Strategic Energy Technology Plan

Geothermal IWG

Implementation Plan

Geothermal Implementation Working Group

5 December 2023

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EXECUTIVE SUMMARY

The Geothermal Implementation Working Group (**IWG** or **Geothermal IWG**) is one of the designated working groups supporting the implementation of the SET Plan, Europe's Strategic Energy Technology Plan. IWG brings together SET Plan countries, the geothermal energy industry, and the research community at a European level. Its mission is to coordinate research and innovation efforts and jointly support the transition to a resilient and climate-neutral Europe which utilises geothermal energy to its full potential. The Geothermal IWG identifies the pressing issues for the development of Europe's geothermal energy market aligning the industry support and R&I activities of its respective member states.

This second update of the Implementation Plan brings the research and innovation ambitions in line with the challenges that Europe faces today. The scope is now extended to all geological and subsurface depth levels, underground thermal energy storage, and co-production of minerals and geothermal energy which are now all part of the focal areas of the IWG and its work.

Geothermal IWG Vision for 2050

The IWG envisages a net-zero Europe in 2050, where:

- Geothermal **heat** supplies more than 25% of Europe's demand for space heating and cooling, and more than 25% in the agricultural sector (greenhouses) and 5% in industrial sectors in the low to medium temperature range.
- 10% of the **power production** in SET Plan countries is from geothermal power.
- **Underground thermal energy storage** supplies more than 10% of Europe's demand for space heating[1] mainly for district heating, thus requiring collective systems.
- **Co-production of minerals and critical raw materials (CRM)** such as lithium for resilient transportation sector and strategic autonomy is established in at least 10 European regions.

In line with EU goals on resilience, the IWG aims to increase resilience of the geothermal energy supply chain, and to have 40% of the supply chain "Made in Europe" by 2030.

Summary of Implementation Plan Priorities

The Research and Innovation (**R&I**) Actions envisaged in the Geothermal Implementation Plan address four priorities for the use of geothermal energy resources. The implementation plan (**IP**) pays due attention to the widely present low and high temperature geothermal energy resources in Europe. The development of these resources, together with that of urban district heating and cooling networks fed by geothermal energy, represents a key opportunity to increase the renewable heat supply. Geothermal electricity can be a major contributor to balancing local effects resulting from the dependence on non-dispatchable renewables, such as wind and PV and solar thermal; attention is paid to developing this capability, with a specific key action in the IP. The plan also identifies the R&I Actions required to develop underground thermal energy storage technologies and co-production of minerals such as Lithium (Li). Key R&I actions are related to the development of materials which can be effective in reducing problems related to scaling and corrosion, both for low- and high-temperature applications, and new exploration techniques and advanced drilling techniques. Strongly connected to the *Declaration of Intent* targets of decreased costs and social acceptance, are the key actions dedicated to performance improvement and to the development of zero-emission geothermal energy plants. Knowledge transfer and data unification issues are also relevant measures of the IP. Key non-technical barriers/enablers (NTBE) have been identified. They are firstly social acceptance in support of a wide-spread development and use of geothermal energy, and secondly geological risk management, with the objective of establishing a European scheme for the management of risk in

[1] *Roadmap for flexible energy systems with underground thermal energy storage towards 2050*, HEATSTORE 2021, GEOTHERMICA – ERA NET Cofund Geothermal and Paardekooper, S., Lund, R. S., Mathiesen, B. V., Chang, M., Petersen, U. R., Grundahl, L., David, A., Dahlbæk, J., Kapetanakis, I. A., Lund, H., Bertelsen, N., Hansen, K., Drysdale, D. W., & Persson, U. (2018). *Heat Roadmap Europe 4: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps*. Aalborg Universitetsforlag.

geothermal energy projects, which is considerable as exploration and field development represent a major investment.

Enhanced Alignment with ETIP Geothermal Priorities

The Geothermal IWG would like to acknowledge our colleagues at the European Technology & Innovation Platform on Geothermal (**ETIP-Geothermal**). The ETIP-Geothermal Strategic Research and Innovation Agenda for 2023 has been a key influence in updating this Implementation Plan. IWG Geothermal and ETIP-Geothermal have now aligned their respective R&I priorities, a move which is most welcome and will further serve to coordinate the entire geothermal energy sector in Europe. It is anticipated that this alignment of activities and priorities to continue in our tight-knit European geothermal energy community.

IWG Actions & Working Mechanisms

The IWG membership, comprised of SET Plan countries, the geothermal energy industry, and the research community are all dedicated to finding synergies and realising meaningful research and innovation projects and other activities that support the mission of IWG Geothermal. This will be implemented through transnational actions, e.g., through the funding vehicles CETPartnership and GEOTHERMICA Initiative, actions in national innovation programmes and in national programmes supporting the further application of geothermal energy, through interaction with the European Commission, in particular Horizon Europe, and through the efforts and creativity of European researchers and the European private sector.

1. Geothermal Energy for a Resilient European Energy System

Geothermal energy is a valuable and local source of energy that can cost-effectively provide heat, baseload/dispatchable electricity, or a combination of both. The heat below our feet is abundant and available whenever we need it. Geothermal energy has a unique role in urban regions, since it does not require large amounts of land (such as wind or solar parks) or increased transport (such as biomass). With these features, geothermal energy has the potential to provide real alternatives to replacing heating systems and power plants emitting greenhouse gases, not only in Europe but also globally. In addition, geothermal reservoirs can also act as sites for storage of thermal energy, and critical raw materials such as Lithium (Li) can be produced in parallel utilising geothermal fluids.

