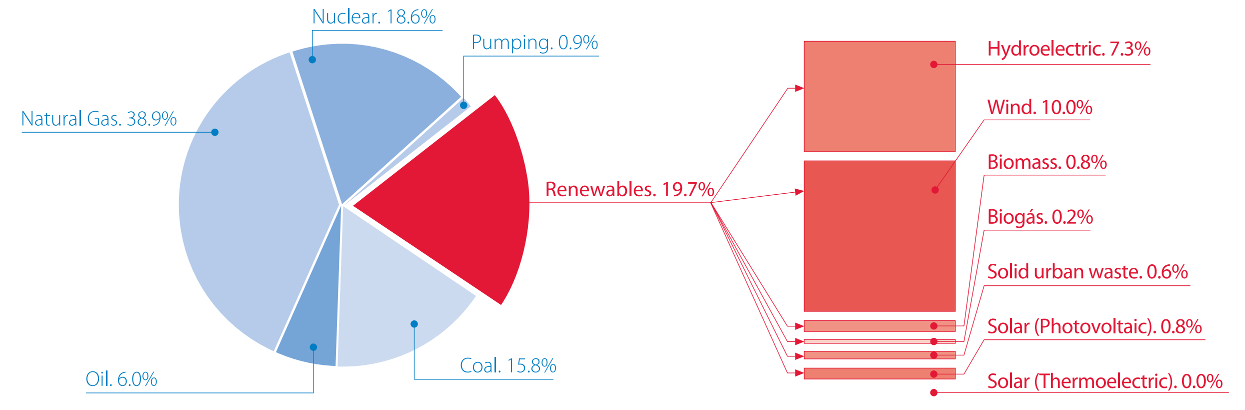
Spain holds a privileged position in the field of renewable energy, due fundamentally to its geographical location and geophysical conditions. These aspects together with the existence of an adequate legal framework for the development of these new energy sources have enabled important advances in the generation of electrical energy from renewable sources. Furthermore, a dedicated industry has literally taken off, which is able to promote technological developments while at the same time becoming an international reference.

PRIMARY ENERGY CONSUMPTION BY SOURCE IN **2008**



SOURCE: MITYC/IDAE.

STRUCTURE OF ELECTRICITY PRODUCTION IN **2008**



SOURCE: MITYC/IDAE

The renewable energy sector in Europe has generated 450,000 jobs and has reached an annual volume of €45,000 million. It avoids a quarter of CO_2 emissions under the European Union's (hereinafter 'EU') commitment with the Kyoto Protocol and has satisfied 10% of the Union's final energy demand in 2008. Furthermore, it is estimated that 2 million new jobs will be created as a consequence of compliance with the 20-20-20 targets for the year 2020 (20% reduction in GHG emissions, 20% of energy from renewable sources and a 20% increase in energy efficiency).

Future challenges facing the renewable energy sector are inextricably linked to the implementation of the European Strategic Energy Technology Plan (SET-Plan) which is the document that constitutes the European Union's technological backbone for energy and climate policies. It entails a roadmap designed to assist the coordinated research in the creation of a portfolio of clean and efficient low-carbon technologies at affordable prices that would enable their penetration in the market at a large scale.

Geothermal energy is included among the technologies considered. The SET-Plan entails an increase in financing for research activities of € 3,000 to 8,000 million annually, which in total would imply an increase in the budget resources for public and private research of € 50,000 million over the next 10 years.

SPECIFIC BENEFITS OF GEOTHERMAL ENERGY

One of the greatest benefits of geothermal energy production resides in its dispatchable nature, which provides a security of supply and thus stability to the electrical system. Furthermore, geothermal energy is characterized by low production costs and a high capacity-to-production ratio, therefore representing a clear opportunity for development in our country given the existing potential.

Low-enthalpy geothermal energy is more extended in Spain, as it possesses significant strengths due to the fact that installation of low-enthalpy geothermal systems (normally associated with heat pumps) implies a substantial reduction of operation and maintenance costs as opposed to conventional HVAC (Heating, Ventilating, Air Conditioning) and DHW (domestic hot water) systems. It is possible to supply heating, cooling, AC and DHW with the same system uninterruptedly 24 hours, 365 days a year.

Space heating, ventilation and cooling using low temperature geothermal systems shows a high a potential in Spain, along with the foreseeable development of a powerful energy capture industry. It is a renewable thermal energy source that both reduces the electricity demand and has a strong capacity to smooth out demand spikes through time.

DEFINITIONS AND DIFFERENCES BETWEEN SHALLOW AND DEEP GEOTHERMAL ENERGY

The European Renewable Energy Directive *(Directive 2009/28/EC of the European Parliament and the Council of 23 April 2009 on the promotion of renewable energy)* establishes a clear definition of Geothermal Energy. Some additional definitions established by the Directive are also worth pointing out:

ONE OF THE GREATEST BENEFITS OF GEOTHERMAL ENERGY PRODUCTION RESIDES IN ITS DISPATCHABLE NATURE, WHICH PROVIDES A SECURITY OF SUPPLY AND THUS STABILITY TO THE ELECTRICAL SYSTEM.
THEREFORE REPRESENTING A CLEAR OPPORTUNITY FOR DEVELOPMENT IN OUR COUNTRY GIVEN THE EXISTING POTENTIAL.

CONCEPT	DEFINITION
Geothermal Energy	Energy stored in the form of heat beneath the surface of solid earth
Aerothermal Energy	Energy stored in the form of heat in ambient air
Hydrothermal Energy	Energy stored in the form of heat in surface water

Other definitions that may be of interest:

CONCEPT	DEFINITION	DESCRIPTION/CHARACTERISTICS
Geothermics	Discipline that studies the earth's interior heat, its origin, distribution and use	• It covers processes and techniques used in the exploration, evaluation and use of geothermal energy.
Geothermal Resource	Part of the geothermal energy that can be used in a technically and economically feasible way.	• Includes not only those that are currently known and whose use thereof is technically and economically viable, but rather those which will also be so in a reasonably near future.
Geothermal Deposit	Physical space in the earth's interior in which a geothermal resource can be found	

CONCEPT	DEFINITION	DESCRIPTION/CHARACTERISTICS
High-Temperature Geothermal Resources	Temperatures above 150º C	• Can be made up of dry steam (in rare cases) or of a mixture of water and steam. • Used fundamentally for electricity generation. • Found principally in areas with high geothermal gradients. • Found at highly variable depths; frequent depths can range between 1,500 and 3,000 meters. • A singular case (although they often involve medium-temperature resources) is that of Hot Dry Rock resources (HDR) which fall under Enhanced Geothermal Systems (EGS), whereby a thermal exchange zone is created within the deep bedrock through stimuli taking place in fractures.
Medium -Temperature Geothermal Resources	Temperature between 100º and 150º C	• They can be used in power generation plants but where the steam-to-electricity conversion occurs at a lower performance, as the use of an intermediary fluid of lower vaporization temperature is required. • Can also be used for thermal purposes in district heating and cooling systems and industrial processes. • Can be found in areas with a high geothermal gradient at depths lower than 1,000 meters and in sedimentary basins at depths between 2,000 and 4,000 meters.
Low-Temperature Geothermal Resources	Temperature between 30º and 100º C	• Used mainly for thermal use in HVAC systems in urban environments and in different industrial processes. • Geothermal fluids are rarely used directly; the most common approach involves using its own energy through exchangers or heat pumps. • They usually require a considerable demand of nearby calorific energy. • Usually found in areas with a normal geothermal gradient at depths between 1,500 and 2,500 meters or at depths lower than 1,000 meters in areas with a higher geothermal gradient.

Shallow or Very Low-Temperature Geothermal Resources	Energy stored in the Earth or in groundwater at temperatures lower than 30ºC.	• The temperatures of these resources usually match the average temperatures of the locations where they are tapped.
		• They use the geothermal energy stored in:
		  • The shallow subsurface (normally less than 250 meters, including heat captured that is associated with construction elements in construction projects).
		  • Groundwater – including that originating from mining and drainage activities associated with civil construction work – which is non-consumptive and is used exclusively for energetic purposes.
		• Thermal uses. Energetic supply to space ventilation, heating and cooling systems and/or processes with or without the use of a heat pump.
		• The renewable energy can be captured in a very efficient manner given the thermal stability of the subsurface in contrast to ambient seasonal changes.

EXISTING TECHNOLOGY

Geothermal energy can be classified according to the following uses:

ELECTRICAL: high-temperature geothermal deposits can be used to produce electricity from:

Conventional geothermal systems

Hot aquifers associated with deep sedimentary basins (known as HSA -hot sedimentary aquifer)

Enhanced geothermal system (EGS).

DIRECT OR THERMAL: includes heating and cooling, district heating networks (which can be backed by cogeneration systems, biomass boilers, etc.), agricultural use (greenhouses, drying of agricultural products), aquaculture (fish farms, algae production), industrial processes and balnotherapy (spas and others).

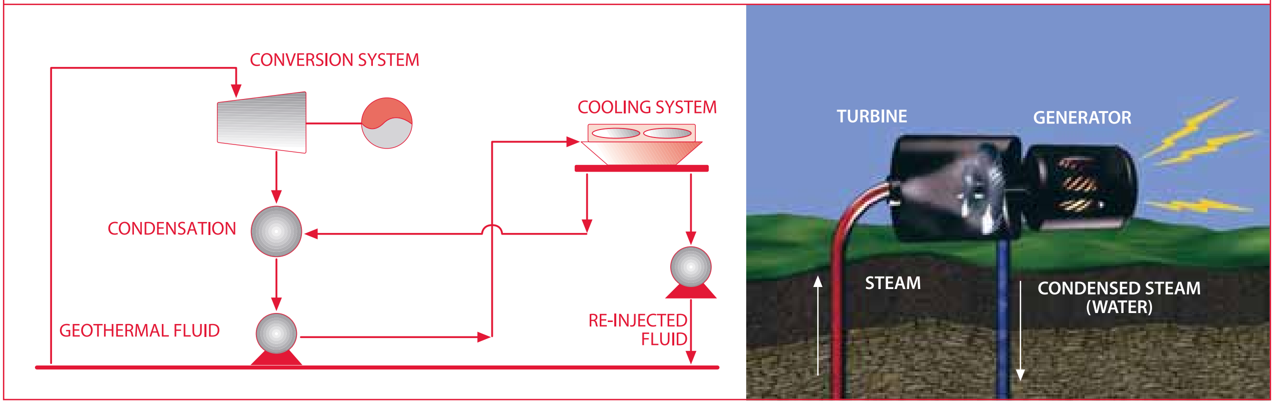
EXISTING TECHNOLOGIES IN DEEP GEOTHERMAL SYSTEMS

There are two technological aspects that control the exploitation of high-enthalpy geothermal resources: extraction of calorific energy and its transformation into a usable form of energy.

THERE ARE THREE TYPES OF GEOTHERMAL PLANTS FOR ELECTRICITY GENERATION DEPENDING ON THE CHARACTERISTICS OF THE GEOTHERMAL FLUID AVAILABLE AS WELL AS ITS DEPTH:

DIRECT STEAM POWER PLANT

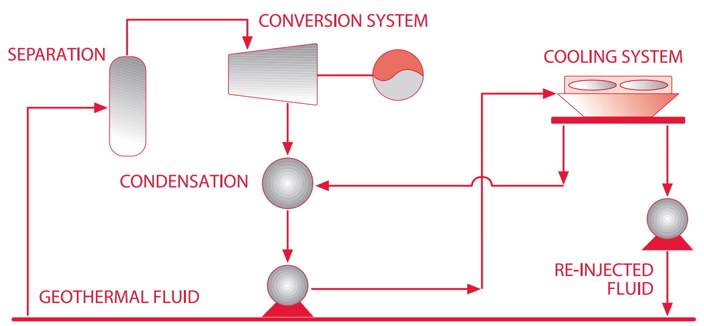
Turbines use the resources in the form of saturated or slightly heated (dry) steam, which reaches the surface through fractures in the underlying materials, generating electricity in a direct manner. Power plant production costs are thus very low.

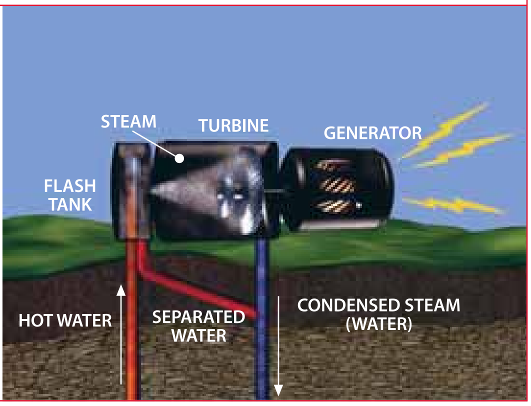


FLASH STEAM PLANT

These power plants are the most indicated to be used with widespread high-enthalpy geothermal resources consisting of a mixture of steam and brine. In this configuration, vapor is first separated from the liquid and subsequently expanded inside a turbine. The rejected brine can be used in other applications such as agriculture and industrial heating processes making use of the technology known as cascading system.

Double-flash vapor systems involve the flow of hot brine through successively lower pressure separators; vapor is then directed to a dual-pressure (or pass-in) turbine from which it flows into a different section thereof. The advantages of this system include improvements in the total efficiency of the cycle and a greater harnessing of the geothermal resource at the expense, however, of higher production costs.

