Deep GEOTHERMAL IWG

SET-Plan - Deep Geothermal IWG Implementation Plan

SET-Plan
Implementation Working Group
Deep Geothermal

Implementation Plan

Draft for consultation

April 2020

Table of content

Table of content 3
Preface 4
Main Key Action/Declaration of Intent 4
Targets of the Declaration of Intents (DOI) 6
Summary 6
State of the Art 7
R&I Activities 7
Non-technical barriers/Enablers (NTBE) 7
Cross-cutting Issues 7
Next Steps 8
Ongoing and planned R&I Activities 10
A - Geothermal heat in urban areas 10
B Integration of geothermal heat and power in the energy system and grid flexibility 12
C Improvement of overall geothermal energy conversion performance for electricity and heating & cooling generation 14
D Closed loop electric and heating & cooling plants integrated in THE CIRCULAR economy 16
E Methods, processes, equipment and materials to ensure the steady availability of the geothermal resources and improve the performance of the operating facilities 18
F Development and exploitation of geothermal resources in a wider range of geological settings 20
G Advanced drilling/well completion techniques 22
H Innovative exploration techniques for resource assessment and drilling target definition 24
NTBE - Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions 26
NTBE B - Risk mitigation (financial/project) 28
International Cooperation 30
Contacts 31

DG IWG Implementation Plan

Preface

This document presents the draft revision of the Deep Geothermal Implementation Plan (IP), that the Deep Geothermal Implementation Working Group has approved in 2020. The predecessor of this document was dated January 2018. The IWG working group that was tasked with the revision of the IP concluded that little changes were needed to make the document ready for the years to come. In particular, the updated Deep Geothermal Implementation Working Plan puts the R&I Activities in a more logical order, starting from the user perspective back to exploration which is underlying to any use of deep geothermal energy.

To increase the transparency and potential of the public and stakeholders to participate in the 2020 revision of this document a special Consultancy Portal has been set up for inputs.

Consultation Portal – click here to take part

Everyone is free to submit a comment or suggestion. It should be noted that, in addition to open consultation on the Internet, there may be other types of consultation process, such as the involvement of key stakeholders in committee work or a special invitation to them for comments.

Main Key Action/Declaration of Intent

Geothermal energy is a valuable and local source of energy that can cost-effectively provide baseload/dispatchable electricity, heat or a combination of both. With these features, it has the potential to provide real alternatives to replace power plants and heating systems emitting greenhouse gases, not only in Europe but also globally, in particular in some developing countries. In addition, geothermal reservoirs may also act as sites for storage of energy as well as CO_2.

This document focuses on deep geothermal energy, which can be directly used as heat or converted into electricity or used for cooling purposes.

Nowadays geothermal heat is directly used, depending on its temperature, in a number of sectors: from balneology to industry, agriculture to district heating. There is great potential for the utilization of geothermal energy for heating in Europe. There are many locations in Europe with district heating systems that can easily be adapted to make use of local geothermal resources instead of relying on imported fossil fuels. This can increase energy security and price stability as well as independence from fossil fuel sources. In addition, there is also a potential for an increased use of geothermal heat in industry and agriculture. Unlocking of this potential will be enabled through research and innovation focused on the improvement of technology and its incorporation 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.

According to the EGEC Market Report Update (2017), as of 2016, there exist 102 operating geothermal power plants in Europe, with a total installed capacity of around 2.5 GW_{el}, of which 1 GW_{el} in the European Union. Altogether, there is an estimated total annual electric production of about 80 TWh worldwide and over 12 TWh in Europe. The total installed capacity in Europe is expected to reach 3GWel in 2020 including the rapidly growing Turkish market.

The geothermal electricity market is particularly dynamic in the USA, Philippines, Indonesia, Mexico and Kenya, and could be invigorated in the near future in the EU if a larger extent of geothermal resources (e.g. EGS, supercritical, magmatic, geo-pressurized, off-shore), can be successfully commercialized under a wide range of geological conditions.

Recent modelling results indicate that EU geothermal power production could reach up to 540 TWh per year in 2050 under a long-term decarbonisation scenario provided that EGS can be deployed on a large scale. In other words, geothermal power could provide 12.5% of electricity demand in EU and neighbouring countries, while exploiting about 20% of the available geothermal technical potential. This market share might be increased significantly if cost reductions associated with drilling or commercial production from a larger extent of geothermal resources (as mentioned above) are realized. On volcanic islands geothermal energy could provide the highest share of renewable heat and electricity.

Geothermal installations are characterized by low OPEX but high CAPEX, used mostly to cover the costs of exploration and drilling, as well as plant construction. In addition, financing costs are high due to high geological risks associated with costly drilling during early-stage exploration. Market financers generally are unwilling to take up these early stage risks and costs, which represents one of the major barriers for geothermal project developers. However, high capacity factors (far higher than for most other renewables) and low OPEX, near zero system costs and externalities, result 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 reduce costs and to improve performance. It is also necessary to widen the geological conditions under which technologies can be applied and develop technologies to harness a larger extent of geothermal resources, including EGS, available for the 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 demonstrated. Furthermore, environmental performance and social acceptability must be improved.