In view of the European Green Deal and the principles of the energy transition, the context for geothermal energy in a majority of European countries is now clearly on geothermal heating and cooling supply. If Europe is to realise the binding targets of net zero greenhouse gas emissions by 2050 as set out in the European Climate Law, geothermal energy must be part of that effort. Here, geothermal energy can play a major role in the supply of renewable heat to newly constructed buildings and existing building stock, and low to medium temperature process heat for the industry. As geothermal energy can offer heating solutions ranging from the regional and city level to the individual building scale and from industrial applications to the climatization of commercial or private houses, the support of the further development of these technologies is key. The war in Ukraine has only highlighted the crucial role of heating and cooling the geothermal sector is uniquely equipped to address.

Geothermal energy can be developed and applied in an integrated way in four different forms: heat generation, electricity generation, thermal storage, and co-production with critical raw materials. Those four priorities are included in the scope of the work of IWG Geothermal. The scope of the IWG Geothermal is not including the installations for ground-coupled individual heat pumps.

The resilience of the supply chains for geothermal projects is becoming increasingly relevant. Geothermal energy projects are mostly constructed with materials that are abundant, and Europe-based drillers and contractors are ready to realise new projects. Understanding potential bottlenecks and highlighting the resilience of the supply chain for geothermal energy is important, alongside with the integration of geothermal energy in Europe’s future energy system.

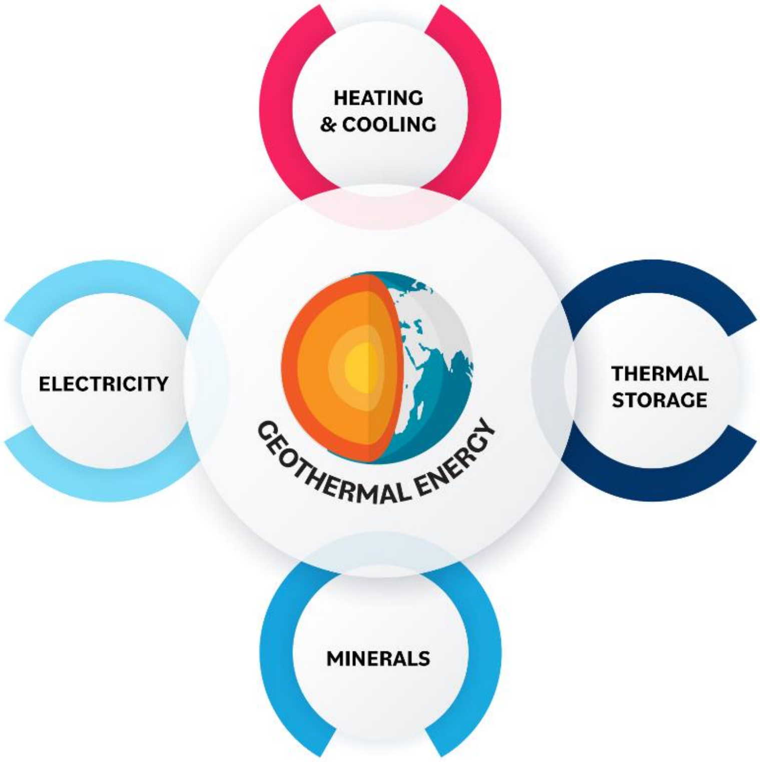

Figure 1: Four Key Priorities for Geothermal Energy.

1.1. Challenges & Opportunities

Geothermal installations are characterized by low operational expenditure (OPEX) and high capital expenditure CAPEX, mostly to cover the cost of exploration and drilling, as well as plant construction. In addition, financing costs are high due to the risks associated with project development. There is a geological risk, related to the unknown nature of the underground resource – often a few kilometres deep. Capital markets are generally less willing to carry the early-stage risks and costs, which represents one of the major barriers for geothermal project developers. Therefore, improving knowledge of the subsurface resource and geological setting is key. Additionally, project risk mitigation tools and financial schemes aimed at de-risking geothermal energy projects have to be further developed and supported. Geothermal installations have high-capacity factors and low OPEX, near zero system costs and externalities, resulting in costs very similar to those of other renewable and low-carbon technologies.

EU industries and operators' experience and leadership, as well as European scientific excellence are recognized worldwide. In order to stimulate the uptake of geothermal energy it is necessary to improve geological and resource information, and economic performance and efficiency of installation. It is also necessary to broaden the geological conditions under which technologies can be applied and to develop technologies to bring a larger extent of geothermal resources to market. In addition, hybrid systems able to integrate energy production from different renewable sources and flexible systems that smooth the geothermal electricity load profile need to be developed and deployed. Furthermore, environmental performance and social acceptability are also key concerns, that geothermal energy projects must address.

1.2. Four Priorities of the Geothermal Implementation Plan

1.2.1. Heating & Cooling

Today, geothermal heat is used depending on its temperature in a number of sectors including balneology, industry, in agriculture, and of course in district heating systems. For the supply of individual houses or smaller districts, small scale installations at shallow depth are combined with heat pumps. This can be coupled with seasonal thermal energy storage for heat storage or for the supply of both heating and cooling with high efficiency factors.

There is great potential for the utilization of geothermal energy for heating in Europe. Many locations in Europe with district heating systems can easily be adapted to make use of local geothermal resources instead of relying on fossil fuels, imported or otherwise. This would increase energy security and price stability, and help to achieve climate neutrality as well as independence from fossil fuel sources. There is also a potential for an increased use of geothermal heat in industry and agriculture. Unlocking this will come through research and innovation focused on the improvement of existing technology and the incorporation of geothermal energy into the energy system. In this way, geothermal energy, together with underground heat storage, will become one of the key options for the transition towards a 100% renewable heat supply in Europe.

