# Strategic Research Agenda

geoplat

SPANISH GEOTHERMAL TECHNOLOGY PLATFORM

UNION EUROPEA
FONDO EUROPEO DE DESARROLLO REGIONAL

GOBIERNO DE ESPAÑA

MINISTERIO DE CIENCIA E INNOVACIÓN

# THANK YOU

We would like to express our thanks to GEOPLAT members for demonstrating their continuous support to the Platform and for turning it, after its two initial years of existence, into the forum that has brought together the Spanish geothermal sector. Launching this valuable technological instrument has been the product of the efforts by each and every one of the entities that are part of the Platform, who have succeeded in making it their own by supplying content and soundness that are representative of each and of the Spanish geothermal sector itself, one that is becoming increasingly consolidated and shows greater future prospects.

And it is toward this immediate, medium and long term future that the sector looks to with yearning. However, doing so without assuming that said future is conditioned by the technological developments of geothermal technologies, which will be the vehicle that would allow moving forward in the path to competitiveness and their large-scale implementation in the Spanish society, would be unthinkable. It is in this first GEOPLAT Strategic Research Agenda where preliminary R&D&i steps relative to geothermal energy in Spain are established, allowing national entities to carry out research projects in the field of geothermal energy and therefore, driving the positive evolution of the sector in our country.

The experience in the sector brought by Javier Urchueguía (UPV), Raúl Hidalgo (PETRATHERM), Iñigo Arrizabalaga (TELUR) and Celestino García de la Noceda (IGME) together with the great work carried out as coordinators of the Training and Education, Deep Geothermal Energy, Shallow Geothermal Energy and Resource Identification Work Groups respectively has been instrumental for this Strategic Research Agenda to be able to collect R&D&i priorities of the Spanish geothermal sector in a balanced way. The result has allowed entities of different nature comprising the sector to gain access to research projects that may be designed based off the needs and nature of the entities themselves. Many thanks to all.

Thanks also to Beatriz Torralba and Borja Izquierdo, National Point of Contact for Energy matters and National Representative of the Energy Committee for the R&D Framework Program respectively, for being exceptional travel partners and for putting CDTI at the service of the Spanish geothermal sector so that it is capable of making its innovative initiatives a reality.

Many thanks to IDAE and its Geothermal Energy Department, efficiently led by Carmen López Ocón. For her constant support to geothermal energy and GEOPLAT. It is fortunate that this sector can count on allies like these.

Many thanks always to the Ministry of Science and Innovation (particularly to Mª Luisa Castaño and Ana Mª Lancha, of the General Sub-directorate for Collaborative Public and Private Strategies) for making GEOPLAT better every day, both in terms of public service and for the opportunities it creates for the Spanish geothermal sector. And this is just the beginning!

**MARGARITA DE GREGORIO**
MANAGER - GEOPLAT SECRETARIAT

Así, se propone:

- Estudio de análisis de las posibilidades de normalización UNE de procedimientos de instalación, tecnología utilizada, etc., no normalizados.

Además, es importante tener en consideración aspectos relativos a la sostenibilidad de los aprovechamientos geotérmicos. Por ello, se propone:

- Realización de estudios de Análisis de Ciclo de Vida (ACV) en instalaciones geotérmicas.

### 1.4. Buenas prácticas.

Una de las amenazas más importantes detectadas para el desarrollo del sector geotérmico en un futuro inmediato, concretamente de aquel asociado a instalaciones someras, es la que provocaría un crecimiento incontrolado del mismo, con la aparición de instalaciones mal diseñadas y ejecutadas. Este problema, fruto de la inexperiencia y de la falta de cualificación adecuada, al no aprovechar y mostrar los importantes beneficios reales de la tecnología, podría ocasionar una serie de dudas o incertidumbres, una desconfianza en el consumidor, que actuaría en claro perjuicio del sector. Por ello, resulta vital, entre otras medidas, el hacer hincapié en los aspectos de las llamadas 'buenas prácticas' que aseguren un crecimiento sólido del sector.

En la actualidad son muy variados los ejemplos de documentación que recogen estas 'buenas prácticas' en otros países. En los países nórdicos existen asociaciones y normas para la realización de una correcta instalación, y los consumidores pueden acudir a organizaciones independientes para asesorarse. Asimismo, en Alemania por ejemplo se ha desarrollado la norma VDI 4640, que viene a realizar una exhaustiva revisión de recomendaciones para la instalación de diversos sistemas geotérmicos. La Asociación Internacional de Bombas de Calor Geotérmicas (IGSHPA) también dispone un conjunto detallado de estándares en este sentido. En España, existen intentos de elaborar textos similares, aunque su difusión y la exhaustividad de los contenidos quizá debieran buscar un mayor alcance.

Por ello, se propone:

- Análisis de la documentación existente y estudio de definición de las bases y contenidos esenciales que debieran constituir un código de buenas prácticas para el diseño e instalación de sistemas geotérmicos en España.

### 1.5. Registro de instalaciones y bases de datos.

España no dispone de un registro de instalaciones geotérmicas regulado hasta la fecha. Sin embargo, la creación de dicho registro permitiría conocer el conjunto de las instalaciones en operación así como sus características, y en consecuencia, la evolución del sector geotérmico en España del que no existen datos oficiales fiables que reflejen la realidad del mismo.

Recientemente se ha logrado que la voluntad de llevar a cabo esta tarea entre 2011 y 2012 quede reflejada en el Plan de Acción Nacional de Energías Renovables (PANER) remitido a la Comisión Europea en junio de 2010. No obstante, ha de plantearse un compromiso firme en relación a este trabajo; para lo cual se plantea lo siguiente:

- Análisis de las posibilidades existentes para desarrollar un sistema efectivo de registro de instalaciones geotérmicas en España y recomendación de las bases (estructura, contenidos a incluir, *software,* etc.) para dicho sistema.

Society is becoming increasingly more conscious about the worrisome situation threatening the sustainability of our development if the current pace of increasing demand for resources is maintained without applying any drastic modifications to the essence of our energy model.

This increasingly serious problem calls for committed action on the part of global economies that must evolve and transition toward a sustainable use of resources through the application of new technologies and the use of increasingly efficient energy sources that are respectful on the environment as well as capable of not placing the wellbeing of future generations at risk.

In this context, renewable energy and in particular geothermal energy must play a fundamental role to face this challenge and become part of the foundations of our energy system. The road toward sustainable growth has already begun; nevertheless, the objectives and timing are demanding and require the use and application of all possible tools.

Innovation and the boost experienced by the evolution and development of the technology make up the drivers that must fuel this transformation and support the continuous advance along the renewable technology learning curve, achieving progressive and efficient cost reduction while guaranteeing their competitiveness against fossil fuels.

Through its European Renewable Energy Directive on the promotion of the use of energy from renewable sources (hereinafter Directive 2009/28/CE), **Europe** has clearly shown its support on the use of energy from renewable sources and the implementation of efficient measures relative to final energy consumption. To this regard, the year 2020 has been established as a key milestone along with a set of objectives to be reached on such date, which will translate into the achievement of high levels of competitiveness and excellence through the period.

Although still at an incipient stage of development but already clearly showing great potential to help contribute to the objectives, geothermal energy should in no way fall behind in this process and must face the challenge of becoming an additional, real and accessible option in the energy market by 2020.

Thus, Europe's strategy under the framework established by Directive 2009/28/CE is founded on two essential pillars: the Strategic Energy Technology Plan (SET-Plan) and Technological Platforms.

The SET-Plan establishes a roadmap for accelerating the development and deployment of clean and efficient technologies in the energy sector, taking into account measures relative to planning, implementation, harnessing of resources and international cooperation. The focus of this plan pursues technological development through the participation of the industrial sector in R&D activities and in pilot or demonstration projects, by empowering innovation and accelerating commercial implementation of these technologies.

On the other hand, European Technological Platforms act as sectorial entities in charge of favoring the participation of the different stakeholders involved in the common strategy defined by the SET-Plan. They in turn develop an advisory role and become the voice of the different sectors they represent, in order to bring forward the issues and needs of the industrial and technological sectors to ensure the European Commission's energy strategy receives the appropriate feedback and is presented with an adequate perspective so as to more efficiently develop the competitiveness and sustainability of the model.

In **Spain**, the new Renewable Energy Plan for the period 2011-2020 (PER 2011-2020) constitutes the strategic guideline prepared by the Government that aims to provide the necessary instruments that would allow integrating the particularities of the situation and the energy potential of our country toward the development of a sustainable national energy model. In this sense, the new PER 2011-2020 constitutes a landmark in the Spanish geothermal sector, as it is the first time geothermal energy, our energy, is incorporated into national energy planning and the harnessing of its potential is taken into account as a contributor to the former.

This entire context provides a sense to the activity of Spanish Technological Platforms involved in the energy sector such as **GEOPLAT (Spanish Geothermal Technology Platform)** and to the content of the herein presented Strategic Research Agenda.

The motivation behind this document is to express the vision the Spanish geothermal sector has on the way in which the latter must take part in the transformation of the aforementioned energy model, by implementing the indispensable technological improvements needed to achieve the desired level of competitiveness in the use of our geothermal resources.

The document is structured in three chapters. The first two and the main sections thereof correspond to the two value chains deriving from the activity taking place in the geothermal space, with its particular characteristics with respect to resources, harnessing technologies and applications associated with each:

- Deep Geothermal Energy.
- Shallow Geothermal Energy.

The third chapter has a horizontal and non-technological nature but is highly important in terms of complementing and supporting the advances in technology. This third section develops under the following section heading and includes two differentiated sub-chapters:

- KEY SUPPORT AREAS FOR DEVELOPMENT
    - Training and Education.
    - Regulatory Framework.

A number of strategic areas have been set forth in each of the chapters. The former span across a wide variety of areas within the sector where developments can be implemented to eliminate barriers and shortages that hinder a more competitive harnessing of the resource. In turn, within each of these areas characteristic to the geothermal sector a series of more precise, prioritized courses of action are defined which give the document its dynamic character. Such courses of action are set for the present time, but shall be subject to reviews during future updates of the Strategic Agenda as the development of the sector progresses.

**Furthermore, this document aims at drilling deeper into the strategic proposal established for the geothermal sector in Spain, which includes more detail planning and prioritizing of the courses of action based on the expected impact, desired timelines, required financial resource forecasts and qualified stakeholders and infrastructure required for their development.**

# 1 DEEP GEOTHERMAL SYSTEMS

The fundamental aspects that govern the viability of deep geothermal projects include temperature, discharge, permeability and depth to the resource. Shallow, high-temperature and high discharge zones – known as conventional geothermal systems – are practically inexistent in our country with the possible exception of the Canary Islands.

The technological challenge therefore entails determining the manner in which existing geothermal resources can be harnessed in a technically and economically viable way, something that will only be achieved through the technological development of the strategic areas that comprise a geothermal project as described next:

1. **Basic investigation.** Indirect determination and characterization of resources.
2. **Subsurface investigation and resource management.** Confirmation and development of the geothermal reservoir at depth including geothermal drilling campaigns that can tap the resource in order to obtain direct confirmation of the resource potential that was indirectly inferred. This phase also includes the development of resource management models that would allow optimization and sustainability thereof.
3. **Optimizing geothermal energy at the surface.** Transformation, distribution and supply of geothermal energy at the surface to end-users.

# 1. BASIC INVESTIGATION.

The assessment of the geothermal potential in our country as well as improvements in the process of identifying and estimating the magnitude of resources constitute one of the greatest challenges facing the development of the sector. Any geothermal project begins with an initial investigation phase where the knowledge base is reviewed and updated together with an analysis of the situation and the identification of preferred target areas. Once permission to conduct an investigation is granted by the regional administration, exploration work activities are kicked off to evaluate the existence of geothermal resources in the area. These initial activities use indirect exploration methods, that is, they estimate or assess a series of resource-specific parameters without actually tapping or coming into contact with it. Low cost techniques are normally used during this phase (when compared to drilling costs) and include structural geological interpretation, geochemical exploration and sampling, geophysical exploration, shallow exploration drilling and the use of heat-flow models.

Temperature, discharge and permeability are the main factors that control the development of geothermal projects. Therefore, the ultimate goal of exploration work resides in the identification of subsurface geological settings capable of generating fluids either naturally or through enhancement techniques, yielding high enough temperature and discharge to generate energy in a technically and economically viable way.

In this sense, geothermal exploration carries with it the following basic investigation activities:

- Identification of geological settings favorable for the existence of high subsurface temperatures.
- Identification of tectono-structural settings favorable for the existence of geothermal reservoirs.
- Identification, characterization and evaluation of geothermal manifestations at the surface: fumaroles, thermal springs, emission of natural endogenous gases, hydrothermal precipitates, etc. through geochemical as well as water and gas isotopes analyses, among others.
- Geophysical campaigns: electrical, magnetic, gravity, seismic and thermal flow methods that can show the presence of structures and formations capable of hosting geothermal reservoirs.

The aforementioned activities – which are listed sequentially in order of execution – aim to identify optimal areas for selecting exploration well drill locations, by reducing the risk of not intercepting geological formations or structures that would yield the expected temperature and discharge values.

Geothermal exploration drilling is eventually the ultimate technique that will provide greater certainty over the existence of a resource, its characteristics and potential (depth, temperature, discharge, etc.). There are however several uncertainties that could be minimized in the pre-drilling phase, which would reduce the economic risks that are inherent to drilling itself. Minimizing uncertainty requires a significant increase in the level of knowledge of certain aspects associated with basic investigations, some of which are highlighted next:

- Improving knowledge of structural aspects applied to geothermal exploration, the study of structurally favorable areas and the identification of tectonically active areas.
- Increasing the knowledge of deep aquifers associated with favorable structural geological settings.
- Development and implementation of three-dimensional geological and thermo-structural models.

The following specific lines of research stem from the above-mentioned aspects as a proposal to pursue increasing levels of knowledge prior to the drilling phase, by providing better decision criteria that would assist the decision-making process associated with drilling activities.

### 1.1 Availability of and access to geothermal data including the development of a single, digital, geo-referenced, multidisciplinary database of the Spanish subsurface.

Access to relevant geothermal data is a fundamental premise of the need to increase the level of interest and competitiveness of private initiatives leading the way toward the development of the geothermal sector in our country. The development of a modern, integrated, high-resolution public database that can be updated brings clear benefits including:

- Minimization of risks during initial site investigations.
- Initial cost reduction resulting from the re-acquisition of data.
- Acting as a catalyst for new research studies.
- Speeding up the discovery of new resources.
- Establishing a public provision of geo-scientific data, which creates equal-opportunity conditions for parties to bid for areas of greater geothermal potential in our country.
- Establishing a public resource that can be utilized as a tool for the design and deployment of sector-specific policies.

The creation of an easily accessible public database where information on prospective areas, potential, quality and quantity of geothermal resources is provided would both save time and financial resources to companies and boost the sector. Public databases already constitute an essential tool in countries such as Germany, France, Australia or the United States, by transforming the geothermal sector into an attractive and dynamic one, while encouraging the arrival of new companies that will compete in the search for projects. It is worth highlighting here the degree of impact experienced by the development of the mining sector in Spain thanks to the vast number of basic investigations undertaken by the Spanish Geological Survey (IGME) over the last decades. This investigation is now favoring the return on investment thanks to the numerous mining projects that have been kicked off over the recent years.

Public databases would provide elements that could help identify geothermal systems capable of developing high to medium temperature projects for the generation of electricity and/or low temperature projects for direct heat use. Public information will encourage detailed investigations of geothermal systems in Spain and will provide the sector with solid foundations on which business decisions can be made.

The fundamental goal of this line of research is to create a Geo-referenced Geothermal Information System (GGIS) that would supply new information of geothermal interest (temperature data in wells, calculated geothermal gradients, thermal flow, etc.) to existing databases in Web Map Server format (e.g. IGME's SIGEOF). These databases integrate surface and subsurface geology with geophysical campaign data that will also become relevant for the definition of geothermal systems, such as electromagnetic, magnetotelluric, seismic reflection and gravity campaigns, among others.

