



# Barriers, Opportunities and RD&D needs for geothermal energy

Update 2018 / 2019

March 2019

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GEOHERMICA D7.2

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geothermal energy

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## **GEO THERMICA**

### **Accelerating the deployment of geothermal energy in Europe**

#### **Why geothermal energy in Europe?**

One of Europe's key challenges is to increase the share of renewable energy for heating and cooling, industrial processes, power generation and energy storage. Geothermal energy is a clean, low footprint and continuously available energy resource, and well positioned to substantially contribute to a safe and secure energy supply in Europe.

#### **Why GEO THERMICA?**

The ERANET Cofund GEO THERMICA is striving to accelerate the deployment of geothermal energy in Europe. The GEO THERMICA consortium brings together national and regional funding bodies that pool their resources to support an accelerated innovation and application of geothermal energy in Europe.

Today GEO THERMICA combines the financial resources and know-how of 18 geothermal energy research and innovation programme owners and managers from 14 countries and regions, which organizes joint calls, enables strategic actions and stimulates the creation of an interconnected and well-coordinated network.

For more information on GEO THERMICA: [www.geothermica.eu](http://www.geothermica.eu).

*Always use colours when printing this report. This is essential for legibility.*

## Executive summary

GEOTHERMICA is a consortium of European funding organisations, that aims to accelerate the deployment of geothermal energy in Europe. The consortium acts through the establishment of joint funding schemes and joint coordination activities. In this report, GEOTHERMICA publishes research development and demonstration (RD&D) priorities along with cross-cutting issues, as identified by the various national and regional funding agencies. The conclusions will be used to shape the GEOTHERMICA work programme until the end of its operational period (December 2021) and beyond.

The report is based on input from the different member countries and regions. Every participant in GEOTHERMICA has listed its key RD&D priorities and its Barriers and Opportunities for deployment of geothermal energy. Significant common ground between the various participating countries and regions exists. This means that there are several opportunities for cross-fertilization and joint progress within the consortium.

It is important to underline that the markets in the various GEOTHERMICA countries and regions are in different phases of maturity. GEOTHERMICA members have different market demands, policy instruments, investments and innovation approaches. To create an effective market, governmental policies (legislation, geological and typically also financial instruments) have to be in place. Collaboration throughout Europe on barriers and opportunities, and on stimulating innovation will support emerging and mature market developments.

There are three key conclusions. Firstly, GEOTHERMICA’s strategic thematic scope has been reaffirmed as an essential approach to direct future innovation actions.

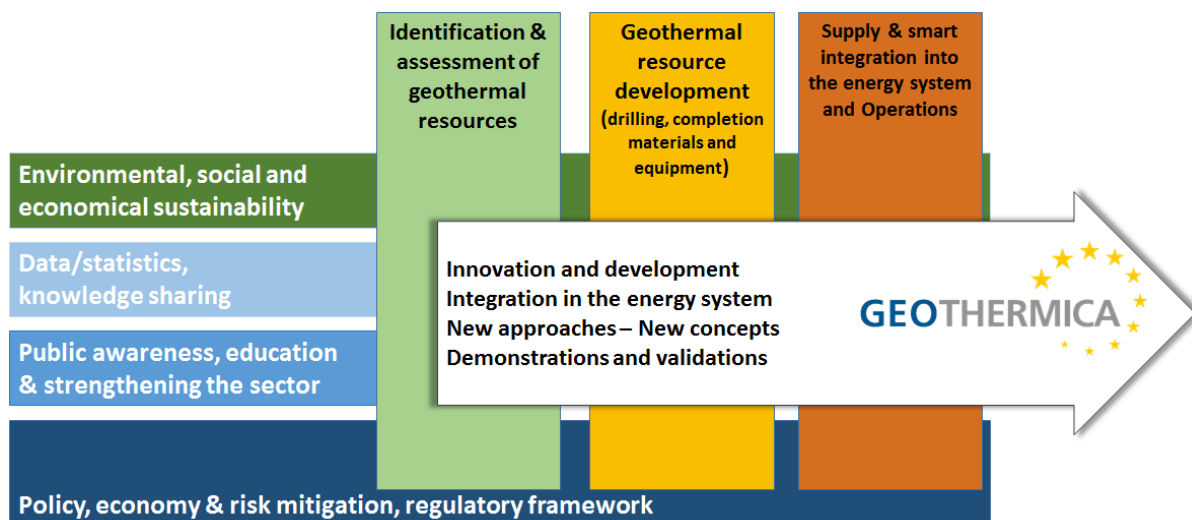


Figure 1 GEOTHERMICA thematic concept

The second conclusion is that GEOTHERMICA’s strategic thematic priorities align very well with the priorities identified in the Strategic Energy Technology (SET) Plan Implementation Plan for Deep Geothermal.

Finally, the individual specific priorities per research theme offer opportunities for further collaboration. This may be between countries/regions with a similar market structure or countries/regions and with similar topical interests. To develop effective cross European collaboration, targeted coordination with other relevant European and international organisations is

required. These include for example the implementation working group (IWG) for the SET Plan Deep Geothermal implementation plan, the European Geothermal Energy Council (EGEC), and the Joint Programme on Geothermal Energy of the European Energy Research Alliance (EERA JP GE).

GEOHERMICA will organize a round table meeting to discuss the insights of this report and guide future activities. The insights of the round table will be offered to the IWG Deep Geothermal. In the short term, GEOHERMICA will use the results in this report to define the 2<sup>nd</sup> joint Call (2019).

## **Acknowledgements**

This document is a deliverable of the GEOTHERMICA project, which has received funding from the European Union's Horizon 2020 Programme for Research, Technological Development and Demonstration under Grant Agreement (GA) Nb #731117.

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## Acronyms and Abbreviations

Especially in the Figures in this report, a number of frequent phrases are abbreviated to improve legibility

DG-IP	Deep Geothermal Implementation Plan, part of the SET Plan
DH, DH&C	District heating, District heating and cooling
EERA JP GE	European Energy Research Alliance, Joint Programme Geothermal Energy
EGEC	European Geothermal Energy Council
EGS	Enhanced Geothermal Systems
ESP	Electrical Submersible Pump
GT, GtE	Geothermal, Geothermal energy
IWG DG	Implementation Working Group Deep Geothermal, implements the DG-IP

NECP	National Energy and Climate Plan
PoS	Probability of Success
RD&D needs:	Research, Development & Demonstration Needs
RE, RES:	Renewable Energy, Renewable Energy Sources
SET Plan:	Strategic Energy Technology Plan of the European Commission
THMC	Thermo-Hydro-Mechanical-Chemical

## **Abstract**

This report describes the RD&D needs, Barriers and Opportunities for geothermal development in countries and regions participating in GEOTHERMICA. The funding organisations participating in GEOTHERMICA have identified national or regional needs. The report defines common ground, and also relates the current needs to the existing GEOTHERMICA thematic concept. The insights will be guide future work of GEOTHERMICA.

# 1 Introduction

Geothermal energy is a renewable energy that is available everywhere below our feet, but the properties of the subsurface, and access to immediate markets, make some locations more attractive than others for commercially viable production of geothermal power, geothermal space heating, process heating, space cooling, energy storage or a combination of them. The overall aim of GEOTHERMICA is to increase the number of locations where geothermal energy can be utilized in a cost-competitive way throughout Europe, and thus contribute to the aims of the Energy Union and the SET Plan Deep Geothermal Implementation Plan (DG-IP). GEOTHERMICA aims at direct use and power generation from geothermal resources in an optimized way, which includes integrated and combined systems (e.g. heat pumps, other forms of renewable energy, and using the underground as a heating and cooling energy storage site).

The ambitions of the countries and regions represented in GEOTHERMICA fit with the European strategy. In 2015, the European Commission launched the Energy Union, which aims to make energy more secure, affordable and sustainable. The Energy Union is centered on five closely related and mutually reinforcing dimensions. Two of them are related to sustainability of energy sources, namely ‘decarbonising the economy’ and ‘research, innovation and competitiveness: supporting breakthroughs in low-carbon and clean energy technologies’<sup>1</sup>.

The Strategic Energy Technology (SET) Plan has been the research and innovation pillar of the EU's energy and climate policy since 2007. It was revised in 2015 to effectively line up with the EU's Energy Union research and innovation priorities<sup>2</sup>. Both the Energy Union and the SET Plan recognize the importance of renewable energy and related technologies including geothermal energy.

## 1.1 Geothermal energy in GEOTHERMICA countries

Status and policies on geothermal energy differ considerably across GEOTHERMICA countries and regions. Several countries or regions have high enthalpy (=hot subsurface temperatures) resources suitable for commercially viable power production. Other GEOTHERMICA countries focus on direct utilization of geothermal heat from medium-low enthalpy reservoirs. In countries with high enthalpy resources, the power production from geothermal is often combined with the significant direct utilization of heat. This supports the transfer of know-how between from high to medium/low enthalpy regions.

EGEC, the European Geothermal Energy Council<sup>3</sup>, publishes an annual report on status and prospects of the geothermal energy sector throughout Europe. This provides a helpful insight into the different markets for geothermal energy in the GEOTHERMICA countries. The earlier Geothermal ERANET executed a more in-depth review of status and policy of geothermal energy, which was published in 2013<sup>4</sup>. This provided a helpful insight into the different markets for geothermal energy in the GEOTHERMICA countries. A more recent 2017 EGEC report shows the following installed capacities for geothermal energy<sup>5</sup>:

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<sup>1</sup> <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/building-energy-union>

<sup>2</sup> For more information, see <https://ec.europa.eu/research/energy/index.cfm?pg=policy&policyname=set>

<sup>3</sup> [www.egec.org](http://www.egec.org)

<sup>4</sup> Breembroek, Dijkshoorn, Ramsak, Geothermal energy status and policy review, dec. 2013, <http://www.geothermaleranet.is/publication/deliverables-/D2.1>

<sup>5</sup> 2017 EGEC Geothermal Market report, key findings, June 2018, downloaded from [www.egec.org](http://www.egec.org)

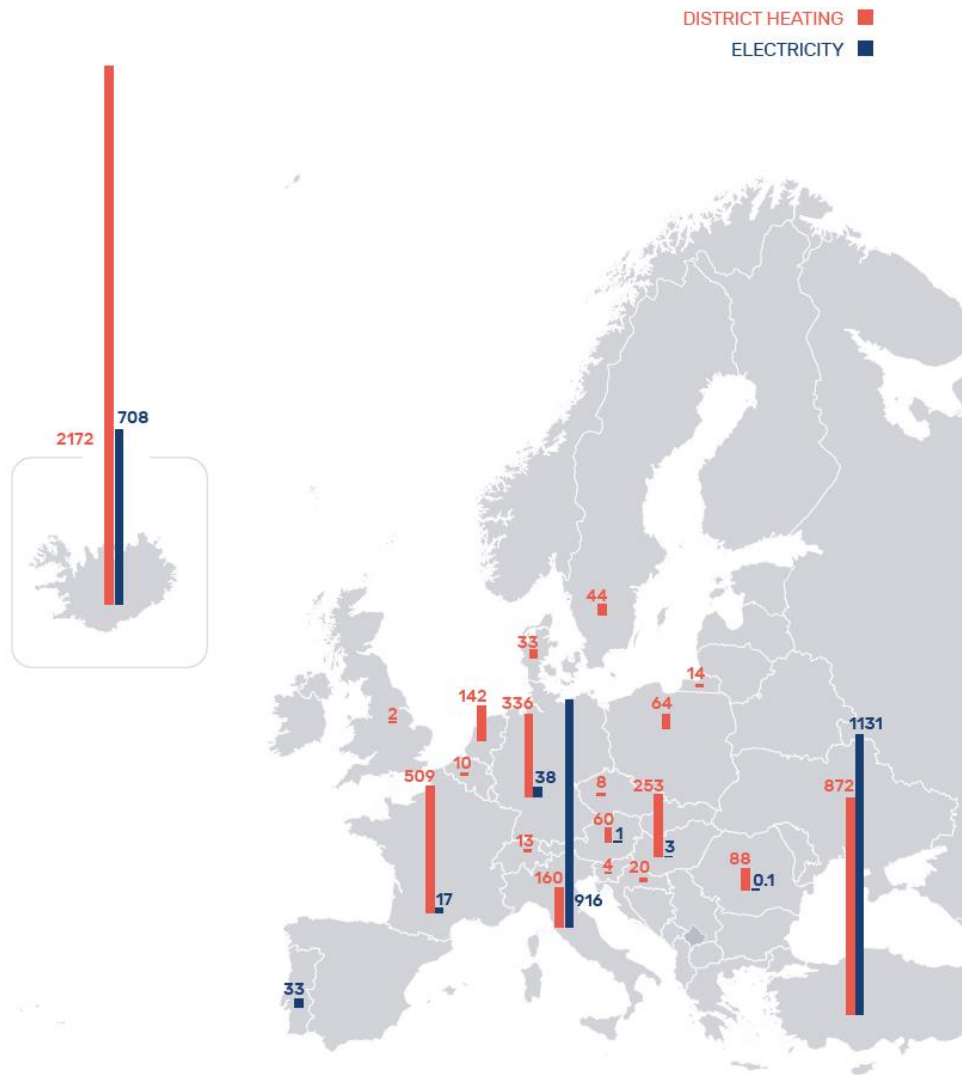


Figure 2. Installed geothermal capacity (MW) for both district heating/direct utilization (orange) and power production (blue). Source: 2017 EGEC Geothermal market report

From Figure 2, the large variations in markets are immediately clear. There are three countries in Europe with a significant electricity production from geothermal: Turkey (1131 MW), Italy (916 MW) and Iceland (708 MW). Concerning district heating, Iceland is the frontrunner with more than 2172 MW installed capacity, and Turkey is the next in line with 872 MW. Countries with more than 100 MW direct use capacity further include France, Germany, Hungary, Italy and the Netherlands. Countries with lower installed capacity, but an interest in developing geothermal energy include Portugal and Azores, Denmark, Flanders, Ireland, Romania, Slovenia, Spain<sup>6</sup> and Switzerland.


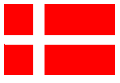

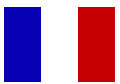


The EGEC 2017 report also gathered data on expected development in Europe. Regarding geothermal power production, the Turkish market is viewed as the most dynamic. Its growth in 2017 was high, and further significant growth is expected, with potentially a doubling of the current number of geothermal power plants to a total of more than 100 plants. Also, significant numbers of power plants are expected to be added in Italy, Germany, France, Iceland, Switzerland, Romania, and various other countries throughout Europe. When it comes to direct utilization of geothermal heat, dynamic growth

<sup>6</sup> Spain has a significant use of heat pumps, which leads to an estimated capacity of 180 MW for geothermal energy, when including shallow applications.

is expected in Germany, the Netherlands, Lithuania, Poland, Switzerland and several other European countries.


The countries and regions that collaborate within GEOTHERMICA are the Azores, Denmark, Flanders, France, Germany, Iceland, Italy, Ireland, the Netherlands, Portugal, Romania, Slovenia, Spain, Switzerland, and Turkey. A brief characterization of the geothermal market and the national targets for 2030/2050 is presented in the table below.