In 2020 there were 350 geothermal district heating systems in operation. More than 200 geothermal district heating (DH) projects are under development at the time of writing. It is estimated that geothermal resources are able to cover 25% of the demand for space heating in the EU. A similar percentage is estimated for agriculture, in particular greenhouses. The potential for heat supply for industrial users is more limited and is equal to approximately 5% of the total heat use in industrial applications.[2]

1.2.2. Electricity

While geothermal electricity production in Europe dates back more than a century, the market can still be considered in its infancy. In the last six years (2017-2023) a resurgence of interest in geothermal power and heat has occurred, after nearly a decade of only small increases in capacity in the sector both for electricity and for heat supply (mainly district heating). By the end of 2022, there were 3.5 GWe of installed geothermal electricity capacity in Europe, distributed over 141 power plants. Geothermal power plants have an average capacity factor that is typically above 75%, with several plants operating 100% of the hours of the year. Among renewables, electricity from geothermal resources is today fully competitive with fossil fuels in choice locations, with average full costs, including system costs and externalities, of about 0.07-0.15 EUR/kWh. According to the GEOELEC project results, thanks to innovative drilling concepts and substantial cost reductions, the economic potential in the EU grows to approximately 2570 TWh in 2050 and more than 4000 TWh when including Iceland and Turkey[3].

There are more than 175 power projects currently under development or investigation, which means that the number of plants operating in Europe could double soon. The growth of geothermal electricity is mainly due to rapid expansion in Turkey, and the construction of power plants in new countries such as Slovakia and Spain.

Geothermal power could provide, on average, some 10% of electricity demand in SET Plan countries. A recent study[4] identified a potential of 4-7% for Western Europe. An earlier version of the IWP talked about 12,5%. Ten percent is the order of magnitude that should be attainable. This market share might be increased if cost reductions associated with drilling or commercial production from a larger extent of geothermal resources (as mentioned above) are realized. In volcanic areas geothermal energy could provide the highest share of renewable electricity.

1.2.3. Thermal Underground Storage

Many sustainable heat supply systems are characterised by high CAPEX and low OPEX. Therefore, an installed capacity tailored to peak demand is not cost effective, while extending the annual operation period is advantageous for meeting energy needs and decarbonisation goals, while reducing levelized cost of energy (LCOE). Optimal utilisation of sustainable heat requires storing large amounts of heat to account for seasonal supply and demand fluctuations. Subsurface thermal storage can support the peak demand in winter by transferring heat from the summer period, where it is mostly unused, to the winter period. Underground thermal energy storage can be used very efficiently for heating in winter and cooling in summer, combined with heat pumps.

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[2] Dalla Longa et all. Scenarios for geothermal energy deployment in Europe – ScienceDirect, 2020

[3] GEOELEC Deliverable n° 2.5 A prospective study on the geothermal potential in the EU, November 2013

[4] Dalla Longa et all. Scenarios for geothermal energy deployment in Europe – ScienceDirect, 2020

Underground thermal storage is a key enabling technology for sector coupling through Power-to-Heat. Underground thermal storage has the potential to serve other energy systems, i.e. to store excess energy from other energy sources such as solar and wind. Underground thermal energy storage (UTES) is applicable in different temperature ranges and there are a number of technological solutions capable for different settings, such as high-temperature aquifer thermal energy storage, pit thermal energy storage, borehole thermal energy storage and mine water thermal energy storage.

The future role of thermal storage in the energy system is multi-faceted and hard to quantify. Space heating is about 60% of the European heat demand. This demand concentrates in three winter months, resulting in a significant peak, which needs solutions for a resilient European energy system. The Geothermal IWG considers that all district heating systems should in the future include underground thermal energy storage systems in a suitable shape. Considering the ambitious goal of supplying 50% of the heat demand through district heating systems[3], estimates show a potential of more than 10% of the heat demand for space heating is covered by underground thermal energy storage[2].

1.2.4. Co-production of Minerals & Geothermal Energy

In light of the electrification of the transport sector and the advancement of renewable energy technologies, minerals such as Lithium and rare earth elements are increasingly important. First studies showed that Lithium could be extracted from geothermal brines in a sustainable way in Europe[5,6]. While supporting the global demand of these materials, the production can contribute towards the economic feasibility of geothermal energy even in areas without optimal geological conditions. Other minerals such as silica and copper could be additional by-products of geothermal energy, if suitable extraction methods are developed.

The Geothermal IWG focuses on the opportunities that co-production of minerals can offer during the continued development of geothermal energy. Whenever the fluid chemistry and operational parameters of a geothermal site are in favour of a co-production of minerals, one should take advantage of these conditions to improve the economic viability of the plant. Additionally, whenever a mineral resource is exploited and delivers useful geothermal brines close to a location with a heating demand, or when production temperatures allow the economical production of power, co-production should be implemented. The Geothermal IWG envisions that co-production of heat and minerals established in at least 10 European regions by 2050.

2. The Geothermal Implementation Working Group

The Geothermal Implementation Working Group (IWG) is one of the currently 14 IWGs that support the implementation of the SET Plan, Europe’s Strategic Energy Technology Plan. It brings together SET Plan countries, the geothermal industry, and the research community at a European level. Member states of the IWG are Belgium, Cyprus, Finland, France, Germany, Iceland, Ireland, Italy, Portugal, The Netherlands, Turkey, Spain, Sweden, and Switzerland. The IWG also includes representatives from the European Commission, the European Geothermal Energy Council (EGEC), the EERA Joint Programme Geothermal Energy (JPGE), and the Geothermal ETIP. The IWG is a forward-looking group that aims for innovation and momentum to the European geothermal sector.

The Mission of the Geothermal IWG is to coordinate research and innovation efforts and jointly support the transition to a resilient and climate-neutral Europe which utilises geothermal energy to its full potential.