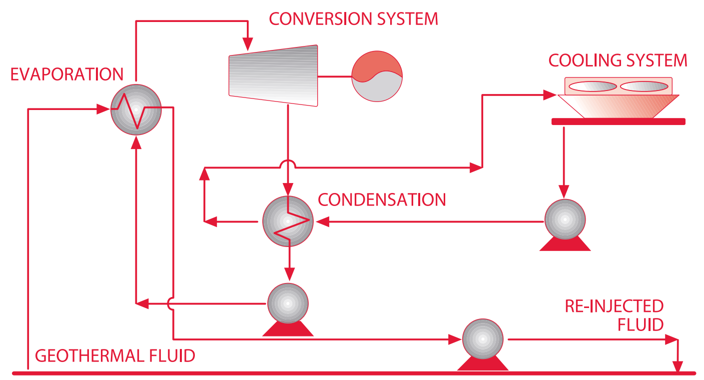


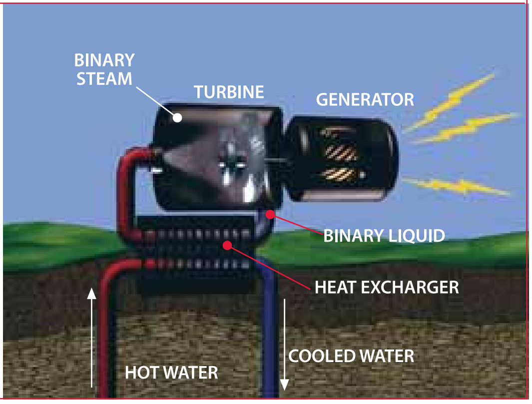


BINARY CLICLE POWER PLANTS

These systems can extract energy more efficiently from medium temperature deposits (>100ºC) and high-salinity geothermal resources than flash-steam plants, resulting also in a lower environmental impact associated with the emission of gases to the atmosphere. They avoid the direct use of the thermal fluid and use instead a secondary fluid that has a better thermodynamic behaviour (low boiling point and high vapor pressure at high temperatures) than the former.

The geothermal fluid delivers heat to the secondary fluid through a heat exchanger which then heats up, vaporizes and expands through the turbine. It then condenses inside a water or air condenser and is pumped back to the heat exchanger to be re-vaporized again. Binary turbines can be Kalina or Organic Rankine Cycle (ORC) types.





Besides electricity generation or direct uses, the combined generation of electricity and direct heat is an option that naturally increments the total energy efficiency of the system by harnessing residual heat from electricity production at temperatures below 80ºC; such heat can be used for example in district heating networks. Some examples include: Neustadt-Glewe (DE, 98ºC, 200 kWe since 2003), Unterhanching (DE, 122ºC, 3.2 MWe Kalina-type plant since 2007) for district heating, and since 2008 for electricity generation.

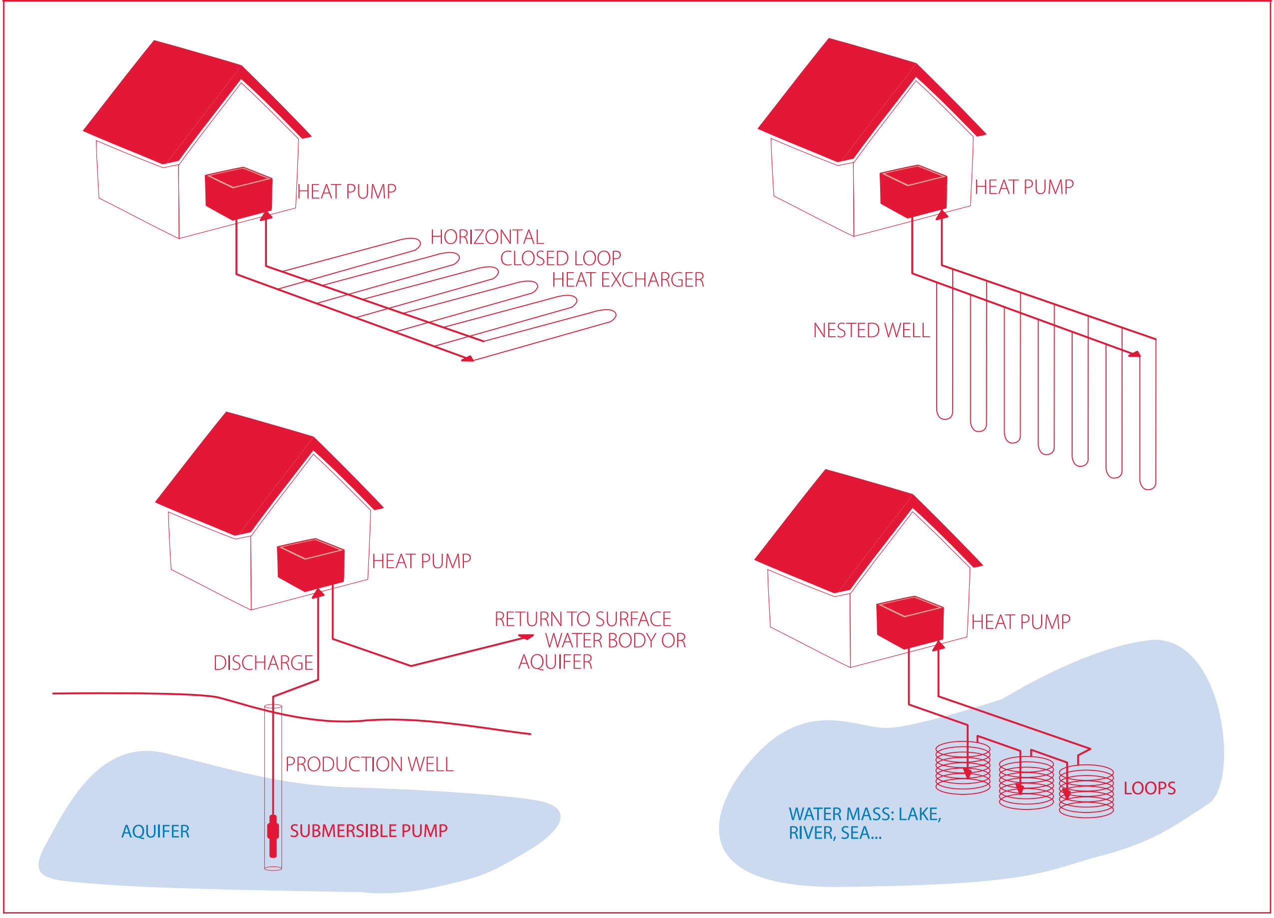
EXISTING TECHNOLOGY IN SHALLOW GEOTHERMAL SYSTEMS

Medium and low-temperature geothermal fluids (>30ºC) can be used to obtain direct heat. For heating applications however, heating pumps are the usual fall-back option when the resource temperature is below 30ºC.

Several technologies have been developed to harness heat from the subsurface based on the accessibility to the geothermal resource.

All these technologies can be classified into two main types: Open circuits, where water is pumped from an aquifer and closed circuits, where an exchanger is installed on-site to exploit the energy resource.

SOME OF THE MOST COMMON TYPES OF GEOTHERMAL HEAT EXCHARGERS



HORIZONTAL CLOSED-LOOP HEAT EXCHANGER

Piping – normally polyethylene (PE) – through which an exchange fluid (water or water-glycol) circulates is installed in trenches at a minimum depth of 0.90 meters. Although usually only two pipes are installed, there are arrangements whereby up to six pipes per trench are used. One variant of this system *(Slinky coils)* involves the placement of loops of PE pipe on the ground and extending them successively while intercalating selected soil types or sand. Heat generation needs are estimated to range between 10 and 35 m/kW depending on lithological characteristics, the degree of soil moisture and the number of PE pipes in the trench. This system commonly has lower costs than borehole drilling. Conversely, a considerable amount of land area with ripable (strippable) thicknesses of over 1 meter is required, which are frequently hard to find.

Furthermore, the system is subject to noticeable variations in temperature and moisture content which penalize seasonal performance. A variant of this system – direct expansion systems – activates the heat exchange via the circulation of cooling fluids through the circuit that is installed on the ground.

VERTICAL CLOSED-LOOP HEAT EXCHANGER

This system requires drilling of boreholes at variable depths, usually between 60 and 200 meters. Boreholes are fitted with PE pipes with diameters between 25 mm (3/4") and 63 mm (2") depending on the discharge flow and the length of the circuit. Performance can range between 12 and 20 m/kW depending on the lithological and hydrogeological characteristics of the ground. A small degree of ground occupation is required and the temperature of the medium at depths greater than 10 meters remains perceptibly constant throughout the year. A variant of this system involves the use of energetic foundations (energy piles and other building foundation elements) whereby deep foundation structures are used to capture and dissipate the thermal energy from the ground. The main weakness of such systems lies in its initial implementation costs.

OPEN CIRCUIT

This system involves capturing and the subsequent replacement of groundwater or, less commonly, surface water. It is a widely used system in our environment particularly in areas with alluvial aquifers that present good productivity and shallow piezometry. The system setup includes a simple installation with low investment costs and high performance ranges. The inconvenience however arises from the fact that they are subject to a more complex and longer administrative process.

EARTH-AIR SYSTEMS

These systems allow pre-treatment of the renovated air of a building's ventilation system via circulation through an arrangement of buried pipes. They are known as earth tubes (also known as 'Canadian wells' or 'Provençal wells') which allow reducing thermal differences that exist between the inside and outside of the building with minimum consumption. The pre-conditioned air is driven to the heat recovery and climatization units thus notably reducing the thermal load of the ventilation.


2009
2010

3 Background and Current Situation

3.1 GEOTHERMAL TECHNOLOGIES

KEY DATES	HISTORICAL MILESTONES IN GEOTHERMAL DEVELOPMENT
1000 b.C.	• China's Qin Dinasty builds important spa facilities. • The Greeks and Romans use thermal waters for bathing and as a source of heating.
1000	Polynesian colonists in New Zealand use geothermal vapor for cooking and heating over the last 1,000 years.
1400	In the heart of France, what can be considered the first geothermal district heating network is developed at Chaudes-Aigues in the XIV centur y.
1510	In Agua Hedionda, Mexico, Aztec ruler Moctezuma spent seasons recovering from stress caused by the role he was historically bound to hold.
1892	The first geothermal district heating system starts operation in Boise (Idaho, US).
1904	The first experiment to produce electricity from geothermal sources was developed by Prince Piero Ginori Conti between 1904 and 1905 in Italy's Tuscany region.
1913	The first commercial plant for the production of electricity (250 kWe) is commissioned in Larderello, Italy.
1928	In Iceland, the use of geothermal resources for home heating begins.
1945	References begin coming to light about the use of open circuits with groundwater and heat pumps in the United States.
1958	New Zealand inaugurates its first geothermal plant in Wairakei.
1960	The United States commissions its first commercial plant at The Geysers.
1970-1980	The successive oil crises in the 70's together with the development of commercial plastics at the beginning of the 80's bring shallow geothermal systems to market costs. These develop in parallel in two principal geographical locations: Sweden and the United States. These countries, followed closely by Germany, Switzerland, Austria and Canada, experience an unstable development through the 90's.

KEY DATES	HISTORICAL MILESTONES IN GEOTHERMAL DEVELOPMENT
1973-1978	The first scientific experiment in the world on the use of hot dry rock geothermal energy is developed in Los Álamos (United States).
1970-1985	In Spain, successive energy crises force the inclusion of geothermal research in the National Energy Plans for the first time, the first result being the creation of the General Inventory of Geothermal Manifestations in National Territory, compiled by Spanish Geological Survey –IGME- in 1974.
1989-2008	The enhanced geothermal scientific project of Soultz-sous-Forêts is developed, which acts as the seed of current commercial-scale geothermal projects for electricity generation in Europe.
2005-2010	At the beginning of the XXI century the crisis of the energy model becomes evident. Analyses from all perspectives of the energy outlook show that needs converge in Europe in general and in Spain in particular about promoting the development and use of renewable energy along with energy savings and energy efficiency. As a consequence, the geothermal sector becomes reactivated in Spain, Europe and the rest of the world.

NO HIGH-ENTHALPY GEOTHERMAL INSTALLATIONS EXIST IN SPAIN AT PRESENT. THERE IS HOWEVER A GREAT AND GROWING INTEREST FUELLED BY THE INITIATIVES FROM THE BUSINESS COMMUNITY ABOUT DEVELOPING PROJECTS OF THIS TYPE IN THE SHORT TERM.
ON THE OTHER HAND, SHALLOW GEOTHERMAL ENERGY IS A REALITY IN SPAIN.

No high-enthalpy geothermal installations exist in Spain at present. There is however a great and growing interest fuelled by the initiatives from the business community about developing projects of this type in the short term.

On the other hand, shallow geothermal energy is a reality in Spain. Open systems that include heat pumps have been widely used for many years, but closed systems do not begin to spread out until the year 2000. Beginning in 2004, new installations of increasing capacity are designed and built for heating and cooling of buildings in the services sector. At present, despite the collapse of the construction sector the expectations about the evolution of energy prices in the coming years are driving constant growth of very low-temperature geothermal installations both in the domestic and institutional domains.