The compilation of available data to date is just as important an initiative as the undertaking of new studies through which new ideas and/or concepts can be applied to harness geothermal potential, as well as the many investigation and exploration techniques that have evolved significantly over the past twenty years. Some of the initiatives that would be developed include:

**1.2. The preliminary structural geological analysis** of the Spanish territory, whereby a preliminary definition of typical structural geological models based on active projects globally would be carried out. The goal would entail identifying and selecting areas that show favorable structures and models that are analogous to those previously defined and which may host geothermal reservoirs and deep aquifers. Selection of these areas of interest would be carried out using geological and structural maps, analyses and prediction models of the evolution of structures at depth, characterization of active faults, drilling and geophysical campaigns, etc. as basic information. The conclusions arrived at from this analysis will help steer the next lines of research.

**1.3. Global geochemical exploration campaigns.** Hydrochemical, geochemical and isotopic studies of anomalous gas flows of endogenous origin such as $CO_2$, Rn222, He, etc. as well as the analysis of crustal transport mechanisms applied to the identification of anomalous heat flow areas. In this case, the starting point would be the compilation of analytical $CO_2$ data and other associated gases from the 1975-1976 National Inventory of Geothermal Manifestations, to be used as a stepping stone for future geochemical exploration campaigns aimed at detecting gases of endogenous origin.

**1.4. Preparation and proposal of geological and thermo-structural models of selected areas of greater interest.** These studies were partially conducted during the preparation of the National Inventory of Geothermal Manifestations mentioned earlier but should be completed and updated in light of the emergence of the latest technologies, the acquisition of new knowledge, the undertaking of new exploration campaigns and the application of new investigation-exploration models.

**1.5. Geophysical exploration campaigns** in selected areas based on the outcome of the aforementioned research activities. Geophysical techniques such as magnetotelluric, gravity surveying and seismic reflection will be applied together with other possible innovative tools that can further improve these techniques. Simultaneously, a petrophysical investigation applied to geological ensembles associated with areas of geothermal potential will be required. The use of these geophysical techniques attempts to evaluate the three-dimensional geological structure of the subsurface and helps to identify favorable structures that can host deep geothermal reservoirs such as deep sedimentary basins that show associated granitic intrusions, zones of deep fracturing within extensional regimes and zones of high permeability at depth (deep aquifers). Moreover, this course of action will assist in defining and understanding the microseismicity characteristics of the aforementioned zones, given the close relationship the former has with fracturing and permeability of deep reservoirs. Likewise, projects in the areas of collected and registered data accuracy and representation, treatment and elimination of environmental noise, etc. will be considered.

**1.6. Geothermal gradient well drilling and thermal conductivity and temperature measurement campaigns.** This study could be undertaken using both existing wells and new ones in which thermal flow and ground conductivity would be measured. These wells would constitute the final phase of the basic geothermal investigation and would help confirm any previously identified anomalies, as well as steer the next geothermal exploration drilling phases and prepare these with greater guarantee of success. Additionally, this program would also contribute to increasing the knowledge of the Iberian Peninsula's thermal regime structure, which is at present relatively unknown except for a number of specific areas. This line of research should help shed light on several questions that surround heat flow models in our country today, namely:

- Current quality and reliability of existing thermal flow data.
- Thermal conductivity characteristics of the country's main geological formations.
- Nature of the variations of thermal and physical properties of rock formations as a function of depth.

## 2. SUBSURFACE INVESTIGATION AND GEOTHERMAL RESOURCE MANAGEMENT.

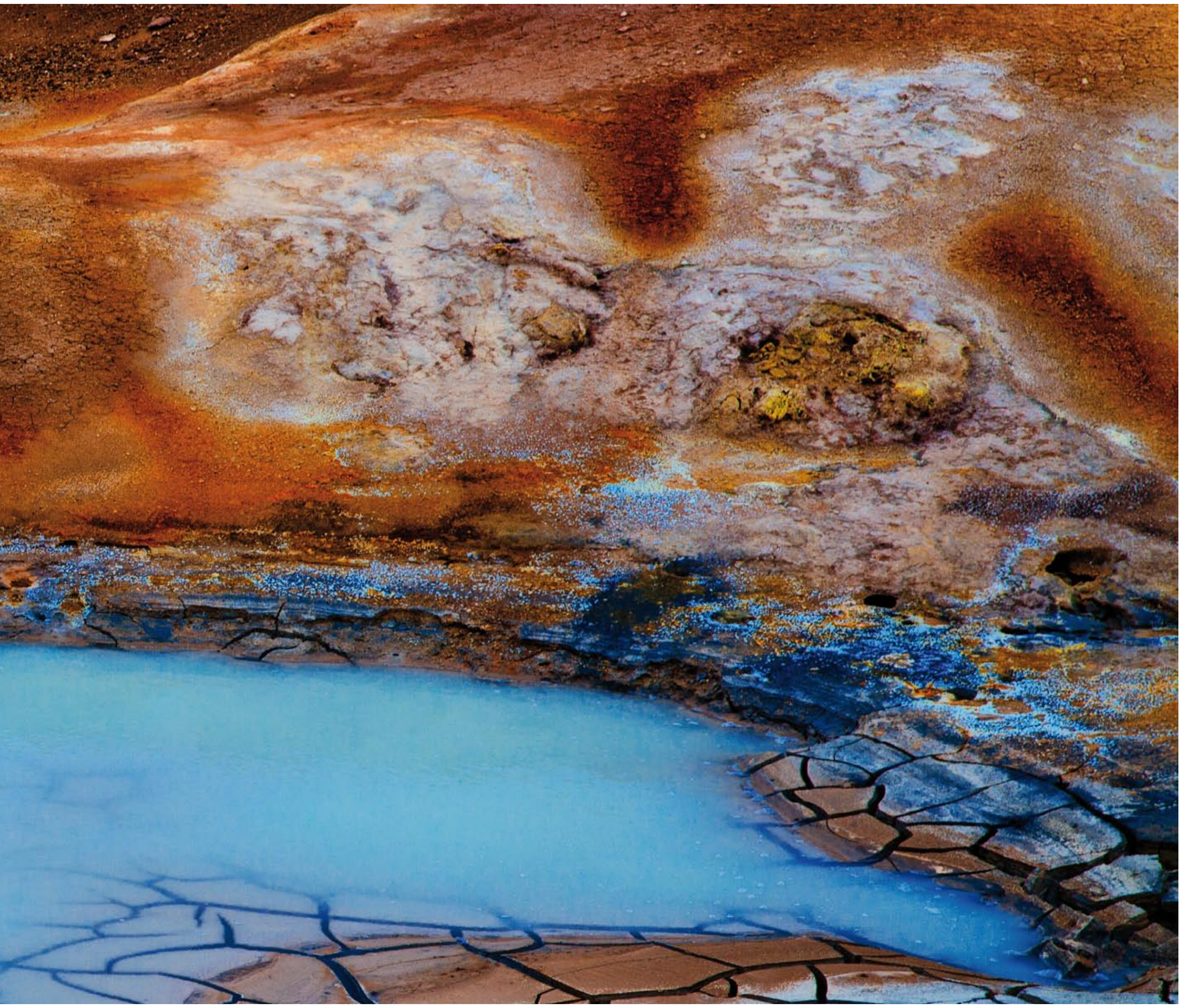
Once areas with the highest geothermal potential have been defined through the application of indirect techniques and the use of gradient wells, the next phase in the development of a geothermal project consists of demonstrating the presence of and characterizing the geothermal resource directly through geothermal well exploration drilling down to the potential reservoir zone.

To date, this phase of the subsurface investigation is poorly developed in Spain. Geothermal drilling constitutes the only useful tool that can help define the characteristics of the geothermal resource and make decisions about the technical and economical viability of the project. Furthermore, it is important to point out that about two-thirds of the capital costs of a geothermal project are related to drilling, which

means that the development of technical solutions that would help improve drilling technologies will have an overall important economic impact, by improving the viability and competitiveness of the sector altogether.

On the other hand, it is worth mentioning that the subsurface investigation phases as well as the process of demonstrating the existence of the resource are closely linked to the overall task of geothermal resource management, which is ultimately aimed at achieving resource sustainability (i.e. reservoir exploitation methods that allow maintaining the initial conditions of the resource being extracted).

The factors that influence decisively the developments of subsurface geothermal investigations are presented next and constitute the greatest challenge for the future: drilling, enhancement of the geothermal resource and sustainability thereof.



## a. Drilling.

A great deal of the drilling technology used in Spain at present comes from the experience acquired in oil and gas exploration. The nature of subsurface geological environments in which geothermal projects are developed however, partly differs from the sedimentary environments proper of oil and gas and therefore, a number of geothermal-specific technological challenges arise that must be dealt with. These are described next:

*Depth.*

Spain's geothermal potential is fundamentally associated with enhanced geothermal systems (EGS) and deep aquifers; it is estimated that in the majority of cases these are found at depths greater than 4,000 meters. Technical drilling capacity in the oil industry allows reaching depths of 10,000 meters, which shows that this factor in itself does not constitute a technological barrier. Technical difficulties derive instead from the need to preserve elements such as natural fracturing at depth, as well as from problems associated with drilling through very hard rock formations such as granite, which frequently make up the crystalline basement that can act as geothermal reservoir targeted by EGS type projects.

*Pressure and Temperature.*

The high temperatures and pressure that can be reached during deep geothermal drilling coupled with corrosion that can derive from the composition of associated fluids require the use of materials that have special resistance characteristics. New studies of drilling equipment and materials (such as casing and rods) are to be conducted in order to adapt these to the harsh conditions they are exposed to during drilling and production phases.

The following initiatives must be studied in detail in order to solve these technological challenges and reduce the cost of drilling taking place at great depths and in extreme conditions:

- Improvements in well cementing techniques at high temperatures.
- Development of techniques aimed at minimizing drilling mud infiltration into the geothermal reservoir zone.
- Development of drilling techniques that minimize affection to the original structure.
- Improving the resistance of materials that are exposed to extreme pressure and temperature conditions, degree of chemical attack and corrosion by elements associated with the drilling process, drill bits, rods, casing, etc.
- Improving drilling monitoring tools that allow obtaining real time information about drilling conditions.

## b. Enhancement of geothermal reservoirs.

In order for a geothermal project to be developed successfully, high temperatures, coupled with a high enough presence of fluids and high permeability must exist. This ideal scenario hardly occurs in the Spanish geological framework, particularly in those aspects relative to the presence of fluids and permeability, making it therefore necessary to artificially improve (i.e. enhance) some of these variables. This leads the way to what is known as Enhanced Geothermal Systems (EGS). Technological developments in the geothermal space are experimenting important advances globally over recent years, whereby successful demonstration of the viability at pilot-scale of these enhanced geothermal systems is taking place. Viability of these systems would make the development of deep geothermal systems possible in large areas of Spain, therefore making it necessary to replicate the European pilot experience at Soultz in our peninsular geological setting and transforming pilot experiences into technically and economically viable industrial projects.

The main challenge facing this technology at present involves improving the enhancement process in order to develop a large enough volume of fracturing to create vast enough geothermal reservoirs that would make the technology viable at a commercial scale. Some of the technological challenges to be solved are presented next:

- Advancing in the application of reservoir enhancement methods (chemo-hydraulic or combined) in different geological settings.
- Developing new fracture and fracture network identification and characterization techniques as well as techniques for defining the geometry and boundaries of the geothermal reservoir and, developing fluid circulation numerical models.
- Conducting risk mitigation analyses associated with induced seismicity including the development of control and monitoring techniques thereof.

### c. Sustainability.

Another challenge in geothermal investigation deals with improving sustainability of the resources. Harnessing geothermal resources more efficiently is deemed highly necessary and should be carried out by studying the geothermal reservoir in order to produce long-term, fluid input-output models that allow establishing sustainable production limits without the risk of reaching resource depletion.

Based on the above, the following proposed lines of research surrounding the strategic area of subsurface investigation are set forth:

**2.1. Technology and costs of drilling methods.** Technological development of improved and more economical drilling, casing and cementing methods applicable to deep geothermal systems, as well as the study of new, more resistant materials and components for drilling in presence of high temperature and pressure and/or corrosive geothermal fluids.

**2.2. Investigating the level of knowledge of enhancement processes and focal microseism generation mechanisms.** Microseismicity is one of the investigation techniques and methods that, when applied to enhanced geothermal systems, allows better characterization of the properties and dimensions of the geothermal reservoir. This line of investigation must have an effective influence on the development and improvement of instrumentation used in passive microseismic exploration methods in order to locate the region's seismic baseline and therefore establish a reference point for future comparisons. Additionally, these techniques will permit detecting fracture systems at depth and will help control enhancement and formation processes of the geothermal reservoir as well as outlining its geometry.

**2.3. Development of three-dimensional numerical models** to define the dynamics of the geothermal reservoir and to evaluate its medium to long-term behavior, while simultaneously simulating the overall sustainability of the project. These mathematical models must be capable of reproducing variables such as reservoir permeability, fluid circulation and temperature, and must simulate the behavior of the system upon variations in any of its parameters, such as an increase in production discharge.

**2.4. Fluid reinjection studies.** Detailed study of problems associated with the re-injection of considerable amounts of discharge into specific geothermal systems.

**2.5. EGS demonstration projects.** The critical aspect surrounding the geothermal space in our country is directly linked to the level of confidence that the Administration and the private sector would attain eventually with respect to the development of pilot projects that are to demonstrate fluid circulation and the viable extraction of energy. Each pilot project would consist of one geothermal well being drilled initially down to the necessary depth where required temperatures values exist. Subsequently and if deemed necessary, the host rock would be enhanced to generate or improve the characteristics of the geothermal reservoir. A second well would then be drilled at several hundred meters distance from the first well to try to intercept reservoir structures that will enable the circulation of fluids between the two wells. Lastly, continuous fluid circulation is to be tested during a period of one month between the two wells, together with monitoring production temperature and discharge. At least half of the cost of pilot projects should be borne by the different Administrations (regional, national and European) while the other half would be picked up by private entrepreneurial initiatives. This line of investigation would help private parties demonstrate the viability of the technology in different geological settings and would make the development of small 3-5 $MW_e$ geothermal energy plants possible within a 5-year timeframe.

# 3. RESOURCE OPTIMIZATION AT THE SURFACE.

Changes in geothermal energy growth trends over the last decades are closely linked to technological advances related to harnessing, transformation and combined use of geothermal energy. The following aspects are considered to have the greatest potential for the development of geothermal resources at surface:

## a. Thermodynamic power cycles.

Among these, the technological developments around binary organic cycles that have made harnessing geothermal energy resources below 180ºC possible could be highlighted. Although twenty years ago these were considered unviable, such technologies have progressively been optimized to the point where they are now able to generate electricity from fluids with temperatures lower than 100ºC. The development of R&D projects for the generation of electricity from low temperature resources as well as the investigation into new uses of geothermal energy such as desalination or cooling generation from geothermal heat could have a significant impact on our country, where cooling and drinking water needs are high and are, to date, satisfied at the expense of high levels of electricity consumption.

## b. Hybridization.

Another area showing great potential for the future is the hybridization of renewable technologies. Hybridization brings important advantages for those technologies that complement one another due to their characteristics, thermal needs, use of residual energy, cooling requirements, etc. that extend beyond the plain sharing of ancillary facilities. In this sense, several countries have already conducted a number of experiments, specifically in the hybridization of geothermal and concentrated solar technology.

## c. Energy efficiency.

Lastly, one of the priority targets set forth by the new national energy model relates to the reduction in energy consumption and improvements in energy efficiency, key initiatives to which geothermal energy has the challenge to contribute by delivering concrete solutions. In this sense, the combined generation of electricity and thermal energy and the optimization of cascade thermal energy production could be highlighted. Advances in the investigation of these applications will allow harnessing energy resources increasingly better over time, which will translate into important national energy savings.