**Table 1 Geothermal market and national targets for geothermal energy in GEOTHERMICA countries and regions**



Geothermal market and national targets in GEOTHERMICA countries and regions			
Country/region		Market	National/regional/sector targets 2030/2050 <sup>7</sup> ; also from NECP draft documents <sup>8</sup>
Azores		Three geothermal power plants supply over 25% of the Azores electricity.	11.5 MWe of geothermal power capacity to be installed before 2023. The 2030 Azorean Energy Strategy is under development and envisages an increase in geothermal electricity and heat.
Denmark		Geothermal for district heating	With the 2018 Energy Agreement, new green solutions and technologies such as geothermal energy are promoted. No specific mentioning of capacity. In NECP draft 2-4% by heat pumps and geothermal.
Flanders		Starting market with major research-related Balmatt site, in Mol	Flemish Energy Plan projects 0.6 TWh for geothermal energy in 2030. The national energy and climate plan mentions 0.05 TWh (ten times less).
France		Dynamic market for geothermal power production, but direct use dominates the market, in particular the extensive Paris network	Targets for France mainland are set at 24 MWe in 2023-2028. Targets in the non-interconnected areas are set at 100 MWe over the same period. For direct use the masterplan aims at producing 2.9 TWh <sub>th</sub> in 2023 and 4-5.2 TWh <sub>th</sub> in 2028.
Germany		Slow but growing dynamic market for direct use. Power production in most cases as by-product. Projects often driven by municipal suppliers.	Biggest potential in the heat sector (district heating). Geothermal can be major player for the “heat transition”. No national sector targets, but in some cases local/regional initiatives set targets (e.g. Munich area).
Iceland		Leading geothermal country worldwide, both for direct use and for power production	Iceland is a closed energy market with over 99% of energy for electricity and heating coming from renewable sources (mainly Hydro and

<sup>7</sup> Expressed either in MW or in GWh. 1000 MWe will translate into 8 TWh<sub>e</sub>/yr for year-round operation. Direct-use applications will have fewer operational hours. Depending on the length of the heating season, 1000 MW<sub>th</sub> will translate into somewhere between 1.5-5 TWh<sub>th</sub>/yr.

<sup>8</sup> <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans>

			Geothermal). Any new development in geothermal is directly linked with new energy users entering the market.
Italy		First geothermal power plant built – Larderello, 1904. Leading geothermal country, mainly in power production.	Italian Geothermal Association forecasts: <u>2030</u> : installed capacity for <i>electricity</i> of 1140 MW <sub>e</sub> (≈ 6.7-7.3 TWh <sub>e</sub> /yr) and <i>heat</i> of 3650-4250 MW <sub>th</sub> (≈ 8.2 TWh <sub>th</sub> /yr) <u>2050</u> : installed capacity for <i>electricity</i> of 2000 MWe (≈ 13-16 TWh <sub>e</sub> /yr); and <i>heat</i> of 8,100-11,350 MW <sub>th</sub> (≈ 14.8-21 TWh <sub>th</sub> /yr) National climate plan is much more modest and foresees growth of 130 MW <sub>e</sub> (power) and 0,3 TWh <sub>th</sub> (heat) until 2030.
Ireland		Starting market, without any installations at this stage.	Two district heating systems in development, plan to supplement with geothermal heat. National roadmap in development – to be completed by end 2019.
Netherlands		Young market focused on direct use, mainly for greenhouses. Expansion to district heating expected.	The sector's "Masterplan aardwarmte" (2018) <sup>9</sup> envisages 14 TWh <sub>th</sub> /yr in 2030 (tenfold today's market) and 55 TWh <sub>th</sub> /yr in 2050 at various temperature levels.
Portugal		Mainland Portugal shows an emerging market, exhibiting a couple of installations at this stage, as well as plans for a district heating integrated project including thermal baths and space conditioning for a village. Power production: 0.17 TWh in 2016 – see Azores for power product.	Portugal's NECP 2030, Dec 2018, up to 2040: <u>Power</u> : Geothermal in the category 'other RES' which is expected to have 2,8% of annual growth.. Overall RES growth is 500 MW/year; <u>Heating&amp;Cooling</u> : Expected RES-based heat uses: ca 23 TWh <sub>th</sub> /yr.
Romania		Good resources and a dozen district heating networks on geothermal in operation.	The increase of 45 TWh of Renewable Energy Sources is equal allocated to wind, geothermal and photovoltaic energy, which double from 20 TWh in 2030 to 44 TWh in 2050.
Slovenia		Few applications for district heating and greenhouse heating	Aerothermal, geothermal and hydrothermal are mentioned as important sources of renewable heat in the NECP (dec. 2018). No specific targets for geothermal.
Spain		Starting market without any installations at this stage. Volcanic islands part of the country (Canary Islands)	The technological platform on geothermal energy envisages the installation of 14 MW of power production in the Canary Island by flash technology.

<sup>9</sup> <https://kennisbank.ebn.nl/en/master-plan-geothermal-energy-in-the-netherlands-2018/>

Switzerland		Dynamic but starting market, both for direct use and power production.	No binding targets for geothermal and any other form of energy; a non-binding goal is to have by 2020 4.4 TWh of power from (new) renewables and 11.4 TWh by 2035. Similar non-binding goals exist for energy and electricity use.
Turkey		Very dynamic market, both for power production and direct use. Possibility to become Europe's largest.	Studies over new incentive systems are continuing. Proper incentive systems are planned to be implemented after 2020. 2030 target is revised to the value of 4.000 MW.

## 1.2 Aim of this report

The GEOTHERMICA consortium brings together national and regional funding bodies that pool their resources to support an accelerated implementation of geothermal energy in Europe, mainly through organizing joint calls, but also in additional ways. Work package 7 “knowledge, strategy and support” supports these aspirations through:

- Exchanging information, knowledge and good practices related to geothermal energy research and innovation policies between the national and regional funding bodies.
- Developing a coordinated strategy to build a durable and long-lasting European research and innovation cooperative for the development of geothermal energy.
- Implementing the strategy via joint activities and programs aimed at coordinated research, innovation and market support for uptake of geothermal energy.

This report aims to support GEOTHERMICA’s strategy by identifying national/regional Barriers and Opportunities for the development of geothermal energy and national/regional RD&D needs. The main benefit of this exercise is the simplified identification of common areas of interest (clusters) and thus possible cooperation partnerships. Countries can easily identify other nations with (i) similar needs, (ii) those countries, which have already reached the next level in the development of geothermal energy and are therefore attractive partners to learn from. Based on the results, strategic recommendations on short- and medium-term priorities in research and innovation will be formulated. This includes recommendations for country working groups, where countries in an early development stage for geothermal energy can discuss issues, join forces on specific topics and can learn from more experienced countries how barriers can be overcome. This forms the foundation for a lasting cooperation agenda between the participating countries. An alignment and a coordinated agenda with the Deep Geothermal Implementation Plan within the framework of the SET-Plan Agenda 2018-2023 will maximize synergies to support the EU SET-Plan.

The previous Geothermal ERANET, that was a predecessor to GEOTHERMICA, has published a set of similar reports. In this update, all GEOTHERMICA partners have been included, and research priorities, barriers, and opportunities have been updated in broad terms.

After the publication of this report, GEOTHERMICA will discuss the findings with other European stakeholders for geothermal energy at a round table meeting. One of the aims of the meeting will be to optimize alignment and coordination on the various priorities and actions.



## 2 Rationale and methodology

This report brings together national ‘Barriers and Opportunities’ as well as ‘RD&D needs’ for geothermal energy from all countries and regions that participate in GEOTHERMICA. The report serves as a basis for future joint activities of GEOTHERMICA, for example future joint calls or additional activities.

The principal elements of this report are two overviews per GEOTHERMICA partner related to current national or regional priorities for the implementation of geothermal energy: one on Barriers and Opportunities, and one on RD&D needs. GEOTHERMICA partners have identified these priorities during the summer of 2018. Each GEOTHERMICA partner decided how: some worked in consultation with relevant parties in their countries, and others worked from their own observation or based on their national RD&D program.

The Barriers, Opportunities and the RD&D needs were analysed and clustered by all participants in a workshop at the GEOTHERMICA project meeting in Bucharest, Romania, September 2018. At the workshop, some countries added additional items. Countries/regions supplying their priorities in advance of the clustering workshop were AZ (The Azores), CH, DE, ES, FL (Flanders), IE, IS, NL, PT and RO. During the clustering workshop, FR, IE and TR put forward their priorities. DK, SI and IT provided information later in the process. The ten-bullet lists of countries/regions that supplied their priorities in advance of the workshop are available as an Annex to this report (restricted access).

In some countries/regions, the scope of the geothermal programmes is limited to the ‘deeper’ subsurface, while in others such programmes are scoped such that they include ground source geothermal heat pumps. The reader is reminded that GEOTHERMICA focuses on geothermal energy for direct use and power generation, but includes integrated and combined systems that combine geothermal with e.g. heat pumps, heat storage, or other forms of renewable energy. However, in countries where all geothermal research and innovation activities are joined in one programme, priorities necessarily include some that are only relevant for shallow applications.

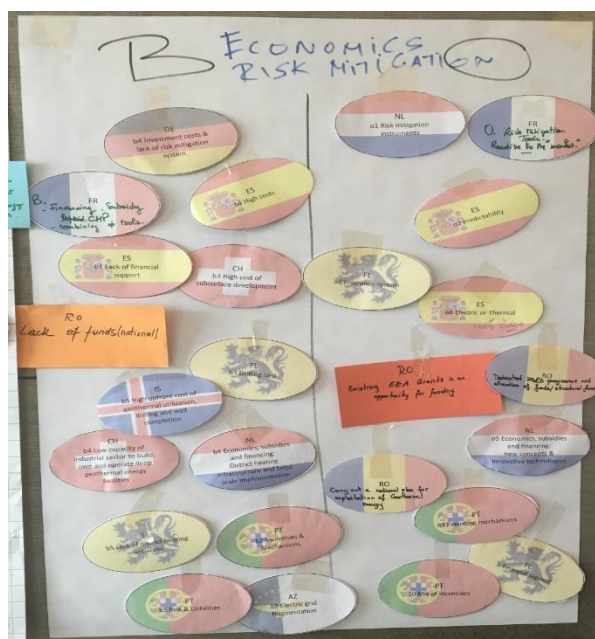


Figure 3 Example of a feedback during the clustering workshop Bucharest, Romania (2018)



This report presents the identified clusters grouped around the thematic priorities of GEOTHERMICA. The thematic priorities are the synthesis of a previous action in the framework of the earlier Geothermal ERANET<sup>10 11 12</sup>.

GEOTHERMICA has identified the following strategic thematic priorities (Figure 4):

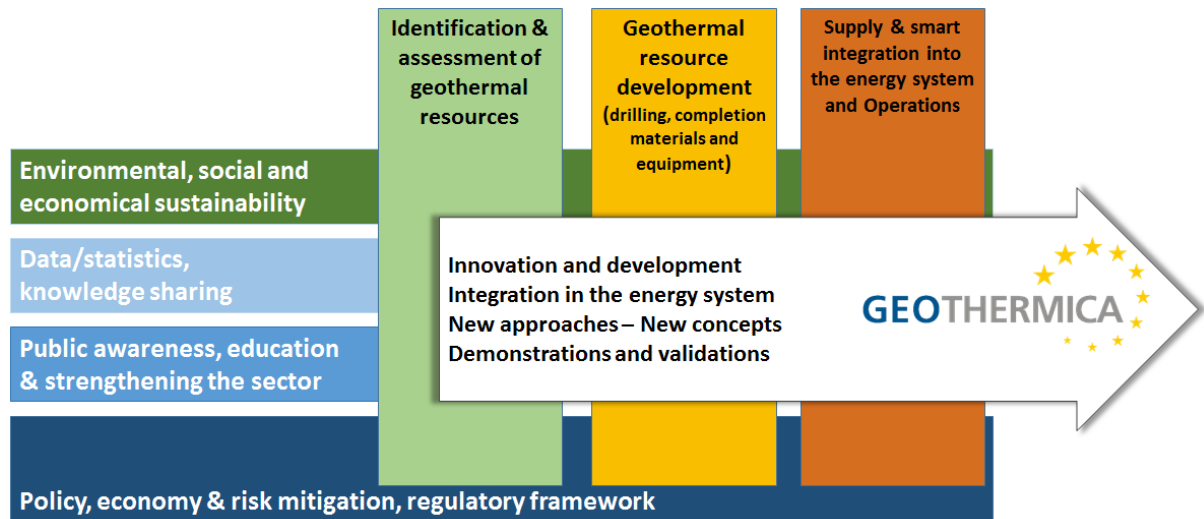


Figure 4 GEOTHERMICA technical and non-technical priorities

The GEOTHERMICA thematic priorities are pictorially arranged in three columns and four rows. The four rows across reflect various non-technical *cross-cutting issues* that are important factors for the implementation of geothermal energy into the energy system:

- Environmental, social and economic sustainability
- Data/statistics, knowledge sharing
- Public awareness, education & strengthening the sector
- Policy, economy & risk mitigation, regulatory framework

The three columns reflect the various *technical challenges* for geothermal energy projects;

- Identification and assessment of geothermal resources
- Geothermal resource development (drilling, completion, including materials and equipment)
- Supply and smart integration into the energy system and operations

The arrow in the middle illustrates the focus of the GEOTHERMICA activities. Innovation, new concepts and demonstration are crucial for an increased uptake of geothermal energy in the European energy system. The technical and non-technical priorities support the development of ‘new concepts’. They need to be in place in order to increase the use of this geothermal resource.

<sup>10</sup> Technical and non-technical barriers and Opportunities, Geothermal ERANET 291866 D2.3, Ramsak, Breembroek, Manzella, Trumphy, sept. 2014, <http://www.geothermaleranet.is/>

<sup>11</sup> RD&D needs, Geothermal ERANET 291866 D2.4, Schreiber, Richter, Ramsak, Breembroek, sept. 2014, <http://www.geothermaleranet.is/>

<sup>12</sup> Actions to bridge gaps, overcome barriers, and promote the use of geothermal energy in Europe, Geothermal ERANET 291866 D2.5, Ramsak, Breembroek, nov. 2014, <http://www.geothermaleranet.is/>

The subchapters in chapter 4 reflect each of the individual GEOTHERMICA thematic priorities (the cross-cutting issues and the technical challenges) in terms of their aspects related to ‘barriers and opportunities’ and ‘research, development and deployment’. The current priorities identified in the 2018 Bucharest workshops are in this way linked to the thematic areas that GEOTHERMICA defined at its start. The results are also compared to the outcome of the Deep Geothermal Implementation Plan<sup>13</sup> (DG-IP) in terms of ‘research & innovation activities’ and ‘non-technical barriers and enablers’ (see subsequent chapter 3). We take note of differences in the analyses that result from GEOTHERMICA’s bottom-up national and regional survey of funding organizations and that of the stakeholders that have developed the DG-IP. Where material (large enough to cause contrarian plans and implementations) differences exist, GEOTHERMICA will address those with the principal stakeholders of the Deep Geothermal Implementation Working Group via its Support Unit.

The individual specific priorities per research theme offer opportunities for further collaboration at a bilateral or multi-lateral level. This may be between countries/regions with a similar market structure or countries/regions and with similar topical interests. To forward and stimulate such collaborations, the GEOTHERMICA consortium has also prepared a matrix with the various interests by country, which is part of the Annex to this report (restricted availability).