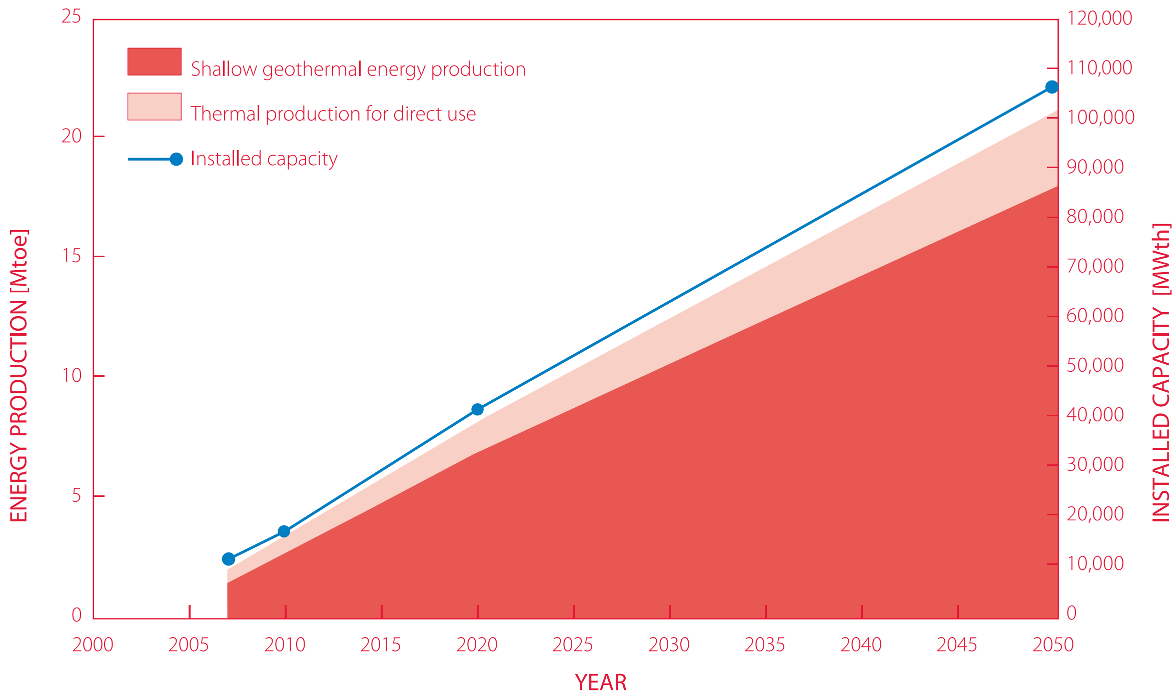
The current installed capacities in both shallow and deep geothermal settings in Spain and Europe are detailed as follows:

DEEP GEOTHERMAL RESOURCES:

THERMAL USES IN EUROPE

Already in 2007 Europe surpassed the 15,000 MW installed thermal capacity, and it is expected that the progressive targets of 20,000 MWth in 2010, 40,000 in 2020 and 80,000 in 2030 will be reached.

ENERGY PRODUCTION FROM SHALLOW GEOTHERMAL RESOURCES AND THERMAL PRODUCTION FOR DIRECT USE IN THE EUROPEAN UNION



SOURCE: 'Research Agenda for Geothermal Energy. Strategy 2008 to 2030' - *European Geothermal Energy Council*, EGEC.

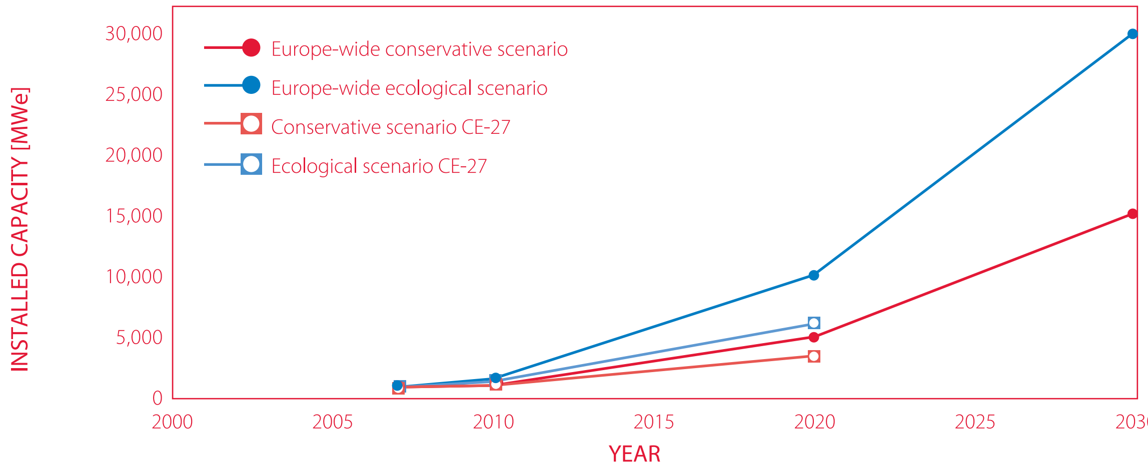
ELECTRICAL USE IN EUROPE

In 2007, the 27 nations making up the European Union were already reaching the threshold of 1,000 MW installed capacity while the rest of the nations supplied close to 500 MW. The targets for installed electric power in Europe are of 6 to 10 GW for 2020 and 15 to 30 GW for 2030. These targets will only be reached through an adequate reduction of costs of the various generation technologies.

IN 2007, AN APPROXIMATE TOTAL OF 2.5 MTOE OF ENERGY FROM GEOTHERMAL SOURCES WERE PRODUCED IN EUROPEAN UNION MEMBER STATES, WHILE OVER 1 MTOE WERE PRODUCED BY OTHER EUROPEAN COUNTRIES.

GEOTHERMAL ELECTRICITY GENERATION-EU-27	2007	2010	2020
Conventional geothermal (MWe)	815	920	1,200
Low temperature binary cycles (MWe)	15	70	300
EGS (MWe)	-	10	4,500
TOTAL installed capacity (MWe)	**830**	**1,000**	**6,000**
Annual energy production (TWh)	**6.5**		**0**

INSTALLED CAPACITY FOR ELECTRICITY USE IN EUROPE (MWe)

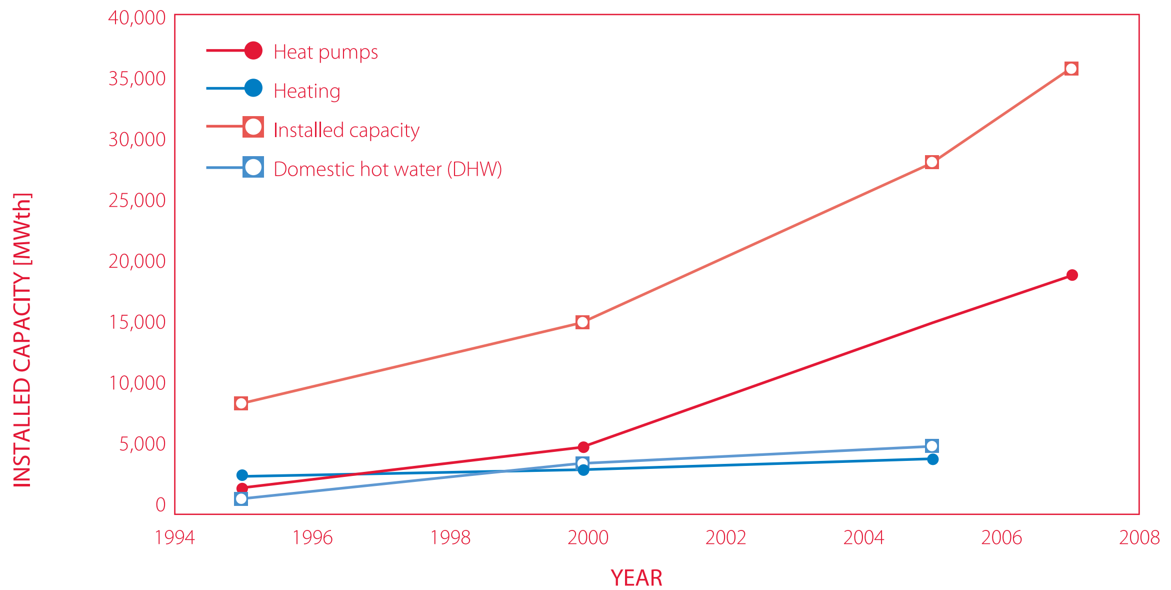


SOURCE: 'Research Agenda for Geothermal Energy. Strategy 2008 to 2030' - *European Geothermal Energy Council*, EGEC.

The main existing technology at present is denominated 'conventional' which is fundamentally related with associated hydrothermal systems in areas of active volcanism. Recently however, the potential of areas associated with deep sedimentary basins and hot dry rock zones or enhanced geothermal systems have been recognized.

Conventional geothermal energy has been successfully developed for over a century. In 2007, the installed capacity amounted to 9,732 MW, where leading nations in the sector are the United States with 2,687 MW (over 25% of the total) and the Philippines, with 1,970 MW, with almost 20% of the world's total; they are followed by Mexico, Indonesia, Italy, Japan, New Zealand and Iceland.

GEOTHERMAL DIRECT USE (MWth)



SOURCE: 'Research Agenda for Geothermal Energy. Strategy 2008 to 2030' - *European Geothermal Energy Council*, EGEC.

DIRECT USE

The total global installed capacity for direct use amounted already in 2007 to 35,000 MWth.

The number of nations that generate energy from geothermal resources could increase from 21 in the year 2000 to 46 in the 2010, while the installed capacity in this same time interval could increase from 8,661 MW to over 10,700 MW according to data from the International Geothermal Association (IGA).

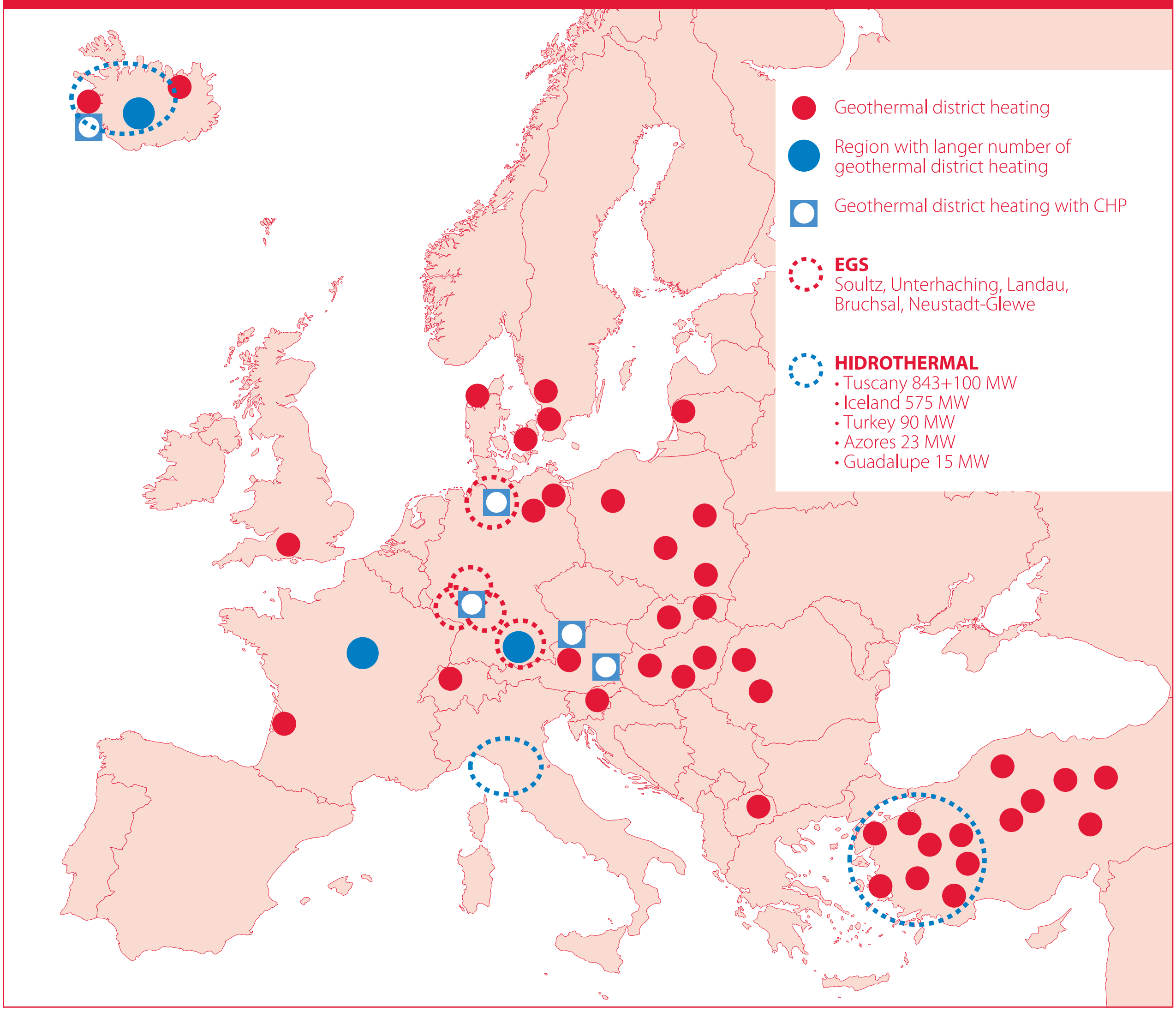
The regions with the greatest geothermal potential are found generally near plate borders, although advances in a diverse number of technological fields now allow exploitation of geothermal resources far away from plate borders via enhanced geothermal systems (EGS). In 2004, El Salvador, Kenya, The Philippines, Iceland and Costa Rica, which represent countries located in very favourable geological contexts, generated more than 15% of their energy from geothermal plants.