According to the above, the following specific lines of investigation are proposed for the development of geothermal resources at the surface:

**3.1. Investigating efficiency improvements of thermodynamic** power cycles that use low temperature resources.

**3.2. Investigating improvements of cooling processes.** Cooling of geothermal plants located in geographic areas with high temperatures must be taken into account. One of the disadvantages in the development of geothermal projects in arid areas has to do with efficiency losses due to the energy-driven difficulties associated with the impossibility to cool the binary exchange fluid with water. Therefore, the development of more efficient air-based cooling systems would improve the overall energy efficiency of the geothermal plant.

Besides application in geothermal plants, it is important to highlight the importance of conducting investigations into advanced cooling system technologies aimed at satisfying the needs of a great number of processes that take place in various types of industrial facilities. In this sense, opportunities must be assessed relative to the use of the ground's heat-dissipating capacity to signifiantly reduce the amount of cooling water necessary, particularly when taking into

account that such a scenario would also help achieve a more sustainable use of water.

3.3. **Investigating the hybridization of geothermal fluids with other renewable technologies.** Geothermal energy that is extracted from the subsurface can function as a preheated fluid to feed technologies such as biomass or concentrated solar power, and can supply electricity during periods when no power generation from solar sources is available.

The hybridization of geothermal energy with other renewable technologies could translate into a reduction of capital investment and the achievement of 100% dispatchable hybrid renewable energy generation projects that would produce electricity continuously. The technological challenge resides in integrating the geothermal fluid as the base fluid for other technologies as well as the replacement and/or complementary utilization of these fluids in energy storage systems.

**3.4. Investigating desalination applications** powered by low temperature geothermal resources in island and coastal areas. Using multi-stage distillation from low-temperature geothermal fluids.

**3.5. Investigating cooling applications through absorption of heat from low temperature geothermal resources.** Current absorption systems are efficient starting at temperatures of 80º-90ºC, which raises the need to develop new lines of research that would achieve efficient cooling generation at lower temperatures.

**3.6. Investigating the production of cascade thermal energy.** Conducting studies to fully optimize harnessing low-temperature geothermal resources by means of cascade distribution schemes as a function of demand temperatures from different types of buildings.

## COURSE OF ACTION:
# BASIC INVESTIGATION

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 1.1 | **Development of a public database.** | Heterogeneity of formats (paper vs. digital).<br><br>Synthesis of the information of the Spanish subsurface. | Assessment of the knowledge base surrounding the geothermal resource. Drawing private investment. Assisting decision-making. Definition of strategies and priorities for the acquisition of new data. | Already in possession of a great portion of baseline information. Entities capable of undertaking the information updating process. | Very High | Public national and regional institutions with competence and oversight over subsurface investigations and information.<br>Research organizations and entities.<br>IGME (Spanish Geological Survey), CSIC (Spanish Scientific Research Council) and private companies coordinated by a GEOPLAT advisory committee.<br>Other technological platforms from the fields of CCS and software. | 1 M€ |
| 1.2 | **Structural geological analysis.** | Information dispersal.<br><br>Development of structural models focused on geothermal systems. | Increase knowledge base of geothermal resources. Definition of strategies and priorities for the acquisition of new data. | Spain has institutions and professionals capable of undertaking this course of action. | Very High | IGME, regional geological surveys. Structural geology departments from universities, research centers and consulting firms. | 0.5 M€<br><br>Structural modeling. |
| 1.3 | **Global geochemical exploration campaigns.** | Improvement of analytical techniques and equipment. Detection of regional geochemical anomalies associated with geothermal systems. | Increase knowledge base of geothermal resources. Definition of strategies and priorities for the acquisition of new data. | There are institutions both at the national and regional level that have the technical capacity to undertake courses of action in a coordinated way nationwide, including laboratories with the capacity to carry out all analytical sampling required. | High | Universities and research centers, laboratories, consulting and project development firms. | 1-2 M€<br><br>Several geochemical gas sampling campaigns, hydro-geochemical sampling, and acquisition of new measu-ring instru-mentation. |
| 1.4 | **Preparation and proposal of geological and thermo-structural models.** | Elaboration of geological syntheses and structural models. | Improve knowledge base and risk management during investigations. Definition of strategies and priorities for the acquisition of new data. | Workgroups such as University of Barcelona's Geomodels in Spain. Support and knowledge exchange available from TNO in The Netherlands. | High | Universities and research centers, laboratories, consulting and project development firms. | 0.5 M€ |
| 1.5 | **Geophysical exploration campaigns.** | Application of geophysical techniques to the discovery of geothermal anomalies. | Increase knowledge base of geothermal resources in the most favorable areas. Risk reduction during investigation phase and discovery of new resources. | Need for international advice to Spanish private firms and institutions. | High | Universities and research centers, geophysical services and other private companies. | 10 M€<br><br>Several campaigns including MT, gravity plus 2D & 3D seismic surveys at least in 10 target areas. |
| 1.6 | **Gradient well drilling, thermal conductivity and temperature measurements.** | Elaboration of regional thermal flow maps. | Discovery of new anomalies. Increase knowledge base of geothermal resources in the most favorable areas.<br>Risk reduction during investigation phase and discovery of new resources. | Several technology centers in Spain have carried out this task in the past. | High | CSIC, Universities, drilling companies, consulting firms and project developers. | 7 M€, to be split as follows: 2 M€ to undertake measurement campaigns in existing wells and 5 M€ for drilling 10 new 750 to 1000 m gradient wells. |

COURSE OF ACTION:
## SUBSURFACE INVESTIGATION AND RESOURCE MANAGEMENT

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 2.1 | **Technology and costs of drilling methods.** | Reduction of drilling costs. | Decrease in energy prices. | Need support from other on-going initiatives. | Medium | Drilling companies, casing manufacturing companies, materials resistance research centers. | |
| 2.2 | **Investigating the level of knowledge of enhancement processes and focal microseism generation mechanisms.** | Improving knowledge of focal mechanisms and stimulation processes. | Transition from pilot-scale EGS system development to industrial scale. | Need support from other on-going initiatives in Europe. | Medium | Universities, research centers, EGS geothermal project developers, consulting firms. | 2 M€ |
| 2.3 | **Development of three-dimensional numerical and geological models.** | Geothermal reservoir simulation models. | Medium to long-term reservoir behavior modeling. Resource sustainability. | Need support from other on-going initiatives in Europe. | Medium | Universities, research centers, geothermal project developers. | |
| 2.4 | **Fluid re-injection studies.** | Managing re-injection of considerable levels of discharge into specific geological structures. | Viability of geothermal projects developed in zones showing adverse structures. | Need support from other on-going initiatives in Europe. | Medium | Universities, research centers, geothermal project developers. | 1 M€ |
| 2.5 | **EGS demonstration projects.** | Dissemination throughout Spain of EGS pilot experiences from Europe. | Development of EGS technology. Cost reduction. | Need support from other on-going initiatives in Europe. | High | Administrations, Universities, research centers, geothermal EGS project developers, power producers, engineering consultants. | 175 M€ in 5 demonstration projects valued at 35 M€ each. This item covers all costs indicated in section 2. |

COURSE OF ACTION:
# AT THE SURFACE

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 3.1 | **Investigating efficiency improvements of thermody-namic power cycles.** | Reduction of the temperature required for electricity generation. | Greater development of geothermal projects associated with medium-to-low temperature resources. | Need support from other on-going initia-tives in Europe. | Medium | Universities, Research centers, turbine manufacturers, geothermal project developers. | |
| 3.2 | **Investigating improvements in cooling methods.** | Improvement of cooling systems, particularly in hot areas with little water to use as cooling fluid. | Improving efficiency of thermodynamic cycles to achieve a reduction of costs in electricity generation. | Need support from other on-going initia-tives in Europe. | Medium | Universities, Research centers, geothermal project developers. | |
| 3.3 | **Investigating the hybridiza-tion of geo-thermal fluids with other renewable technologies.** | Use of geothermal fluid as pre-heated base fluid for other thermo-electric renewable technologies. | Hybridization of geother-mal and concentrated solar technologies. Reduction of investment costs and energy prices. Improving dispatchability to grid and guaranteeing continuous power gene-ration. | Need support from other on-going in-ternational initiatives (Australia). | Medium | Universities, research centers, geothermal and concentrated solar power project developers. | |
| 3.4 | **Investigating desalination applications powered by geothermal resources.** | Use of multi-stage distillation from low-temperature geothermal fluids. | Cost reduction of reverse osmosis desalination processes. | Need support from other on-going in-ternational initiatives (Greece). | Medium | Universities, research centers, geothermal project developers, desalination companies. | |
| 3.5 | **Investigation into cooling generation via heat absorp-tion from low temperature geothermal resources.** | Obtaining cooling efficiently from geothermal fluids at decreasingly lower temperatures. | Application of geothermal energy for cooling, particularly in warm latitudes. | Need support from other on-going international initiatives. | High | Research centers, geothermal project developers. | 0.5 M€ |
| 3.6 | **Investigating cascade ther-mal energy production.** | More efficient harnessing of low temperature geothermal resources. | Increasing energy efficiency and reduction of energy generation costs. | Need support from other on-going international initiatives. | Medium | Research centers, Administration and geothermal project developers. | |

# DEEP GEOTHERMAL SYSTEMS

| COURSE OF ACTION | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| **Basic Investigation** | | | | | |
| Development of a public database | x | x | x | | |
| Structural geological analysis | | x | x | | |
| Global geochemical exploration campaigns | | x | x | x | |
| Preparation and proposal of geological and thermo-structural models | | x | x | | |
| Geophysical exploration campaigns | | x | x | x | |
| Gradient well drilling, thermal conductivity and temperature measurements | | | x | x | x |
| **Subsurface** | | | | | |
| Technology and costs of drilling methods | | | x | x | x |
| Investigating the level of knowledge of enhancement processes and focal microseism generation mechanisms | | | x | x | x |
| Development of three-dimensional numerical and geological models | | | x | x | x |
| "Development and improvement of instrumentation used in passive microseismic exploration methods" | x | x | x | x | |
| Fluid re-injection studies | | | x | x | |
| EGS demonstration projects | x | x | x | x | x |
| **At the Surface** | | | | | |
| Investigating efficiency improvements of thermodynamic power cycles | x | x | x | | |
| Investigating improvements in cooling methods | | | | x | x |
| Investigating the hybridization of geothermal fluids with other renewable technologies | | x | x | x | x |
| Investigating desalination applications powered by geothermal resources | | x | x | | |
| Investigation into cooling generation via heat absorption from low temperature geothermal resources. | x | x | x | | |
| Investigating cascade thermal energy production | x | x | | | |

# 2 SHALLOW GEOTHERMAL SYSTEMS

The preparation of the Strategic Research Agenda for shallow geothermal energy in Spain is based on the document 'Vision for 2030' that was published in April 2010. This document describes a set of technological challenges in the field of shallow geothermal energy that include:

- Cost reduction of geothermal circuit.
- Improving ground evaluation methods and increasing well, well field and ground heat exchange system productivity.
- Increasing the efficiency of energy generation equipment.
- Developing competitive, low temperature emission systems.
- Developing building retrofitting systems that enable transition from high temperature single boiler-radiator combinations to shallow geothermal energy based systems.
- Standardizing the use of geothermal systems in buildings, especially hybrid geothermal heating - solar regeneration ones, as well as those combining heating and cooling.

These challenges make up the basis for the Strategic Research Agenda and are described in detail next.

# 1. COST REDUCTION OF GEOTHERMAL CIRCUITS.

Setup costs of geothermal heat exchange circuits are highly influenced by the type of construction techniques used. Reduction of such costs represents a key element for the advancement of the technology, as initial investment costs constitute the main barrier that hinders its development. Important differences exist as a function of the type of selected geothermal circuit and ground characteristics. The basic elements that comprise closed loops are the exchanger, piping and distribution collectors. The main portion of costs corresponds to the exchanger whose basic elements include drilling (or excavation), exchange piping and filling/packing materials.

Drilling and excavation alone comprise between 30% and over 60% of geothermal system implementation costs. Systems that have lower costs include:

- Horizontal loops.
- Open systems.

Both types require the existence of very special geologic conditions.

Circuits that are installed in structural elements built for other purposes represent an intermediate situation. The clearest case is that of thermo-active foundations, which will be discussed in detail in section 1.1.5.

Systems that carry higher costs correspond to vertical closed loops. These represent the most versatile systems and therefore must be treated preferentially.

## 1.1. Potential for technological development: Drilling.

Drilling technologies have reached a very high degree of maturity. However, there is still large room for improvements in performance and cost structure. Also, it is worth noting that the evolution of drilling techniques in unconsolidated and competent rock formations differs substantially.

### 1.1.1. Drilling in unconsolidated formations.

This type of drilling has evolved in our country from traditional methods, from direct or reverse mud circulation drilling to dual-bit drilling systems. These systems allow reducing preparation and mud handling costs, as well as increasing considerably equipment productivity particularly in subsurface environments where consolidated formations underlie unconsolidated ones that may be tens of meters thick. All these equipment along with their associated ancillary components are not manufactured domestically, which means that purchasing thereof requires a significant investment that many companies are unable to handle, particularly in the present situation. On the other hand, these techniques pose a number of limitations due to the high number of dual drill-sets required, especially during deep drilling campaigns or drilling in anhydrous rock environments that are relatively more frequent in our own geological setting.

The application of other drilling methods such as sonic drilling has not been sufficiently tested yet in our environment, despite the fact that they may have important applications.

### 1.1.2. Drilling in competent formations.

Drilling in competent rocks is undertaken mainly through pneumatic roto-percussion systems coupled with a down-the-hole (DTH) hammer drill. Advances in drilling speed brought about by this technology, which can frequently reach over 20 meters per hour, do not constitute a limiting factor and leave little room for optimization. The promising application of hydraulic DTH hammer drills contrasts with the high volumes of water required for its operation, which represents an important limitation given our geomorphological and hydrological setting.

The main opportunities for cost reduction can thus considered to be found through:

- Task automation.
- Improving personnel working conditions and thus, increasing productivity.
- Increasing drilling equipment reliability and cutting down repair and down times.
- Improving the quality and costs of ancillary equipment and drilling tools.
- Reducing energy use during drilling as well as consumption by ancillary equipment, particularly compressors.

### 1.1.3. Other drilling techniques.

Drilling techniques that have been scarcely used in our country due to high costs such as horizontal directional drilling can experience important developments particularly in system retrofitting-type projects. Similarly, the opportunity to drill a large number of wells in already consolidated urban areas that have limited space and vehicle height clearance limitations will become a key challenge for the development of highly productive compact equipment that have the capacity to complete the work at competitive costs and with minimum setbacks.

On the other hand, these aspects raise the possibility of undertaking other essential research initiatives in the field of innovative drilling systems based on other techniques, as well as the development of improved drilling tools that can be more readily mounted and can complete drilling in less time.

### 1.1.4. Drilling cuttings, mud and discharge management.

Drilling frequently requires the use of mud and environmentally unfriendly products. Moreover, drilling activities can generate large volumes of cuttings and other related debris and waste that have high water content. Lastly, and specially in the case of air rotary drilling, considerable volumes of water with a higher content of suspended solids and turbidity values than what is established by discharge limits are generated. The solutions that have been adopted and which contemplate the use of debris/mud waste pits, decanting basins and discharge to collector drains are frequently insufficient in projects with multiple drilling locations.

It is thus considered that a potential for improvement exists in relation to:

- Compact debris pump and treatment systems.
- Drilling water treatment systems adapted to the average settings and costs associated with geothermal circuits.
- Mud recirculation systems that allow closed loop operation.