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<sup>13</sup> [https://setis.ec.europa.eu/system/files/setplan\\_geoth\\_ip.pdf](https://setis.ec.europa.eu/system/files/setplan_geoth_ip.pdf)

### 3 The SET Plan Deep Geothermal Implementation Plan (DG-IP)

The Strategic Energy Technology Plan (SET Plan)<sup>14</sup> of the European Commission aims to accelerate the development and deployment of low-carbon technologies. There are 10 priorities, and technology leadership in renewable energy is one of them. Deep geothermal (as opposed to shallow geothermal) is one of the technologies that is of strategic importance, within this theme. The Deep Geothermal Implementation Plan<sup>15</sup> (DG-IP), that has been agreed between the members of the working group<sup>16</sup>, and endorsed by the SET Plan Steering Committee January 2018, sets out eight ‘research and innovation activities’, two ‘non-technical barriers/enablers’, and two cross-cutting issues:

#### R&I priorities:

1. Geothermal heat in urban areas
2. Materials, methods and equipment to improve operational availability (high temperatures, corrosion, scaling)
3. Enhancement of conventional reservoirs and deployment of unconventional reservoirs
4. Improvement of performance (conversion to electricity and direct use of heat)
5. Exploration techniques (including resource prediction and exploratory drilling)
6. Advanced drilling/well completion techniques
7. Integration of geothermal heat and power in the energy system and grid flexibility
8. Zero emission power plants

#### Non-technical barriers/enablers

1. Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions
2. Risk mitigation (financial/project)

#### Cross-cutting issues

1. Knowledge transfer and training
2. Recommendation of an open-access policy to geothermal information

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<sup>14</sup> <https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan>

<sup>15</sup> [https://setis.ec.europa.eu/system/files/setplan\\_geoth\\_ip.pdf](https://setis.ec.europa.eu/system/files/setplan_geoth_ip.pdf)

<sup>16</sup> Composition of the Temporary Working Group

[https://setis.ec.europa.eu/sites/default/files/20171113\\_twg\\_composition\\_geothermal.pdf](https://setis.ec.europa.eu/sites/default/files/20171113_twg_composition_geothermal.pdf)

These themes can be shown in a graphic representation, similar to the GEOTHERMICA thematic areas presentation.

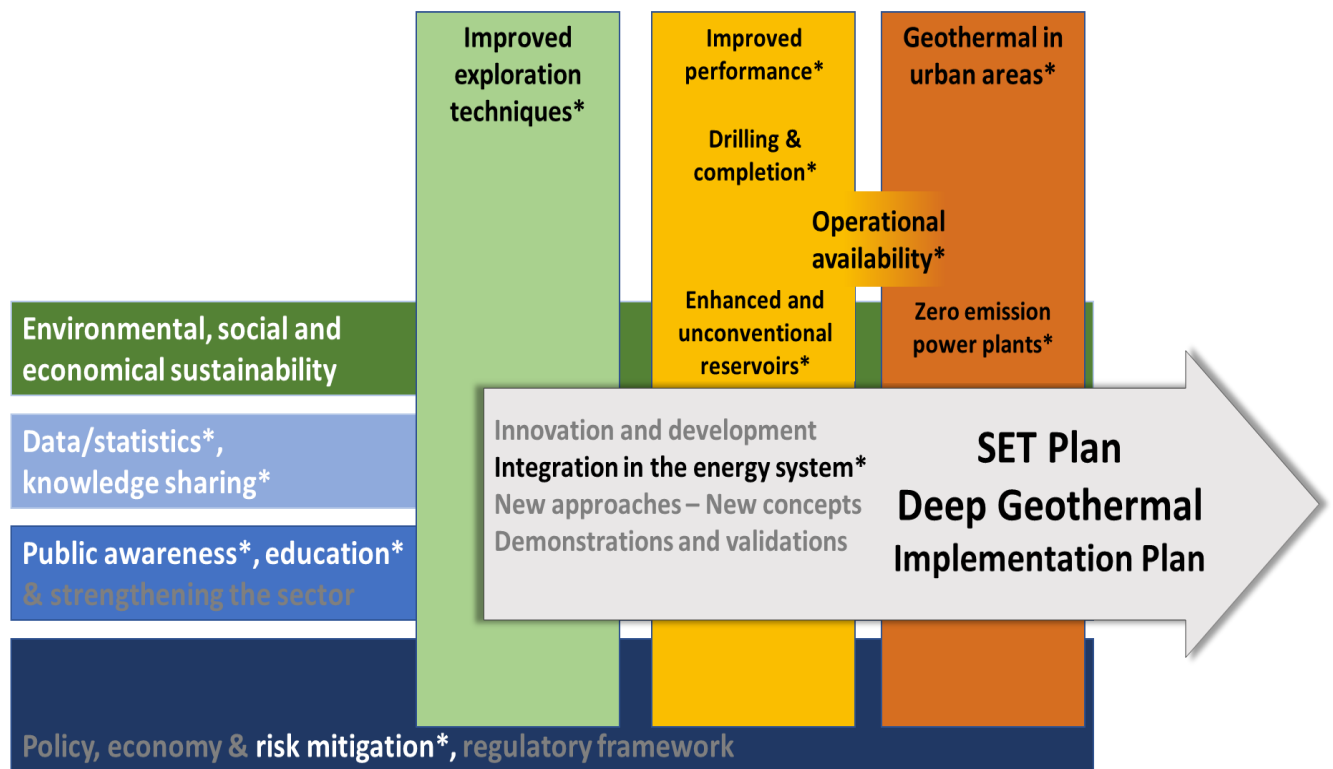


Figure 5 SET Plan Deep Geothermal priorities presented as in GEOTHERMICA thematic areas

The Figure shows that the SET Plan DG-IP and the GEOTHERMICA thematic priorities are highly complementary with significant common ground concerning the development of geothermal energy in Europe.

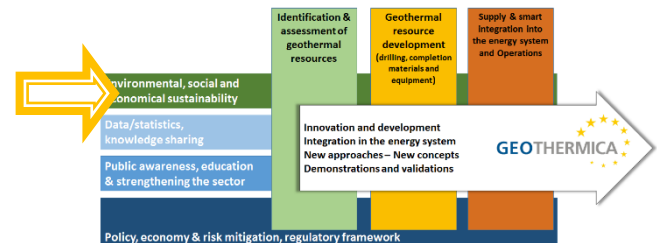
The priorities of the SET Plan DG-IP can easily be connected to the GEOTHERMICA thematic priorities. Within the SET Plan priorities, there is attention for identification and assessment (green column), resource development (yellow column) and integration into the energy system (orange column). Also, the GEOTHERMICA cross-cutting themes are mentioned as important DG-IP non-technical barriers and enablers.

## 4 Barriers & Opportunities and RD&D Needs

For each GEOTHERMICA strategic theme the barriers, opportunities and RD&D needs will be discussed in this chapter. Per theme conclusions will be stated and a potential link with the DG-IP will be discussed.

### 4.1 Thematic priority: Environmental, social and economic sustainability

The first cross-cutting theme in the GEOTHERMICA thematic areas is ‘Environmental, social and economic sustainability’. This underlines that any geothermal energy project needs to be environmentally, socially and also economically sustainable.



There are three clusters identified within this thematic priority, one in Barriers and Opportunities, two in RD&D needs.

#### 4.1.1 Barriers & Opportunities

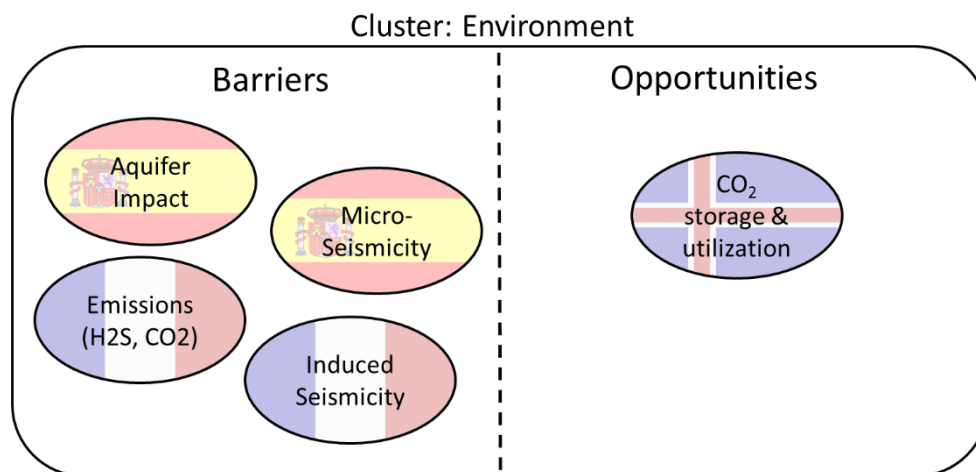


Figure 6 Barriers and Opportunities: Environment

The Barriers and Opportunities cluster ‘Environment’ identifies a limited number of issues, such as impact of geothermal on aquifers, emissions of non-condensable gases, induced seismicity and microseismicity. Induced seismicity/microseismicity is addressed more thoroughly in Section 4.6.1. In countries with pressures on usable water systems e.g. Spain, there is a concern related to the potential impact of geothermal development on aquifers and/or stricter regulations in this field.

An environmental opportunity is also identified. Geothermal exploration increases knowledge of the subsurface, which in turn can open the door for CO<sub>2</sub> capture, storage and utilization (CCS & U) projects in a variety of geological settings. The storage of CO<sub>2</sub> in the subsurface, or the utilization of (co-produced) CO<sub>2</sub> for other products offers an opportunity for geothermal projects to provide additional revenue streams and reduce the environmental impact of the energy system. In Iceland, these options are demonstrated in the prominent “Carbfix” project<sup>17</sup>. However, these technologies have to be adapted for different geological settings.

<sup>17</sup> [www.carbfix.com](http://www.carbfix.com)

#### 4.1.2 RD&D Needs

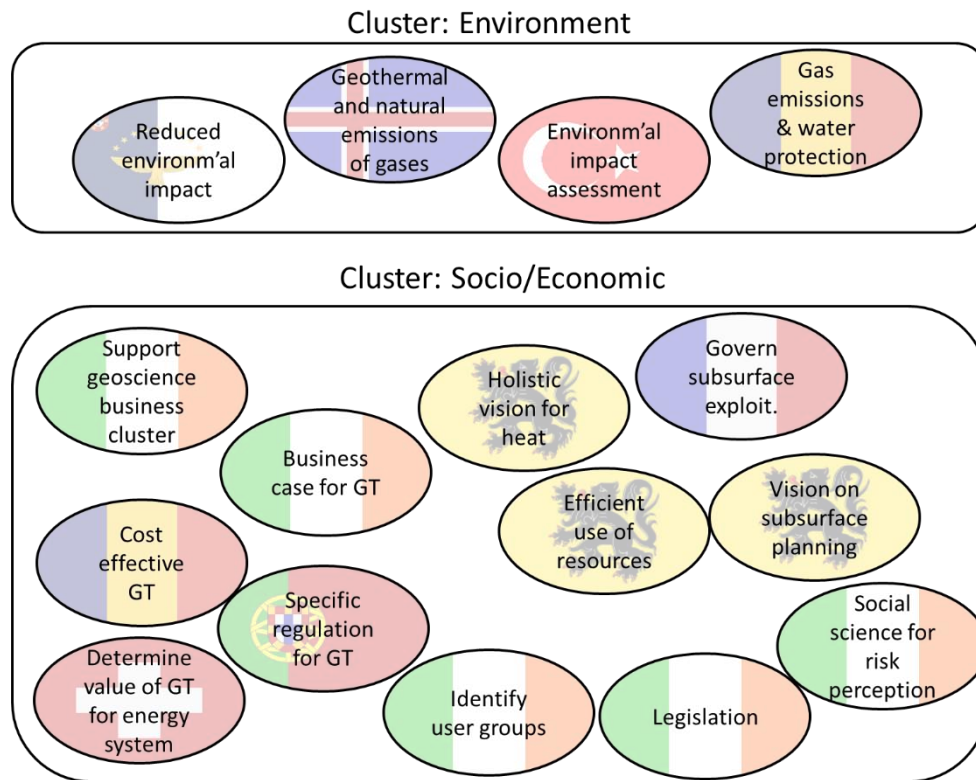


Figure 7 RD&D needs: Environment and Socio/economic

The RD&D needs of the ‘Environment’ cluster largely mirror the identified Barriers and Opportunities. Essentially, two priorities are mentioned: research to improve control and mitigation of associated (naturally occurring, non-condensable) gas emissions from geothermal operations, and methodologies to measure and reduce the environmental impact of the geothermal operations. Geothermal utilization can decrease greenhouse gas emissions but in some geological settings, the emission management strategies for co-produced gases are important, also for the life cycle analysis of geothermal systems.

The ‘socio-economic’ cluster covers a wide spectrum of research needs. Historically, the value of geothermal energy was illustrated using a ‘levelized cost of heat/electricity’. Today, the focus shifts to identifying and describing the value of geothermal energy within an appropriately scaled energy system; capturing and quantifying benefits related to energy system services, to the internalization of environmental costs and benefits, to employment benefits etc., and the business opportunities that result. An emerging theme relates to spatial planning of the subsurface and on surface e.g. modelling and identification of key parameters that influence decision making processes for geothermal zones with respect to planning and development of district heating networks is useful.

Citizens of Europe are increasingly concerned with the impact of energy projects on their way of life and on occasion perceive such projects to be threats to their well-being. Geothermal energy projects in particular are often perceived as “risky undertakings” despite the lack of evidence of excessive risks. There is a need to understand and develop strategies that address perceptions (which may, or may not, be based on factual evidence).

### 4.1.3 Link to DG-IP and other relevant actions

Environmental and socio-economic sustainability is an important cross-cutting issue. Common ground exists between the DG-IP in the field of ‘research & innovation activity’ 8 (Zero Emission Power Plants - particularly for stakeholders from Industry, FR, IS, IT, PT and TR. Here, the DG-IP proposes dedicated industry funds, national funding programs, a number of Horizon2020 calls<sup>18</sup> and funding mechanisms for demonstration projects, such as the Innovation Fund<sup>19</sup>.

GEO THERMICA will continue to expect successful projects in GEO THERMICA Calls to contribute to the relevant crosscutting, non-technological themes. However, owing to the focus of GEO THERMICA’s calls on research and innovation related to technical challenges, calls will not address topics related to environmental and socio-economic sustainability in an exclusive manner.

Beyond that, GEO THERMICA has also identified topics to address DG-IP’s ‘non-technical barrier and enabler’ NTBE-A (Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions). Specific topics related to Health, Safety and Environment in general, and to the social dimension of managing induced seismicity in particular will benefit from GEO THERMICA’s focus on technical challenges. The benefit derives from the expectation that novel technology-based processes and tools will contribute to a project’s ability to obtain social licenses-to-operate.

This is particularly relevant to stakeholders of the DG-IP from the geothermal industry, FR, IS, IT, PT and TR. DG-IP proposes the following vehicles to address research and innovation needs in the following manner: national funding programs (incl. public & private contributions), possibly combined in bi- or multilateral projects. Germany, Portugal, Switzerland, Netherlands, France and Iceland estimate that around €4.5 million need to be allocated to this topic. Italy has indicated a potential investment of €8 million for work to be undertaken. The Deep Geothermal Implementation Working Group has also identified a pan-European approach via a GEO THERMICA call, which would also trigger a participation of the European Commission to the tune of € 8.5 million.

In summary, GEO THERMICA is in agreement with the DG-IP and aims to continue the support of research and innovation that lowers barriers and strengthens enablers. In addition, GEO THERMICA will use its convening power to improve the management of induced seismicity risk; be it through coordinated planning for research and innovation, coordinated piloting and demonstrating of new management techniques, and common approaches to regulation and regulatory oversight.