In Europe, there are a number of EGS projects that have been profiled as pilot projects in this field. In June 2008, the Soultz-sous-Forêts plant in Alsace (France) was inaugurated as a pilot plant, becoming the first 1.5 MWe installed capacity Organic Rankine Cycle module. At the beginning of 2008 in Landau in der Pflaz (Germany), the first commercial-scale plant fuelled by an enhanced geothermal deposit was completed in a record time of 3.5 years, with an installed capacity of 3.6 MWe and 8 MWth.

IN EUROPE, THERE ARE A NUMBER OF EGS PROJECTS THAT HAVE BEEN PROFILED AS PILOT PROJECTS IN THIS FIELD.

The rest of the EGS project sites are located in Roquette (Rhine Graben, France), Bruschal, Groß Schönebeck and Unterhaching (Germany), Fábiánsebesyén and Zala Counties (Hungary), the Icelandic Deep Drilling Program (Iceland), Podhale (Poland), Košice (Slovakia) and Green Campus Izmir (Turkey).

GEOTHERMAL AND COGENERATION ELECTRICITY PRODUCTION IN EUROPE, AT THE BEGINNING OF 2010



SOURCE: *European Geothermal Energy Council*, EGEC.

The following projects stand out among the European initiatives aimed at developing geothermal sources for the production of electricity:

The European ENGINE project *(Enhanced Geothermal Innovative Network for Europe)*, is a coordinated action in the 6th Framework program of the European Union and developed between 2005 and 2008, whose main objective consisted in establishing a bridge between research and development initiatives relative to enhanced geothermal systems, so as to set the foundation of the geothermal resource research program that would enable their exploitation and tackling the evaluation of associated socio-economic impacts. The final strategic document as well as the book of good practices on EGS projects establishes the upcoming lineaments for action in this field.

In December 2009 GEOELEC is kicked off *(Technology Platform on Geothermal Electricity)*, whose fundamental objective is to boost drive the development of electricity generation technologies from geothermal energy sources in Europe.

The European GEOFAR project (Geothermal Finance and Awareness for Deep Geothermal Projects in European Regions) sets out to shed light on the non-technical barriers and difficulties that hinder the initial stages of geothermal energy projects, which are the cause of the lack of these types of investments in Europe. One of GEOFAR's main objectives is to propose achievable solutions and raise the awareness level about geothermal energy among responsible parties, particularly at the regional level, in order to help drive new investments.

IN DECEMBER 2009 GEOELEC IS KICKED OFF (TECHNOLOGY PLATFORM ON GEOTHERMAL ELECTRICITY), WHOSE FUNDAMENTAL OBJECTIVE IS TO BOOST DRIVE THE DEVELOPMENT OF ELECTRICITY GENERATION TECHNOLOGIES FROM GEOTHERMAL ENERGY SOURCES IN EUROPE.

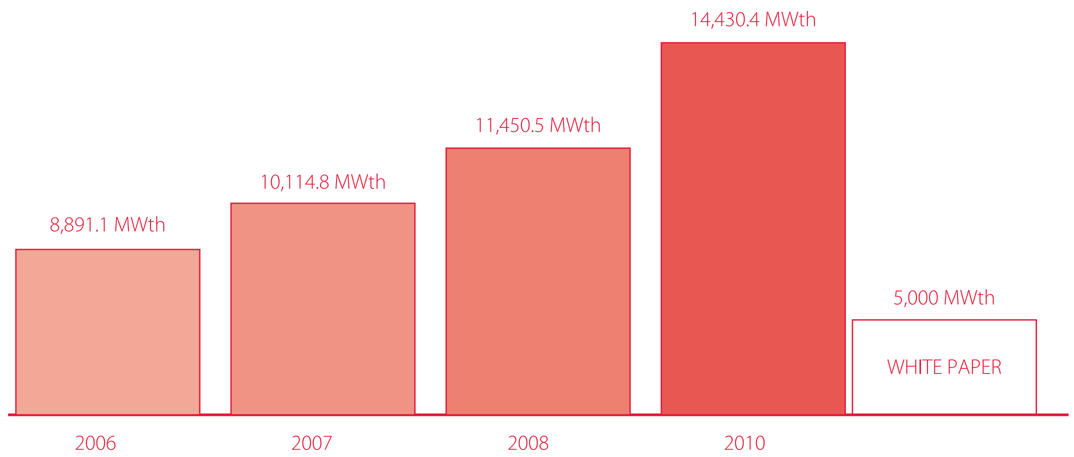
SHALLOW GEOTHERMAL ENERGY:

In the European Union, the installed capacity from very low-temperature geothermal energy amounted, at the end of 2008 to 8,920 MW with a total of 782,460 installations throughout the European Union. Adding direct use geothermal production, the total installed capacity equals 11,450 MW.

As observed in Figure 8, in 2007 European White Paper of Renewable Energy (1997) 2010 forecasts have doubled. Furthermore, the trends point to the fact that by the end of 2010 these targets will have tripled.

COMPARISON BETWEEN CURRENT TRENDS AND WHITE PAPER OBJECTIVES FOR GEOTHERMAL HEAT PRODUCTION*

* GHSP and low and medium energy geothermal resources.



SOURCE: EurObserv'ER 2009.

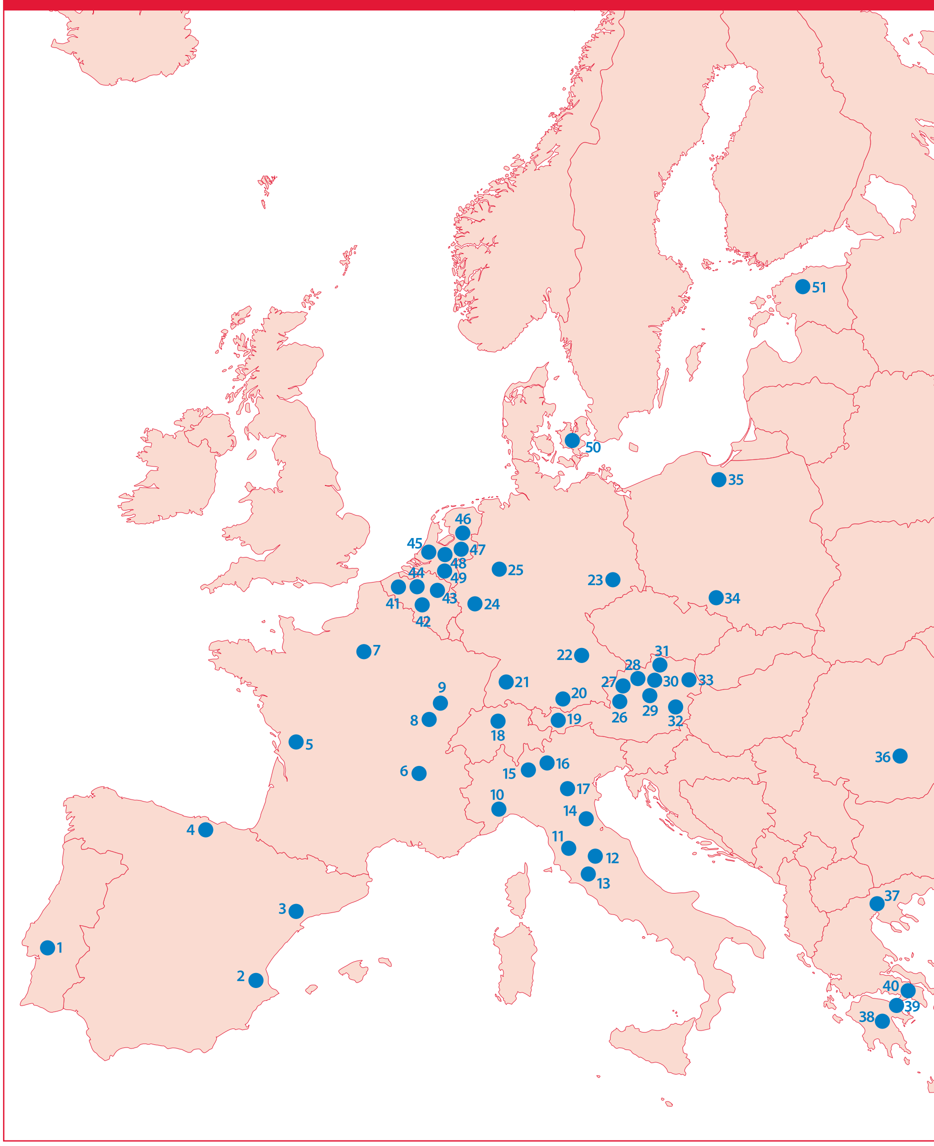
With respect to Spain, there are no specific objectives or reliable statistics available to date of installed capacity from shallow geothermal energy sources. Maps that continuously collect the implementation and advance of geothermal energy in Europe show a clear lack of data for the Iberian Peninsula.

European Directive 2009/28CE on the promotion of renewable energy sources includes this type of energy and sets the criteria for the calculation of the corresponding contributions to the 20-20-20 targets. Having taken into account the gap that is yet to be bridged to reach these targets it becomes evident that measurement and recording thereof must constitute a priority objective for the sector, let alone the basis for a proper prognosis to be undertaken with a minimal level of rigor.

Available data from records of subsidies allocated by the various Regional governments (compiled by APPA in 2008) yield a value of installed capacity of 8.4 MW. However, this data do not cover the same period for all autonomous regions, as some correspond to the end of 2007 while others to 2008. Furthermore, the information belongs to nine autonomous regions who subsidize this type of energy and also, a number of regions such as Aragón, Castilla-La Mancha and specially Cataluña, whose contribution could significantly increase this figure, are missing. Other sources (Eclareon 2009) state a total of 650 installations at the end of 2008 and estimate a 30% growth (850 installations) up to 2009. There is no mention of the average installed capacity which in any case could be sensibly larger to that of Europe (≈ 12 kW). According to this information, the installed capacity in this segment at the end of 2009 in Spain could exceed 15MW.

On the other hand, statistics do not pick up a good number of existing installations that feed off groundwater from alluvial aquifers in some large rivers. These are open circuit facilities with capacities of tenths to hundreds of kW used for cooling buildings that have been constructed mainly over the last 30 years. The most representative example could be Zaragoza, but also Barcelona or Seville who also have facilities of this type. There are also a considerable number of hotels that take advantage of coastal aquifers – frequently saline – for thermal use. On the basis of all these installations, the sector estimates that the total installed capacity in Spain could range between 60 to 80 MW.

SINGULAR SHALLOW GEOTHERMAL ENERGY PROJECTS



1 Setubal, Portugal
2 Valencia, Spain
3 Sabadell, Spain
4 Durango, Spain
5 Meursac, France
6 Lyon, France
7 Lex Mureaux, France
8 Besançon, France
9 Marloz, France
10 Savona, Italy
11 Pistoia, Italy
12 Bucine (Arezzo), Italy
13 Buonconvento, Italy
14 Imola, Italy
15 Milano, Italy
16 Oggiono (Lecco), Italy
17 Ponti sul Mincio, Italy
18 Grafstal, Switzerland
19 Hohenems, Austria
20 Lindenberg, Germany
21 Donaueschinger, Germany
22 Rudelzhausen, Germany
23 Dresden, Germany
24 Aachen, Germany
25 Düsseldorf, Germany
26 Gosau, Austria
27 Ohlsdof, Austria
28 Eferding, Austria
29 Schwertberg, Austria
30 Guatu, Austria
31 Freistadt, Austria
32 Ternitz, Austria
33 Vienna, Austria
34 Rudy, Poland
35 Sopot, Poland
36 Bucharest, Romania
37 Thessaloniki, Greece
38 Athens, Greece
39 Zografou (Athens), Greece
40 Pikermi (Athens), Greece
41 Melle, Belgium
42 Zoerle – Parwijs, Belgium
43 Antwerp, Belgium
44 Antwerp, Belgium
45 Amsterdam, Netherlands
46 Zutphen, Netherlands
47 Zetten, Netherlands
48 s- Hertogenbosch, Netherlands
49 Goirle, Netherlands
50 Naestred, Denmark
51 Tallin, Estonia

SOURCE: Heat Pump Best Practice Database - GROUNDREACH Project (www.groundmed.eu/hp_best_practice_database/).