In 2017, the Geothermal IWG drafted the first Implementation Plan on Deep Geothermal Systems, that contained R&I activities, and proposed relevant funding opportunities, which are considered essential

[5] Goldberg, V., Nitschke, F. & Kluge, T.; H*erausforderungen und Chancen für die Lithiumgewinnung aus geothermalen Systemen in Deutschland – Teil 2: Potenziale und Produktionsszenarien in Deutschland*. Grundwasser - Zeitschrift der Fachsektion Hydrogeologie 27, 261–275 (2022). https://doi.org/10.1007/s00767-022-00523-4

[6] Sanjuan, B., Gourcerol, B., Millot, R., Rettenmaier, D., Jeandel, E., Rombaut, A.; Lithium-rich geothermal brines in Europe: An up-date about geochemical characteristics and implications for potential Li resources, Geothermics, 101, 2022, 102385, https://doi.org/10.1016/j.geothermics.2022.102385

for achieving the agreed set of targets. Since then, the IWG was established as a permanent network responsible for the execution, regular update, and monitoring of the Implementation Plan.

The IWG focuses on coordinating research and innovation as a means to support its vision. However, other measures will be needed at various levels to realise the full potential of geothermal energy. Therefore, the IWG considers technical and non-technical barriers as well as cross cutting issues, relevant for the entire geothermal market. Innovation and momentum should go hand-in-hand. Fair market prospects justify innovation efforts. In collaboration with its stakeholders, the IWG can contribute to discussions on non-technical barriers and cross-cutting issues, with the aims of mutual learning, promoting best practices and eventually promoting an energy system where the full potential of geothermal energy is realised.

3. Declaration of Intent 2017, IP 2018 & IP 2020

The initial Declaration of Intent which resulted in the establishment of the Geothermal IWG set the following targets:

1) Increase reservoir performance including underground heat storage, resulting in power demand of reservoir pumps to below 10% of gross energy generation and in sustainable yield predicted for at least 30 years by 2030;

2) Improve the overall conversion efficiency, including bottoming cycle, of geothermal installations at different thermodynamic conditions by 10% in 2030 and 20% in 2050;

3) Reduce production costs of geothermal energy (including from unconventional resources, EGS, and/or from hybrid solutions which couple geothermal energy with other renewable energy sources) below 10 €ct/kWhel for electricity and 5 €ct/kWhth for heat by 2025;

4) Reduce the exploration costs by 25% in 2025, and by 50% in 2050 compared to 2015;

5) Reduce the unit cost of drilling (€/MWh) by 15% in 2020, 30% in 2030 and by 50% in 2050 compared to 2015;

6) Demonstrate the technical and economic feasibility of responding to commands from a grid operator, at any time, to increase or decrease output ramp up and down from 60% - 110% of nominal power.

This Declaration of Intent resulted in the first Implementation Plan, approved January 2018, which identified eight R&I priorities, two cross-cutting issues for joint work, and two non-technical barriers and enablers. In 2020, these R&I priorities were revisited and reorganised according to their place in the chain of geothermal energy production, from geothermal heat in urban areas down to exploration techniques.

Members of the IWG have contributed to the R&I priorities through a large number of projects, with an annual value of about M€ 100, and M€ 40 in addition every 2nd year through joint Calls of GEOTHERMICA. These projects have contributed to e.g. improved materials for realising geothermal wells, better control of operational issues, and a great leap in technology readiness level of various types of underground thermal energy storage.

The initial fiches for defining the activities to be implemented are no longer up-to-date in 2023. Still, improvements in all elements of the chain of geothermal energy production are welcome and possible. This is also reflected in the SRIA of the Geothermal ETIP. However, the relevance of such improvements needs to be considered in the light of the targets and the various types of implementations in society that Europe wants to achieve. The urgency of the heat transition and the climate transition has only increased since 2017. It is therefore that the Geothermal IWG has now identified what we expect as a realistic contribution of geothermal energy in 2050, and these contributions govern the R&I priorities, cross cutting issues and non-technical barriers and opportunities in the IP.

4. Geothermal IWG Vision for 2050

Geothermal IWG Vision for 2050

The IWG envisages a net-zero Europe in 2050, where:

- Geothermal heat supplies more than 25% of Europe's demand for space heating and cooling, and more than 25% in the agricultural sector (greenhouses) and 5% in industrial sectors in the low to medium temperature range.

- 10% of the power production in SET Plan countries is from geothermal power.

- Underground thermal energy storage supplies more than 10% of Europe's demand for space heating[7] mainly for district heating, thus requiring collective systems.

- Co-production of minerals and critical raw materials (CRM) such as lithium for resilient transportation sector and strategic autonomy is established in at least 10 European regions.

In line with EU goals on resilience, the IWG aims to increase resilience of the geothermal energy supply chain, and to have 40% of the supply chain "Made in Europe" by 2030.

5. Key Activities of the Geothermal Implementation Plan & Enabling Framework

In order to increase the contribution of geothermal energy in the European energy mix and to reach the vision set out on the Geothermal IWG Vision for 2050, key activities are defined in this section. The section shows necessary R&I activities per key priority, as well as required cross cutting actions. The mapping relates the various R&I Activities to the chain of geothermal project development; Assessment; Access and development; and Operation and integration. This is also the system that the ETIP Geothermal uses to organise their R&I Activities.

5.1. Heating & Cooling

Many R&I Activities are relevant for the further development of geothermal heating and cooling. Geothermal heating and cooling in urban areas, is the all-encompassing activity with full relevance for geothermal heating and cooling. Integration of geothermal electricity and heating and cooling in the energy system responding to grid and network demands is relevant, because the match of supply and demand and needs to be further developed. The potential of cascade use of heat should be optimised. Also relevant for heating and cooling are activities related to development of the geothermal project, and assessment of the geological resources. These activities have generic relevance for all IWG Geothermal priorities. For heating and cooling, also unconventional heat sources, such as shallow and mid-depth wells or unconsolidated aquifers, and technologies suitable for using mine water heat need to be considered. Finally, geothermal heat for application in industry would probably look at the match between the industrial demand and the required temperature ranges in the industrial application, and potentially re-use of heat at lower temperature levels (cascading use).