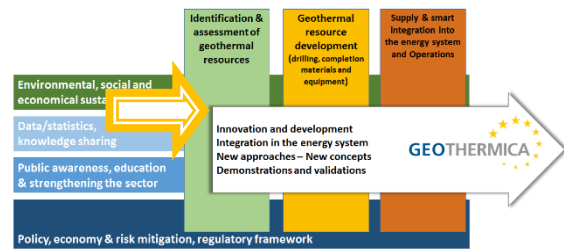
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<sup>18</sup> One such example is GEO-ENVI <https://www.egec.org/h2020-geoenvi-project/>, a H2020 funded project that addresses environmental concerns for deploying geothermal energy in Europe

<sup>19</sup> Innovation Fund of European Commission, first call for projects expected in 2020: [https://ec.europa.eu/clima/policies/innovation-fund\\_en](https://ec.europa.eu/clima/policies/innovation-fund_en)

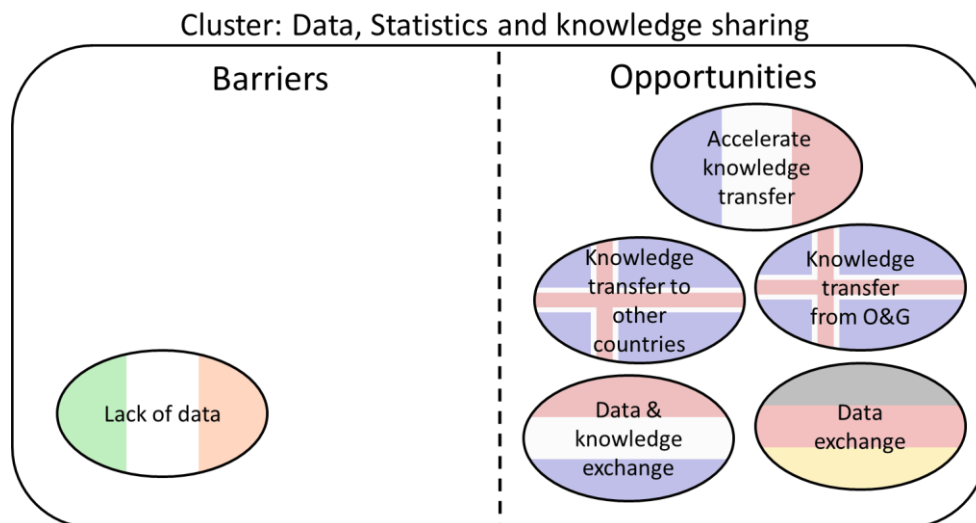
## 4.2 Thematic priority: Data/ statistics, knowledge sharing

The second cross-cutting theme in the GEOTHERMICA thematic areas is ‘Data/ statistics, and knowledge sharing’. This underlines that progress in geothermal energy project development is only possible if there is sufficient availability of data and transfer of knowledge.



As discussed below within ‘Data/statistics, knowledge sharing’, there are two related clusters, one in Barriers and Opportunities, one in RD&D needs. Other issues related to data (more focused on subsurface questions) are mentioned in the technical innovation theme ‘Identification & assessment of geothermal resources’ and described in paragraph 4.5.1.

### 4.2.1 Barriers & Opportunities



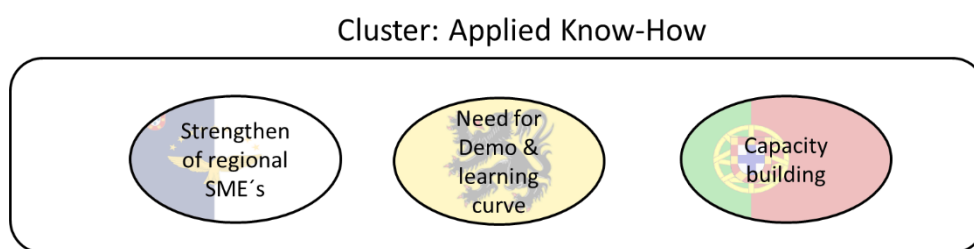
**Figure 8 Barriers and Opportunities: Data/statistics and knowledge sharing**

Within the cluster of knowledge sharing and statistics, better sharing of exploration and exploitation data within the geothermal sector, but also from the oil and gas industry, and the minerals industry, is an opportunity for the geothermal sector. European countries have different levels of geological knowledge and geothermal expertise due in parts to different regulatory situations and the different exploration status. Therefore international knowledge exchange by research and industry players in the field has a high potential to overcome those barriers and issues, which have already been solved in other countries. International cooperation presents an obvious opportunity to develop knowledge, ideas, partnerships and relevant commercial projects. GEOTHERMICA’s efforts in establishing a platform dedicated to identifying, compiling and addressing ‘issues during geothermal operations’ via OpERA<sup>20</sup> is a case. GEOTHERMICA’s additional activities can help capture an opportunity to improve knowledge transfer beneficial to the geothermal sector.

<sup>20</sup> See OpERA publications on <http://www.geothermaleranet.is/publication/reports/>



## 4.2.2 RD&D Needs



**Figure 9 RD&D Needs: Applied know-how**

Though not RD&D in a strict sense, there is a need for bringing together and sharing know-how, in particular in countries and regions with a less well-developed market. A learning curve to increase the technical and operational geothermal skills and capacities of regional SME's is needed in various GEOTHERMICA countries. As international cooperation brings together countries with a long geothermal history and countries where this technology is still at the beginning, sectorial organization such as Iceland's GEORG cluster serves as a practice worth replicating. Recently, the GEO-ENERGY EUROPE metacluster was established<sup>21</sup>, which unites 'geothermal clusters' across Europe, each of which can be a national or regional group of organizations with a common interest in geothermal energy.

Progress on experience and learning curves in experienced countries may be readily accelerated by fostering knowledge exchange. Some countries still need a successful demonstration of the geothermal technology, also in terms of economic viability, to attract subsequent projects that further develop the sector.

## 4.2.3 Link to DG-IP and other relevant actions

Data, statistics and knowledge sharing is an important cross-cutting issue. The ongoing GEOTHERMICA additional activities 'JoProdat' and 'JoProShow' address one of the identified needs at least on the level of national funding bodies; namely to have a better international knowledge exchange on existing progress and projects. The database 'JoProShow' (joint project showcase) will become available in spring 2019 through [www.geothermica.eu](http://www.geothermica.eu). A further consequence is the set-up of shared platforms such as OpERA (operational issues for geothermal energy) that will be launched in the course of 2019.

Also, there are several other organizations that share knowledge on geothermal energy, such as the IEA Geothermal with its working groups<sup>22</sup>, the International Partnership for Geothermal Technology and its working groups, the International Geothermal Association<sup>23</sup>, ThinkGeoEnergy<sup>24</sup> and very important for Europe, EGEC<sup>25</sup>, and EERA JP GE<sup>26</sup>. A number of efforts are underway to enhance the technology transfer between geothermal and the upstream oil and gas sector, as well as gas (CH<sub>4</sub>,

<sup>21</sup> <https://www.clustercollaboration.eu/escp-profiles/geo-energy-europe>

<sup>22</sup> <http://iea-gia.org/>

<sup>23</sup> <https://www.geothermal-energy.org/>

<sup>24</sup> <http://www.thinkgeoenergy.com/>

<sup>25</sup> [www.egec.org](http://www.egec.org)

<sup>26</sup> <https://www.eera-set.eu/eera-joint-programmes-jps/list-of-jps/geothermal/>

CO<sub>2</sub>, H<sub>2</sub>) storage sector, such as the 2019 3<sup>rd</sup> Hydrocarbon Geothermal Cross-over Technology Workshop<sup>27</sup>

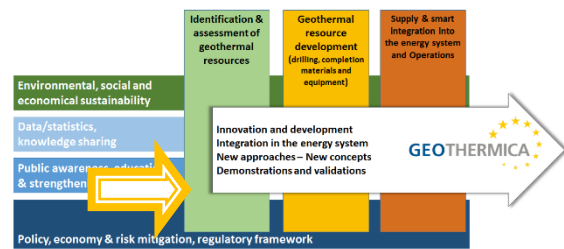
Concerning the availability of subsurface data, regulations (Section 4.4) might offer the best opportunities for addressing this barrier. GEOTHERMICA recognizes that legal issues themselves have to firstly be resolved at a national level to enable the concept of data exchange. In parallel to regulatory work, GEOTHERMICA recognizes that in terms of Earth science data relevant for geothermal energy, GEO-ERA has launched a number of projects (MUSE, HotLime, GeoConnect3d)<sup>28</sup>, and EPOS<sup>29</sup>(European Plate Observing System) also brings together European researchers and databases on the subsurface structure. GEOTHERMICA can help by establishing specific links between countries with similar geological settings. GEOTHERMICA and GEO-ERA have established communication channels through GEOTHERMICA’s Irish partner and the Irish and Swiss partners are also representatives in EPOS.

While there is no direct linkage and no explicit mention of this point in the Deep Geothermal Implementation Plan, GEOTHERMICA’s take-up of this topic does address a larger need.

### 4.3 Thematic priority: Public awareness, education & strengthening the sector

The third cross-cutting theme in the GEOTHERMICA thematic areas is ‘Public awareness, education & strengthening the sector’. Education and public awareness are enablers for the development of the geothermal sector.

Within this cross-cutting thematic area we have identified Barriers and Opportunities around ‘public awareness’ and ‘education’.



<sup>27</sup> <https://www.eiseverywhere.com/ereg/index.php?eventid=353866>

<sup>28</sup> <http://geoera.eu/projects>

<sup>29</sup> <https://www.epos-ip.org/>

### 4.3.1 Barriers & Opportunities

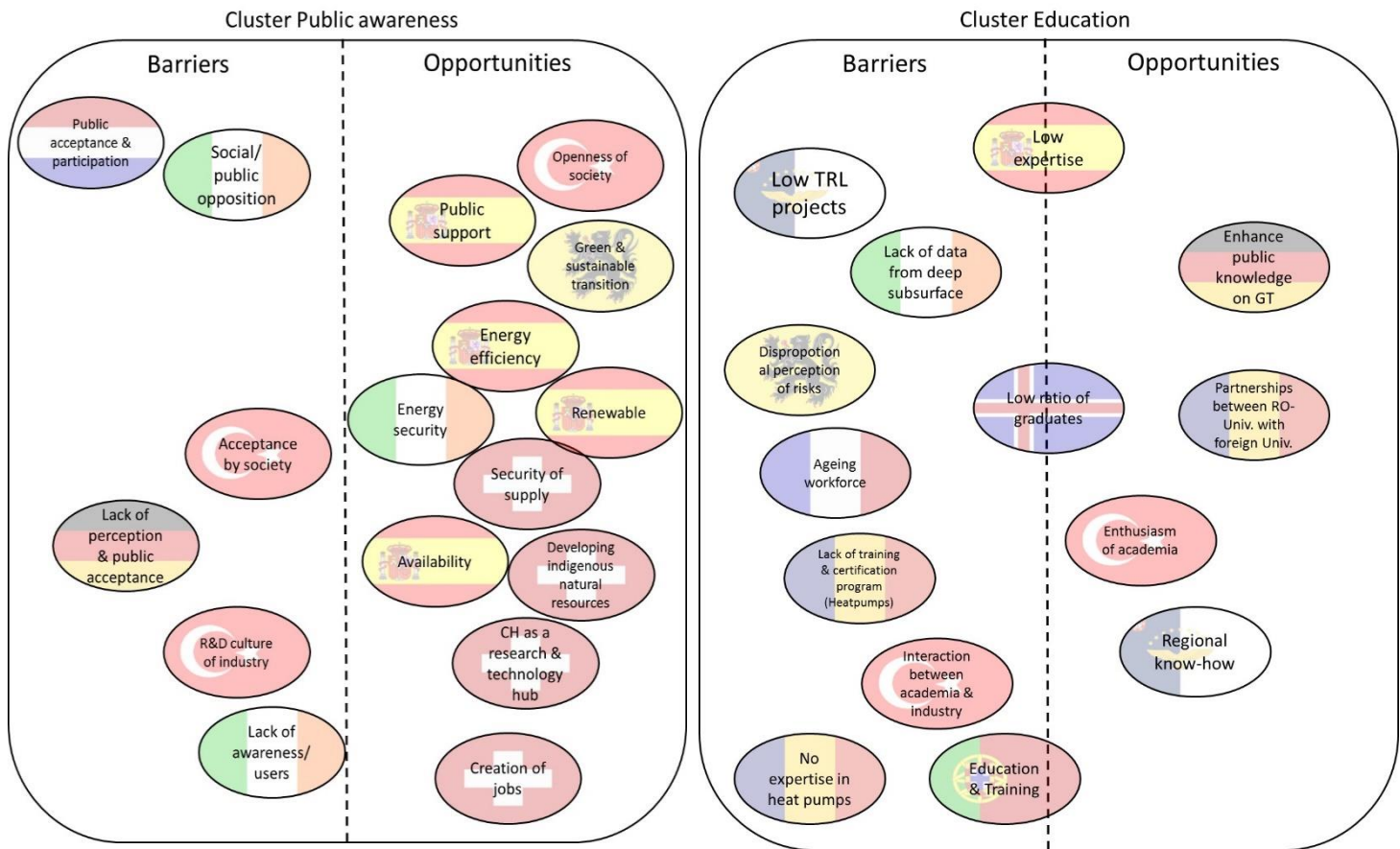


Figure 10 Barriers and Opportunities: Public awareness and education

Many countries identify public awareness and support as crucial enablers. ‘Developing indigenous natural resources’; ‘security’; ‘green and sustainable transition’; which, if communicated well can support the development of the technology. Concerning barriers, there is the lack of awareness and the threat the public support might evaporate with perceived negative incidents. Ensuring a dialogue on benefits and concerns is an important part of all geothermal project development.

The other cluster that is identified as relevant is ‘Education’. It addresses the development of a knowledgeable and well educated geothermal workforce and the education of other stakeholders e.g. end-users, policy makers, and politicians. Sometimes, issues are viewed both as barriers and as opportunities. The levels of knowledge are different across Europe, countries and regions. Knowledge differences are also mentioned between research and commercial activities. There is an opportunity to improve the interaction between academia and industry.

The issue of educating other stakeholders is closely related to the “Public Awareness” cluster. If the general information of geothermal energy and the applied technologies can be shared with communities, the general knowledge of the benefits of geothermal can be enhanced. This will allow a better assessment of the risks and the perception of risks compared to the benefits by each citizen and will balance a possible negative perception of the technology.

### 4.3.2 Link to DG-IP and other relevant actions

Public awareness, education and strengthening the sector remain important cross-cutting issues, recognized in many GEOTHERMICA countries and regions. The DG-IP identifies non-technical barrier/enabler (NTBE) A ‘Increasing awareness of local communities, and involvement of stakeholders in sustainable geothermal solutions’ within this theme. Also, it identifies ‘Knowledge transfer and training’ and ‘Open-access policy to geothermal information’ as important cross-cutting issues. The latter issues relate to capacity building and cooperation in academic and professional training, efficient use of the pan-European ‘Geo Energy Test Beds’<sup>30</sup>, and facilitating access to geothermal information in Europe.

This is a broad theme with many aspects to it. From the perspective of GEOTHERMICA, education should not only be directed to (future) professionals and the general public, but also politicians and policy makers should be educated concerning geothermal energy.