3.2 REGULATORY FRAMEWORK

2004
Directive 2001/77/EC, as well as the 2004 Report of the European Commission on the implementation of this Directive, recognizes high-enthalpy geothermal energy as a source of electricity production.
MARCH 2007
In March 2007, the European Council of Heads of State and Government decides to establish mandatory objectives for the European Union for 2020, among which, the requirement to reach 20% of the Community's overall share of energy from renewable sources.
JANUARY 2008
The European Commission presents on January 23, 2008 the energy and climate change package which includes, as a fundamental component, the Proposal for a Directive from the European Parliament and the Council relative to the promotion of the use of energy from renewable sources.
DECEMBER 2008
On December 17, 2008, the European Parliament approves a proposal for a Directive relative to the promotion of the use of energy from renewable sources, which recognizes geothermal energy as an additional renewable energy and includes it in the definition of 'energy from renewable sources.' It stipulates that geothermal energy captured by heat pumps shall be included in the 'gross final consumption of energy from renewable sources for heating and cooling' calculation for each Member State.
APRIL 2009 –EUROPEAN RENEWABLE ENERGY DIRECTIVE
Approval of Directive 2009/28/EC relative to the use of energy from renewable sources (and by which Directives 2001/77/EC and 2003/30/CE are modified and revoked) in which geothermal technologies are recognized in the terms approved by the European Parliament. As to what concerns geothermal energy, this Directive supposes a qualitative change since: • It establishes a clear definition of what geothermal energy is (as opposed to what the Directive calls aerothermal and hydrothermal energy). • It settles the sterile polemic around the renewable character of geothermal heat production, both in its direct use mode or with heat pumps. • It establishes a formula to quantify the quantity of renewable heat produced by the heat pumps as a function of their seasonal performance. • It establishes the obligation to have – by 2012 – an accreditation system in place throughout the European Union for what the Directive calls *'Shallow geothermal installers.'* • It includes the promotion of district heating and cooling networks fed by renewable energy, where geothermal energy is identified as one of the most efficient and economically profitable sources of energy. • Furthermore, it establishes that each Member State must elaborate a Renewable Energy Action Plan before June 30, 2010 in which targets for all uses of renewables are set forth: heating and cooling, electricity and transport. Such plans must contemplate all necessary measures to be implemented to achieve said targets and must be reviewed in case of non compliance with indicative intermediate targets until 2020.

The following projects have been developed in the European Union with the goal to drive sectoral development:

GEOTHERMAL REGULATION–HEAT. Its purpose is to identify regulatory barriers and deficiencies, establish legislative solutions and strengthen and expanding the cooperation network relative to geothermal energy legislation.

GROUND-REACH. Its purpose includes the compilation of best practices as well as applicable legislation relative to heat pumps in Europe, and the establishment of measures to overcome barriers that could hinder a greater penetration thereof, including legal/regulatory-type ones.

THROUGH THE FRAMEWORK PROGRAM, the European Union's principal R&D financing instrument, a number of projects in the field of geothermal energy have been financed, among which the following are highlighted:

- **Ground-Med** *(Advance ground source heat pump systems for heating and cooling in Mediterranean climate)*, with a global budget of € 7.25 million.

- **Geothermal Communities** –GEOCOM- *(Demonstrating the cascading use of geothermal energy for district heating with a small scale RES integration and retrofitting measures)*, with a global budget of € 5.7 million.

- **Geiser** *(Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs)*, with a global budget of € 7.1 million.

EUROPEAN TECHNOLOGY PLATFORM FOR RENEWABLE HEATING AND COOLING - ETP-RHC. Constituted in March 2009, it has a Geothermal Energy Panel in addition to the Biomass and Thermal Solar panels. It intends to constitute the forum in which the different agents from the sectors at stake from the field of renewable climatization meet to bring up their R&D&i needs, so that they can be escalated to the institutions of the European Union that have competences over R&D project design, research projects, etc.

European Geothermal Energy Council –EGEC- participates in all the aforementioned European initiatives until now; it is a business association headquartered in Brussels that sits under the umbrella of EREC (European Renewable Energy Council), which is the organization that brings together the interests of the renewable energy sector in Europe, including producers and promoters, research organizations and investment groups.

EUROPEAN GEOTHERMAL ENERGY COUNCIL –EGEC- PARTICIPATES IN ALL THE AFOREMENTIONED EUROPEAN INITIATIVES UNTIL NOW; IT IS A BUSINESS ASSOCIATION HEADQUARTERED IN BRUSSELS THAT SITS UNDER THE UMBRELLA OF EREC (EUROPEAN RENEWABLE ENERGY COUNCIL), WHICH IS THE ORGANIZATION THAT BRINGS TOGETHER THE INTERESTS OF THE RENEWABLE ENERGY SECTOR IN EUROPE, INCLUDING PRODUCERS AND PROMOTERS, RESEARCH ORGANIZATIONS AND INVESTMENT GROUPS.

In Spain the legislation is poorly developed, especially with respect to very low-temperature geothermal energy. Very limited advances have been made to regulate this form of energy or to reduce existing administrative barriers.

• Geothermal resources are included in the mining legislation. Access to research and use thereof must be conducted according to such legislation.

• On the other hand, in numerous phases including research and the phases previous to exploitation of the resource, environmental impact assessments must be carried out which will include time extensions of the administrative process under the protection of the corresponding environmental legislation.

• Numerous are the cases in which the consultation with the hydraulic authority is also necessary to avoid possible problems that may affect the geothermal resource (fundamentally, as in the case of environmental authorities, when borehole drilling is required and specifically in the case of open systems that use groundwater; this scenario will also contemplate time extensions of the administrative process).

• Lastly, the final use of the geothermal resource conditions the legislation that will be applied, among which are the ones relative to electricity production, applicable special regimes, thermal installations in buildings, climatization, etc. In addition to all of these, different local legislations must be taken into account (fundamentally municipal ones) which may have an effect on these resources.

DATE	LEGISLATION		HIGHLIGHTED ASPECTS
	TYPE	NAME	
July 1973 - November 1980	Mining	Law 22/1973, of 21 July, on Mines (modified by Law 54/1980, of 5 November)	• Geothermal resources are classed under Section D, together with resources of energetic interest. • A process involving concessions and permits applies. • The Law does not have a text that is adapted to the constitutional norms relative to the transfer of competences to autonomous regions.
December 1978	Mining	General regulations relative to the Mining Regime (Decree 2857/1978, of 25 April)	Its article 5.1 defines geothermal resources and attempts to differentiate them from thermal waters. '*Geothermal resources are, as included in this Section, geological resources which due to their temperature are capable to, among other applications, capture energy – particularly thermal – through fluids. Thermal waters, as defined in this same article, are left out of Section C)*.'
June 1985 - February 1996	Mining	General regulations relative to Basic Mining Safety Norms (R.D.863/1985, of 2 April)	• Chapter VI refers to special works, surveys and drilling. • Developed through Complementary Technical Instructions. CTI 06.0.06 refers to the use of geothermal resources. • Drilling activities in particular are subject to this legislation.
April 1986	Water	Regulations relative to the Hydraulic Public Domain (R.D. 849/1986, of 11 April)	Regulates the research, use and effects on groundwater as well as the discharge permitting process.
December 1999	Energy	Plan for the Promotion of Renewable Energy (2000-2010)	Does not mention geothermal energy in its text (only on two charts and considering it completely insignificant).
December 2000	Energy	Transport, distribution, commercialization, supply and authorization procedures for electric energy installations (R.D.1955/2000, of 1 December)	Stipulates the administrative resolutions required for the construction of an electrical installation.
July 2001 - December 2003	Water	Redrafted Text of the Water Law (R.D. Legislativo 1/2001, of 20 July 2001) modif. by Law 62/2003, of 30 December, on fiscal and administrative measures and the social order	• Drilling activities must avoid any impact on aquifers. • Open geothermal systems that use groundwater as climatization fluid are also subject to this legislation.
August 2005	Energy	Spanish Renewable Energy Plan (PER) 2005-2010, in effect	• Makes reference to geothermal energy in a couple of occasions, establishing a target equal to zero in their 2005-2010 incremental targets table.
March 2006	Housing (energy aspects)	Technical Building Code (R.D. 314/2006, of 17 march)	• Although geothermal energy is not implicitly included it is however implicitly considered under 'other renewable energy'.
May 2007	Energy	Electricity production under the Special Regime (R.D. 661/2007, of 25 may)	• Establishes the legal and economic regime of installations that can be subject to the Special Regime. • Within its scope of application, installations which solely use geothermal and hot dry rock energy as primary energy are indeed considered in group b.3. • In the annexes to the Royal Decree (R.D.), dispatchable renewable energy sources are classified; however, group b.3 on the other hand does not consider them as dispatchable, something that is considered a great error.

DATE	LEGISLATION		HIGHLIGHTED ASPECTS
	TYPE	NAME	
July 2007	Energy	2008-2012 Energy Savings & Efficiency Strategy Action Plan	Does not mention geothermal energy; (neither does Madrid Autonomous Community's 2004–2012 Energy Plan)
August 2007	Energy	Regulations for Thermal Installations in Buildings (R.D. 1027/2007, of 20 July)	Does not consider geothermal energy among the alternatives of thermal renewable energy but does consider heat pumps. In any case, any thermal or HVAC installation must be registered.
January 2008	Environ-mental	Redrafted text of the Environmental Impact Assessment Law (R.D. Legislativo 1/2008, of 11 January)	• Specifically considers that the corresponding environmental body must analyze geothermal well drilling activities on a case-by-case basis, deeming all such geothermal drilling activities 'deep' in nature (ignores shallow geothermal scenarios) and comparing them with oil industry drilling activities. • Autonomous Regions legislation can establish that all projects must be subject to an environmental impact assessment. Almost all Autonomous Regions have their own legislation to this regard but criteria are quite heterogeneous throughout.

At present, competences over the legislative development and execution of basic National legislation relative to the Mining and Energy Regime have been transferred to autonomous regions. There has not been however a reform of the Mining Law that would contemplate modifications made to the competences held by both the National and regional governments nor modifications of the environmental legislation, which generates widespread confusion about the development of these types of projects. There have been however actions initiated by the State through the Spanish Institute for Energy Diversification and Saving – IDAE – in the form agreements with regional administrations to co-finance assistance packages for renewable energy, energy efficiency and energy saving. Likewise, the Institute for Energy Diversification and Saving – IDAE – in collaboration with the Spanish Geological Survey – IGME – has published a Geothermal Manual in 2008 which includes a section on administrative and legislative aspects.

Although administrative legislation and barriers have note evolved much, financial assistance certainly has. There are a number of regional calls for initiatives that are able to shed some light on the future outlook; some examples include Madrid Autonomous Region, Basque Energy Board (EVE), Castilla y León Regional Energy Entity (EREN), Cantabria Energy Management Company (GENERCAM), Valencia Energy Agency (AVEN), Murcia Regional Energy Management Agency (ARGEM) and Extremadura Energy Agency (AGENEX). All of the aforementioned entities have established multiyear agreements with the Institute for Energy Diversification and Saving – IDAE – (Ministry of Industry, Tourism and Trade -MITYC) with the goal of promoting geothermal energy through the subsidy of a percentage (usually 30%) of the geothermal installation costs.

There are no specific regulations that cover each and every one of the possibilities that technologies aimed at harnessing geothermal resources provide today. At present, there are a number of norms that are being applied which are generic in nature, and whose requirements in many cases result excessive for the type of application at hand.

3.3 TRAINING

A number of training-related projects are currently being carried out in Europe such as the following:

EU-CERT.HP was financed by the European Union under the Intelligent Energy Europe program and concluded in December 2006. Its goal was to strengthen training on the subject and establishing a European certification system for heat pump technology installation technicians. Training schemes and certification systems developed through this project are now under the supervision of the European Heat Pump Association Education Committee (EHPA) and training courses continue to be set up periodically for installation technicians in countries that participate in the initiative.

QUALICERT is financed by the European Union under the Intelligent Energy program. Its goal is to anticipate the application of Article 14 of Directive 2009/28/EC, which obliges all Member States to develop and recognize accreditation and certification schemes for small scale renewable energy installation technicians at the European level. A manual containing success criteria for these schemes is to be created, which is to be validated by the main interested parties.

GEOTRAINET is financed by the European Union under the Intelligent Energy program. Its objective is to develop a European program that leads to the certification of geothermal installations, centered on drilling technician and designer training. To this effect, courses and certification systems are to be developed so that eventually individual professionals may obtain standardized or approved training and certification. The Universidad Politécnica de Valencia (UPV) participates in this project.

THE UNIVERSIDAD POLITÉCNICA DE VALENCIA (UPV-POLYTECHNIC UNIVERSITY OF VALENCIA) PARTICIPATES IN THE GEOTRAINET PROJECT FINANCED BY THE EUROPEAN UNION UNDER THE INTELLIGENT ENERGY PROGRAM. ITS OBJECTIVE IS TO DEVELOP A EUROPEAN PROGRAM THAT LEADS TO THE CERTIFICATION OF GEOTHERMAL INSTALLATIONS, CENTERED ON DRILLING TECHNICIAN AND DESIGNER TRAINING.

4

Geothermal
Potential in Spain

The existing potential of Shallow Geothermal Energy has an enormous reach. It is a renewable energy that is available, initially, at any site in which a building is planned for construction. The limitations of this technology are mainly economic and are associated with the costs of implementation of the geothermal exchange system, the building's energy demand and energy prices. With today's existing cost schemes, a simple return on investment period ranging between 5 and 15 years is currently being considered.

The thermal energy that heat pumps transfer between the building and the ground multiply the electric energy consumed by a factor between 3 and 5. It would be technically feasible - through technological improvements of the elements at stake and the integration of the most advanced components available in the market - to increase such multiplier effect up to a range between 6 and 8 and even all the way up to the theoretical limit close to 14. Following the philosophy of the European Renewable Energy Directive, the differences between the flow of useful thermal energy generated by the geothermal system and the primary energy consumed can be considered as renewable thermal energy that can count toward the Directive's targets.