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[7] *Roadmap for flexible energy systems with underground thermal energy storage towards 2050*, HEATSTORE 2021, GEOTHERMICA – ERA NET Cofund Geothermal and Paardekooper, S., Lund, R. S., Mathiesen, B. V., Chang, M., Petersen, U. R., Grundahl, L., David, A., Dahlbæk, J., Kapetanakis, I. A., Lund, H., Bertelsen, N., Hansen, K., Drysdale, D. W., & Persson, U. (2018). *Heat Roadmap Europe 4: Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps*. Aalborg Universitetsforlag.

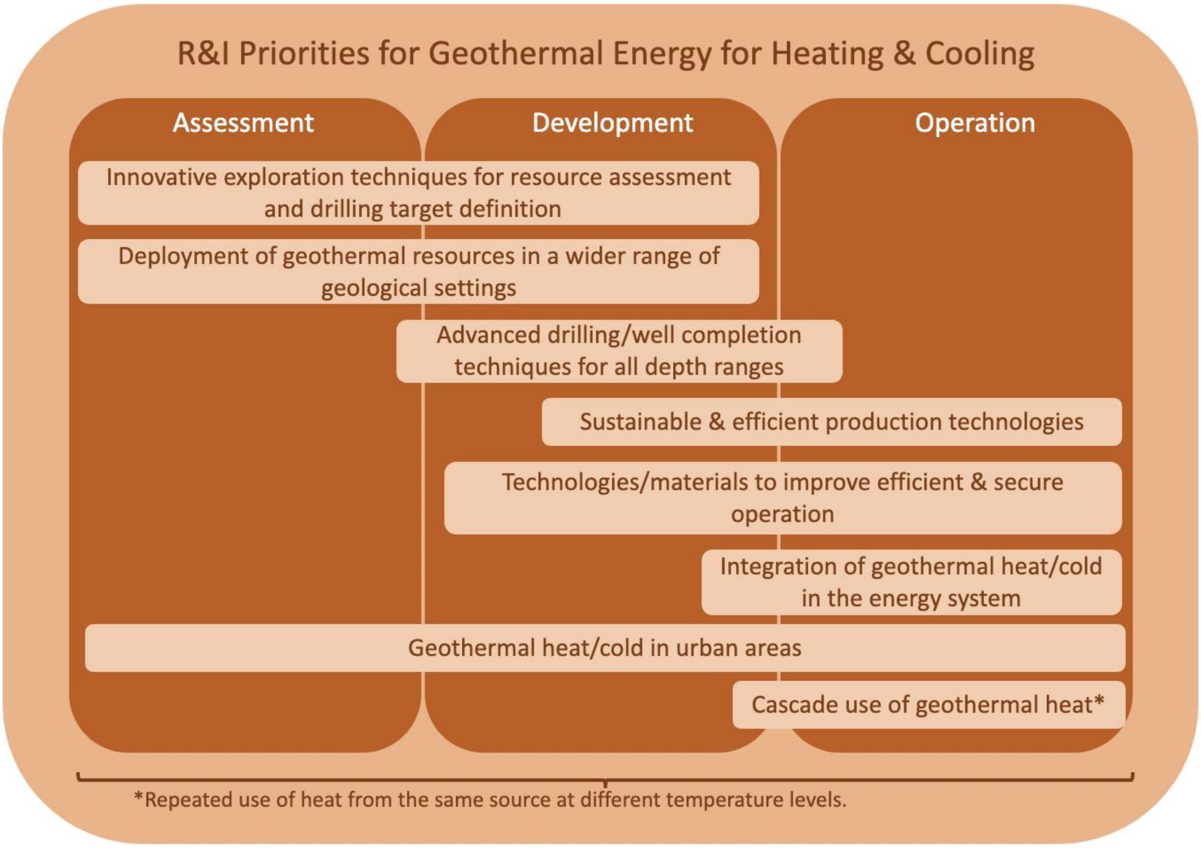

Figure 2: R&I Priorities for Geothermal Energy for Heating and Cooling.

5.2. Power Generation

Research and Innovation (R&I) are the two cornerstones for the further development of geothermal technologies for electric power production. The existing technologies will be improved and demonstrated for applications and market uptake while new ones will be developed. The priorities for R&I will be driven by industrial needs aiming at increasing the power production in an even more demanding social and environmental context. Key industrial and technological drivers defining the general frame of the geothermal electric power generation are the following:

- Implementation of Artificial Intelligence and Machine Learning high performance computing and robotization to enhance resource assessment and development, which will lower levelized cost of energy for operations and promote safe and sustainable project deployment.

- Enhancement of the performance of power plants through the optimization of the processes and application of innovative environmentally-friendly solutions and materials which will increase reliability, availability, and grid-balancing flexibility of the geothermal power systems.

- Development of new tools and approaches for the industrialization and standardization of a “common geothermal project” which fits the social and environmental frame and supports the optimal decision-making process for techno-economic performance evaluation of projects.

Figure 3 summarizes the main R&I priorities for the assessment, development and operation of geothermal systems for electric power generation.