Concerning public awareness, the challenge is to assess the nature of social and environmental concerns, and elements that influence the perception on geothermal energy. Progress in this area will be a combination of socio-economic understanding and influencing of the risk and benefit perception, but also of technical progress through improved risk management. At the same time, public awareness has a strong national or regional character, and a national or regional approach to public awareness is always required. Addressing public awareness issues could be a mandatory part of any subsidized demonstration project, and e.g. Germany has good experiences with such an arrangement. Behavioural scientists in funded projects could be very beneficial, depending on project scope.

A trans-national knowledge exchange on public acceptance and risk perception was organized by the Geothermal ERANET<sup>31</sup>. The report of this workshop also highlights European activities by e.g. EGEN on this theme. As already mentioned in section 4.3.1, the DG-IP NTBE A reserves significant investments for forwarding ‘[...] involvement of stakeholders in sustainable geothermal solutions’. Of particular note is Italy’s contribution of € 8 million on this topic, through the Tuscany “Geothermal Compensation Funds”. Only municipalities in the Tuscany region can profit from those funds, but there can be European benefit in spreading the learnings.

Concerning education and training, the cross-cutting theme in DG-IP mentions capacity building and knowledge transfer as important topics. There are Various existing programmes for academic mobility can support this, e.g. Marie Curie, Erasmus etc.. The International Geothermal Association publishes extensive information on training possibilities for geothermal on their website<sup>32</sup>. In addition, training and education possibilities were collected within the Geothermal ERA-Net<sup>33</sup>.

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<sup>30</sup> <https://www.epos-ip.org/data-services/community-services-tcs/geo-energy-test-beds-low-carbon-energy>

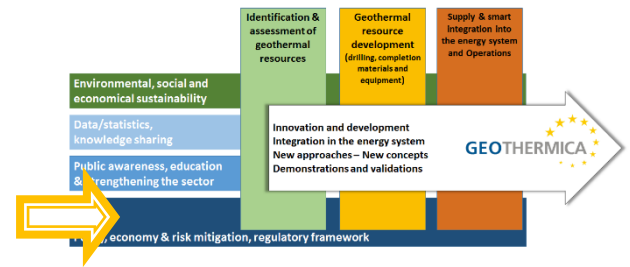
<sup>31</sup> <http://www.geothermaleranet.is/media/publications-2015/Geothermal-ERA-NET-JA-PR-Geo.pdf>

<sup>32</sup> <https://www.geothermal-energy.org/education/courses/global-geothermal-courses/>

<sup>33</sup> [http://www.geothermaleranet.is/media/publications-2015/Geothermal-ERA-NET-D6\\_1-Report-with-an-Inventory-of-Existing-Mobility-and-Training-Programmes-NT.pdf](http://www.geothermaleranet.is/media/publications-2015/Geothermal-ERA-NET-D6_1-Report-with-an-Inventory-of-Existing-Mobility-and-Training-Programmes-NT.pdf)

## 4.4 Thematic priority: Policy, economics, risk mitigation and regulatory framework

The fourth cross-cutting theme in the GEOTHERMICA thematic areas is ‘Policy, economy & risk mitigation, regulatory framework’. Policies, risk mitigation and regulatory frameworks guide the development of the geothermal sector. ‘Risk mitigation’ relates to the mitigation of the risks of geothermal to the investor.



Within this cross-cutting GEOTHERMICA theme we have identified three clusters of Barriers and Opportunities. The clusters are centered on ‘policy’, ‘economy & risk mitigation’ and ‘regulatory framework’. We have not identified specific RD&D needs as a priority in the involved countries and regions.

### 4.4.1 Barriers & Opportunities

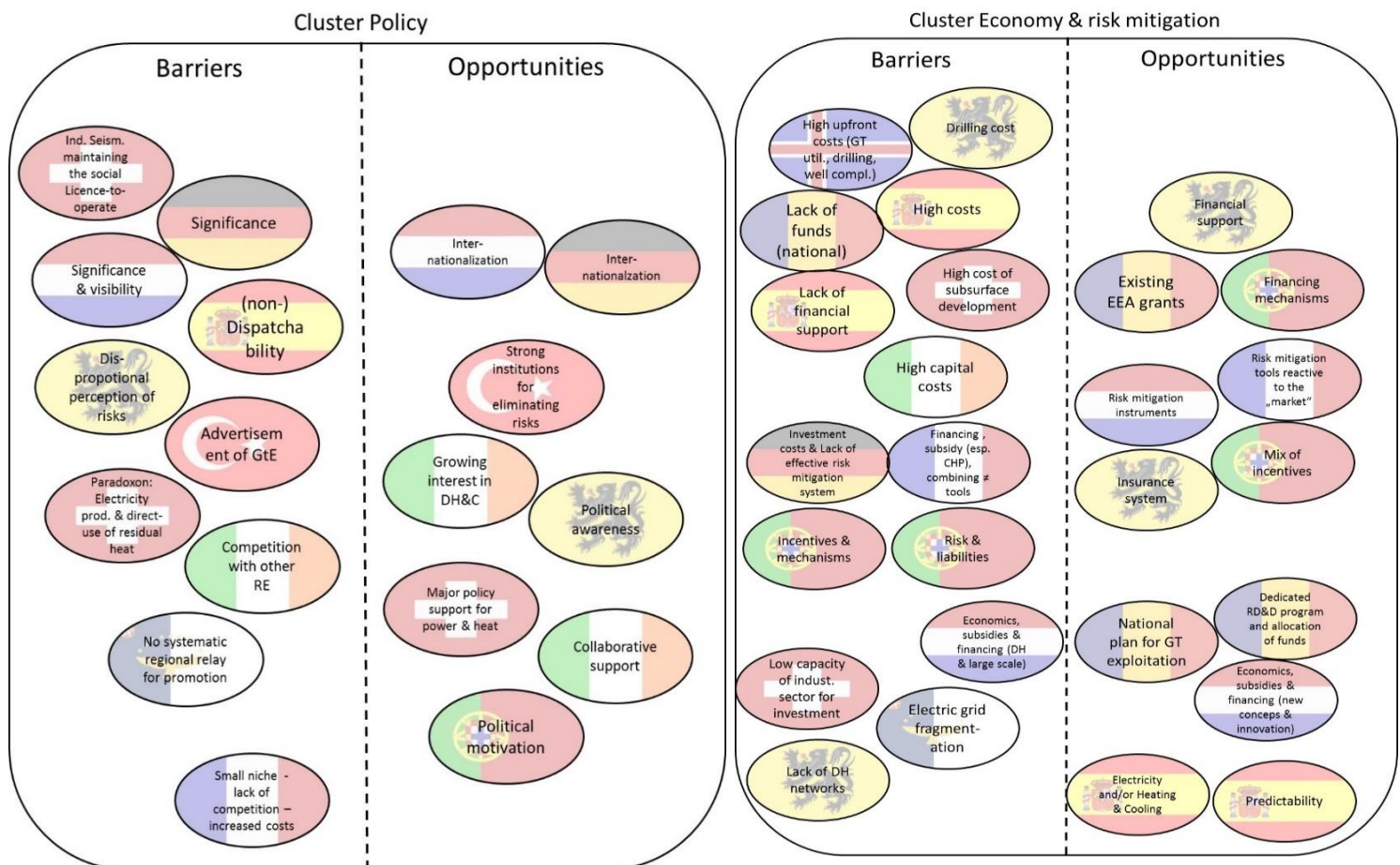


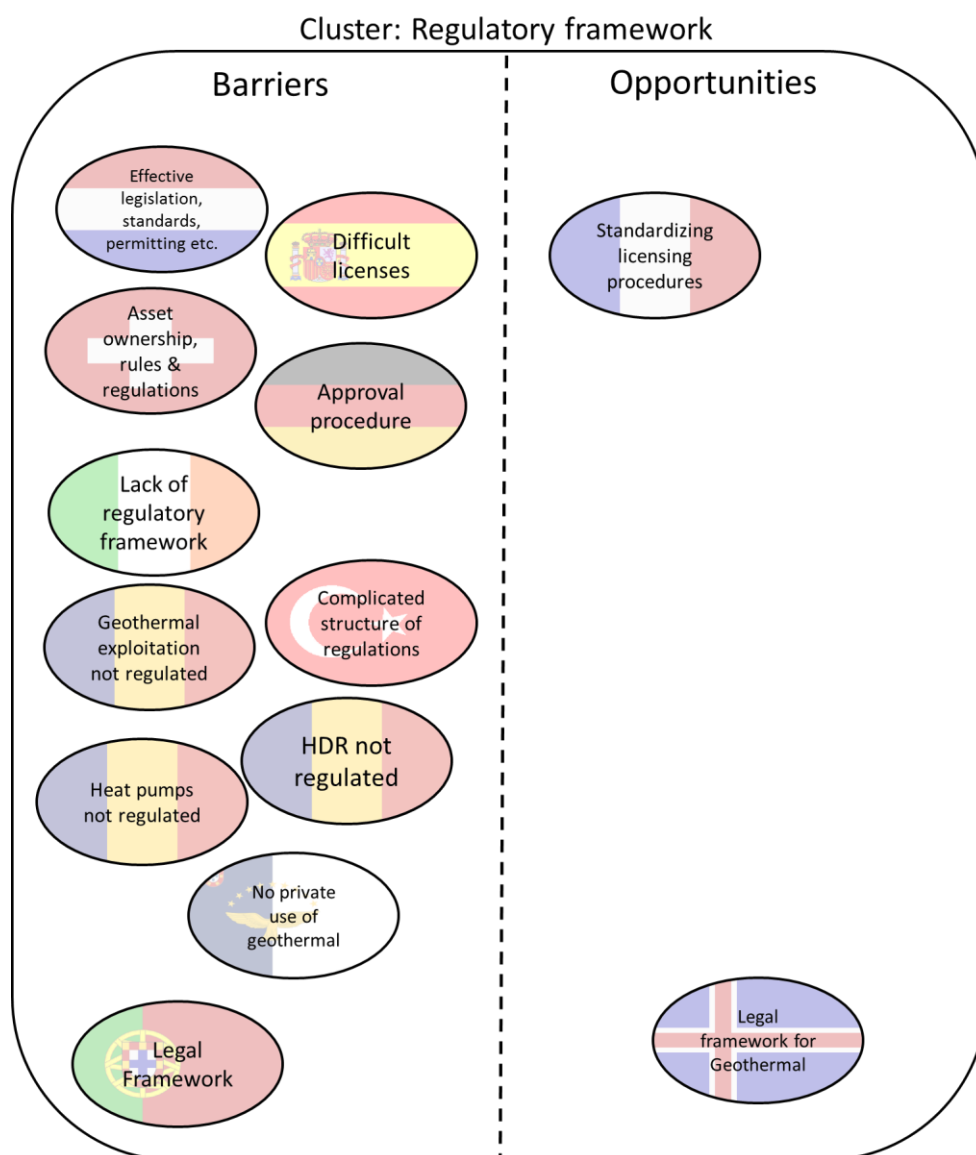
Figure 11 Barriers and Opportunities: Policy, Economy & risk mitigation

The first cluster ‘Policy’ addresses various topics. Significance and visibility of the geothermal sector is often mentioned, both as a barrier and as an opportunity. In many countries, politicians and policy makers play a significant role in the growth of the renewable energy sector. Geothermal energy is often a small sector with few visible installations, and therefore, political and policy support tends to



be low. However, in various countries and regions a growing interest in geothermal energy is noted due to local and national government response to calls for climate action. Growing interest for district heating and cooling and, more generally, the issue of heat supply presents, opportunities for direct use of geothermal energy.

The second cluster ‘Economy & risk mitigation’ brings together barriers and opportunities related to cost, availability of district heating networks, and supporting financial frameworks. The circumstances differ in the various countries. Common barriers are the high upfront investment and drilling cost. In a significant number of countries, there are instruments that promote investment in geothermal installations. In particular, risk mitigation instruments and ‘soft’ loans can enable the development of geothermal energy. Such instruments can act as insurances, in cases when the geological quality of a reservoir proves lower than expected. All financial instruments must follow new market developments, which can be viewed as a challenge and an opportunity at the same time.



**Figure 12 Barriers and Opportunities: Regulatory framework**

The third cluster focuses on the ‘regulatory framework’, which is different from country to country, and can be different from region to region. As geothermal energy is a young market in many of the

GEOHERMICA countries and regions, there is a lack of specific regulations, which may lead to long procedures, or actively deter private investment in the sector. An effective administrative procedure will provide new opportunities for the geothermal sector.

#### 4.4.2 Link to DG-IP and other relevant actions

Ultimately, a viable business case based on principles of sustainable development causes the uptake of geothermal energy. The path to a sustainable and commercially viable business proposition requires in countries without access to world-class geothermal resources, a host of measures to offset technical, economical, commercial, organizational and political/societal risks. Some of the measures to transfer risk from the project developer to the public i.e. governmental assistance to private developments are successful and plausible. Examples are supporting research and innovation, and developing legal and regulatory frameworks that are conducive for the development of a geothermal sector. In addition, there are specific circumstances, such as poor knowledge of the subsurface that may justify the transfer of exploration risk to the public, or providing other policy support to encourage the uptake of renewables in the market (feed-in premiums, heat premiums, etc.).

The need and the possibility to support the business case for renewable energy generation, is a matter that is mostly discussed at a national level. This discussion also relates to the quality of the resources. In the case of geothermal energy, it is also wise to consider instruments that address the exploration risk. The previous Geothermal ERANET organized a workshop on financing and a session on risk mitigation schemes. The GEOHERMICA partnership will be useful when reforms of the financial instruments or the regulatory framework are planned. A country working on regulatory reforms or financial instruments could contact others to discuss potential improvements through the GEOHERMICA partnership.

The DG-IP has identified ‘risk mitigation (financial/project)’ as ‘non-technical barrier and enabler’ B. The Implementation Working Group recommends such mitigation schemes to be largely executed at the national levels, including some minor investment (€1 million between 2018-2023) by industry. For pan-European efforts specific calls within the Horizon2020 framework may provide appropriate support. A case in point is the H2020 supported GEORISK project<sup>34</sup> which aims at establishing such a risk insurance scheme that covers exploration risk. GEOHERMICA has its Swiss partner participate in the GEORISK project and thus has an existing link.

Concerning the legal framework for geothermal energy, these are national or even regional issues. However, GEOHERMICA can gather good practices to highlight the issue of the legal base, for example for data exchange. Experience from other countries or regions may be shared with the relevant domestic legislative and regulatory authorities. This is particularly relevant when regulatory reforms are planned.

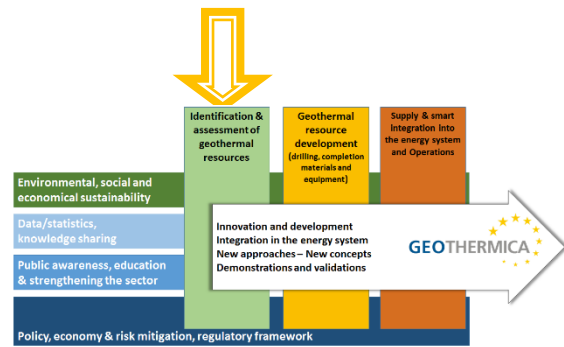
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<sup>34</sup> <https://www.egec.org/georisk-project/>

## 4.5 Thematic priority: Identification & assessment of geothermal resources

The first technical innovation theme in the GEOTHERMICA thematic areas is ‘Identification & assessment of geothermal resources’.

Within this theme, there is a large cluster of different RD&D Needs.