Given all the above, the high energy savings and renewable energy generation potential of shallow geothermal systems becomes quite clear. Different methodologies have been used to obtain estimates of the impact on primary energy savings that could derive from a large-scale use of this technology. Although such technologies have not been systematically applied in the Spanish case or in Europe, there are estimates from the US Department of Energy –DOE- which, given climatic and market condition similarities, could well allow for a dimensioning and contextualization of the national shallow geothermal energy potential.

The estimates referred to consider as a starting point the annual savings that could be generated if at some point typical conventional equipment would be substituted by current-technology geothermal equipment in cases and applications where this would be technically and economically reasonable. Such substitution would not include:

1. Buildings with high loads per unit floor (typically found in cities or densely populated areas).
2. Applications that require a high thermal demand for cooling, which are typically served by centrifugal or rotary screw compressors.
3. District heating systems or individual type 'split' units.

The US Department of Energy –DOE- estimates annual potential energy savings of 65 to 80 Mtoe. This implies a 6.5% to 8% consumption of primary energy in buildings – which is somewhat greater than 1,000 Mtoe – recorded in the United States in 2005.

In the Spanish case, the Institute for Energy Diversification and Saving – IDAE – has estimated the energy consumption of the construction sector in Spain (domestic and residential) at 21.7 Mtoe. An extrapolation of the analysis conducted by the US Department of Energy –DOE- to our case would set the theoretical limit for energy savings that could be reached through the implementation of shallow geothermal energy systems in the current conditions in the 1.4 to 1.7 Mtoe range.

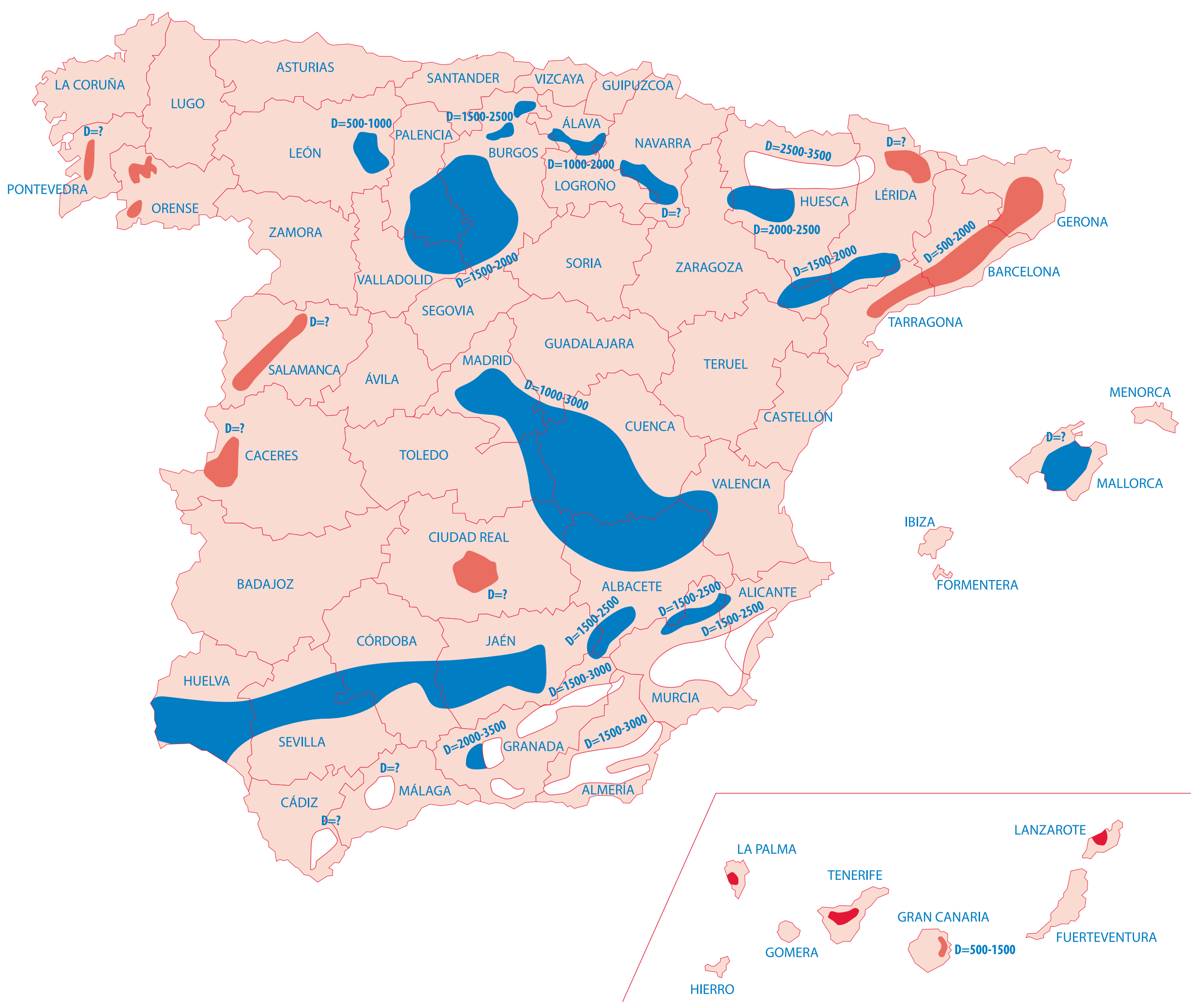
Another key aspect to consider – in the case of shallow geothermal energy – is its capacity to smooth out demand peaks in the electric grid particularly due to demand associated with cooling. The US Department of Energy –DOE- estimates this reduction to be 91 to 105 MW of installed capacity based on the analysis of a 4,000 single-family home project carried out in Fort Polk (Lousiana). This implies a 42% to 48% reduction of the additional capacity required by the United States electric grid in the year 2030.

Per the scenario forecasted by the Institute for Energy Diversification and Saving – IDAE – for 2012, considering an energy demand from the construction sector of approximately 23.6 Mtoe and a thermal consumption (heating + domestic hot water + climatization or air conditioning) of 15.6 Mtoe (66% of the total) the impacts on a national energy system with an installed capacity of 1,000 MWth would imply energy savings and a renewable thermal energy production of approximately 100 ktoe, along with emissions reductions in the order of 300 kilotons of CO_2.

Picture courtesy of Max Weishaupt GmbH

Lastly, it is worth pointing out that potential shallow geothermal energy applications go beyond the scope of the construction sector. There are important industrial and agricultural uses (desalination, greenhouses, refrigerating chambers, etc.), an analysis of which – in terms of each sector's potential – is beyond the scope of this document. With regard to Deep Geothermal Energy, research conducted by different entities, principally Spanish Geological Survey –IGME-, fundamentally in the 70's, 80's and at the beginning of the 90's of the XX century, clearly demonstrated the large amounts of geothermal resources available, both in the form of conventional high, medium and low enthalpy resources and shallow ones that harness groundwater temperature in vast amounts of territory, as well as heat from the subsurface in any part thereof. The largest amount of information corresponding to the different research projects is available at IGME's document library and can be accessed through its website www.igme.es.

G E O T H E R M A L   A R E A S   I N   S P A I N



LOW TEMPERATURE AREAS
T<100 ºC

MEDIUM TEMPERATURE AREAS
100 ºC T< 150 ºC
EXTENDED RESERVOIRS (CARBONATED)

MEDIUM TEMPERATURE AREAS
100 ºC T< 150 ºC
LOCATED RESERVOIRS (FRACTURATED BASEMENT)

HIGH TEMPERATURE AREAS
T>150 ºC

UNKOWN OR NOT INTERESTING AREAS
T>150 ºC

D=1500-3000 AREAS WITH RESERVOIRS
(LIMIT: DEPTH BETWEEN 1,500-3,000m)

D=? THERE ARE NOT DATA
TO ESTIMATE THE DEPTH

Source: Spanish Geological Survey –IGME–

A very preliminary estimation made by the Spanish Geological Survey (IGME) in the 80's on the foreseeable potential of conventional geothermal resources that could be harnessed in Spain gave a number of 600 ktoe/year of energy that could be exploited in about 10 years, if appropriate conditions for the promotion of the activity were in place.

Key areas include the Canary Islands, which show potential for the development of conventional geothermal energy and the great sedimentary basins of the Iberian Peninsula, which have the capacity to develop geothermal systems in deep sediments and associated aquifers as well as in areas of deep fractures through which high-temperature fluids circulate, which in turn can also be susceptible of developing enhanced geothermal systems.

GEOTHERMAL SYSTEMS ASSOCIATED WITH DEEP SEDIMENTARY BASINS

Over 50% of peninsular Spain is made up of large Cenozoic basins that cover thermally active Hercinic granites (ITGE, former Spanish Geological Survey –IGME-, 1991). The superposition of important thicknesses of low thermal conductivity sedimentary materials over these heat-producing granites make up an adequate geological framework for the development of geothermal systems associated with deep sediments. Oil exploration boreholes have been drilled in the Madrid and Pyrenean basins which have measured temperatures over 150-180ºC at 3,500 and 4,500 meters depth associated with limestones of Jurassic and Cretaceous age.

ENHANCED GEOTHERMAL SYSTEMS (EGS)

These systems are located in deeply-fractured granitic zones through which hot fluids circulate and which, upon reaching the surface, give place to natural manifestations such as the Caldas de Montbul thermal springs in Cataluña and Orense in Galicia, with temperatures of 75 to 80ºC (FERNÁNDEZ ET AL 1990). Deep zones (below 3,000 meters) associated with these convective systems represent favourable environments for the development of medium-enthalpy enhanced geothermal systems (above 150ºC). In areas of low permeability, stimulation of existing fractures will be necessary to allow the circulation of fluids through the hot dry rock.

AREAS WITH GREATER POTENTIAL

According to reports developed by Spanish Geological Survey (IGME), the resources with the greatest geothermal potential are found in the following areas:

CANARY ISLANDS

In the island of Gran Canaria, aquifers with temperatures of up to 70ºC at 1,500 meters depth have been identified. High-enthalpy and low permeability (hot dry rock) geothermal resources have also been detected in the islands of La Palma and Lanzarote. Additionally, a high-temperature hydrothermal system is currently under investigation in Tenerife.

PENINSULAR NORTHWEST (GALICIA)

Granites with a high degree of fracturing, temperatures of up to 80 ºC are reached starting at 500 meter depths.

CENTRAL PYRENEAN ZONE (JACA SABIÑÁNIGO AREA)

A thermal aquifer (> 140ºC) has been detected through oil borehole drilling in Palaeocene-Miocene materials at over 3,000 meters depth.

EBRO BASIN

- Three potential aquifers:
- Lérida: Triassic aquifer lodged in limestones and other detritic Rocks at 1,500 meters depth with a temperature of 60ºC.
- Huesca: Jurassic aquifer in limestones with temperatures near 90ºC starting at 2,000 meters depth.
- Vitoria-Treviño: Cretaceous aquifer in limestones showing temperatures of up to 60ºC at 2,000 meters depth.

CATALAN COASTAL RANGES

- A series of basins (grabens) in the north-eastern margin of the Peninsula showing important geothermal manifestations:
- Vallés-Penedés Graben: thicknesses of 1,000 m to 3,000 m composed of Miocene materials. The geothermal resource is located in the main fault (NW) with average temperatures of 90ºC at 1,000 meters depth.
- La Selva Graben: Shows similar characteristics to the Vallés-Penedés Graben and is located north of it.
- Ampurdán Graben: carbonate aquifer of Eocene age with a thickness of 4,000 meters and temperatures of up to 150ºC.

BÉTICA RANGES

Includes several basins such as Granada, Guadix-Baza, Almería, Mula, Mazarrón, Cartagena, Guadalentín, Lluchmajor (Mallorca), etc. The general lithological sequence of these basins consists of Tertiary sediments that sit over an alloctonous carbonate formation which is relatively permeable and highly complex. Aquifers of temperatures of 50ºC have been identified at depths lower than 1,000 meters.

ALBACETE-CUENCA

Carbonate aquifers of Mesozoic age with temperatures of up to 80ºC at 2,000 meters depth.

GUADALQUIVIR BASIN

Jurassic dolomite aquifer at 2,000 meters depth showing temperatures of up to 80ºC.

SALAMANCA-CÁCERES

Extensively fractured Palaeozoic granites and metasediments.

The resources cited until now could be used for electricity generation in case sufficient temperatures and discharge are found (generally above 140ºC and over 30 l/s respectively). In the case of medium to high-enthalpy aquifers, perspectives appear to be highly favourable since the technology developed for enhanced systems will enable a better harnessing of these resources. The Spanish geological framework favours the development of enhanced geothermal projects. In fact, several studies have been initiated in a number of areas in the country – led by business sector – aimed at localizing favourable areas and assessing the eventual potential of the resources, which constitutes an essential previous step before the decision to move ahead with the development stage is made.

Low-temperature resources (below 120ºC) that have adequate discharge would also be subject to thermal uses, whether for heating-cooling applications or agricultural and industrial ones, as long as they are found near the areas where demand is required.

THE SPANISH GEOLOGICAL FRAMEWORK FAVOURS THE DEVELOPMENT OF ENHANCED GEOTHERMAL PROJECTS. IN FACT, SEVERAL STUDIES HAVE BEEN INITIATED IN A NUMBER OF AREAS IN THE COUNTRY – LED BY BUSINESS SECTOR – AIMED AT LOCALIZING FAVOURABLE AREAS.