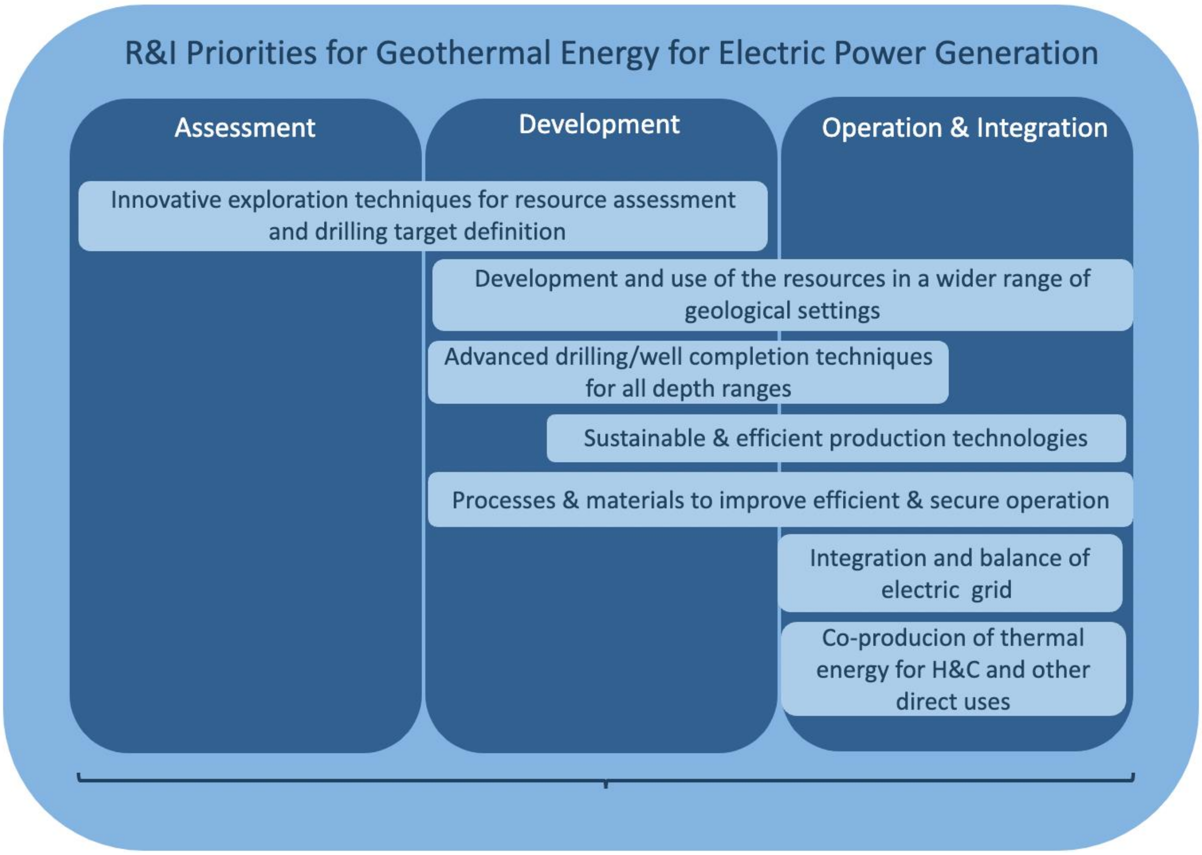

Figure 3: R&I Priorities for Geothermal Energy for Electric Power Generation.

5.3. Underground Thermal Energy Storage

Underground thermal energy storage, along with other types of thermal energy storage, has been gaining momentum. Research, development, and innovation are expected to lead to improved systems with better performance and lower costs. Such improvements will address the whole development chain of UTES systems, including assessment, development of the UTES system, and integration of UTES in the energy system. Assessment includes re-use of existing infrastructure. In terms of development, bespoke wells and completion will offer improved characteristics. When it comes to integration in the energy system, the sector coupling potential is an important topic. It is important to stress that seasonal thermal storage, which uses both heating and cooling thermal energy is an interesting possibility with a large potential. Such a seasonal switch of the thermal energy of interest can lead to very efficient and agreeable space conditions solutions.

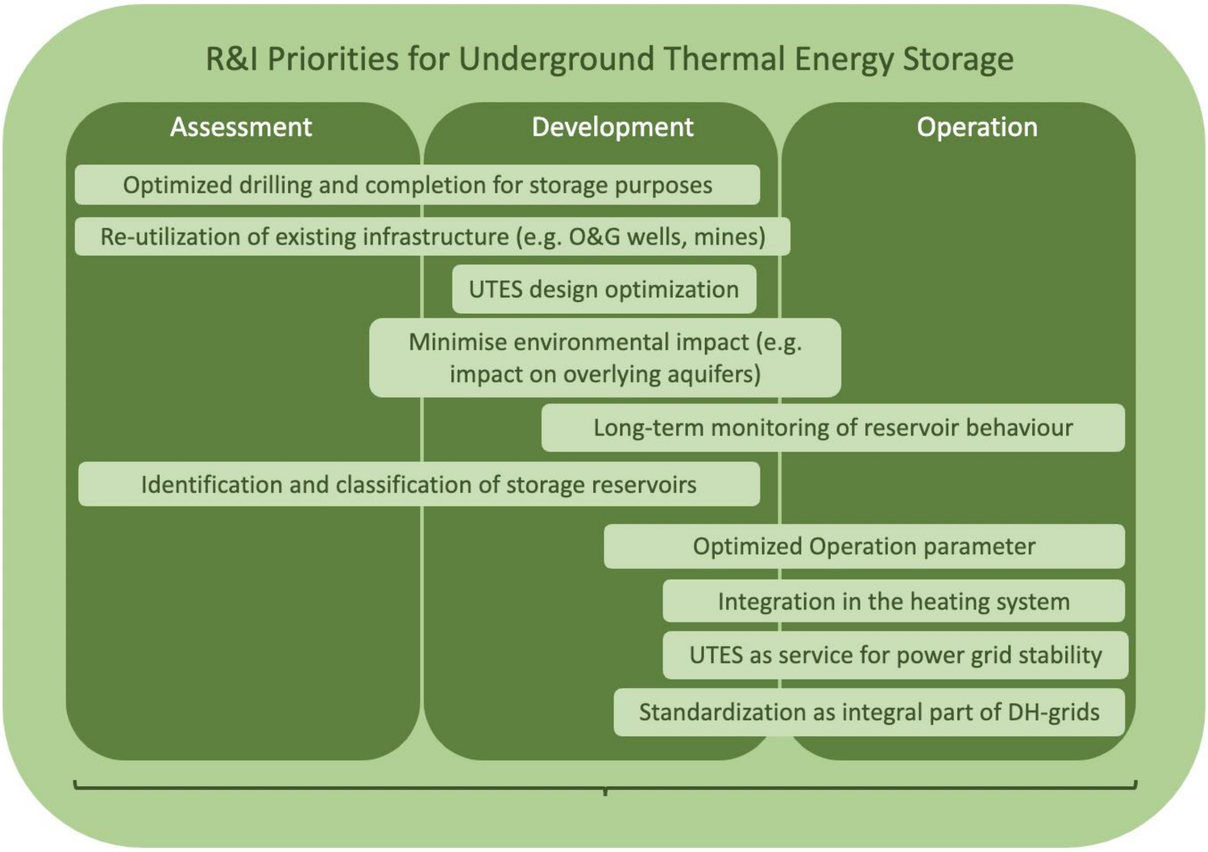

Figure 4: R&I Priorities for Underground Thermal Energy Storage.