### 1.1.5. Thermo-active foundations.

Thermo-active foundations represent a type of technology that is applied to elements within reinforced concrete structures, concrete slabs, pilings and diaphragm walls. Geothermal exchange therein takes place through a closed loop installed in the foundation reinforcement.

Due to the structural function of this type of installations materials such as concrete (which has very good thermal properties) in slabs, piling and diaphragm walls are predominantly used in order to meet the required structural characteristics.

It is thus considered that potential for improvement exists through:

- Investigation into the dimensioning and construction of thermo-active foundation structures.
- Investigation into new types of piping. It is considered that piping must withstand temperatures of over 40º C and specific stress during grouting of subsurface structures and consequently, it is an area where manufacturers

also need to become involved to contribute to the research and development of new materials and technologies.

- Investigation into probe installation systems within structures and placement devices during construction work.
- Investigation into foundation control and ground behavior after start-up of the geothermal installation.
- Investigation into aggregates and cement types used in concrete that can warrant thermal conductivities above those of the resource-bearing formation being harnessed.

Moreover and in relation to the design of these systems, it is worth mentioning that the market presently supplies specialized software to carry out the design of thermo-active structural systems, mainly concrete slabs and pilings, but not diaphragm walls.

Finite element software that could carry out these types of calculations do exist in the market but are always associated with specific designs that focus on research. Finite element software that can simulate heat transfer is generally not user friendly, and requires high computing power to carry out "short-term" simulations. It must be noted that simulations of this type of systems generally look ahead 25 years, which is the reason why finite element software is rendered invalid.

It is thus considered that potential for improvement exists through:

- Investigations into new specific heat transfer models.
- Development of ground behavior models.

## 1.2. Potential for technological development: Heat exchanger piping.

A wide variety of heat exchanger designs – frequently named probes – have been tested to date, to the point where there are today a large number of patents in Europe alone. Nevertheless, single and double-circuit high-density polyethylene exchangers predominate given their simplicity, robustness, durability, cost and ease of installation. Furthermore, this polymer has a thermal conductivity of 0.4 W/mK, which is relatively high in comparison to other plastics. One of the main limitations of high-density polyethylene (PE80 and PE100) has to do with the temperature range in which it is to be used and which is usually confined to a maximum of 40º C, for use thereof in temperatures over this threshold considerably reduces its useful life. The majority of existing applications are designed taking into account lower temperatures due to performance losses experimented in conditions of higher condensation temperatures. Nevertheless, climatic conditions in the Mediterranean region and temperature demand profiles of buildings in Spain coupled with industrial and heat accumulation applications will require systems that can operate under higher temperature conditions as well as materials that are better adapted to such conditions. Furthermore, hybridization projects with other renewable energy sources will also require materials that can withstand higher operating temperatures. This need is currently satisfied through the use of reticulated polyethylene (PEX) and polybutylene (PB), which can withstand operating temperatures of up to 95º C. Thus, developing probes for operating temperatures over 70º C and with costs similar to PEAD's as well as medium depth probes (250-700 m) for direct heating applications that do not require the use of heat pumps constitute an area of great interest given the operating conditions in our country.

Similarly, other lines of investigation that pursue the development of new polymers for the manufacture of ducts that show better thermal properties together with the development of new or modified probes (new coaxial models, helicoidally-shaped, etc.) are strongly considered.

## 1.3. Potential for technological development: packing materials.

The purpose of packing materials placed in the well annulus between the casing and the well bore is to facilitate heat transfer between the circuit and the formation, stabilizing the latter by preventing crushing of the casing resulting from drops or collapse of borehole walls and ensuring sealing of the annular space to prevent any environmental affection to the quality or quantity of the groundwater resource. Improving the thermal characteristics of annular packing materials implies a reduction of well thermal resistivity and therefore translates into a reduction of implementation costs coupled with an increase in overall system performance. The main systems currently in use in the following geographical locations are:

- Scandinavian countries. The well annulus is not filled with packing materials; instead it is filled with groundwater up to its piezometric level and with air from that point to the surface. The annular space is then sanitary sealed with cement between the formation and surface casing and includes the installation of a packer. The production zone of the well thus remains limited to the saturated zone, which means this system is applicable only in areas with shallow piezometric levels.
- Central Europe. The well annulus is cemented completely via grouting (which usually consists of standard or technically-improved bentonite) using a tremie pipe that is raised progressively as the grout fills the annular space immediately below. Although packing materials theoretically satisfy all of the requirements, in practice numerous problems arise. Low thermal conductivity of such materials coupled with high costs thereof, dehydration at high operating temperature conditions, cracking during freeze-thaw cycles and the rheological characteristics of the packing material itself hamper secure installation of the system in formations that have higher permeability ranges, thus preventing the former from complying with its environmental purpose. These are usual problems that must be tackled carefully during the installation of any system. Additionally, the use of products that do not guarantee non-leaching can generate environmental problems that may be greater than those that the very system attempts to prevent.
- Both of the aforementioned systems coexist in our country together with a third one in which packing materials are made to adapt to the hydrogeological conditions of the target zone. In hydrogeologically favorable conditions (low Darcy velocity, minimal vertical piezometric differences, homogeneous hydrochemical conditions, etc.) and particularly in geothermal circuits where water acts as the heat-transfer fluid, a granular annular packing consisting of inert, siliceous aggregate, completely innocuous and with high thermal conductivity can be used coupled with an annular sealing applied through grout injection in those sections that so require it. This system needs an adequate level of hydrogeological supervision to warrant protection of the groundwater masses from a qualitative and quantitative standpoint. On the other hand, it must be noted that in certain hydrogeological settings in our country the possible affection to groundwater created by the geothermal circuit cannot be solved even if sealing is effectively applied after wellbore completion. These situations may even require casing and sealing before tapping the aquifer itself or rejecting the project altogether because it may simply be rendered environmentally unfeasible.

It is thus considered that potential areas for improvement exist through:

- Investigation into new products. It is considered that packing materials must adapt to the geological conditions of the project. Therefore, packing materials that are adequate for anhydrous, expansive, karst, alluvial and other types of geological environments must be properly designed. This is a well-known fact that drilling mud manufacturers and users are familiar with, but difficulties remain in terms of providing the product with minimal thermal conductivity.
- The use of aggregates and local products can reduce the cost of packing materials considerably while warranting thermal conductivities above those of the surrounding formation.
- Review into well packing material installation processes, which make up a considerable portion of total operational time and therefore of execution costs and which present altogether clear opportunities for improvement.

Furthermore, investigations should also focus on the development of new, inert packing materials that have optimal thermal exchange properties and minimal leaching effects. The use of packing materials based on sub-products from other companies or sectors (ornamental rock-cutting waste sludge, ceramic sludge, etc.) must be considered as alternatives to conventional packing materials. Lastly, efforts must be made to develop innovative injection systems capable of infiltrating packing materials into the ground so as to increase thermal conductivity.

## 1.4. Potential for technological development: Heat-transfer fluids.

The purpose of heat-transfer fluids in geothermal systems is to transfer thermal energy between the ground and the heat pump. With the exception of direct expansion systems such as *Sofath®*, Heat Pipes, etc., that directly evaporate the refrigerant in the geothermal circuit, aqueous mixtures of different antifreeze products that allow operating at evaporator exit temperatures lower than 5ºC are primarily used. Consequently, this increases both the gradient between the circuit and the ground and the energy captured for any given surface. Although a larger number of products had been utilized in the past, use thereof has been discontinued due to their high corrosiveness (as in the case of sodium/calcium chloride brines) or toxicity (as in methyl alcohols). The main products used include:

- Glycols. Usually ethylene glycol or propylene glycol with concentrations between 20% and 40%. They represent the most widely used antifreeze products used in Central Europe. Ethylene glycol, which is used generally as engine antifreeze, has lower viscosity and better thermal properties, but shows on the other hand a higher toxicity. Propylene glycol, which can even be acquired with a food quality certificate, is not toxic, but its high viscosity and poor thermal properties do not make it the most suitable product, particularly at high concentrations.
- Alcohols. They are widely used in Scandinavian countries and consist of water-methanol (or ethanol) mixtures in proportions lower than the flammability limit. Thermally and hydraulically, they are far superior to glycols, but their volatility and flammability pose serious inconveniences. Methanol is also toxic, and use thereof may be restricted due to environmental reasons. Ethanol – which is much less toxic – is commercialized in Spain after undergoing a denaturalization process that increases its toxicity. The use of this product may introduce compounds into the environment that can adversely interact with polyethylene.

All water-antifreeze mixtures being used show clear disadvantages when compared to water. They increase the scope of action of geothermal systems but adversely affect thermal performance, increase ancillary equipment electricity consumption and introduce undesirable compounds from an environmental standpoint. It is thus considered that potential areas for improvement exist in the development of:

- New antifreeze products that integrate thermal and mechanical properties of alcohols, reducing inflammability and toxicity.
- New heat-transfer fluids with high latent heat based on phase change materials aimed at improving thermal exchange.
- More efficient geothermal circuit design that allows expanding the use of water as heat-transfer fluid.


geothermal

# 2. IMPROVEMENT OF GROUND EVALUATION METHODS: INCREASING WELL PRODUCTIVITY

Scientific evaluation and dimensioning techniques of geothermal exchange circuits must become generalized when designing installations over 30 kW and mandatory for installations over 70 kW. Selection of the most appropriate geothermal circuit type must be carried out applying global knowledge of the mechanical, hydrogeological and thermo-geological characteristics of the ground. Similarly, an understanding of ground behavior will allow optimizing geothermal capture system design in order to significantly improve productivity thereof.

## 2.1. Potential for technological development.

Classical methods for conducting geological and hydrogeological assessments are not very extended within the sector in Spain, where all too often Thermal Response Tests (TRT) is the only tool used. This test provides valuable data for dimensioning geothermal systems but is far from being capable of assessing full scenarios as a whole. Therefore, it is considered that the following areas show an interesting potential for development:

- Creation of online cartographical databases and data sets of relevant information, which should include both geological information as well as other information of interest such as affected utilities, information on geothermal investigation projects already developed and operational geothermal projects. The initiative should not entail the creation of an unrestricted database that is open to public access, but rather one that is only available to companies and entities that commit to facilitate and provide all information they have on the subject.

- Registration and monitoring of geothermal facilities. This initiative would warrant sustainable management of resources through reservoir evolution modeling, the establishment of a set of criteria to warrant long-term resource sustainability and the proposal of alternatives in those cases where these are deemed necessary.

- Geological control of drilling campaigns is a basic tool that must be extended among geothermal exchange circuit designers and construction professionals. There is great potential for improvement surrounding lithological, discontinuity, piezometric and discharge control during drilling activities. The most sophisticated techniques have been developed for deep drilling scenarios and have associated costs that shallow geothermal projects simply cannot bear.

- One ever-present concern new professionals find upon entering the field of shallow geothermal projects relates to their attempt to finding reliable and relatively cheap information about the thermal characteristics of the subsurface. These are not the only characteristics to consider however, as tabular data or even data displayed on surface maps can only provide very basic preliminary information. On the other hand, the application of TRT to small projects is far too costly, which makes finding a less costly but at the same time sufficiently reliable alternative to TRT that would warrant a valid solution all the more necessary. The following is thus proposed:
  - » Development of profiling equipment aimed at reducing costs and incorporating thermal conductivity and diffusivity as measurable parameters, in addition to the ones already available.
  - » Improving and developing equipment to conduct in situ determinations of hydrogeological parameters at higher resolution.
  - » Development of thermal exchange evaluation methods and models that allow discriminating the influence of groundwater from test results.

» Development of autonomous and flexible TRT equipment.

- Improving methods and systems to evaluate possible affections to artificially recharged systems.
- Developing adequate software applications to simulate different types of shallow resource harnessing models with regard to aspects relative to resource pre-exploitation (natural) conditions and the modification thereof that may take place during such stages, in order to be able to predict long-term evolution during this phase as well as in subsequent periods, so as to warrant harnessing the resource in a sustainable way.
- Developing containment systems that reduce heat losses in thermal storage systems.
- Developing geothermal well drilling and well construction equipment systems and tools that can readily adapt to the hydrogeological characteristics of the setting.
- Investigation into standing column systems in semi-open circuits.
- Developing recharge systems in open circuits that minimize modifications in the hydrochemistry of the resource.
- Correlating ground geophysical and thermal properties using simple and versatile geophysical methods, thus avoiding the need for previous drilling.

# 3. SURFACE SYSTEMS. PROPOSAL OF ASSOCIATED KEY STRATEGIC AREAS.

The aforementioned sections described the strategic areas and courses of action relative to subsurface systems in shallow geothermal installations. These items are characteristic of our sector and as such must be dealt with almost exclusively within. However, the development of low temperature geothermal systems is associated with another series of challenges that rather make reference to surface systems that are part of the installation and which share many aspects with other sectors. In order for the shallow geothermal sector to grow and develop effectively, it is essential to combine efforts from all sectors involved so as to face these series of challenges more effectively. To this effect, a general description of those areas that must guide these courses of action is provided next. Closure of these actions will be subject to the type and level of collaboration proposed here.

- Increasing the efficiency of energy generation equipment.

Investigation into geothermal heat pump technologies to help improve operational characteristics thereof so as to achieve actual performance levels that are as close as possible to the theoretical ones established by the Carnot factor. This constitutes one of the key lines of research to achieve drastic improvements surrounding the global efficiency of shallow geothermal installations.

One of the key points to reduce operational failure of these equipment while increasing quality and reliability thereof, as well as obtaining energy savings, rests on the need to focus in the development of a certain number of standard concept installations that would allow investigating, implementing improvements and acquiring an optimal level of understanding of the technology.

- Developing competitive low temperature emission systems.

Discharge temperatures required by conventional emission systems to ensure adequate operation bring about an important limiting factor that directly affects the development of a geothermal installation for heating and cooling purposes. Geothermal installations use low temperature technologies for heat distribution, while most of the buildings that have been constructed over the past few years use high temperature (80ºC to 60ºC) radiators. These temperatures fall outside of the operating range of a geothermal heat pump as these can only reach discharge temperatures of 60ºC to 65ºC but at performance levels that may be too low to make them worthwhile. Geothermal energy is ideal to operate with low temperature emission systems such as heated floors, heated baseboards, fan coils, etc.; (i.e. systems that provide heated water at a maximum temperature of 45ºC to 50ºC). The economical advantages of shallow geothermal energy are thus greater within this temperature range. Therefore, future R&D efforts must focus on increasingly investigating more efficient low temperature emission equipment, as well as improving design methods of full installations that may bring about solutions based on this type of emission equipment for these to be capable of optimally satisfying the building energy demand from an economical and energy standpoint.

• Developing building retrofitting systems.

The ideal market niche for shallow geothermal energy is that of new building construction, partly due to the work that must be carried out outside or beneath the building (i.e. catchment area, drilling or horizontal heat exchangers) but mostly because buildings that have been constructed present a series of barriers in their distribution and emission systems similar to those described earlier, together with certain efficiency issues associated with their energy behavior.

In relation to the first of these considerations the following strategic course of action can be highlighted which does not relate to the surface system part of the installation:

- Investigating into the adaptation of drilling systems, ancillary equipment and drilling cutting and sludge discharge to building/residential areas already constructed.
- Development of smaller, more compact, higher-mobility/maneuverability drilling equipment.

With regard to the second item, it is worth highlighting that the viability of many geothermal projects for building heating and cooling is strongly tied to the energy rating of the buildings themselves. Older existing buildings in particular do not possess the required attributes of sustainable and efficient energy consumption to be able to fully benefit from the potential offered by shallow geothermal systems. Because of this, the importance of carrying out investigations into how to evolve from heat generation and distribution arrangements based on high temperature single boiler-radiator combinations to shallow geothermal energy based systems must be highlighted:

- Improving energy efficiency of building envelopes. Investigations into the development of evaluation and retrofitting systems or modernization of insulation systems in buildings that help reduce the energy demand.
- Developing 'Energy Management Systems' (EMS) and "control and regulation technologies' as complementary development tools to facilitate promotion of geothermal energy and increase the viability of geothermal installations. In this sense, it is important to focus the efforts on the development of monitoring and measuring technology in order to obtain usable and applicable technical and energy parameters. Likewise, Information and Communications Technology (ICT) tools must be applied to develop intelligent measurement, control and management models of geothermal systems along with associated system management software.