5 Future challenges and opportunities

5.1 MARKET AND POSITIONING OF GEOTHERMAL ENERGY

ELECTRIC USE

Geothermal energy can generate electricity continuously and is therefore a dispatchable type of energy. Considering that renewable energy will be progressively acquiring a greater share of our country's energy mix, geothermal energy will be faced with the challenge of becoming an important grid regulation agent.

Another challenge brought forward is the development of projects with new technologies that are being tested in pilot projects in other areas of Europe. Binary cycles and medium temperature geothermal deposits bring the greatest potential for development in our country and must therefore be accompanied by adequate incentive policies in their initial stages to drive their momentum and growth into the mid to longer term.

THERMAL USE

Another important challenge is the impulse and development of district heating and cooling networks that can supply energy to vast residential and service areas in which geothermal energy may act as the primary energy for the production of heat and cold. Centralized systems, which are not too well implemented in our country, are widely developed in other European countries and make up the ideal solution to encourage energy saving and emission reductions that are at present associated with most heating & cooling systems and domestic hot water (DHW) that run on fossil fuels.

In a scenario of progressive reduction in the amount of subsidies for shallow geothermal energy projects, it becomes necessary to empower the design and development of systems that can enable the competitiveness of this type of energy before conventional systems and its implementation in areas that have thermal demands beyond those of HVAC and DHW. Access of this renewable thermal energy to climatization systems in buildings (and its chances of gaining market share) crashes however with this technology's high implementation costs, particularly in comparison with natural gas-based heating systems.

According to the 2008-2012 Spanish Energy Efficiency and Saving Plan (PAEE) the best of foreseeable scenarios for 2012 – the so-called E4+ – predicts a final energy demand of 13,898 ktoe corresponding to thermal use in buildings, which implies a total primary energy volume of 20,847 ktoe. Planned investments in E4+ aimed at obtaining a reduction in the demand of primary energy of 3,585 ktoe/year amount to a total of € 13,500 million, which translates into an average ratio of € 3.76 million/ktoe. The investment ratio required for the measures that aim to reduce the thermal demand equals € 4.99 million/ktoe. On the other hand, other thermal renewable energy types such as solar thermal have characteristic ratios, according to Spanish Renewable Energy Plan (PER) 2005-2010, of € 7.8 million/ktoe.

Low-enthalpy geothermal energy can add to this effort by generating additional savings of € 4.9 million/ktoe.

FORECASTED SCENARIO IN THE 2008-2012 PAEE Y PNA (2008-2012)							
	MEASURES	ACTION PLAN 2008-2012					
		INVESTMENT	PUBLIC SUPPORT	SAVINGS IN PRIMARY ENERGY (ktoe)		AVOIDED CO_2 EMISSIONS ($ktCO_2$)	
		€		2012	2008-2012	2012	2008-2012
1	REHABILITATION OF EXISTING BUILDING ENVELOPES	2,677,295	175,150	606	2,176	1,458	5,232
2	ENERGY EFFICIENCY IMPROVEMENTS OF THERMAL INSTALLATIONS IN EXISTING BUILDINGS	3,179,205	243,315	704	2,528	1,796	6,452
3	ENERGY EFFICIENCY IMPROVEMENTS OF INTERIOR AND EXTERIOR LIGHTING COMPONENTS IN EXISTING BUILDINGS	2,694,681	176,292	1,396	5,010	4,999	17,937
4	PROMOTING THE CONSTRUCTION OF NEW BUILDINGS AND THE REHABILITATION OF EXISTING ONES THAT HAVE HIGH ENERGY RATINGS	3,969,362	208,914	658	1,973	1,774	5,322
5	REVIEW OF ENERGY REQUIREMENTS CURRENTLY IN BUILDING CONSTRUCTION REGULATIONS	408,934	0	222	222	598	598
TOTAL IN CONSTRUCTION SECTOR		13,469,477	803,671	3,585	11,906	10,625	35,540

Note: Conversion factor taken into account for the construction sector: Primary Energy = 1.5004 x Final Energy

SOURCE: Institute for Energy Diversification and Saving, IDAE.

5.2 SUSTAINABILITY

Sustainability in the use of geothermal resources must be understood in several different ways:

Energy sustainability, defined as the effort to maintain the thermal conditions of the resource – which will continuously tend to reach equilibrium with thermal loads – that will allow safeguarding the use thereof beyond the life of the project.

Environmental sustainability of the resources that will help guarantee the preservation of pressure levels in geothermal deposits, thus avoiding a decrease of available fluid volumes.

Environmental sustainability must also ensure a minimum affection to the medium, particularly groundwater, trying to avoid the possible interference with aquifers and whatever other subsurface resources may exist, and singularly, to other neighbouring geothermal deposits, mineral and thermal waters. Lastly, environmental sustainability must also contemplate the closure and abandonment of geothermal sites, guaranteeing their adequate restoration.

SUSTAINABILITY IN THE USE OF GEOTHERMAL RESOURCES MUST BE UNDERSTOOD IN SEVERAL DIFFERENT WAYS: ENERGETICALLY AND ENVIROMENTALLY.

Energy sustainability in deep geothermal environments requires a balance between the energy that is extracted and that which the Earth is capable of supplying to the system, in order to ensure a constant production over time and a minimal affection to the geothermal deposit (particularly in the vicinity of extraction and injection wells) through the life of the project.

Establishing a production rate in which energy is extracted no faster than fluid is naturally generated will enable a sustained exploitation of the resource at a stable and sustainable rhythm over time. In geothermal exchange systems, energetic sustainability can be interpreted as the capacity to satisfy forecasted thermal demands through the life of the building. Beyond the lifetime of the exchanger units (which normally equals that of the building) an attempt to reach equilibrium among the natural components of the system, extractions and injections is established. This requires a rational design of the system based on the knowledge available about the building's thermal loads and demand as well as the geological, hydrogeological and thermo-geological characteristics of the ground. The goal is to balance the injections and extractions of thermal energy that the ground can bear with its natural regeneration capacity. It is a complex system that can show great variations and one which requires a customized assessment.

Environmental sustainability around the use of conventional geothermal resources will require sufficient warranties so that production can take place in a way that fluid re-injection is possible once thermal energy has been extracted. The only exceptions to this norm would be those cases where environmental protection of the resources that are under the direct environmental, hydraulic or mining authority specifically establishes the inconvenience of proceeding in this manner. Likewise, there should be guarantees to ensure that groundwater will not be affected and that the appropriate restoration of the environment – once exploitation activities are over – is carried out. Environmental sustainability is perfectly contemplated and guaranteed through the application of and compliance with the existing environmental legislation.

The use of groundwater as a geothermal resource in shallow geothermal environments must guarantee that any affections to the water mass that may be generated from a quantitative (extraction activities without re-injection) and qualitative standpoint are well known and environmentally acceptable.

On the other hand, in the coming years closed circuit systems will come accompanied by an important number of drilling campaigns in urban areas which have not experienced this type of groundwork activities before or its possible affections. There is also the risk that companies and professionals that lack the necessary technical capacity and experience enter the drilling sector. To this regard, it will be essential to establish intelligent measures to ensure minimal possible affection to the medium without hindering the implementation of this net environmentally positive type of energy.

Design and selection of geothermal exchange well annulus filling and sealing systems must be carried out based on a thorough knowledge of the hydrogeological dynamics of subsurface materials. Minimal affection to aquifer materials and an optimal thermal performance of the geothermal exchanger must be guaranteed at all times.

5.3 ADAPTATION TO THE CURRENT LEGAL FRAMEWORK

A complex legislative scheme intervenes during the start of geothermal projects which can be detrimental to the future development of geothermal energy in Spain. A number of aspects are highlighted next which can resolve the current setbacks:

Those aspects that are relative to the mining legislation must be adapted so that the different types of geothermal resources that may exist at any location can be investigated and exploited; these should be characterized according to temperature, depth and the geological context in which they are found, even if there are different project owners carrying out the investigations. For shallow geothermal resources, a simpler and more homogeneous system for handling the paperwork and government concessional regime must be established in all autonomous regions. In the case of shallow geothermal resources that show very low energy potential, an even simpler regime should be established. The mining administration must oversee the possible interaction and compatibility between the use of thermal and mineral waters and the different geothermal resources, ensuring in all cases that any tasks that are undertaken during the investigation and the use of certain resources do not affect pre-existing geothermal energy uses.

In the case of environmental and water legislation, efforts must be made to shorten long administrative processes which at present may render many geothermal projects unviable.

A specific financing program must be established in relation to the important risks (geologic risks) that are inherent to the initial stages of deep geothermal projects (location of sites, setup and tests conducted during the first drilling campaigns).

Current uncertainties that are generated in relation to the retribution framework – associated with the production of electricity using geothermal energy – through the life of the project must be avoided. Likewise, similar schemes must be implemented for geothermal-based heating and cooling systems.

Geothermal renewable energy is to be contemplated in all energy regulations relative not only to the production of energy from renewable sources but also to the production of HVAC.

GEOTHERMAL RERENEWABLE ENERGY IS TO BE CONTEMPLATED IN ALL ENERGY REGULATIONS RELATIVE NOT ONLY TO THE PRODUCTION OF ENERGY FROM RENEWABLE SOURCES BUT ALSO TO THE PRODUCTION OF HVAC (HEATING, VENTILATION AND AIR CONDITIONING) AND DHW (DOMESTIC HOT WATER).

5.4 PROMOTION OF TECHNOLOGICAL DEVELOPMENTS

DEEP GEOTHERMAL ENERGY

The development of deep geothermal energy in our country lags behind the developments that have been taking place in our neighbouring countries. Spain has hardly had any presence in almost none of the R&D initiatives related to geothermal energy in Europe in the last decades, initiatives which have already borne fruits in the form of new technological developments in the field of EGS in countries such as Germany and France. Spain's geological framework is particularly favourable for the development of EGS and low temperature projects, and it is precisely in these fields where important technological advances are taking place at a worldwide scale over the last few years. In clear contrast, a detailed classification of all potential geothermal resources continues to be one of our main pending subjects.

Given this situation, Spain has the opportunity to leverage R&D experiences that are being developed in neighbouring countries and to transfer and develop this new knowledge through an adequate adaptation to our particular reality and geological framework. This would undoubtedly favour basic investigation activities as well as the development of pilot projects which may translate into opportunities to drive enhanced and low-temperature geothermal energy projects in our country.

Lastly, R&D together with innovation must become the key tools to achieve a progressive reduction of energy production costs, thus improving the competitiveness of geothermal systems before other sources of energy generation.

THE DEVELOPMENT OF DEEP GEOTHERMAL ENERGY IN OUR COUNTRY LAGS BEHIND THE DEVELOPMENTS THAT HAVE BEEN TAKING PLACE IN OUR NEIGHBOURING COUNTRIES. SPAIN HAS HARDLY HAD ANY PRESENCE IN ALMOST NONE OF THE R&D INITIATIVES RELATED TO GEOTHERMAL ENERGY IN EUROPE IN THE LAST DECADES.

The main technological challenges to realize the take-off of geothermal energy can be summarized in:

- Investigation of conventional resources: geology, geochemistry and geophysics.
- Development of geological techniques and applications (3D, etc.).
- Development of analytical techniques to determine tensional and structural states of deep deposits (including micro-seismic surveys).
- Application of new geophysical techniques to conventional resources, low-temperature geothermal environments and enhanced geothermal systems (EGS).
- Propel different lines of investigation in Spain – as currently under way in other countries – that work on minimizing undesirable seismic-induced effects caused by the stimulation of deposits. The Basel (Switzerland) experience sets out new lines of action in this sense.
- Modelling of geothermal deposits: transport and heat flux modelling adapted to shallow aquifer geothermal use as well as subsurface and deep deposits. timulation and creation of geothermal reservoirs.
- Improvement of the efficiency of thermodynamic cycles that would allow the generation of electricity from progressively lower temperatures.
- Hybridization of geothermal energy with other renewable technologies.

SHALLOW GEOTHERMAL ENERGY

Geothermal exchange technologies are currently at an incipient stage in Spain. A number of different barriers have hindered the implementation of this technology which has positioned us almost 20 years behind with respect to the most advanced European Union nations.

Lower thermal demand and energy costs in our country (which explain part of our lagging behind other countries) draw the attention around technological developments that either allow a reduction of implementation costs or an increase of savings generated by these types of systems. The main technological challenges are associated with the following aspects:

- Reduction of project execution costs of geothermal circuits.
- Improvement of the methods of evaluation and an increase of well and well field productivity and of ground-exchange systems.
- An increase of the efficiency of energy generation equipment.
- Development of competitive low-temperature systems.
- Development of home rehabilitation methods that drive the evolution toward single boiler-high temperature radiator ensembles.
- Standardization of geothermal systems in buildings, especially hybrid ones that involve geothermal heating together with solar regeneration as well as those that combine heating and cooling.

5.5 TRAINING OF QUALIFIED PROFESSIONALS

It will be essential to develop lines of action that allow widespread diffusion about the possibilities this new energy source brings. This can take place through collaboration with official learning centers (i.e. public and private schools) to introduce the concept of geothermal resources and their useful applications.

- Development and recognition at the European level of not only accreditation and certification systems for small-scale renewable energy installation technicians but also of all active personnel that make up a geothermal installation, that is, installation technicians, drillers, designers, maintenance technicians, trainers and auditors.
- Inclusion of geothermal contents in university, professional certification and post-graduate academic curricula.
- Consolidation and homogenization of certification and training programs at the European level, which will be subject to review as technological advances develop. It is essential that such programs are based on the foundation of environmental sustainability.