### 4.5.1 RD&D Needs

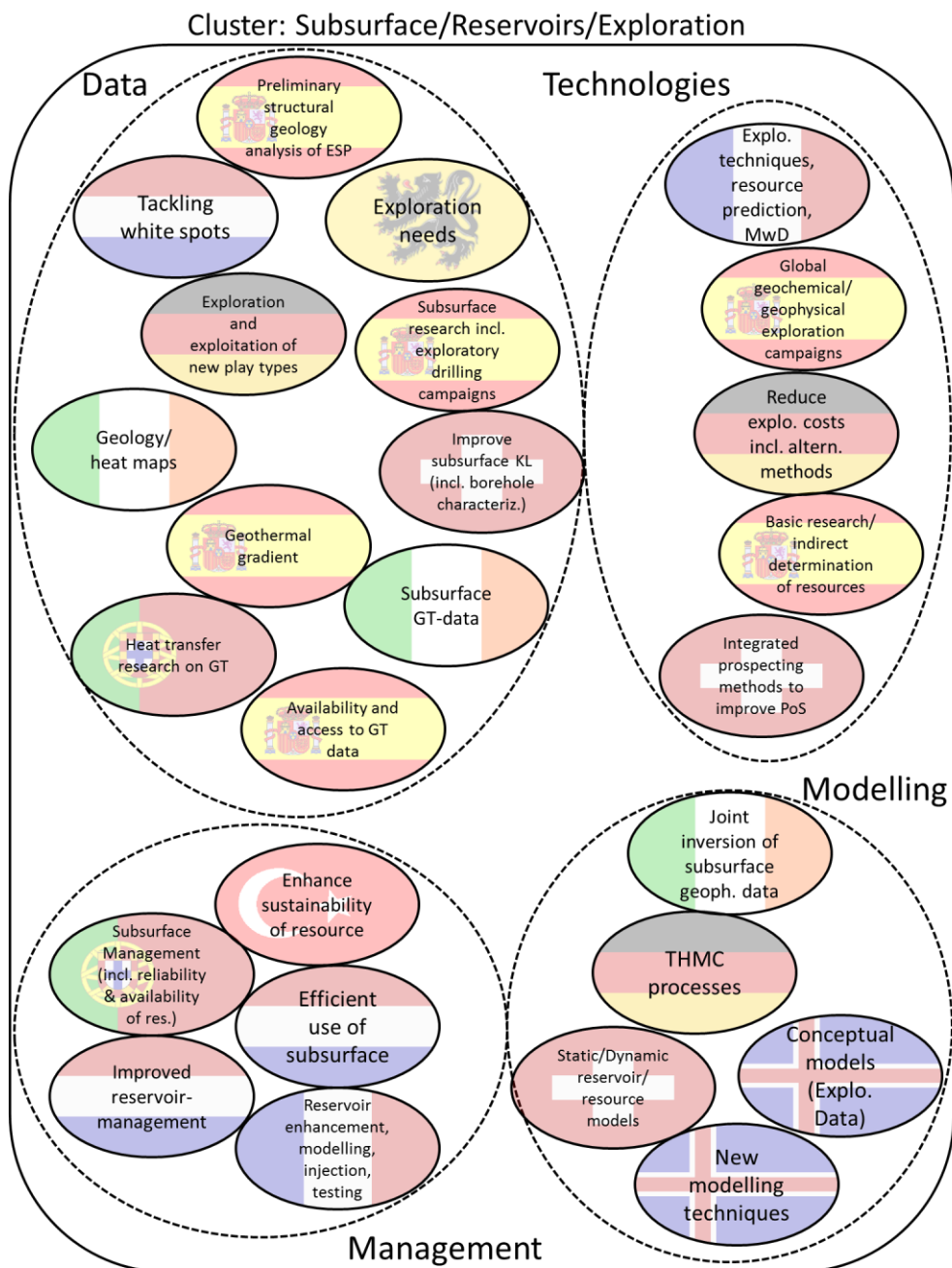


Figure 13 RD&D Needs: Subsurface/ Reservoirs/ Exploration



The various GEOTHERMICA countries report a significant number of RD&D priorities related to identification and assessment of geothermal resources. This cluster can be split in ‘data’, ‘technologies’, ‘reservoir management’ and ‘modelling’. It is abundantly clear that there is a wide spread of knowledge related to the identification and assessment of resources. Some countries have hardly begun to prospect and explore the subsurface (e.g. Switzerland, Spain, Portugal mainland), other countries seek to expand horizons (e.g. the Netherlands wishes to develop geothermal resources at depths in excess of 4000 m) and others wish to optimize use of and reduce unit technical cost of exploring and finding reservoirs (e.g. Germany, France, Iceland, Azores).

The subgroup ‘data’ within this cluster focuses on increasing the understanding of the geology / subsurface. As no geothermal project can be realized without subsurface data, these are obvious needs, for individual countries, but also across borders to cover geologically determined geothermal plays. Data issues are also linked to the cross-cutting innovation theme ‘data/statistics, knowledge sharing’ in paragraph 4.2. The collection of data for the specific needs of geothermal energy installations has to be carried out in situ. However new approaches for mapping and ‘good practices’ on national exploration campaigns are of transnational interest.

With geological data available, this technical cluster further mentions improved ‘reservoir management’, ‘technologies’ and ‘modelling’. The subgroup ‘reservoir management’ includes efficient use of the underground for different purposes, better understanding of the reservoir and optimal production conditions. Appropriate knowledge supports the efficient use of the subsurface by optimal design of an entire geothermal area/region. The cluster also addresses producing and operating reservoirs in a sustainable fashion; there is a close link to the operational cluster (Chapter 4.7).

The subgroup ‘technologies’ relates to improved or new exploration techniques, which can help to improve the probability of finding a reservoir, improve data quality and thus reduce the unit finding cost (€ / MW<sub>resource capacity</sub>).

‘Modelling’ reservoirs, be it static to derive geological models or be it dynamic to develop an understanding of a geothermal system is a vital ingredient for all stages of project maturation, from prospecting to exploration, reservoir development and the production phase. Both data acquisition suitable for model generation, computational methods required to build models, as well as history matching and forecasting reservoir behavior are at the core of modeling efforts.

We mention in passing that new technologies are key to reducing exploration, drilling and operational cost. New technologies are also linked to the development of ‘New concepts’ (Chapter 4.8).

#### **4.5.2 Link to DG-IP and other relevant actions**

The DG-IP dedicates one ‘research and innovation activity’ 5 – Exploration techniques (including resource prediction and exploratory drilling) to this technical theme. Interested countries (CH, DE, FR, IS, IT, PT), the European Commission and industry envisage a combination of sources of financing technological development relevant for this theme for the period 2018-2023. Whereas the majority is expected to be derived from national funding programs (€ 22.5 million), industry is expected to invest on the order of € 15 million, with Horizon2020 and GEOTHERMICA calls to invest €8-10 million each.

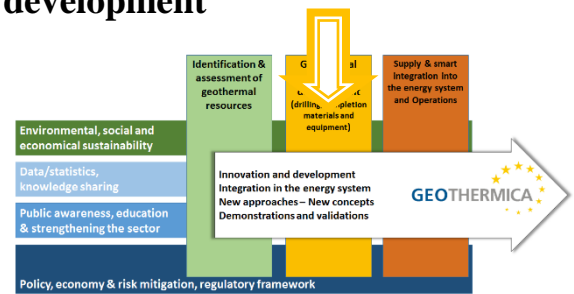
GEOTHERMICA partners see here excellent alignment between the DG-IP’s vision and that of GEOTHERMICA. In addition GEOTHERMICA perceives substantial scope for transnational

collaboration on exploration techniques and methodologies. This technical innovation theme will continue to feature explicitly in GEOTHERMICA’s future calls.

## 4.6 Thematic priority: Geothermal resource development

The second technical innovation theme in the GEOTHERMICA thematic areas is ‘Geothermal resource development’.

Within this theme, there are two clusters of different RD&D Needs. The clusters build around ‘drilling/ completion’ and ‘seismicity/ stimulation/ safety’, which also has a link to environmental sustainability, Chapter 4.1. The RD&D needs per cluster are described below.



### 4.6.1 RD&D Needs

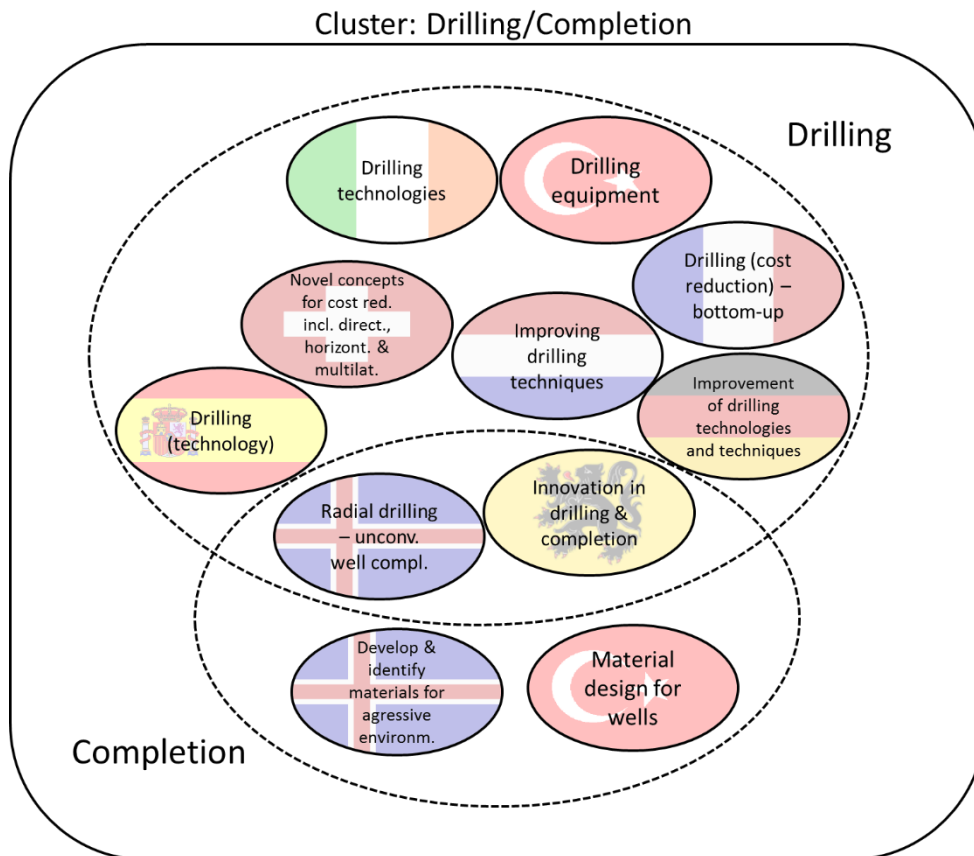


Figure 14 RD&D Needs: Drilling/ Completion

Considering drilling and completion, there is a need for improved drilling techniques shared by almost all countries collaborating in GEOTHERMICA. Improvement of well completion technologies, and the utilization of new technologies such as radial drilling for geothermal is mentioned as a focus by some countries, too. These topics address the reduction of unit drilling and completion costs (€/MWh) as well as the durability of geothermal installations in terms of work-over periods. New drilling technologies are also expected to lead to enhanced borehole stability even in complex geological settings.

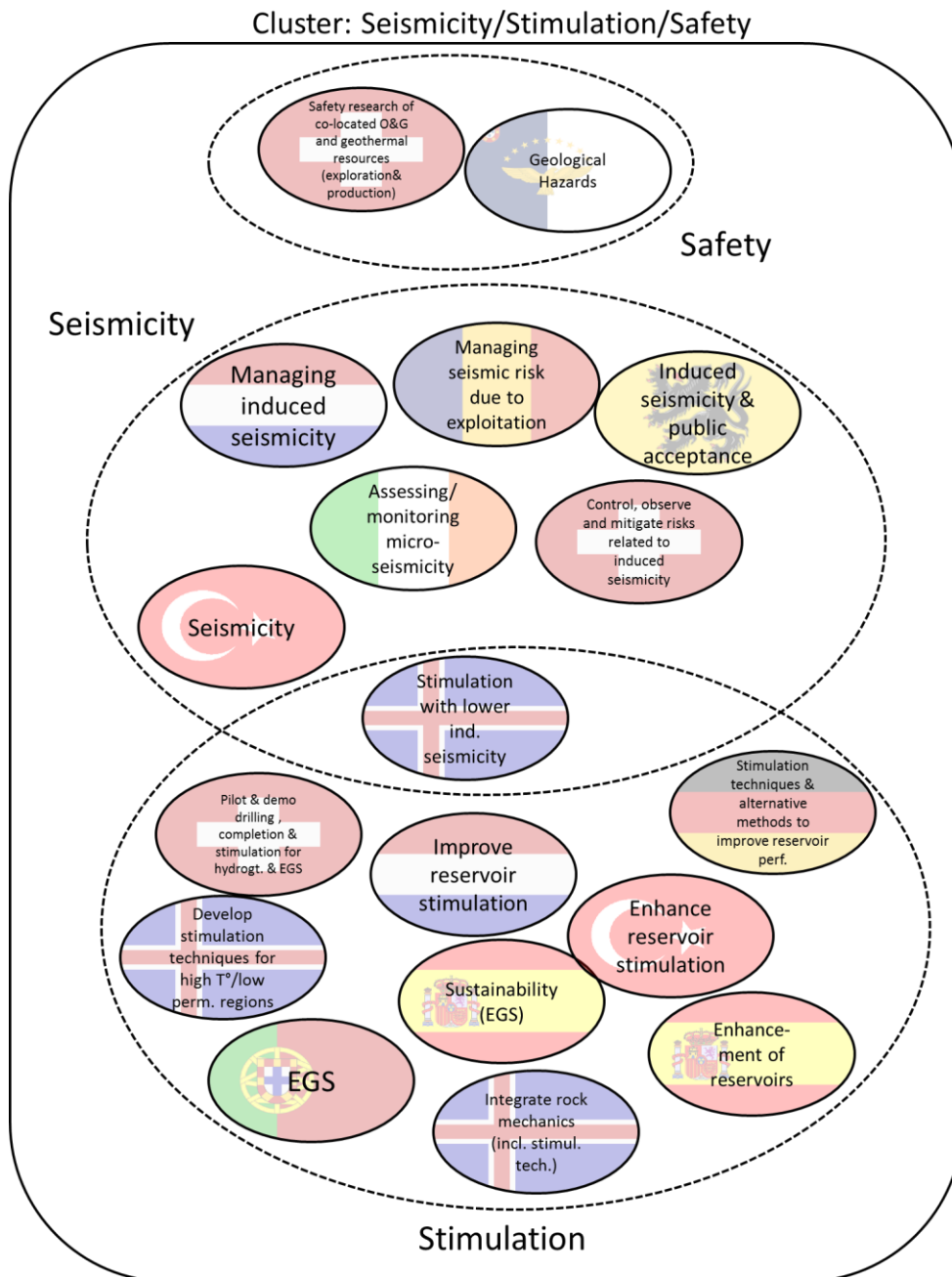


Figure 15 RD&D Needs: Seismicity/ Stimulation/ Safety

The theme “seismicity, stimulation and safety” brings together a group of interrelated research topics that are related to drilling and completion, but go beyond that at the same time. Well stimulation may be part of any geothermal operation, and better and more controlled methods for well stimulation are needed. Enhanced Geothermal Systems technology should be improved, which means creating geothermal production through ‘enhancing’ low permeability and high temperature reservoirs e.g. through hydraulic stimulation of reservoirs. This may cover novel stimulation methods, such as radial jetting.