• Standardization of geothermal systems in buildings

R&D initiatives mentioned in this section must focus on the development of standards relative to hybrid heating and domestic hot water (DHW) installations (geothermal energy in combination with other renewable energy sources such as solar, biomass, etc.) and combined systems for heating and cooling applications that have considerable potential given Spain's climatic region.

There are numerous solutions in this field relative to combined heating & cooling technologies based on geothermal systems that are progressively being developed. The most advanced concepts include solar and geothermal energy combinations that are applied to different DHW and heating & cooling schemes with solar collectors and geothermal heat pumps or solar cooling technologies based on absorption devices coupled with geothermal-based condensation systems. This variety of options however shows that system standardization must be attained at some point together with optimization of their efficiency and performance characteristics.

Two of the key factors that must be considered to achieve effective management of hybrid systems include:

- Control over all installation components in a coordinated way so that these can optimally contribute to overall performance at all times.
    - » Reading of key operating parameters (temperature, discharge, pressure).
    - » Management and oversight of main component operating regimes (generators, accumulators).
    - » Control over secondary component operation (variable flow pumps, proportional mixing valves).
- Operating regime design and selection adapted to the region's climatic conditions.

It is thus considered that there is considerable potential for development in the following areas:

- Investigation into the design and optimal development of geothermal systems which are capable of satisfying cooling and heating demand during summer and winter respectively in the most efficient possible way, either through the use of reversible heat pumps or the combination of several energy sources.
- Investigation and development of methodological standards aimed at achieving optimal heating & cooling systems design based on the use of the ground as a seasonal energy storage system.
- Investigations into efficiency optimization of geothermal energy systems that are integrated with other renewable energy sources (not just solar) according to the operating regime required and the region's climatic limiting factors.
- Investigation into the development of equipment and protocols for hybrid system management.

COURSE OF ACTION:

## COST REDUCTION OF GEOTHERMAL CIRCUITS

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION |
|---|---|---|---|---|---|---|
| 1.1 | **Drilling.** | Absence of domestic equipment manufacturers. | | | | |
| 1.1.1 | **Drilling in unconsolidated formations.** | High drilling and mud drilling equipment costs. | Reduction of drilling mud preparation and management and productivity increase. | Existence of qualified domestic companies. | High | Private companies and technology centers. |
| 1.1.2 | **Drilling in competent formations.** | Lack of task automation. High energy consumption. | Reduction of costs and energy consumption and productivity increase. | Existence of qualified domestic companies. | High | Private companies and technology centers. |
| 1.1.3 | **Other drilling techniques.** | Oversized equipment. | Application in rehabilitation projects and in consolidated urban areas. Reduction of costs, drilling time and affections generated by the process.<br>Increased productivity. | Existence of qualified domestic companies. | High | Private companies and technology centers. |
| 1.1.4 | **Drilling cuttings, mud and discharge management.** | Generation of large volumes of drilling waste. Insufficient solutions for sustainable management thereof. | Cost reduction. Reduced environmental impact derived from this process. | Existence of qualified domestic companies. | High | Ancillary equipment manufacturers. |
| 1.1.5 | **Thermo-active foundations.** | Must improve knowledge base to optimize foundation design and dimensioning.<br>Piping still to be adapted to this scheme.<br>Absence of specific software for system design. | Reduction of additional costs of installation.<br>Bringing added value to building foundations. | Existence of qualified domestic companies. | Medium | Engineering and foundation design companies, pipe manufacturers, software developers and numerical model engineering experts. |
| 1.2 | **Heat exchanger piping.** | Temperature restrictions of the materials currently used. | Improvements in heat transfer processes.<br>Adaptation to higher-temperature applications. | Existence of materials that are closer in characteristics to those required (PEX and PB) plus on-going investigations into other materials. | Medium | Pipe manufacturers. |
| 1.3 | **Packing materials.** | Inadequate thermal properties for optimal heat transfer. | Improvements in exchanger efficiency. Reduction of costs and execution times. | Companies and workgroups currently working in this field. | Medium | Companies and technology centers. |
| 1.4 | **Heat-transfer fluids.** | Toxicity of certain fluids. Thermal and mechanical properties could be improved. | Cost reduction and improvements in heat exchange process efficiency.<br>Reduction of risks associated with fluid toxicity. | | Medium | Companies and research centers. |

COURSE OF ACTION:

## IMPROVEMENT OF GROUND EVALUATION METHODS. INCREASING WELL PRODUCTIVITY.

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION |
|---|---|---|---|---|---|---|
| 2.1 | **Creation of online cartographical databases and data sets of relevant information.** | Lack of sufficient information to undertake shallow geothermal projects. | Reduction of investment risk. Improvement of knowledge base. Boost to geothermal sector. | Numerous installations in operation as well as data of geothermal interest coming from previous investigations and characterization assessments already conducted. | High | Administration, public entities together with collaboration from companies that have data on existing installations and research projects. |
| 2.2 | **Registration and monitoring of geothermal facilities.** | Lack of awareness on the number and type of existing shallow geothermal installations in Spain. | Improvement and transfer of knowledge base for the development of future projects. | Fully monitored installations and project sites. | High | Administration, public entities together with collaboration from companies that have data on existing installations and research projects. |
| 2.3 | **Geological control of drilling campaigns.** | Lack of knowledge of applicability of geological information. | Improvements in overall quality of drilling campaigns. | Existence of private companies and apt professionals. | High | Designers and equipment installation companies. |
| 2.4 | **Development of cheaper alternatives to TRT.** | Information lacking from surface cartography.<br>High costs associated with the use of TRT. | Reduction of costs.<br>Improvement of knowledge base of local geological characteristics.<br>Increased reliability of equipment and methods. | Numerous equipment development projects exist at the local level that need to be extended in practice at the technical level. | High | Private companies, technology centers and universities. |
| 2.5 | **Improving methods and systems to evaluate possible affections to artificially recharged systems.** | High costs of hydrogeological system characterization and simulation. | Reduction of environmental impact. | A well established hydrogeology knowledge base exists that must be integrated. | Medium | Private companies, technology centers and universities. |
| 2.6 | **Developing adequate software applications to simulate different types of shallow resource harnessing models.** | Limitations in the level of applicability of common software packages. | Guaranteed resource sustainability over time. | Capacity exists to create new applications or interfaces from existing software platforms. | Medium | Software development firms. |
| 2.7 | **Developing containment systems that reduce heat losses in thermal storage systems.** | Applications at incipient stages of development. | Improvement in storage efficiency. | A well established hydrogeology knowledge base exists that must be integrated. | Medium | Research and technology centers. Private firms and universities. |
| 2.8 | **Developing geothermal drilling and well construction equipment systems.** | - | Better adaptation to the hydrogeological characteristics of the setting. | A well established hydrogeology knowledge base exists that must be integrated. | Medium | Research and technology centers. Private firms and universities. |
| 2.9 | **Investigation into standing column systems in semi-open circuits.** | Applications at incipient stages of development. | Reduction of environmental impact. | A well established hydrogeology knowledge base exists that must be integrated. | Medium | Research and technology centers. Private firms and universities. |

COURSE OF ACTION:

## IMPROVEMENT OF GROUND EVALUATION METHODS. INCREASING WELL PRODUCTIVITY.

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION |
|---|---|---|---|---|---|---|
| 2.10 | **Developing recharge systems in open circuits that minimize modifications in the hydrochemistry of the resource.** | Evaluation of hydrochemical characteristics of the resource and its vulnerability to thermal changes. | Improvement of knowledge base, encouraging investments through risk reduction. | Technical adaptation and tools already in use in other disciplines. | Medium | Universities, private firms and different Administrations. |
| 2.11 | **Developing systems capable of correlating ground geophysical and thermal properties.** | High costs of existing techniques and no readily available solutions at hand. | Improvement of knowledge base, encouraging investments through risk reduction. | - | Medium | Research and technology centers. Private firms and universities. |

COURSE OF ACTION:

## SURFACE SYSTEMS. PROPOSAL OF ASSOCIATED KEY STRATEGIC AREAS.

| | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION |
|---|---|---|---|---|---|
| **3.1 Increasing the efficiency of energy generation equipment.** | Mature technology equipment requiring highly innovative improvements. Existence of defective installations due to poor knowledge. | Improvement of knowledge base. Increased reliability of equipment and installations. | Interaction with other sectors. | High | Research centers and heat pump manufacturers. |
| **3.2 Developing competitive low temperature emission systems.** | Inadequate emission systems or systems not optimally adapted to shallow geothermal applications. | Improving viability of geothermal installations and increasing efficiency thereof. | Interaction with other sectors so as to better combine collective efforts across the board. | High | Manufacturers. |
| **3.3 Developing building retrofitting systems.** | Problems of equipment access to residential building areas. Inefficient installations and systems in older buildings (distribution, envelopes, etc.). | Improved efficiency. Reduction in energy consumption. Great area of opportunity for geothermal energy. | Interaction with other sectors. | Medium | Drilling and ancillary equipment manufacturers. Drilling waste handling & treatment equipment manufacturers. Engineering and auditing firms. Software developers and ICT solution providers in the field of energy management. |
| **3.4 Standardization of geothermal systems in buildings.** | Great variety of existing solutions that require homogenization. | Improving knowledge base and system design. Increased efficiency. Procedure optimization and reduction of engineering times and costs. | Not starting from scratch with respect to hybrid systems and combined heating & cooling applications. Experiences acquired in this field in Spain and other countries can contribute to the effort. | Medium | Engineering firms, equipment and control system manufacturers. |

# SHALLOW GEOTHERMAL SYSTEMS

| COURSE OF ACTION | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| **Cost reduction of geothermal circuits** | | | | | |
| Drilling | x | x | x | x | x |
| *Drilling in unconsolidated formations* | x | x | x | x | x |
| *Drilling in competent formations* | x | x | x | x | x |
| *Other drilling techniques* | x | x | x | x | x |
| *Drilling cuttings, mud and discharge management* | x | x | x | x | x |
| *Thermo-active foundations* | x | x | x | x | x |
| Heat exchanger piping | x | x | x | x | x |
| Packing materials | x | x | x | x | x |
| Heat-transfer fluids | x | x | x | x | x |
| **Improvement of ground evaluation methods. Increasing well productivity** | | | | | |
| Creation of online cartographical databases and data sets of relevant information | x | x | x | x | x |
| Registration and monitoring of geothermal facilities | x | x | x | x | x |
| Geological control of drilling campaigns | x | x | x | x | x |
| Development of cheaper alternatives to TRT | x | x | x | x | x |
| Improving methods and systems to evaluate possible affections to artificially recharged systems. | x | x | x | x | x |
| Developing adequate software applications to simulate different types of shallow resource harnessing models | x | x | x | x | x |
| Developing containment systems that reduce heat losses in thermal storage systems | x | x | x | x | x |
| Developing geothermal drilling and well construction equipment systems | x | x | x | x | x |
| Investigation into standing column systems in semi-open circuits | x | x | x | x | x |
| Developing recharge systems in open circuits that minimize modifications in the hydrochemistry of the resource | x | x | x | x | x |
| Developing systems capable of correlating ground geophysical and thermal properties | x | x | x | x | x |
| **Surface systems. Proposal of associated key strategic areas.** | | | | | |
| Increasing the efficiency of energy generation equipment | x | x | x | x | x |
| Developing competitive low temperature emission systems | x | x | x | x | x |
| Developing building retrofitting systems | x | x | x | x | x |
| Standardization of geothermal systems in buildings | x | x | x | x | x |

# 3 KEY SUPPORT AREAS FOR DEVELOPMENT

## TRAINING AND EDUCATION

Among its many considerations, GEOPLAT's document '*Vision for 2030*' includes a series of general objectives relative to geothermal training and education that make reference to '*the development of guidelines aimed at promoting and raising awareness of the possibilities offered by this energy source, by collaborating with training centers to introduce and spread knowledge on the nature of geothermal resources and potential use thereof*'. In this sense, the document focuses on three priority lines of work, which the Strategic Research Agenda attempts to specify and move to a pre-operational stage. Specifically, these comprise the:

- Development and recognition at the European level of not only accreditation and certification schemes for small-scale renewable energy installation professionals but for all active personnel that make part of a geothermal facility which includes installation technicians, drillers, designers, maintenance personnel, trainers and auditors.
- Incorporation of geothermal-related content into university, Technical and Vocational School (hereinafter TVS) and postgraduate curricula.
- Consolidation and unification of certification and education programs at the European level that are also to be revised as advances in technology take place. It is also essential that such programs be founded on environmental sustainability.

The development of research lines resulting from the priorities set forth in the document 'Vision for 2030' must focus on analyzing the true state of the sector, so as to identify the course of action that will lead to the achievement of the various goals established. To that end, the GEOPLAT Training Workgroup has prepared a SWOT (strengths, weaknesses, opportunities, threats) analysis through which to capture and synthesize those aspects that specifically affect training and education.

## Current state of training and education on geothermal energy in Spain.

According to analyses conducted by the Training Workgroup, Spain has sufficient infrastructure capacity to provide education in the field of geothermal energy which, coupled with the availability of specific training contents from international sources, renders the task of training geothermal energy professionals completely viable. In the current sphere of opportunities, geothermal energy is a growing sector whose development relies on the continuous preparation and education of individuals that can become qualified geothermal energy professionals. To this effect, it is worth noting here that a requirement already exists which calls for the setup and implementation of a geothermal installation professional certification by the end of 2012 (according to European Directive 2009/28/EC). There are also a number of training and educational projects at the international level (EU-CERT.HP, QUALICERT, GEOTRAINET), which undoubtedly serve as a reference to this regard. Other European countries offer Master's degrees in the field of high-enthalpy geothermal energy that include training content and experiences that can be readily used in Spain. Lastly, a certain level of flexibility is provided that allows adapting to a changing legislative framework relative to professional certifications.

Weaknesses on the other hand are numerous and include, for example, a poor level of education and qualification in a number of technical disciplines (e.g. drilling techniques, contractor work in the domestic realm, etc.), installation and maintenance workers' lack of awareness of the technology and the existence of poorly specialized and professionally developed suppliers, among others. Training programs are not homogenized across Europe and are not adapted to the contents that the geothermal sector requires, mainly because of the lack of specific materials and regulations. In contrast with the American International Ground Source Heat Pump Association benchmark (hereinafter IGSHPA), the European geothermal sector has been unable to compile a similar model for the development of a Code of Best Practices or Technical Guide. There is a lack of coordination at the regional level in Spain with regard to the creation and launch of educational and training programs, a swarm of multiple and/or duplicate representatives and entities that have criss-crossing competencies over decisions that affect the sector and lastly, a widespread lack of geothermal related content in university, Technical and Vocational School and postgraduate curricula.

Leaving these weaknesses unsolved would generate a number of serious threats including the risk of becoming technologically dependent on other countries coupled with the more than probable adoption of inadequate norms and uses that are not in accordance with the inherent characteristics of Spain, which may also inevitably bring associated technological risks. Last but not least, the imbalance between the opportunities offered by the sector and the demand for qualified professionals may attract an unqualified workforce that could hinder the sector's very own development.

The main strategic areas to be considered during the investigation phase of a geothermal resource can be grouped into:

### 1. ADAPTING PROFESSIONAL PROFILES TO THE REQUIREMENTS OF THE GEOTHERMAL SECTOR AND PARTICULARLY TO THOSE OF EUROPEAN DIRECTIVE 2009/28/EC.