5.4. Co-production of Energy and Minerals and Critical Raw Materials (CRM)

Many of the research priorities that are relevant for the first two key priorities (Geothermal Heating and Cooling and Geothermal Power) are equally important for the co-production of energy and valuable raw materials, since a co-production can only be successfully implemented if the geothermal reservoir can be assessed, developed, and operated.

Additionally, the R&I activities indicated in figure 5 are necessary to further improve the understanding of the occurrence of minerals in geothermal fluids, enable the extraction and ultimately foster the co-production of energy and minerals or Critical Raw Materials (CRM). A screening and mapping of the occurrence of raw materials in geothermal fluids is crucial, along with investigations of host rocks, reservoir formations and fluid pathways, in order to understand the source of minerals and CRM, their mobility and potential for sustained extraction from different geological settings. Extractions technologies for a variety of elements have to be developed or adapted and need to be optimised to geothermal conditions (temperature, pressure and chemical composition of the fluid). At the same time, the understanding of the chemical processes during the extraction of heat and raw materials needs to be improved to optimise operations, avoid deleterious effects and minimise maintenance costs. Finally, the assessment of the economic viability requires a long-term testing and monitoring of combined extraction of heat and materials.

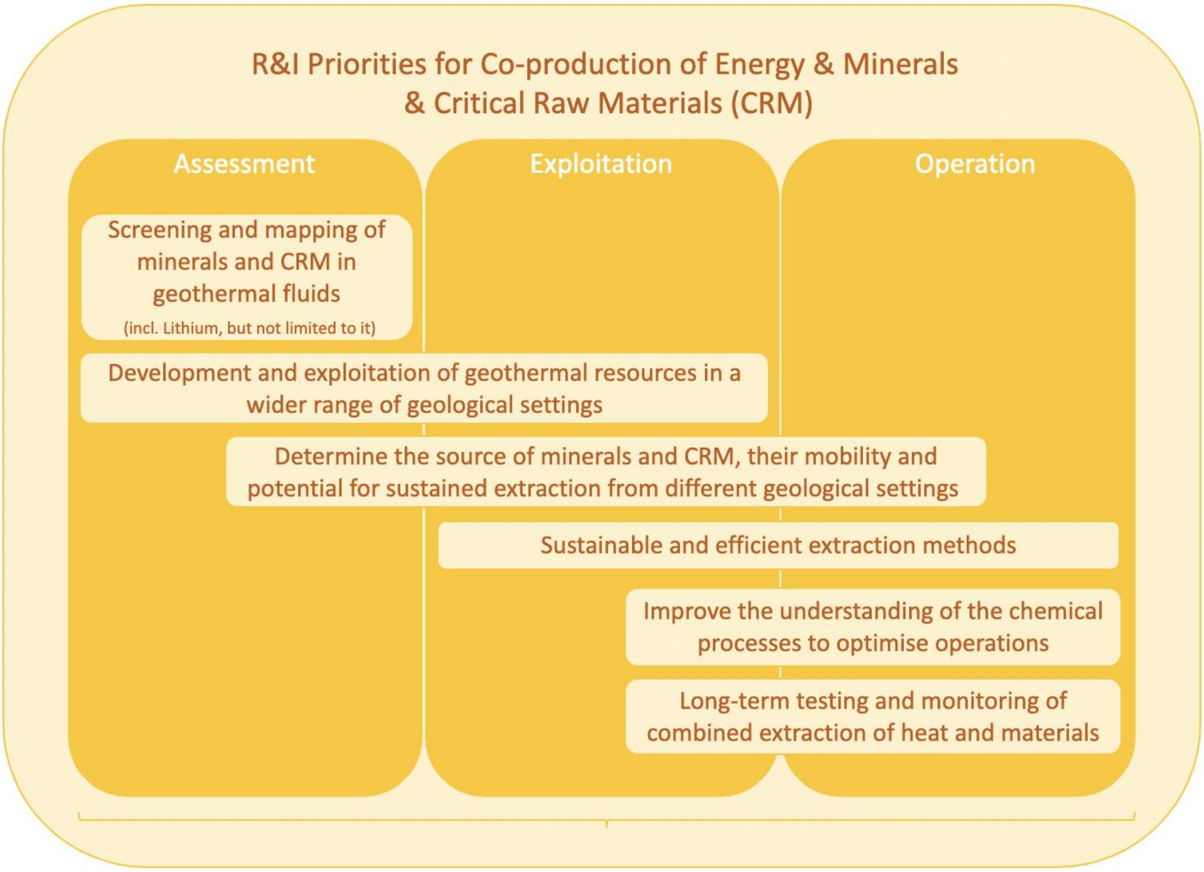

Figure 5: R&I Priorities for Co-Production of Energy and Minerals and Critical Raw Materials (CRM).

5.5. Non-technical Barriers/Enablers & Cross-cutting Topics

In parallel to technological progress, geothermal energy options also need progress on several cross-cutting issues and non-technical barriers and opportunities.