A concern with stimulation techniques, both at the well and at the reservoir scale, and a concern with any geothermal project during the production phase (production and re-injection) is the hazard presented by existing faults in the subsurface. Injection itself can be seismogenic, as well. Understanding and managing induced/ triggered seismicity is therefore a research need related to geothermal resource development. There is also an opportunity: induced seismicity is also used as a

reservoir management tool that helps identify the reservoir circulation system and develop remedial actions. At the same time, it relates to the environmental, social and economic sustainability (section 4.1). Safety concerns of a more generic nature, e.g. when co-producing oil and gas, are the last sub-cluster in this group of RD&D topics.

#### 4.6.2 Link to DG-IP and other relevant actions

Technical improvements of drilling and completion and reservoir development will contribute substantially to the viability of geothermal energy. Concerning the theme of “geothermal resource development” there is strong parallelism with the SET-Plan Deep Geothermal Implementation Plan’s research & innovation activity 5 (Exploration techniques incl. resource prediction and exploratory drilling), research & innovation activity 6 (Advanced drilling/well completion techniques) and research & innovation activity 3 (Enhancement of conventional reservoirs and development of unconventional reservoirs). Most of the investment will derive from the range of national and regional research and innovation programs for 2018-2023:

- some € 33 million mostly from DE, PT, CH, NL, FR, IS for R&I activity 3 (including GEOTHERMICA funneled investments);
- some € 22.5 million mostly from DE, PT, CH, NL, FR, IS for R&I activity 5, and
- some € 30 million mostly from DE, PT, CH, NL, FR, IS for R&I activity 6.

For the latter 2 R&I activities GEOTHERMICA is expected to contribute up to € 8.5 million each.

The theme of “induced seismicity” was addressed in several national European and national RD&D projects within the participating countries, for the last 5-7 years. These projects were mostly focused on the fundamental technical and geological aspects of induced seismicity. It is now essential to convert fundamental insights via directed research or pilot and demonstration projects into processes, procedures and tools that help the management of induced seismicity on an operational level, both by operators and by regulatory authorities. In addition, framing the discussion around induced seismicity and achieving stakeholder acceptance needs to become a methodology built on experience.

The social aspects of the topic are often driven by regional conditions. A knowledge exchange on good-practices and/or research projects on the reasons for the different dynamics in different regions can help. In short, this topic is very much within GEOTHERMICA’s remit for research and innovation and also within GEOTHERMICA’s aim to facilitate the cooperation of national and regional permitting and regulatory oversight authorities.

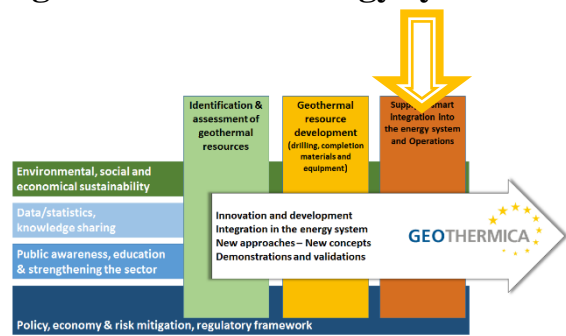
This is also identified in the SET-Plan Deep Geothermal Implementation Plan’s “non-technical barrier and enabler” NTBE-A (Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions), and in particular in Scope B (Best practices for managing HSE aspects of geothermal projects. Seismic monitoring and mapping of seismic events, guidelines for stimulation indicators in order to prevent surface impacts.). Via GEOTHERMICA some € 8.5 million are to be invested during the period of 2018-2023, complemented by national funding programs from DE, PT, CH, NL, FR and IS of € 4.5 million.

GEOTHERMICA’s first Call also resulted in a number of funded projects that contribute to geothermal resource development: CAGE (Composite casing); COSEISMIQ (induced seismicity); GeCONNECT (flexible couplings); and ZoDrEx (drilling and completion). More information is available through [www.geothermica.eu](http://www.geothermica.eu).

## 4.7 Thematic priority: Supply & smart integration into the energy system and operations

The third and final technical innovation theme in the GEOTHERMICA thematic areas is ‘Supply & smart integration into the energy system and operations’. Five clusters have been identified by the countries.

Within this technical innovation theme there are two clusters of Barriers and Opportunities, and three clusters of RD&D needs.



### 4.7.1 Barriers & Opportunities

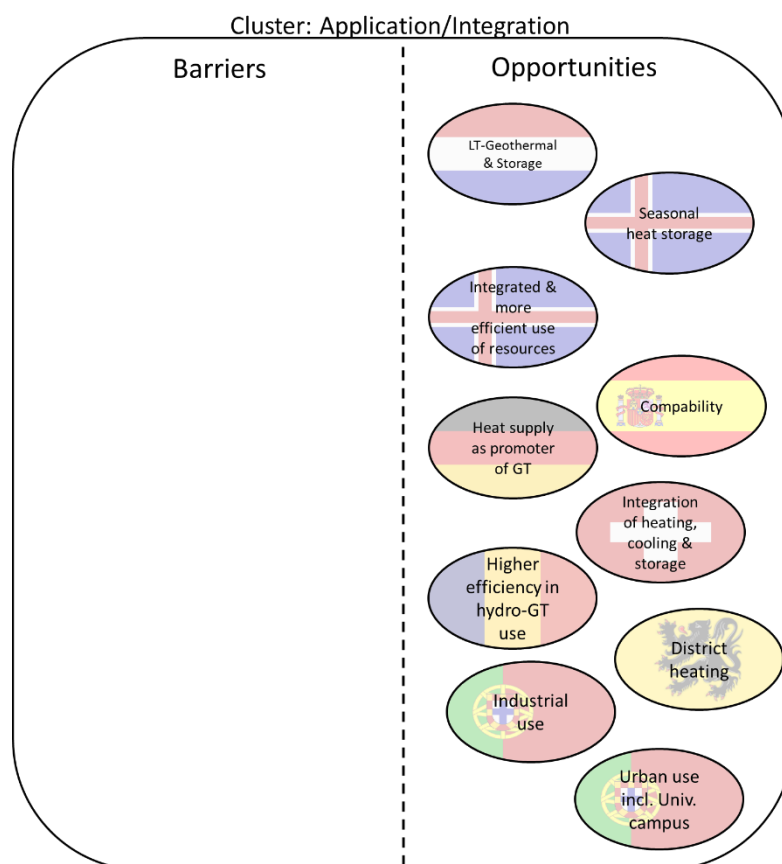
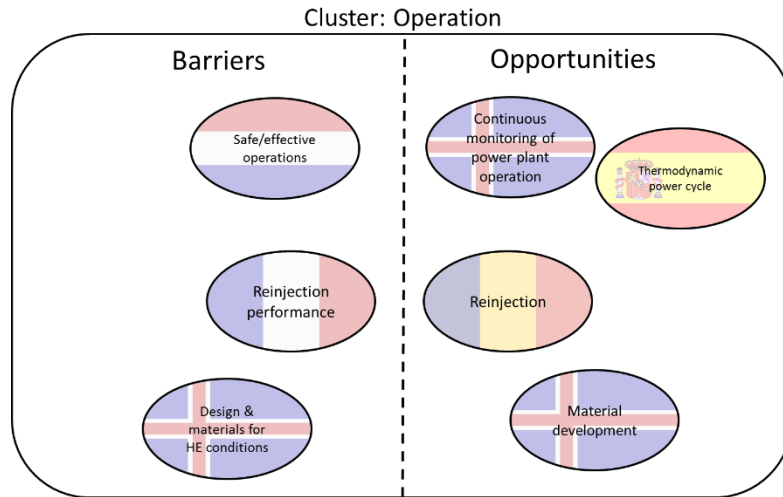


Figure 16 Barriers and Opportunities: Application/ integration

The first cluster focuses on ‘application/ integration’. Various opportunities have been identified as outlined in figure 16. Geothermal energy can be combined with seasonal heat storage. Integrated cooling, heating and storage solutions are attracting more attention because of potentially very large gains in energy efficiency; for example, seasonal heat storage increases the efficiency of reservoir utilization. Geothermal reservoirs are highly complementary and buffer variable energy demand and supply options. Availability of very large energy storage facilities by way of subsurface reservoirs on the one hand, and on the other hand, the ability to be spatially closely linked to industry applications extract value from the low surface footprint of geothermal energy.

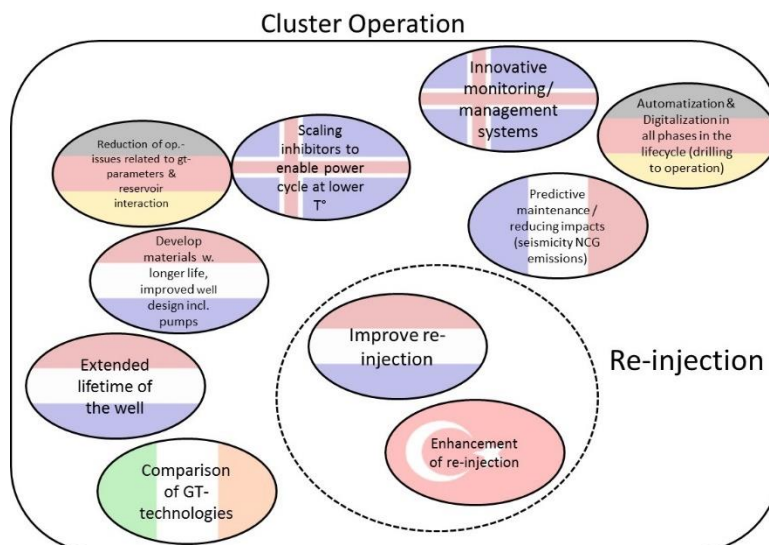


**Figure 17 Barriers and Opportunities: Operations**

The second cluster deals with ‘operations’. The main focus is on the durability and long term performance of the geothermal resource. Besides operational safety and efficiency of surface facilities, geothermal operations are often limited by reinjection capacity constraints. In some countries, reinjection is not a standard way to dispose of cooled geothermal brine. Reinjection, however, provides an opportunity to enhance the sustainability of the geothermal operation principally to delivering pressure support and avoiding pressure depletion of the reservoir. Focused R&D, new materials for surface and well installations, but also better monitoring techniques are relevant development strategies. Dealing with and solving of these operational issues support one of the key arguments for geothermal energy, the availability on 365 days 24h a day and minimal down times of the installations. If these can be further reduced, the economic viability of projects will be improved in different geological settings. Needless to say, future flexible operations of geothermal heat or power plants will also offer new operational challenges which need to be addressed, principally by first gaining operational experience and identifying any potential issues that require research and innovation.

#### 4.7.2 RD&D Needs

The three clusters in RD&D Needs are ‘operation’, ‘shallow’ and ‘electricity/ surface’.



**Figure 18 RD&D Needs: Operation**

In the RD&D Needs cluster ‘operation’ improving and maintaining efficiency and durability are addressed. Energy efficiency could be stimulated through the development of cost efficient scale inhibitors that will enable utilization of the geothermal fluid at lower temperatures and thus improve the efficiency of the cycle. The efficiency could also be improved by developing innovative monitoring systems and predictive maintenance. Re-injection RD&D should aim to prevent a declining injection capacity during the production phase of a reservoir. This all requires an increasing insight into (geochemical) processes and thermal effects at the injection well and in subsurface reinjection horizons. All topics aim to optimize the operational period of a plant. Increasing availability and reliability, and maintaining stability of operations maintain the unique value proposition of utilizing geothermal energy.

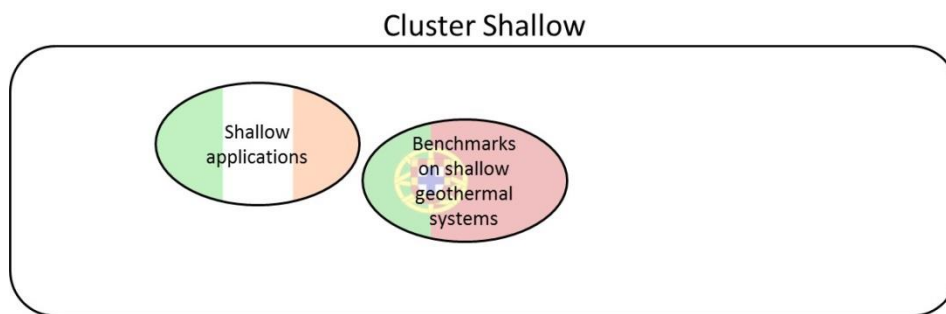


Figure 19 RD&D Needs: Shallow

The cluster ‘shallow’ relates to studying shallow geothermal systems, and benchmarking their energy efficiency. Understanding the efficient combination of heating, cooling and storage supply into an energy system is important, and such systems can include direct use of geothermal energy and heat-pumps. As GEOTHERMICA is primarily focused on deep geothermal applications, not all countries integrated shallow geothermal utilization in their answers to the GEOTHERMICA survey. To get a reliable impression on shallow depth geothermal barriers, opportunities and RD&D needs, it can be specifically questioned during the next update of the clusters.

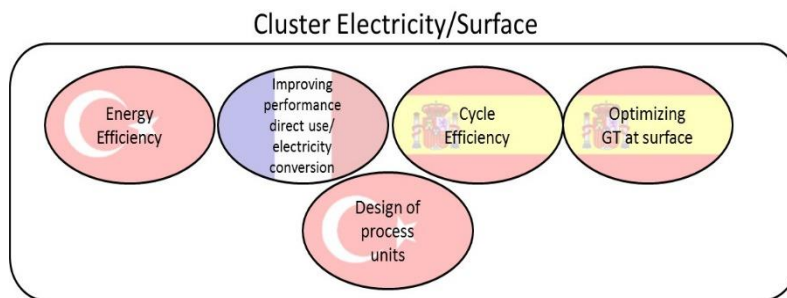


Figure 20 RD&D Needs Electricity/ Surface

The final cluster addresses ‘electricity/ surface’. Improving the energetic efficiency of thermodynamic cycles is of relevance. This will stimulate the electricity generation from sources with lower temperatures. However, most countries that have abundant medium-low enthalpy geothermal resources, see the biggest opportunities for geothermal in the heat sector. At current conditions in the European electricity markets, geothermal electricity is either the least cost option (Iceland, Turkey and Italy) if the quality of resources is very good, or a very expensive option if resource quality is lower. Despite some promising fundamental research into revolutionary energy conversion technologies, a credible path to commercialization is not yet there at this stage. But, national and regional funding bodies expect the situation to change in the medium term, particularly if growth into the electricity



sector can be underpinned by strong and commercially viable performance in the heat (and storage) sector.

### 4.7.3 Link to DG-IP and other relevant actions

Many opportunities and a significant number of RD&D needs are related to ‘supply and smart integration in the energy system’ and ‘operations’. The challenge to develop new ways to fully exploit the potential of geothermal energy is at the core of any GEOTHERMICA Call. Going beyond metrics such as “levelized cost of heat/power”, GEOTHERMICA’s funding bodies wish for projects that demonstrate and enable the quantification of the value of integrating geothermal energy into the energy system. Also, GEOTHERMICA is implementing an additional support action on operational issues, under the acronym ‘Opera’.