- 1.1. Setting up a stable structure to enable the transfer of geothermal sector experience and know-how from international sources.
- 1.2. Establishing a professional competencies or strategic professional qualifications roadmap or manual that includes a list of the necessary profiles required by the sector.
- 1.3. Adaptation of Technical Guides and Codes of Best Practices using as a basis European benchmarks and adapting the former to the inherent characteristics of our country.
- 1.4. Piloting training initiatives geared at drillers and equipment installers based on previous European project models.

## Strategic courses of action.

Spain's national education system is currently undergoing changes due to the introduction of academic curricula that have been designed in accordance with the Organic Law on Education (L.O.E.). After careful review of existing information from the National Institute of Qualifications (INCUAL) and the National System for Professional Qualifications, a number of academic curricula have been identified that fall within the scope of thermal installations and extraction industries, and are considered to have an adequate fit into future training and educational contents on geothermal energy. In particular, four undergraduate curricula have been identified whose details follow:

- *Higher Technical Degree in the Development of Thermal Installations and Fluid Systems.*
- *Higher Technical Degree in Maintenance of Thermal Installations and Fluid Systems.*
- *Higher Technical Degree in Energy Efficiency and Solar Thermal Energy.*
- *Higher Technical Degree in Renewable Energy (pending imminent approval).*

Additionally, two other intermediate-level undergraduate technical curricula (currently in preparation) have also been identified:

- *Technical Degree in Refrigeration, Heating & Cooling installations.*
- *Technical Degree in Heating and Solar Thermal installations.*

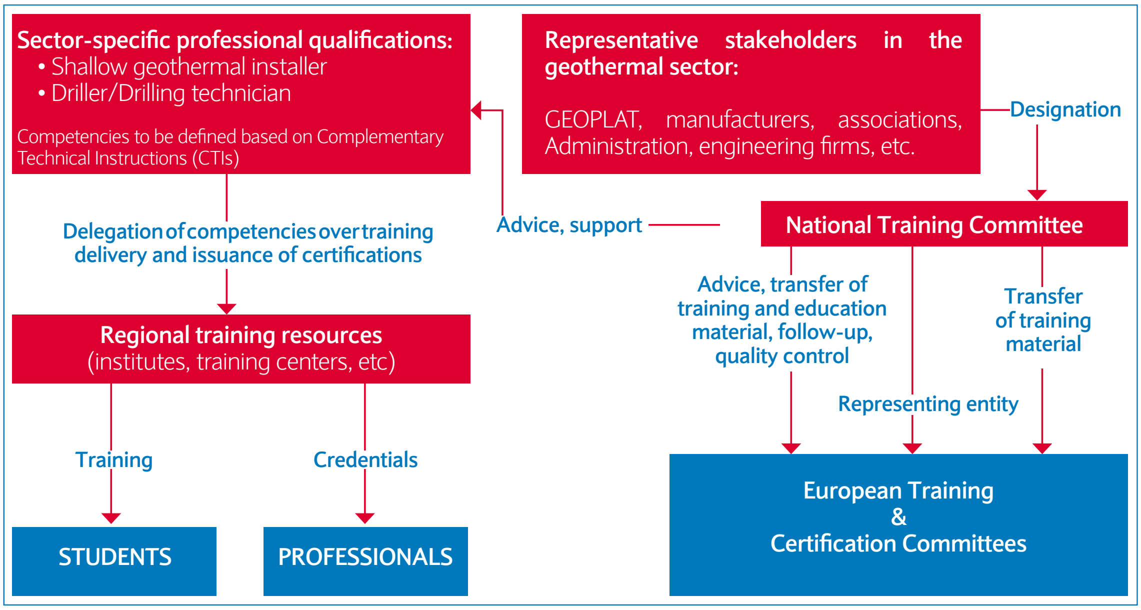
Drillers training and education is currently captured and imparted through an intermediate-level vocational program that includes drilling technology and operations with the types of machinery and equipment covered in the *'Technical Diploma in Operations and Maintenance of Construction Equipment'*. It is considered however, that this level of training is insufficient for geothermal-type drilling projects and therefore, specific training programs on geothermal drilling technology and methods must be developed. It must be mentioned however, that a Level 2 professional qualification titled 'Well drilling' currently exists that belongs to the professional qualification family 'Extractive Industries', which may be sufficient to satisfy the gaps identified in the structure of current training programs.

On the other hand, the European Directive 2009/28/EC obliges Member States to bring forward certification schemes for renewable energy system installation technicians before 2012. Such schemes must include the 'shallow geothermal installers' certification that is also to be mutually recognized across different Member States. Training and educational contents for national qualifications therefore must take into account European frameworks and certification systems both per the nature and reach of the subject matter and implementation thereof.

Several European projects focusing on the area of professional qualifications including EU-CER.HP, GEOTRAINET and QUALICERT have articulated around the subject of professional certifications. The first two of the aforementioned European projects specifically considered the development of manuals and training content specific to heat pump installers (in the first case) and shallow geothermal drillers and designers in the second. QUALICERT attempts to move forward with the development of certification schemes for qualifying renewable energy system installers. Additionally, it is worth mentioning that Spanish entities participate in both GEOTRAINET and QUALICERT programs.

Aside from the creation and development of guides and training content, one of the most relevant outcomes from the aforementioned projects relates to the creation of European committees that can guarantee updating, diffusion and proper management of training and educational content in the different areas, as well as interoperability across the various national settings. To that effect, a group has been already created at EU-CERT.HP and another is under way at GEOTRAINET called 'European Training Committee' whose functions will be supported by national entities called 'National Training Committee' that will be in charge of training as well as issuance of certificates as appropriate.

The creation of a 'National Training Committee' is proposed as a first step toward the adaptation of professional profiles to the requirements set forth by the European Directive 2009/28/EC. The former should be responsible for comprehensive training efforts in the different areas in the field of geothermal energy as well as for upkeeping, coordinating and representing the Spanish geothermal sector before European and national spheres, as described in the following organizational chart:




The Committee's first action should include sections 1.2 and 1.3 of the strategic actions proposed above. On the one hand, a competencies manual or professional qualifications strategic roadmap must be established that includes a list of the profiles required by the sector, as well as the type and level of knowledge, professional attributes and certification strategy associated therewith. In this sense and generally speaking, professionals working in the geothermal sector must have competencies in the following categories or professional profiles:

- **Drilling and Well Installation:** Tasks include drilling, casing, drill truck/equipment mounting and subsequent well packing and installation of required control devices.
- **Construction Work:** Ditch excavation, piping installation and back filling, as well as installing and building all required control elements (wellheads, equipment room access, etc.).
- **Installer and Maintenance Technician:** Maintenance of equipment room access including the installation itself, individual heat-emitting equipment (radiators, fan coils, etc.) or surface (floors, ceilings, heated baseboards). This category not only includes the installation itself but also all necessary control systems.
- **Project Designer:** Responsible for the design and planning of the entire installation including maintenance procedures thereof.
- **Quality Control Technician:** Responsible for quality control during construction and setup of the entire installation.

On the other hand, content from technical guides that derive from multiple subject-matter content harmonized by the European Training Committee must be adapted to the Spanish situation so as to specifically and practically identify, update and present all relevant criteria associated with the execution of geothermal projects.

Parallel to the creation of the 'National Training Committee' and to the development of the aforementioned courses of action, it is proposed to conduct pilot training initiatives in the field of professional qualifications for drillers and geothermal installers by use of prior training experience acquired at GEOTRAINET and other European projects mentioned earlier together with the support from training centers that have the appropriate equipment and facilities.

This initiative would allow assimilating progressively the European experiences that surround such training schemes for drillers and installers while adapting the resulting final training package to national particularities. The future National Training Committee would at all times supervise the development of this initiative, progress and results thereof.

Furthermore, two key aspects must be highlighted that are related to the aforementioned method for defining and establishing professional profiles and associated competencies:

- The need to obtain recognition from all stakeholders and the possibility of using two complementary routes through:
  - Achieving strong participation from highly recognized geothermal sector professionals and private firms for the development and establishment of sector-specific professional qualifications.
  - Making the proposals of the National Catalog of Professional Qualifications official. Both routes are necessary and perfectly compatible. INCUAL (National Institute of Qualifications) and the Water and Energy Group who has carried out similar work in other renewable energy sectors over the past few years could be used as learning vehicles for this purpose.
- The second aspect related to training and certification of professionals in the field geothermal energy has to do with the need to introduce mechanisms into the system that allow to recognize and value professional competencies acquired through experience in the geothermal field. In this sense, Royal Decree 1224/2009 on the evaluation and recognition of professional competencies acquired through experience (whose sphere of application corresponds with professional training) can turn into an effective means for officially certifying and recognizing driller, installer and maintenance technician qualifications built on experience acquired at geothermal installations.

Lastly, it must be mentioned that it is equally important that specific training and education within the geothermal sector also be complemented by the Environmental, Health & Safety sector, particularly with respect to waste management.

## 2. INCORPORATING GEOTHERMAL ENERGY CONTENT INTO UNIVERSITY CURRICULA

2.1. Imparting lectures in existing Master's and post-doctoral university programs.

2.2. Creation of one or several specific undergraduate or Master's degrees.

2.3. European Master's Degree in Geothermal Engineering.

### Strategic course of action

The current university system is undergoing changes so as to adapt to the European Higher Education Area (EHEA). Several engineering degrees in which it would be essential to include geothermal content have been already identified, such as Energy, Mining, Industrial or Civil Engineering. Bachelor's Degrees such as Geology or Physics should be included in this aspect. Depending on the specialization and orientation of said academic curricula, a distinction must be made between Deep Geothermal Energy and Shallow Geothermal Energy. In this sense, it is considered that the best way to achieve this objective is through research programs in the field of geothermal energy that would allow the flourishing of specialized research groups at our Universities.

There is another series of parallel mechanisms to boost the creation and activity of research groups that work in the field of geothermal energy such as:

- Subject-specific or specialized scholarships for students.
- Boosting professor exchange networks with the goal of increasing the level of collaboration in the field of geothermal research (which is undoubtedly multidisciplinary in nature).
- Supporting international mobility in order to favor the exchange of experiences with other countries, specifically in the field of high-

enthalpy geothermal systems.

- Networks – particularly with Latin American countries that have clear high-enthalpy potential as in the case of Mexico – to exchange academic experiences in the field of resource exploration.

A key challenge that is to be completed by 2020 entails the creation and launch of a European Master's Degree in Geothermal Engineering program, in which international specialists from the geothermal sector together with universities from all European countries would take part. To reach this objective, a university-level postgraduate degree at the national level should be designed together with the participation of a number of schools through their Geology, Mining and Civil Engineering departments. Finally, it would be recommended that this program have shared content but be split eventually into deep and shallow geothermal energy components.

## 3. INCORPORATING GEOTHERMAL ENGINEERING OR TECHNOLOGY STUDIES INTO SPAIN'S TECHNICAL AND VOCATIONAL SCHOOL (TVS) CURRICULA.

3.1. Identifying Technical and Vocational School diplomas that are most similar to the type of work carried out during project development, drilling, installation and maintenance work at geothermal facilities and also including complementary reference content and knowledge.

3.2. Designing and implementing a specialized post-graduate course for higher technical education students that may be interested in pursuing and developing their professional career in the field of geothermal energy.

### Strategic course of action

As mentioned previously in this document, at this time a number of training programs can be found that stem from the National System for Professional Qualifications and which allow obtaining diplomas related to thermal installations and extractive industries that are deemed adequate for complementing specific geothermal training.

On the other hand, technical and vocational school curricula can make use of an alternative which has not yet been developed officially (although several initiatives already exist in a number of Autonomous Regions), which consists of offering specialization courses upon completion of official TVS education (additional provision number nine to Royal Decree 1538/2006 of December 15, on the establishment of a new organization of the Technical and Vocational School system). Despite some differences, this tool would be analogous to the Master's degrees that supplement Bachelor Degrees, but at the TVS level. For example, a TVS higher technician graduate in renewable energy could complete a 400-hour specialization course on geothermal installations.

## 4. PROMOTION AND DIFFUSION OF GEOTHERMAL ENERGY IN PRE-UNIVERSITY AND CONSUMER ENVIRONMENTS.

4.1. Diffusion of the geothermal sector through the set up of courses, conferences, workshops, etc. that are to be monographic in nature to attract interest from different sectors individually. Diffusion aimed at the university spectrum is to be separated from that aimed at professional associations.

4.2. Preparation of academic materials so as to circulate information and insights into the field of geothermal energy, its benefits and possibilities at the early stages of education in order to increase interest thereof and attract future professionals.

COURSE OF ACTION:

## ADAPTING PROFESSIONAL PROFILES TO GEOTHERMAL SECTOR REQUIREMENTS (EU DIRECTIVE 2009/28)

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 1.1 | **Setting up of a stable structure to enable the transfer of geothermal sector experience and know-how from international sources.** | Coordination. | Ensure harmonized development with other EU countries. | Precedents exist in Europe. | Very High | GEOPLAT, associations, private firms and public entities. | 300,000 € |
| 1.2 | **Establishing a professional competencies or strategic qualifications roadmap or manual.** | Coordination among stakeholders involved. | Set the basis for sharing all key knowledge surrounding the geothermal sector. | Sufficient material as well as qualified professionals exist. | High | Training centers, private firms, associations and competent administrative bodies. | 100,000 € |
| 1.3 | **Adaptation of Technical Guides and Best Practices.** | Coordination among stakeholders involved. Possible problems associated with confidentiality issues and companies' hesitance to provide or share information. | Harmonizing best practices in the private sector. | Some work in this area is currently under way. | Medium – High | Private firms, associations and training centers. | 200,000 € |
| 1.4 | **Pilot training initiatives geared at geothermal drillers and equipment installers based on previous European project models.** | | Expand the number of qualified professionals. | Precedents as well as sufficient training material exist. | Medium - High | Training centers with appropriate means and qualified personnel. | 500,000 € |

COURSE OF ACTION:

## INCORPORATING GEOTHERMAL ENGINEERING CONTENT INTO UNIVERSITY CURRICULA.

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 2.1 | **Imparting lectures in existing Master's and post-doctoral university programs.** | Identifying student demand for geothermal engineering studies. Coordination among universities that show highly heterogeneous profiles. | Impact in the mid-term on the technological development of the sector. Increased technological capacity. | Sufficient capacity within the Spanish university system. | Medium | Universities and private firms. | 200,000 € |
| 2.2 | **Creation of one or several specific undergraduate or Master's degrees.** | Identifying student demand.<br>Coordination among universities that have very heterogeneous profiles. | Increased technological capacity in the mid-term. | Spanish university system prepared and capable of undertaking this training and educational task. | Medium | Universities and private firms. | 500,000 € |
| 2.3 | **European Master's Degree in Geothermal Engineering Program.** | Identifying student demand.<br>Difficulties in coordinating universities located in different countries. | Simultaneous development with other European countries. | Precedents exist. | Medium | Universities and private firms in other countries. | 500,000 € |

COURSE OF ACTION:

## INCORPORATING GEOTHERMAL ENGINEERING AND/OR TECHNOLOGY STUDIES INTO SPAIN'S TECHNICAL & VOCATIONAL SCHOOL (TVS) CURRICULA.