Public awareness of local communities, public acceptance, and involvement of stakeholders in sustainable geothermal solutions are key areas that need effort. Life Cycle Impact Assessments (LCIA) taking into consideration environmental, social, ethical, political, economic, and legal aspects should be applied for the different forms of geothermal energy utilisation, including co-production of minerals and CRMs. Furthermore, activities towards a more coherent regulatory framework would support the market deployment of geothermal energy technologies. In addition, approaches towards geological and financial risk mitigation are needed.

It is important that the SET Plan countries demonstrate capacity building and transfer of know-how. Important for this cross-cutting action is training and educating new geothermal energy professionals. An open-access policy to geothermal information would support geothermal energy.

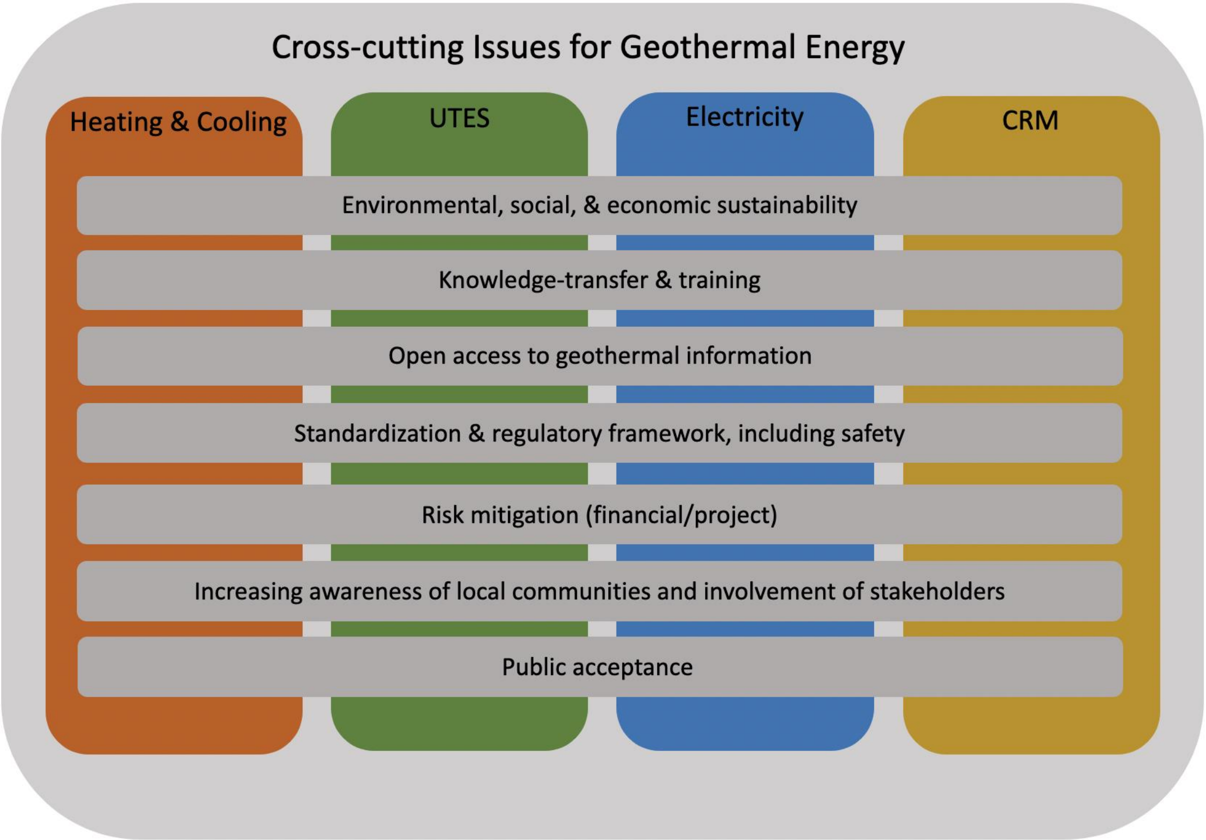

Figure 6: Non-technical Barriers/Enablers & Cross-cutting Issues for Geothermal Energy.

5.6. ETIP Geothermal Research & Innovation Priorities

The ETIP Geothermal is the European Technology and Innovation Platform on geothermal energy, which brings together the geothermal industry and the research community. In 2023, ETIP Geothermal is updating its Strategic Research and Innovation agenda (SRIA). The main technical topics identified in that agenda are grouped into four categories:

- Prediction and assessment of geothermal resources.
- Resource access and development.
- Geothermal resource exploitation.
- Sustainable development and market uptake.

These four priorities are coherent with the columns in the figures in this implementation working plan; where priority D includes non-technical barriers and cross-cutting issues.

5.7. Enabling Framework for the Geothermal IWG's Efforts on the Implementation Plan

5.7.1. GEOTHERMICA

The European Commission has successfully encouraged a number of European SET-Plan countries (and beyond) and their geothermal research and innovation funding organisations to collaborate and pool resources across the innovation cycle. The transnational collaboration GEOTHERMICA builds on a common understanding of the research and innovation needs in GEOTHERMICA countries and regions, the identification of common challenges and resulting from this realization a comprehensive set of activities that serve to address the common challenges for the geothermal energy sector. A cornerstone are joint calls for transnational research and innovation projects and a number of additional activities. The first such call has been co-funded by the European Commission with subsequent calls being supported only by GEOTHERMICA countries.

5.7.2. The Clean Energy Transition Partnership

Building on the success of a number of such ERANETs across energy technologies, EU member states and associated countries together with the European Commission envisage a next stage in the cooperation: the establishment of a co-funded “Clean Energy Transition” partnership (CETP). The Geothermal IWG expects that this challenge driven CETPartnership will provide ample opportunities to launch calls and additional activities that are not only driven by technology and scientific needs but are more appropriately framed in the context of challenges that Europe faces on her journey to carbon neutrality and beyond.

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