6

2030 Vision

6.1 PRELIMINARY SUSTAINABILITY CRITERIA

The vision scenarios presented next must take into account the following sustainability criteria, independently of any of the cases or hypotheses that may be considered:

- Special attention must be placed on the analysis of possible interferences with other types of uses, particularly those associated with thermal and mineral waters that make use of thermal fluids or groundwater which may become affected.
- Special attention must be placed on the updated maintenance of databases relative to the use of geothermal energy, with the goal of setting the criteria for carrying out a rational use of resources and favouring a harmonized and dynamic development of the sector.
- Models of geothermal energy use must be prioritized with the goal of driving combined electric and thermal energy production, as well as hybridization with other renewable energy.
- Each installation must be designed in the most sustainable and efficient way possible, taking into account the complete life cycle thereof and utilizing antifreeze, refrigerants and other non-toxic and environmentally friendly products.
- Follow-up measures and seismic monitoring networks must be established in advance in those areas where enhanced geothermal systems (EGS) are to be investigated and exploited.
- For thermal applications, shallow geothermal energy will cover the residual demand after passive climatization, heat recovery and free cooling techniques aimed at reducing consumption have been applied. Design and construction of the installations must ensure a primary energy index above 1.2.

THE VISION SCENARIOS PRESENTED NEXT MUST TAKE INTO ACCOUNT THE FOLLOWING SUSTAINABILITY CRITERIA, INDEPENDENTLY OF ANY OF THE CASES OR HYPOTHESES THAT MAY BE CONSIDERED.

6.2 VISION SCENARIOS

Vision scenarios (in particular the 2020 scenario) will be established and conditioned by the new 2011-2020 Spanish Renewable Energy Plan (PER) and the National Action Plan which develops the national targets of the European Renewable Energy Directive.

2020 SCENARIO

For shallow geothermal energy, uncertainties about the current degree of implementation make it difficult to establish objective criteria on the progress of this technology in our country. The rapid advance experienced by this technology over recent years translates into cumulative annual growth rates of over 30%.

In line with the developments that have been experienced in some neighbouring countries like France, a target of 20 MWth per million inhabitants for 2020 can be established. This implies an installed capacity of nearly **1,000 MW thermal** in said year. Achievement of this goal requires the installation of around 900 MWth over the next 10 years. With the current available figures in hand, it is estimated that the installed capacity must experience an interannual growth rate close to 50% over the next 10 years.

With regard to production targets for deep geothermal energy, a recent* study concludes that if the appropriate conditions are met (i.e. measures that drive research which contributes to a better understanding of the resources, together with a feed-in tariff that provides an impulse to the development of the sector at an initial stage) an installed capacity of **1,000 MW electrical and 300 MW thermal** could be reached by 2020.

*Geothermal Potential in Spain and Support Schemes Necessary to Facilitate Geothermal Developments" study carried out on behalf of APPA by consulting firms SKM and GeoThermal Engineering.

2020 SCENARIO

With regard to shallow geothermal energy and continuing along the lines expressed for the 2020 scenario, in 2030 ratios equivalent to those of other European nations displaying characteristics of a mature market should be reached. For example, in the case of convergence with the current Austrian ratio of 66 MWth per million inhabitants, production should remain steady at around 15,000 installations/year through the decade of the 20's.

As for deep geothermal energy targets, it is expected that by 2030 a significant reduction of electricity and thermal generation costs will take place, which should translate into an important growth driver for the sector. Taking as a reference the growth estimations described in the report drafted by European Geothermal Energy Council –EGEC- at the beginning of 2009, a three-fold growth over the figures estimated for 2020 is expected, which indicates that by 2030 an installed capacity of **3,000 MW electrical and 1,000 MW thermal** could be reached.

6.3 STRATEGIC OBJECTIVES

1 TAKE-OFF AND DEVELOPMENT OF GEOTHERMAL ENERGY AS AN ENERGY SECTOR WITHIN RENEWABLES.

The objective entails demonstrating the viability of deep geothermal energy to a deep enough level in which the risks and requirements of geothermal projects are understood and assumed by private investors. It also entails increasing investment in shallow geothermal energy so as to enable the development of projects that are economically viable, with the goal of reaching maturity in the sector.

Strategies

Inclusion of geothermal energy in the new 2011-2020 Spanish Renewable Energy Plan (PER) with specific objectives (thermal and electric) for 2020. PER will propose the necessary measures to achieve the targets established for both shallow and deep geothermal energy, taking into consideration their corresponding technical and developmental particularities.

Establishment of a s**pecial regime for thermal supply** based on renewable energy sources and particularly on geothermal energy.

Development of a regulatory **framework that is specific to the thermal geothermal sector**, which contemplates the inclusion of geothermal energy in RITE (Regulations on Thermal Installations in Buildings), CTE (Technical Building Code), energy classification programs, etc.

Harmonization of the regulatory framework among the different areas involved (water, mining, energy, etc.) in a stable, consistent and coordinated fashion among the local, regional and national Administration.

Development of **pilot programs** that prove via geothermal drilling the potential of the resources and the production of geothermal energy, with the associated transformation into electricity or thermal energy at commercial scale.

Development of **aid and risk reduction** programs for geothermal exploration drilling.

Creation of knowledge networks that enable both fluid communication and the sharing of experiences among members of the geothermal sector including other external agents, and conjunctively analyzing needs while defining actions and combined strategies and participating in international forums.

Development of **communication policies and strategies** focused on convincing all stakeholders involved in the development of the sector (industry, Administration, investors, local communities, energy end consumers, etc.) that geothermal energy is a clean, safe, competitive and viable option within the Spanish energy mix.

2 SUSTAINED UPDATING AND MANAGEMENT OF THE KNOWLEDGE OF SPAIN'S GEOTHERMAL POTENTIAL.

Through access to public databases of high-quality geo-scientific information that is prepared and tailored specifically for the sector, so as to reduce the technical and economical risks that are inherent to the initial stages of geothermal investigation.

Strategies

Acquiring quality information through the development of several lines of investigation that would produce useful geo-scientific data for the geothermal sector. Similarly, the compilation of subsurface information obtained by sectors such as gas, oil and CO_2 and other waste storage in general and the modification of control and public submittal of information procedures from exploration and investigation campaigns carried out by private companies who own the rights thereto.

Management of a unique and public database for the sector that integrates all acquired updated information in a digital and georeferenced way.

3 DEVELOPMENT OF R&D&i PROGRAMS THAT ARE ADAPTED TO SECTOR PARTICULARITIES IN OUR COUNTRY.

Empower research and development of our own innovation capacity to implement significant technological advances and progressively reduce energy generation costs.

Strategies

Development of new geological investigation techniques applicable to basic exploration and geothermal resource assessment phases.

Development and improvement of **drilling, enhancement and modelling of the geothermal reservoir as well as fluid re-injection** technologies in enhanced geothermal systems (EGS). Development, adaptation and improvement of drilling support tools that come from the oil sector.

Technological impulse to improve **energy efficiencies of thermodynamic** cycles that would allow the efficient generation of electrical energy at lower temperatures.

Development of technologies, tools and protocols that aim at the **reduction of possible associated impacts** such as induced seismicity and acoustic contamination during drilling and geothermal plant construction phases, as well as potential liquid or gaseous emissions.

Development and standardization of methodologies and systems which enable the **integration of low-enthalpy geothermal energy in the sustainable building chain.** Development of new distribution techniques and cool air generators adapted to home cooling needs which may increase the added value of geothermal energy.

Integration of the ground's **thermal storage capacity** with high efficiency systems, thus improving system regulation and manageability.

Continuous improvement of the efficiency of **heat pumps and ancillary equipment**. Standardization and simplification of regulatory and control elements. Cost reduction during fabrication and installation phases to facilitate the implementation of these systems. Popularization and improvement of DHW (domestic hot water) storage systems.

Development of techniques and systems aimed at r**educing design and execution costs of geothermal exchange circuits,** ensuring their quality and the lowest impact and risk possible. Scientific dimensioning and evaluation techniques must become generalized for the design of installations above 30 kW. Development of drilling systems, designs, materials and equipment adapted to our geologic and market condition and development of good practice manuals.

4 DEVELOPMENT AND IMPLEMENTATION OF A TRAINING AND CERTIFICATION MODEL ACROSS THE DIFFERENT AREAS OF THE GEOTHERMAL SPACE.

Ensure that apt professionals are available (and groomed) who are capable of leading the launch of the sector in our country.

Strategies

Training of installation and maintenance technicians in the shallow geothermal energy field (accreditation to be demonstrated through professional licenses), drillers (clearly outlining the needs of shallow and deep geothermal environments), designers (involving specific training via official courses or masters programs that include contents of diverse levels and depth) and auditors (through the generation of specific knowledge required by the sector).

Development of **work platforms and structures** (national and European) responsible for guaranteeing the coordination of principles and contents, qualification/training schemes and their subsequent verification/certification, which are to be carried out independently (for example, National Training/Certification Coordinator at the national level and National Training/Certification Institutions at the local level).

6.4 ESSENTIAL CONSIDERATIONS REGARDING GOAL ACHIEVEMENT

- A decisive support and leadership by the Administration (national, regional and local) during the initial phases of projects (in which the regulatory, remuneration and specific regulatory frameworks are developed, pilot projects are promoted, complementary risk mitigation measures are supported and initiatives are easily processed) in order to generate sufficient confidence in companies, promoters, investors and financers, etc. to launch and develop the sector.

- Promotion and support of new initiatives in the geothermal sector both aimed at existing and new companies, through investment aid programs as well as programs for the acquisition of technology, process improvement, internationalization, etc. in order to create a network of geothermal development, subcontractor and ancillary companies.

- Development of the value chain within the geothermal sector in a complete and balanced way – maintaining a long-term vision as a national strategy and avoiding any other short-sighted, speculative visions – through market stimulus and support, the capture and retention of knowledge, business creation and the development of professionals that bring sufficient capacities and competencies to generate a critical mass of successful projects.

- The impact of the evolution of the learning curve on the reduction of design and execution costs of geothermal installations, through continuously fueling the development and competitiveness of the sector while guaranteeing quality; ensuring minimal impact and risks as well as the adaptation to our geologic and market conditions.

- Creation of a shared vision about geothermal energy by society as a whole (companies, universities, learning centers, technological centers, the Administration, end users, etc.) as a renewable technology capable of sustainably supplying both homes and the Spanish industry with clean and competitive electric energy.

- Driving the creation at the European level of work groups, committees, experience sharing platforms, expert and knowledge networks, etc. with respect to normalization, investigation and universities, R&D&i and technology.

6.5 EXPECTED BENEFITS

- An increase in the supply of renewable energy with a parallel decrease of primary energy consumption.
- Improvement of the manageability of the system.
- Creation of a sustainable industrial sector highly or fully protected against delocalization.
- A reduction on the dependence of fossil fuel based energy.
- Reduction of GHG emissions.
- Improvement of the trade balance.
- Smoothing of peaks in electricity demand associated with heating and air conditioning consumption.
- Better regulation of distributed generation systems through storage of thermal surpluses.
- Integrated, more rational, low-consuming heating and cooling systems.

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8 Acknowledgements

The creation of GEOPLAT as a Technology Platform and the drafting of its first position document have been made possible thanks to the commendable effort of many entities of different nature, but above all, to the considerable effort and constant hopes brought together by a group of individuals without whom none of this would have been possible.

Firstly, we would like to extend our gratitude to the Ministry of Science and Innovation and especially to Mª Luisa Castaño and Ana Mª Lancha from the General Subdirectorate for Public-Private Collaborative Strategies for the constant support and confidence demonstrated both in the sector and the project. Likewise, we would like to thank IDAE (Ministry of Industry, Tourism and Commerce) and its Department of Geothermal Energy, led by Carmen López and Carmen Roa, for the leadership demonstrated during the launching of GEOPLAT as well as the continuous drive shown toward the achievement of the goals established.

Many thanks to the members of GEOPLAT Steering Committee for being the soul of the Platform and for tirelessly giving their best to achieve the successful development of geothermal energy in Spain. Thanks to Iñigo Arrizabalaga (TELUR), President of GEOPLAT, for the analytical capacity and agility imprinted on the functioning of the Platform. Of course, many thanks as well to Javier Urchueguía (VALENCIA POLYTECHNICAL UNIVERSITY) and Raúl Hidalgo (PETRATHERM) for their determination in making GEOPLAT big, both in Spain and abroad; and also to Celestino García de la Noceda (IGME-Geological Survey of Spain) whose experience and key knowledge of the geothermal sector make up one of GEOPLAT's pillars. Our thanks go out also to Laura Arias (DALKIA) and Mikel Sojo (ACCIONA ENERGÍA) for their responsibility and good practice to make everything work correctly; to Beatriz Torralba and Borja Izquierdo (both from CDTI) for their valuable advice and support; and many thanks to Paloma Pérez, advisor of GEOPLAT's Technical Secretariat, for always being there and looking after the Platform and everyone who is part of it.

But it is the geothermal sector altogether in Spain without a doubt what shapes GEOPLAT, what fuels its evolution and drives it toward success. Thanks to the trust placed in the Platform, the sector will definitely succeed in achieving its technological development which is inherently linked to its business success. Thank you very much to all.

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