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 3.1 | **Identifying Technical & Vocational School diplomas that best relate to geothermal discipline.** | Select official TVS diplomas that best fit shallow geothermal energy/engineering disciplines. Adapt old TVS diplomas to new diplomas in accordance with standardized European educational standards. Take advantage of Autonomous Regions' regulatory capacity over aspects related to official academic curricula content. | Better quality guarantees of equipment installation and maintenance in numerous cases. | A national expert group is currently active which should be expanded with the incorporation of experts from the field of geothermal installations who are currently working on defining the types and levels of qualifications at INCUAL (National Institute of Qualifications). | High | Ministry of Education and Regional Secretariats. Training to be imparted at TVS. Private firms and experts working in the latter must participate in the design and adaptation of curricula. | 100,000 € |
| 3.2 | **Designing and implementing a postgraduate specialization course for higher Technical & Vocational School professionals.** | Lack of domestic and international benchmarks. Need to design innovative tools to adequately adjust the level and degree of specialization of training programs to the requirements needed by TVS graduate technicians. | Better quality guarantees of equipment installation and maintenance. | Current TVS norms make reference to specialization courses but these have not been sufficiently developed. Another alternative consists of developing this type of course in one or several Autonomous Regions that may be willing to prepare professionals in this field. | Medium - High | Autonomous Regions or, otherwise Ministry of Education could undertake this initiative. In either case, a workgroup made up of technological and training experts should be created. Such group would become integrated into and would work collaboratively with a number of institutional centers (the latter perhaps in a second phase). | 300,000 € |

COURSE OF ACTION:

## PROMOTION AND DIFFUSION OF GEOTHERMAL ENERGY IN PRE-UNIVERSITY AND CONSUMER ENVIRONMENTS

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| 4.1 | **Setting up courses, conferences, workshops, that are to be monographic in nature.** | Coordination among stakeholders responsible for executing course of action and audience attraction. | In the long term: Public knowledge about the technology and the opportunities it has to offer. | Sufficient material as well as qualified professionals exist. | Medium-Low | Private companies, associations, training centers. | 200,000 € |
| 4.2 | **Preparation of academic materials in the early stages of education.** | Coordination among stakeholders responsible for executing course of action. | In the long term: Public knowledge about the technology and the opportunities it has to offer. | Sufficient material as well as qualified professionals exist. | Medium - Low | Private companies, associations, training centers. | 200,000 € |

# TRAINING AND EDUCATION

| COURSE OF ACTION | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| **Adapting professional profiles to geothermal sector requirements.** | | | | | |
| Setting up of a stable structure to enable the transfer of geothermal sector experience and know-how from international sources | x | x | | | |
| Establishing a professional competencies or strategic qualifications roadmap or manual | x | x | | | |
| Adaptation of Technical Guides and Best Practices | x | x | x | | |
| Pilot training initiatives geared at geothermal drillers and equipment installers based on previous European project models | x | x | | | |
| **Incorporating geothermal engineering content into university, TVS and postgraduate curricula.** | | | | | |
| Imparting lectures in existing Master's and post-doctoral university programs | | | x | x | |
| Creation of one or several specific undergraduate or Master's degrees | | | x | x | |
| European Master's Degree in Geothermal Engineering Program | | x | x | x | |
| **Incorporating geothermal engineering and/or technology studies into Spain's Technical & Vocational School (TVS) curricula.** | | | | | |
| Identifying Technical & Vocational School diplomas that best relate to geothermal discipline | | x | x | | |
| Designing and implementing a postgraduate specialization course for higher Technical & Vocational School professionals | | x | x | | |
| **Promotion and diffusion of geothermal energy in pre-university and consumer spheres.** | | | | | |
| Setting up courses, conferences, workshops, that are to be monographic in nature | | | | x | x |
| Preparation of academic materials in the early stages of education | | | | x | x |

# REGULATORY FRAMEWORK.

The framework regulating the geothermal sector is of paramount importance in the sense that the presence or lack of concrete policies and initiatives within such a regulatory framework is considered to be a determining factor in the development of the sector.

GEOPLAT's Regulatory Framework Workgroup can recommend measures and actions that can favor the legal and economic regimes that make up the regulatory framework governing geothermal energy. Such recommendations would also contemplate the inclusion of any norms necessary to achieve a successful development of the sector so it can undergo solid and well-structured growth. In order to achieve these goals the following actions must be undertaken in the two strategic areas listed next:

- Analysis of the current legislation affecting the geothermal field, but also of geothermal systems and processes, with the goal of acquiring sufficient knowledge thereof in order to open the door to an adequate regulation of the geothermal sector and the inclusion of sector-specific particularities.
- Proposal of necessary amendments to encourage acquisition of the resource, production and use thereof.

## 1. ANALYSIS OF THE CURRENT LEGISLATION.

### 1.1. Regulatory framework.

Geothermal energy is subject to a set of regulations that are split among national, regional and European administrations and which make application of the former both problematic and cumbersome in the majority of cases.

The regulatory framework governing deep, high-enthalpy geothermal systems comprises the following:

- Mining regulations: Mines Act of 1973, Regulations on the Mining Regime of 1978, which grants exploration and exploitation permits as well as exploitation concessions and the General Regulations on Basic Safety Standards in Mines of 1985.
- Environmental regulations: Royal Legislative Decree 1/2008 (at the national level), which approves the text for the Law on the Assessment of Environmental Impact of Projects. Several different specific regulations exist at different levels in each Autonomous Region.
- Industry Regulations: procedure for the authorization of electrical installations (Royal Decree. 1995/2000, on the regulation of transport, distribution, commercialization and supply of electricity and authorization procedures of electrical installations). It regulates administrative authorizations, approval of the execution of projects and authorization for the exploitation of activities.

The regulatory framework governing shallow geothermal systems comprises the following:

- Mining regulations. Mines Act of 1973 and General Regulations on Basic Safety Standards in Mines of 1985.
- Water regulations: The Water Act and the Regulations on the Public Hydraulic Domain regulate the concessions granted for both the extraction of water and recharge (water that returns to the aquifer).

- Environmental legislation.
- Industry regulations: which establish the requirement for domestic hot water (DHW) installations to be registered according to the same procedures as for any installation of this type that uses a conventional energy supply.
- Technical Building Code (CTE) and Regulations on Thermal Installations in Buildings (RITE), details of which follow:
  - *The Technical Building Code (CTE)* constitutes the regulatory framework that establishes the requirements all buildings must comply with in relation to basic safety and habitability requirements set forth in Law 38/1999 of November 5, on Urban Planning (L.O.E.).
  - *The Regulations on Thermal Installations in Buildings (RITE)*, approved by the Council of Ministers on July 20, 2007 sets forth the requirements all installations that are destined to satisfy temperature and hygienic conditions through heating, cooling and domestic hot water systems must comply with to achieve a rational use of energy. This Royal Decree is, in essence, a basic National regulation regardless of the fact that Autonomous Regions have the capacity to introduce additional requirements in connection with these aspects when the installations are based in their territories.

Both CTE and RITE regulations make reference to general aspects that affect thermal installations in buildings and the use of renewable energy in conjunction with such installations. They do not explicitly mention however any regulation on nor make specific reference to geothermal technologies. Both regulations are heavily influenced by European Directive 2002/91/EC relative to energy efficiency in buildings, which has been recently revised and has led to the publication of European Directive 2010/31/EU. The transposition of this last one or the otherwise modifications to CTE and RITE necessary for Spain to adapt to this new regulation, constitute a great opportunity to incorporate other sources of renewable energy into both texts (currently only solar energy is contemplated).

On top of all the aforementioned regulations, the Spanish Renewable Energy Plan (to be published in 2011) as well as the Energy Efficiency and Renewable Energy bill should be taken into account. Both the Plan and the future Law will become the cornerstone of Spanish national policy on renewable energy in the coming years, and probably until 2020. It must therefore be ensured that both texts give geothermal energy the appropriate status, recognition and importance it deserves in preparation for the new upcoming scenario.

The following include specific actions on which the regulatory analysis of the current legislation must be based:

- Study into the different regulatory frameworks affecting the geothermal sector and sub-sectors in order to achieve proper unification and homogenization of such frameworks across all Autonomous Regions in accordance with the guidelines established by the European Union.
- Study into the different policies that support the existing geothermal energy scenarios in different countries. Analysis of the impacts these support measures have had on the evolution and growth of the sector in the different countries analyzed.
- Analysis of the environmental impacts caused by different geothermal systems with the goal of breaking these down into a set of measurable and controllable environmentally associated elements and parameters. This initiative would also include a proposal for developing an environmental impact evaluation method specific to geothermal systems with the goal of improving Environmental Impact Assessment planning and execution processes that apply to the sector.
- Analysis of possible areas of interference and regulatory overlap with other sectors, particularly the overlap between geothermal-type resources currently regulated under

section D of the Mines Act with other resource types contemplated both in the same Law and other regulations. Study into the regulatory adjustment possibilities that would bring about solutions to land use restrictions imposed by the co-existence of different resources at the same location and to possible speculative situations associated with geothermal resources.

- Conducting viability studies on the implementation of district heating networks in Spain with the goal of assessing where and under what conditions such networks could be potentially implemented.
- Studies into the development and validation of criteria that allow comparing different types of projects and alternatives, not only geothermal but also other sources as well. This particular aspect is deemed essential for geothermal activity to develop and must be assessed carefully for each type of reservoir based on its singularities.

### 1.2. Economic framework and subsidies.

The economic framework surrounding deep geothermal systems is captured in Royal Decree 661/2007, which regulates electricity production activities from renewable energy and co-generation technologies and establishes the economic and legal regime these types of installations may adhere to. This regulation establishes a fixed feed-in tariff of 7.2892 €cent/kWh generated. This same decree establishes the right to receive specific economic compensation for each installation within the first 15 years since start of production.

Shallow geothermal resources receive aid during the installation phase from all Autonomous Regions thanks to agreements signed between the former and the Spanish Institute for Energy Diversification and Saving (IDAE). On top of this aid, some Autonomous Regions also finance installations that are constructed in their territory. The amounts and scope of such aid is published annually and differs from one Autonomous Region to another.

Based on the above, the following actions are proposed:

- Study into the compensation frameworks surrounding electricity production from geothermal energy in various countries including assessing the impact that these compensation support schemes have had on the evolution and growth of the sector in the different countries analyzed.
- Study into the different support frameworks (subsidy type) affecting the sector and its sub-sectors in order to achieve a correct unification and homogenization of such frameworks across all Autonomous Regions.
- Study into financing schemes for geothermal projects and installations (district networks or single installations) in buildings based on the partial increase of costs thereof on housing prices in order to progressively adapt to the limiting factors and peculiarities that exist in our country.
- Study into the viability of implementing an economic compensation system for thermal energy generation that can be sustained by that already in place for the generation of electricity.
- Study into the homogenization of criteria with regard to quantifying production and cost data of installations that harness geothermal energy, with the goal of generating greater confidence among end-users and the public opinion with respect to the real nature of the technology. Additionally, the development of tools to manage reservoir economics as well as the definition of reservoir evaluation and quantification codes must be assessed.

### 1.3. Certification (technical standardization) and sustainability.

At present, Spain does not have specific technical regulations in the field of geothermal energy. Nevertheless, the development of standardization and certification activities contributes to improving the quality of companies' operations and management thereof, their products and services and to protect the environment while progressing toward society's wellbeing. Thus, it is essential to have norms of this kind that can support the development of the technology.

To this day, AENOR (Spanish Association for Standardization and Certification) together with the open participation of all entities and agents that are involved as well as interested in the work carried out by this committee is immersed in the process of preparing an UNE norm (Spanish standardization) relative to heating and cooling systems powered by shallow geothermal energy. It is worth pointing out that it is equally important to work along these lines to expand the efforts to other sub-sectors in the field of geothermal energy.

Thus, the following course of action is proposed:

- Study into the analysis of the possibilities of preparing UNE norms regarding non-standardized installation procedures, uses of technology, etc.

Moreover, it is important to take into consideration those aspects relative to the sustainability of geothermal resources. In this sense it is proposed to:

- Conduct Life Cycle Analyses (LCA) at geothermal facilities.

## 1.4. Best practices.

One of the greatest threats that have been detected and that could play against the development of the geothermal sector in the immediate future (particularly affecting shallow geothermal facilities) is an uncontrolled growth of the sector itself as a result of the start-up of poorly designed or poorly operated facilities. The problem, which can arise from inexperience or the lack of appropriate qualifications that would otherwise allow taking advantage of and showing the true key benefits of the technology, could generate a series of doubts, uncertainties or mistrust on the consumer side that would severely play against the sector. Therefore, it is vital to stress, among other things, those aspects related to the so-called "best practices" that can warrant solid and steady growth of the sector.

At present, examples of documentation that reflect such "best practices" in other countries vary considerably. Scandinavian countries have associations and norms that govern the correct execution of any installation, while consumers can readily flock to independent organizations for advice on the project. Likewise, Germany for example, has developed Norm VDI 4640, which serves as tool to conduct extensive reviews of recommendations for the installation of different types of geothermal systems. The International Ground Source Heat Pump Association (IGSHPA) also has a detailed set of standards in this sense. In Spain, attempts are under way to draft up similar texts although diffusion and the extent of contents thereof should perhaps focus on striving to reach a greater audience.

In this sense, it is proposed to:

- Analyze the existing documentation and conduct a study into how to best set the foundations and structure the essential contents that should comprise a code of best practices for the design and installation of geothermal facilities and systems in Spain.

## 1.5. Geothermal facility registry and databases.

Spain does not have an official registry of geothermal facilities to date. However, the creation of such a registry would enable collecting information about facilities in operation together with their characteristics. Consequently, knowledge of the evolution of the geothermal sector in Spain (for which no reliable official data exists) would then become available, shedding some light also on the actual state thereof.

Recently, there has been commitment to reflect the undertaking of this task between 2011 and 2012 in the Spanish National Renewable Energy Action Plan (NREAP) submitted to the European Commission in June 2010. Nevertheless, a firm commitment in relation to this task must be made and should be supported by the following course of action:

- Conducting an analysis of the possibilities to develop an effective system for registering geothermal facilities in Spain as well as recommendations on the basic elements required (structure, contents, software, etc.) for such a system.

## 2. PROPOSALS FOR AMENDMENTS WITHIN THE LEGISLATION RELATIVE TO THE SECTOR.

Based on the results obtained through research projects, which could also be eventually undertaken not only in the regulatory area but also in any other within the geothermal sector, measures could be proposed that would fit the regulations that govern the different aspects relative to the application of geothermal technologies.

Thus, strategic actions that must be undertaken in relation to the regulatory framework associated with geothermal energy in Spain must not be limited to an analysis and study of the current legislation and documentation. Next steps should build upon said studies in order to draft formal proposals for the aforementioned texts as well as concrete measures that would imply the development of systems and processes that could support and complement such regulations.

Based on this and according to the items described in the previous section, the following actions are proposed:

### 2.1. Regulatory Framework.

- Draft recommendations for the implementation of measures aimed at boosting technological advances in the field of geothermal energy which could be synthesized in a specific and detailed "Document of Recommendations" that will result from the outcome of the analyses of the regulations mentioned in the previous section.

- Provide advice to the different Administrations on the development of a regulatory framework that fits and satisfies sector needs (RITE, CTE, Mines Act, etc.).

    - o Proposal to include aspects that are specific to the field of shallow geothermal energy in building codes and regulations (CTE and RITE).

    - o Proposal to include geothermal energy in municipal urban planning.

    - o Proposal to adapt and update the current Mines Act.

- Draft a proposal to develop and implement the necessary regulatory instruments to provide the sector with as thorough information as possible about geothermal energy in order to reduce investment risk as well as to generate incentives for investment.

- o Urge the Administration to regulate on the mandatory requirement for companies to make all useful information deriving from geothermal projects publicly available once a convenient confidentiality period has concluded.

- Development of a pilot program to study critical aspects that surround the current legislative system in the field of geothermal energy with the aim of clarifying the former in order to develop more effectively the applicability of the regulatory framework.

### 2.2. Economic framework and subsidies.

It is a fact that the quantity of financial support for implementing geothermal energy systems in Spain is still very small in comparison to other support schemes currently existing in several European countries, particularly when taking into account the potential of this energy source in Spain.

As previously mentioned, the production of electricity is regulated by Royal Decree 661/2007 which establishes a feed-in tariff of about 7 €cent/kWh. In other European countries where the geothermal sector is experimenting a very positive evolution this figure reaches approximately 20 €cent/kWh, including the special case of Portugal where the new feed-in tariffs are even higher.