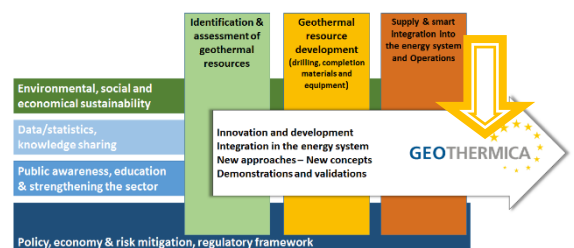
The SET-Plan Deep Geothermal Integration Plan places great importance on the research & innovation activity 1 (Geothermal Heat in urban areas) and 7 (Integration of geothermal heat and power in the energy system and (enabling) grid flexibility). For the period 2018-2023, DE, PT, CH, NL, FR, IS and IT have indicated that up to € 41 million will be invested in the research & innovation activity 1. A portion of the € 8-9 million derived by pooling resources of GEOTHERMICA countries, and possibly the EC, will be channeled via GEOTHERMICA Call(s). The integration of geothermal heat and power into the energy system, also addressing grid flexibility requires investment into research and innovation of some € 12 million according to the SET-Plan Deep Geothermal Implementation Plan with only minor amounts (€1.5 million) from national and regional funding bodies. It goes without saying that both R&I activities 1 and 7 may have site-specific very strong overlap.

GEOTHERMICA’s first Call also resulted in a number of funded projects that contribute to this issue: PERFORM (operational issues); HEATSTORE (opportunities through heat storage); and GEO-URBAN (geothermal in urban environments).

## 4.8 Thematic priority: New approaches – New Concepts

GEOTHERMICA has identified the importance of ‘New Concepts’, which integrate technologies and market needs. ‘New concepts’ can identify and develop pathways to large-scale commercial implementation of geothermal energy.

In the ‘New Concepts’ cluster there are two sub-clusters, one for Barriers and Opportunities and one for RD&D needs.





#### 4.8.1 Barriers & Opportunities

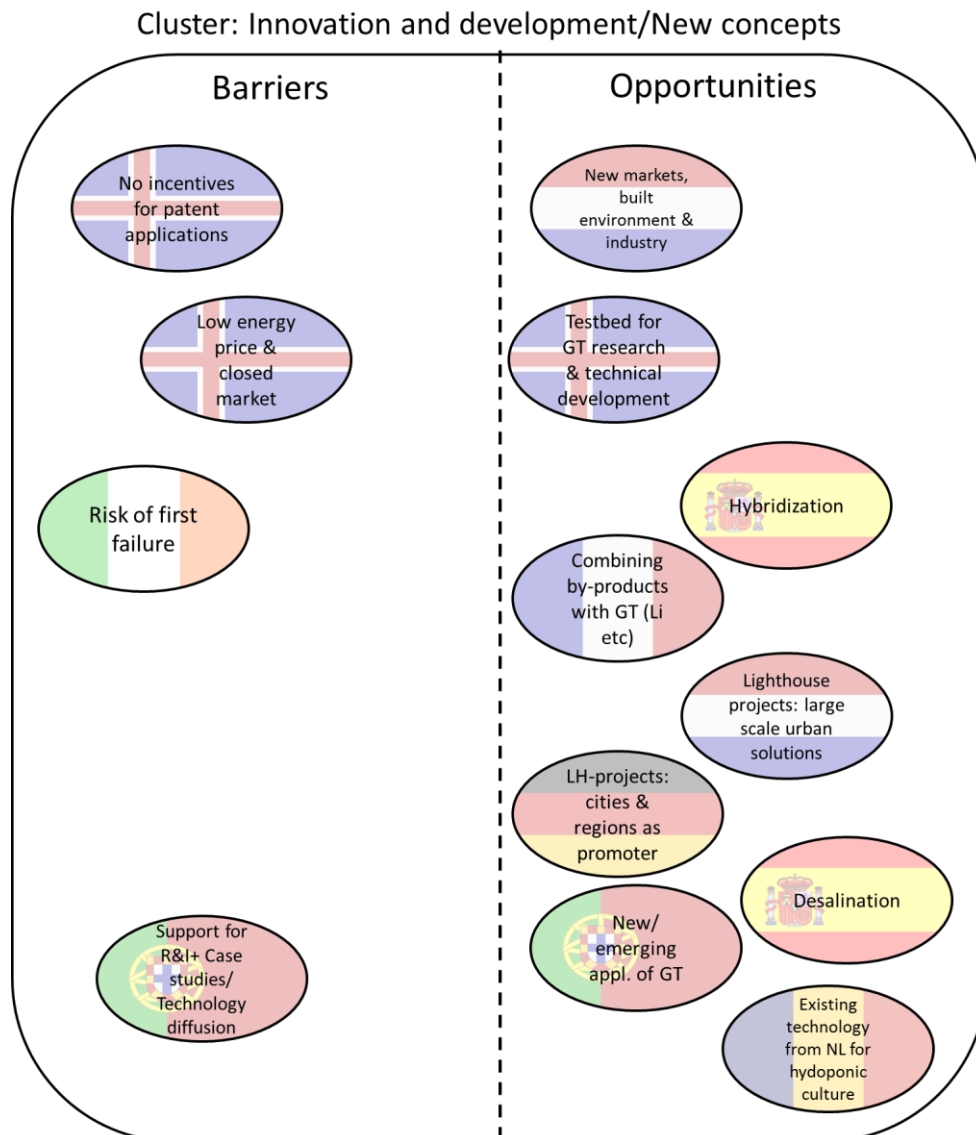
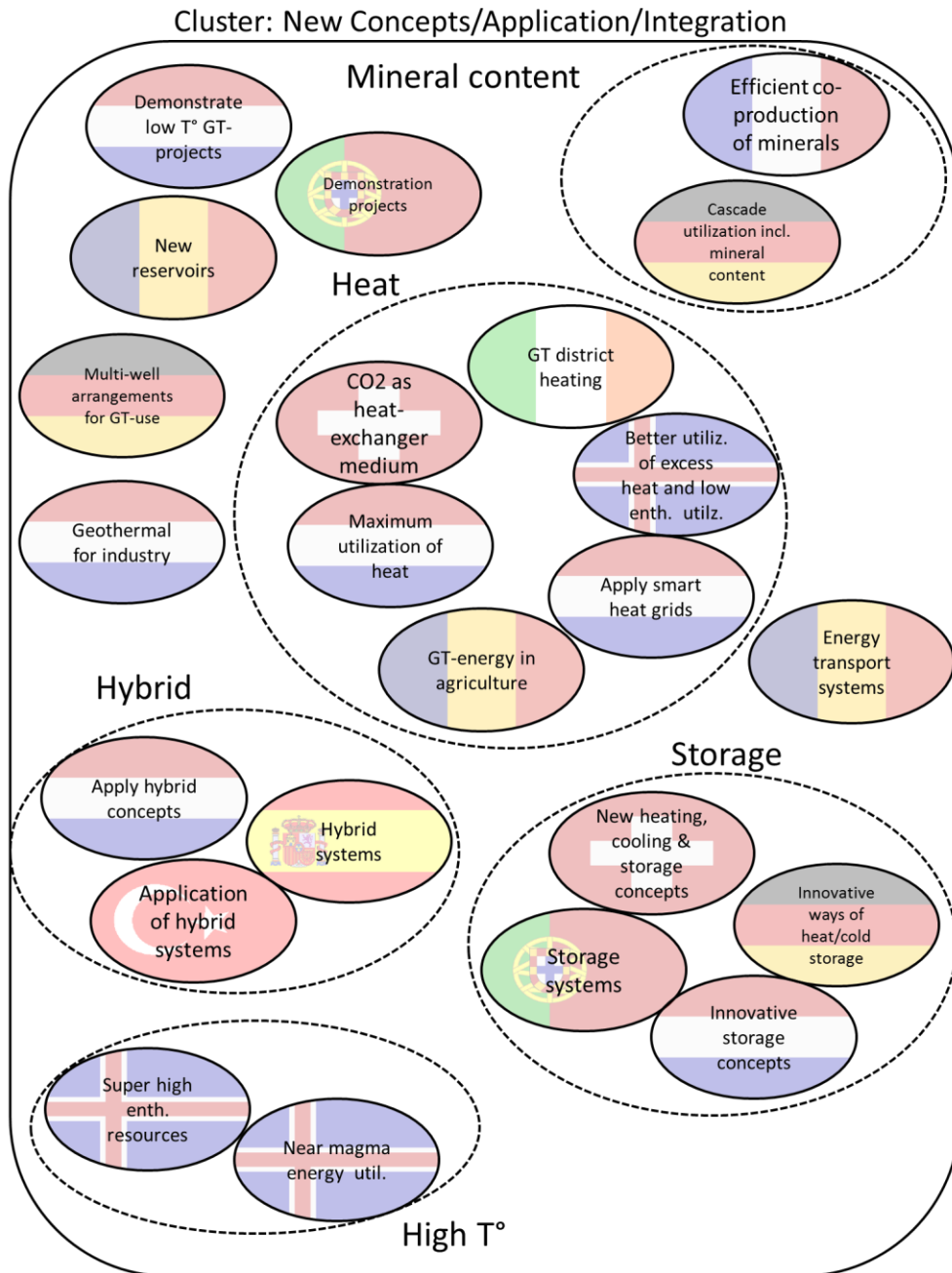


Figure 21 Barriers and Opportunities: Innovation and development/ New Concepts

The cluster ‘New concepts’ identifies opportunities which are related to system integration. ‘Lighthouse’ projects can demonstrate the benefits of geothermal energy at a large and integrated scale, setting examples to stimulate other regions and countries. It is crucial to share the lessons learned, because some countries fear the risk of first failure. A threat that is really common to all immature markets. To control risks, in another way, Iceland mentions the opportunity to realize a testing environment for new geothermal concepts. Finally, the opportunities in this cluster also include various opportunities for diversification of the use of geothermal energy; in industry, in horticulture, for desalination etc. Another barrier mentioned that no incentives are given for patent applications. This hampers innovation. In other countries (e.g. Germany), costs for patent applications coming from a funding project can be at least partly covered for SMEs.

## 4.8.2 RD&D Needs

The RD&D cluster focused on New Concepts addressed several topics, some general, and some clustered. The main cluster topics are ‘mineral content’, ‘heat’, ‘hybrid’, ‘storage’ and ‘high temperature’.



**Figure 22 RD&D Needs New concepts/ Application/ Integration**

‘Mineral content’ relates to the efficient co-production of minerals from geothermal fluids. As e.g. Lithium is getting more and more important in other sectors (e.g. electromobility), to co-production of minerals can support the economic success of geothermal projects. ‘Heat’ addresses the maximum utilization of heat through the development of improved distribution through cascading and smart grids. Hybrid systems are related to this. In such systems, geothermal and other heat sources (e.g. biomass, solar heat etc.) are linked to one ‘hybrid’ network. Other technologies should be assessed in order to establish synergies, and the modification of existing networks is another relevant theme.

Energy ‘storage’ is one of the relevant enablers for the growth of renewable energy supply. Demonstration of underground heat storage is relevant, in order to effectively exploit and utilize geological formations. For example high temperature storage in aquifers and storage at different depths (shallow-ultra deep).

‘High temperature’ is a different theme within the ‘New concepts’ group. In recent years, drilling has revealed that magma is stored at accessible depths in some countries. Specific wells with an output of 6-8-fold of world average would be possible, but there are numerous challenges, such as corrosion and erosion resistant casing and well head materials as well as techniques for either silica scaling inhibition or turbines resistant to silica erosion.

### **4.8.3 Link to DG-IP and other relevant actions**

Many opportunities and a significant number of RD&D Needs are related to ‘New Concepts’. The challenge to develop new ways to fully exploit the potential of geothermal energy will invariably be part of any GEOTHERMICA Call. Supporting new concepts in the geothermal sector can foster innovation and elevate geothermal energy supply to the next level. GEOTHERMICA’s first Call also resulted in one notable project that very directly contributes to this issue: GEOFOOD<sup>35</sup>, a project that aims for a circular approach in growth of crops and fish, using geothermal heat in a cascade.

The existence of the DG-IP demonstrates the importance that European stakeholders connect to forwarding geothermal energy by research and innovation i.e. new concepts. Such new concepts can be incremental or disruptive, but both will contribute to unlocking the potential of geothermal and its incorporation into the energy system.

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<sup>35</sup> <https://geofoodproject.eu/>

## 5 Conclusions

Geothermal energy is a valuable and local source of energy, that can contribute significantly to our future energy system, both for power generation and supply of heating and cooling. To develop a mature industry, collaboration throughout Europe on barriers and opportunities, and on stimulating innovation for geothermal energy is very important. GEOTHERMICA is a collaboration of 18 funding organisations for research, innovation and market development in 14 European countries and regions. This report brings together RD&D priorities and Barriers and Opportunities for the increased deployment of geothermal energy, as identified by the 18 GEOTHERMICA members.

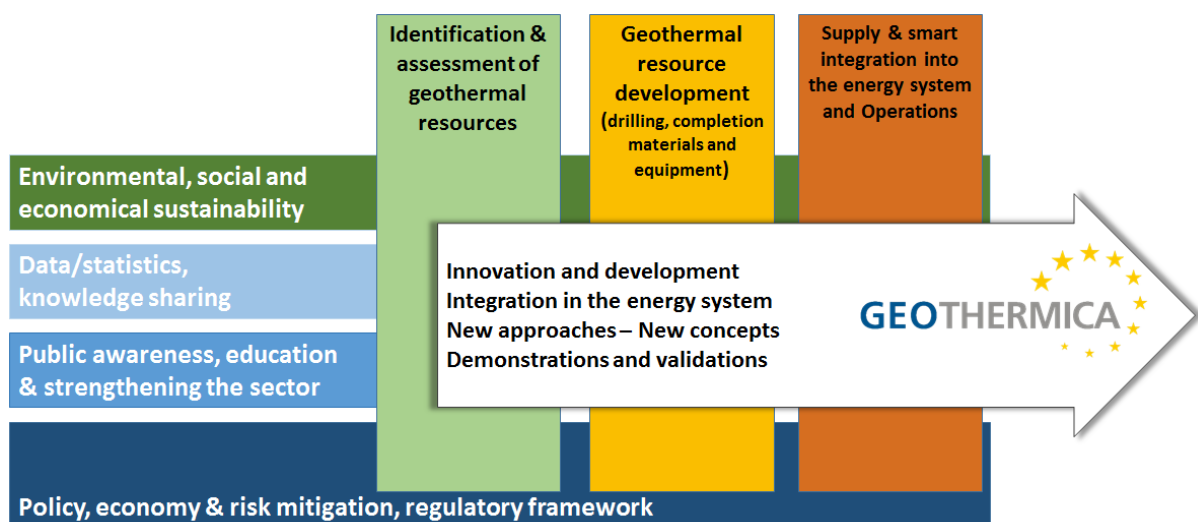


Figure 23 GEOTHERMICA technical and non-technical priorities

GEOTHERMICA's original thematic scope, as presented in the project description and in the joint call text, has been reaffirmed as a useful tool to direct future actions, in particular the second joint Call of GEOTHERMICA. Also, the GEOTHERMICA thematic priorities and the needs identified in this report coincide very well with the priorities mentioned in the DG-IP, the Deep Geothermal Implementation Plan.

The individual specific priorities per research theme offer opportunities for further collaboration on a bilateral or multi-lateral scale. This may be between countries/regions with a similar market structure or countries/regions and with similar topical interests. To develop effective cross-European collaboration, targeted coordination with other relevant European and international organisations is essential. Such organisations include for example the implementation working group (IWG) for the SET Plan DG-IP, the European Geothermal Energy Council (EGEC), the Joint Programme on Geothermal Energy of the European Energy Research Alliance (EERA JP GE).

GEOTHERMICA will organize a round table meeting with the relevant transnational and international organisations, to discuss the insights of this report and guide future activities. The insights of the round table meeting will be offered to the IWG Deep Geothermal.



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