Currently about two-thirds of the energy consumption in Spain is linked to the thermal energy demand. However, the contribution to the reduction in consumption, imports of fossil fuels and emission of harmful gases that renewable thermal energy could otherwise attain is not encouraged through any of the mechanisms that are similar to those currently defined in the special regulatory regime for electricity production.

To this effect, the measures proposed in this section include:

- Preparation of a proposal that is adequately justified and aimed at revising compensation to electricity production from geothermal sources that would allow increasing the quantity of existing compensation levels in Spain so as to match those of other European countries.
- Proposal to design a compensation framework that is specific to the production of thermal energy from renewable sources. Such sources would include the ones currently listed in Directive 2009/28/CE of April 23, 2009 on the promotion of the use of energy from renewable sources.

### 2.3. Certification (technical standardization) and sustainability.

- Preparation of specific technical norms relative to the different geothermal technologies.

With respect to sustainability aspects, it is of paramount importance to focus the efforts on the implementation of the Life Cycle Analysis (LCA) protocol for each different geothermal technology, in order for such protocols to enable the identification of both key and less relevant stages within the sustainability evaluation processes thereof. The following course of action is thus proposed:

- Preparation of Life Cycle Analysis (LCA) protocols and procedures that are adapted and tailored to geothermal facilities.

### 2.4. Best practices.

- Promoting best practices during the process of implementation of shallow geothermal systems via preparation of a Code of Best Practices or Technical Guide according to the models of other European texts, that is to adapt as closely as possible to most of the singularities currently existing in Spain. Moreover, the diffusion and promotion of such Code or Guide must be extensively carried out.

### 2.5. Geothermal facility registry.

- Proposal to develop software systems to build and maintain a registry of geothermal facilities in Spain.
- Development of an online platform or a service department within the structure and functions of regional governments capable of managing and integrating all relevant information associated with the implementation of low-enthalpy geothermal installations. Such a system would assist project developers from the initial supply of useful and valuable project-related information relative to the geothermal resource: characteristics of the target area, etc., to the registration of the new facility in the system.

COURSE OF ACTION:

## ANALYSIS OF CURRENT LEGISLATION

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| **1.1 REGULATORY FRAMEWORK** | | | | | | | |
| **1.1.1** | Study into the different regulatory frameworks affecting the sector in order to achieve proper homogenization thereof across all Autonomous Regions. | Regulatory heterogeneity that hinders the development of projects and installations. | Regulatory harmonization. | Personnel qualified to undertake these studies. | High | GEOPLAT, associations, universities, research centers, technological centers, and consulting firms. | 100,000 € |
| **1.1.2** | Study into the characteristics of support policies currently existing in other countries. | Cumbersome and difficult data compilation and updating task. | Gap and existing problem resolution pertaining to Spanish regulations on geothermal energy. | Personnel qualified to undertake these studies. | High | | 100,000 € |
| **1.1.3** | Analysis of environmental impacts caused by different geothermal systems. | Inexistence of standardized environmental impact assessment process for geothermal installations. | Creation of a protocol to unify criteria for the analysis of environmental impacts in geothermal projects. | Personnel qualified to undertake these studies. | Medium-High | | 200,000 – 300,000 € |
| **1.1.4** | Analysis of possible areas of interference and overlap with other sectors. | Coordination among the different sectors involved. | Adequate development of the geothermal sector in harmony with other sectors it interacts with. | Personnel qualified to undertake these studies. | Medium | | 100,000 € |
| **1.1.5** | Conducting viability studies on the implementation of district heating networks in Spain. | Absence of practical cases in the area of district heating networks in Spain. | Favor the development of district heating networks in Spain. | Personnel qualified to undertake these studies. | High | | 50,000 € |
| **1.1.6** | Study into the development of criteria that allow comparing different types of projects. | Definition of optimal criteria for the sector. | Capacity to crosscheck projects to boost the sector in accordance with common standards. | Personnel qualified to undertake these studies. | Medium-High | | 100,000 € |

COURSE OF ACTION:
## ANALYSIS OF CURRENT LEGISLATION

| | | RETOS, PROBLEMAS A RESOLVER | IMPACTO EN EL DESARROLLO DE LA GEOTERMIA | CAPACIDAD PARA DESARROLLAR LA ACTUACIÓN | PRIORIDAD | AGENTES RESPONSABLES DE LA ACCIÓN | COSTES ESTIMADOS |
|---|---|---|---|---|---|---|---|
| **1.2 ECONOMIC FRAMEWORK / SUBSIDIES** | | | | | | | |
| 1.2.1 | Study and impact analysis of different compensation frameworks surrounding electricity production from geothermal sources in other countries. | Cumbersome and difficult data compilation and updating task. | Identification of financial support schemes most favorable to the development of electricity production from geothermal sources. | Personnel qualified to undertake these studies. | Medium-High | GEOPLAT, associations, universities, research centers, technological centers, and consulting firms. | Between 250,000 € and 300,000 € for all studies referring to compensation framework (about 50,000 € – 60,000 € per project). |
| 1.2.2 | Study of compensation frameworks affecting the sector to achieve correct unification and homogenization of the former across all Autonomous Regions. | Heterogeneity in financial support schemes. | Harmonization of financial support schemes. | Personnel qualified to undertake these studies. | High | | |
| 1.2.3 | Study into financing schemes for geothermal projects and installations in buildings. | Absence of precedents | Integration of geothermal installation costs into the total cost of the building where they are installed. | Personnel qualified to undertake these studies. Existing experiences in countries in settings similar to Spain. | High | | |
| 1.2.4 | Study into the viability of implementing a compensation system for generation of thermal energy. | Absence of precedents. | Favor the conditions for the implementation of geothermal installations. | Personnel qualified to undertake these studies. | High | | |
| 1.2.5 | Study into the development of tools to manage reservoir economics as well as the definition of reservoir evaluation and quantification codes. | Lack of economic data from projects in Spain that could serve as a reference. Absence of public geothermal resource evaluation and quantification data. | Facilitate the availability of useful techno-economical data for the development of subsequent projects in Spain. | Personnel qualified to undertake these studies. | High | | |

COURSE OF ACTION:

## ANALYSIS OF CURRENT LEGISLATION

| | | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|---|
| **1.3 CERTIFICATION (TECHNICAL STANDARDIZATION) AND SUSTAINABILITY** | | | | | | | |
| 1.3.1 | Study into the analysis of the possibilities of preparing UNE norms regarding non-standardized installation procedures, uses of technology, etc. | Specific characteristics of the Spanish situation. Coordination of stakeholders involved. | Readily access to available standardized norms for the implementation of geothermal installations. Prevent development of malpractice and the application of inadequate techniques. | Personnel qualified to undertake these studies. | Very High | GEOPLAT, associations, universities, research centers, technological centers, and consulting firms. | 150,000-200,000 € |
| 1.3.2 | Conducting Life Cycle Analyses (LCA) at geothermal facilities. | Lack of LCAs carried out at geothermal facilities. | Creation of an LCA protocol specific to geothermal installations. | Personnel qualified to undertake these studies | Medium-High | | 200,000 € |
| **1.4 BEST PRACTICES** | | | | | | | |
| 1.4.1 | Analysis of existing documentation. | Consensus among stakeholders involved. | Prevent the development of malpractice and the application of inadequate technologies that could result in negative consequences for the successful development of the sector. | Personnel qualified to undertake these studies. A number of codes exist in other countries and some Autonomous Regions. | High | GEOPLAT, associations, universities, research centers, technological centers, and consulting firms. | 50,000 € |
| **1.5 GEOTHERMAL FACILITY REGISTRY** | | | | | | | |
| 1.5.1 | Analysis into the possibility of developing an effective Spanish geothermal facility registry as well as defining the structure thereof. | Difficulties of creating an inventory of geothermal facilities in Spain. Difficulties to establish an optimal and efficient system for both project developers and the Administration. | Awareness update of the real situation of the sector in terms of installed capacity. | Personnel qualified to undertake these studies. | Very High | GEOPLAT, associations, universities, research centers, technological centers, and consulting firms. | 100,000-200,000 € |

LÍNEA DE ACTUACIÓN:

## PROPOSALS FOR AMENDMENTS WITHIN THE LEGISLATION

| | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|
| **2.1 REGULATORY FRAMEWORK** | | | | | | |
| 2.1.1 | Draft recommendations for the implementation of measures aimed at boosting technological advances within the field of geothermal energy. | These proposals for amendments derive from the execution of projects that are designed and implemented based on the courses of action listed earlier (Strategic Area 1: sections 1.1.1 through 1.5.1). Positive impacts from these on the development of the Spanish geothermal sector will come from the understanding and ownership over said courses of action by all stakeholders that have the required competences to turn them into a reality for the sector. | | | GEOPLAT, Associations, business confederations, etc. | In this second strategic area no associated cost estimates are contemplated as it entails "proposals for amendments" that do not require this type of funding. |
| 2.1.2 | Provide advice to the Administration on the development of an adequate regulatory framework that fits sector needs (RITE, CTE, Mining Act, etc.). | | | | | |
| 2.1.3 | Draft a proposal to implement the necessary regulatory instruments to provide the sector with as thorough information as possible on geothermal energy. | | | | | |
| 2.1.4 | Development of a pilot program to study critical aspects surrounding the current legislative system in the field of geothermal energy. | | | | | |
| **2.2 ECONOMIC FRAMEWORK / SUBSIDIES** | | | | | | |
| 2.2.1 | Preparation of a proposal aiming at revising compensation to the electricity production from geothermal sources. | These proposals for amendments derive from the execution of projects that are designed and implemented based on the courses of action listed earlier (Strategic Area 1: sections 1.1.1 through 1.5.1). Positive impacts from these on the development of the Spanish geothermal sector will come from the understanding and ownership over said courses of action by all stakeholders that have the required competences to turn them into a reality for the sector. | | | GEOPLAT, Associations, business confederations, etc. | In this second strategic area no associated cost estimates are contemplated as it entails "proposals for amendments" that do not require this type of funding. |
| 2.2.2 | Draft a proposal to design a compensation framework that is www.geoplat.org Page \| 66 specific to the production of thermal energy from renewable sources. | | | | | |

LÍNEA DE ACTUACIÓN:

## PROPUESTA DE ENMIENDAS EN EL ÁMBITO LEGISLATIVO

| | CHALLENGES / PROBLEMS TO SOLVE | IMPACT ON THE DEVELOPMENT OF GEOTHERMAL SECTOR | CAPACITY TO EXECUTE COURSE OF ACTION | PRIORITY | STAKEHOLDERS RESPONSIBLE FOR COURSE OF ACTION | ESTIMATED COST |
|---|---|---|---|---|---|---|
| **2.3 CERTIFICATION (TECHNICAL STANDARDIZATION) AND SUSTAINABILITY.** | | | | | | |
| 2.3.1 | Preparation of specific technical norms relative to the different geothermal technologies. | These proposals for amendments derive from the execution of projects that are designed and implemented based on the courses of action listed earlier (Strategic Area 1: sections 1.1.1 through 1.5.1). Positive impacts from these on the development of the Spanish geothermal sector will come from the understanding and ownership over said courses of action by all stakeholders that have the required competences to turn them into a reality for the sector. | | | GEOPLAT, Associations, business confederations, etc. | In this second strategic area no associated cost estimates are contemplated as it entails "proposals for amendments" that do not require this type of funding. |
| 2.3.2 | Preparation of Life Cycle Analysis (LCA) protocols adapted to geothermal facilities. | | | | | |
| **2.4 BEST PRACTICES** | | | | | | |
| 2.4.1 | Preparation of a Code of Best Practices. | These proposals for amendments derive from the execution of projects that are designed and implemented based on the courses of action listed earlier (Strategic Area 1: sections 1.1.1 through 1.5.1). Positive impacts from these on the development of the Spanish geothermal sector will come from the understanding and ownership over said courses of action by all stakeholders that have the required competences to turn them into a reality for the sector. | | | GEOPLAT, Associations, business confederations, etc. | In this second strategic area no associated cost estimates are contemplated as it entails "proposals for amendments" that do not require this type of funding. |
| **2.5 GEOTHERMAL FACILITY REGISTRY** | | | | | | |
| 2.5.1 | Draft a proposal to create a registry of geothermal facilities and develop the necessary software. | | | | GEOPLAT, Associations, business confederations, etc. | In this second strategic area no associated cost estimates are contemplated as it entails "proposals for amendments" that do not require this type of funding. |
| 2.5.2 | Creation of an integrated geothermal information management service across the Autonomous Regions. | | | | | |

# REGULATORY FRAMEWORK

| COURSE OF ACTION | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|
| **Analysis of current legislation** | | | | | |
| **Regulatory framework** | | | | | |
| Study into the different regulatory frameworks affecting the sector in order to achieve proper homogenization thereof across all Autonomous Regions | x | x | | | |
| Study into the characteristics of support policies currently existing in other countries | x | x | | | |
| Analysis of environmental impacts caused by different geothermal systems | x | x | | | |
| Analysis of possible areas of interference and overlap with other sectors | x | x | | | |
| Conducting viability studies on the implementation of district heating networks in Spain | x | x | | | |
| Study into the development of criteria that allow comparing different types of projects | x | x | | | |
| **Compensation framework / subsidies** | | | | | |
| Study and impact analysis of different compensation frameworks surrounding electricity production from geothermal sources in other countries | x | x | | | |
| Study of compensation frameworks affecting the sector to achieve correct unification and homogenization of the former across all Autonomous Regions | x | x | | | |
| Study into financing schemes for geothermal projects and installations in buildings | x | x | | | |
| Study into the viability of implementing a compensation system for generation of thermal energy | x | x | | | |
| Study into the development of tools to manage reservoir economics as well as the definition of reservoir evaluation and quantification codes | x | x | | | |
| **Certification (technical standardization) and Sustainability** | | | | | |
| Study into the analysis of the possibilities of preparing UNE norms regarding non-standardized installation procedures, uses of technology, etc. | x | x | | | |
| Conducting Life Cycle Analyses (LCA) at geothermal facilities | x | x | | | |
| **Best practices** | | | | | |
| Analysis of existing documentation and definition of essential contents that should constitute a code on best practices | x | x | | | |
| **Geothermal facility registry** | | | | | |
| Analysis into the possibility of developing an effective Spanish geothermal facility registry as well as defining the structure thereof. | x | x | | | |
| **Proposals for amendments within the legislation** | | | | | |
| **Regulatory framework** | | | | | |
| Draft recommendations for the implementation of measures aimed at boosting technological advances within the field of geothermal energy | | | x | x | |
| Provide advice to the Administration on the development of an adequate regulatory framework that fits sector needs (RITE, CTE, Mining Act, etc.) | | | x | x | |
| Draft a proposal to implement the necessary regulatory instruments to provide the sector with as thorough information as possible on geothermal energy | | | x | x | |
| Development of a pilot program to study critical aspects surrounding the current legislative system in the field of geothermal energy | | | x | x | |
| **Compensation framework / Subsidies** | | | | | |
| Preparation of a proposal aimed at revising compensation to electricity production from geothermal sources | | | x | x | |
| Draft a proposal to design a compensation framework that is specific to the production of thermal energy from renewable sources | | | x | x | |
| **Certification (technical standardization) and Sustainability** | | | | | |
| Preparation of specific technical norms relative to the different geothermal technologies | | | x | x | |
| Preparation of Life Cycle Analysis (LCA) protocols adapted to geothermal facilities | | | x | x | |
| **Best practices** | | | | | |
| Preparation of a Code of Best Practice | | | x | x | |
| **Geothermal facility registry** | | | | | |
| Draft a proposal to create a registry of geothermal facilities and develop the necessary software. | | | x | x | |
| Creation of an integrated geothermal information management service across Autonomous Regions | | | x | x | |