The worldwide importance of geothermal energy has recently become acknowledged at the political level with the launch of the Geothermal Global Alliance at COP21. This is a coalition of 46 countries and over 39 development and industry partners that have joined political forces to increase the share of geothermal energy in the global energy mix. The Geothermal Global Alliance aspires to achieve a 500% increase in global installed capacity for geothermal power generation and a 200% increase in geothermal heating by 2030. The opportunity for Europe and the European industries, with their knowledge and leadership, in reaching these goals should not be missed.

Targets of the Declaration of Intents (DOI)

1. Increase reservoir performance* in sustainable yield predicted for at least 30 years and reduce the power demand of operating facilities to below 10% of gross energy generation by 2030;
2. Improve the overall geothermal energy conversion efficiency, including bottoming cycle, of geothermal installations at different thermodynamic conditions by 10% in 2030 and 20% in 2050;
3. Ensure production costs (CAPEX and OPEX) of geothermal energy (including from unconventional resources, EGS, and/or from hybrid solutions which couple geothermal with other renewable energy sources) below 10 €ct/kWh$_{el}$ for electricity and 5 €ct/kWh$_{th}$ for heat by 2025**;
4. Demonstrate the technical and economic ability of innovative exploration approaches and tools to increase the drilling success rate by 20% in 2025 and 50% in 2030 compared to 2015*;*
5. Reduce the unit cost of drilling (€/MWh) by 15% in 2025, 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 or heat production;
7. Demonstrate the technical and economic feasibility of geothermal heating, cooling and high-temperature storage in a flexible heating system; cover 5% of demand in Europe by 2030 and 25% by 2050.

** Reservoir performance includes underground heat storage.*

*** Costs have to be confirmed establishing at least 5 plants in different geological situations, of which at least one with large capacity (10 MWel or, if for direct use only, 20 MWth).*

Summary

The research and innovation (R&I) Actions envisaged in the Deep Geothermal Implementation Plan address relevant issues crucial for the development of the use of geothermal energy resources, both as heat and electricity. The implementation plan (IP) pays due attention to the widely present low and high temperature geothermal resource in Europe and whose development, together with that of urban district heating networks fed by geothermal, represents a key opportunity to increase 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. Other key actions are related to 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 technologies and advanced drilling techniques. Strongly connected to the DOI targets of cost decrease, and to issues of social acceptance, are the key actions dedicated to performance improvement and to the development of zero-emission geothermal plants. Knowledge transfer and data unification issues are also relevant measures of the IP. Non-technical barriers/enablers were finally identified: Social acceptance, in support of a wide-spread and accepted development of geothermal energy; and risk management, with the objective of establishing a European scheme for the management of risk in geothermal projects, which is considerable as exploration and field development represent a major investment.

State of the Art

The use of geothermal energy, particularly for heating applications, is steadily increasing across Europe. The growth of geothermal electricity is mainly caused by the rapid expansion in Turkey, which is set to continue. Italy, France, Germany and The Netherlands are focusing their geothermal strategies, and further new and innovative projects are also expected in other countries in the near future.

Among renewables, electricity from geothermal resources is today fully competitive with fossil fuels in choice locations, with costs of about 0.07 EUR/kWh including systems and operation for large-scale systems. The European industry performs excellently in the geothermal sector.

District heating and cooling has been a real success story for geothermal, since it is still expanding into new markets. Deep geothermal for heating and cooling encompasses supply to industrial and service sectors. There are 280 such plants in Europe with a total installed capacity of about 5 GW_{th}. With about 200 new plants in planning, the installed capacity is set to grow up to 6.5 GW_{th} by 2020.

Geothermal energy can represent a relevant contribution to the transition towards a more sustainable energy system. Combined heat and electric power, hybridization with other renewables (solar, biomass), and support to local and sustainable economic development, security of supply and load flexibility are already recognized qualities of geothermal energy, which will find a further boost from the adoption of the implementation plan.

R&I ACTIVITIES

A. Geothermal heat in urban areas
B. Integration of geothermal electricity and heating & cooling in the energy system responding to grid and network demands
C. Improvement of overall geothermal energy conversion performance for electricity and heating & cooling generation
D. Closed loop electric and heating & cooling plants integrated in the circular economy
E. Methods, processes, equipment and materials to ensure the steady availability of the geothermal resources and improve the performance of the operating facilities
F. Development and exploitation of geothermal resources in a wider range of geological settings
G. Advanced drilling/well completion techniques
H. Innovative exploration techniques for resource assessment and drilling target definition

NON-TECHNICAL BARRIERS/ENABLERS (NTBE)

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

CROSS-CUTTING ISSUES

The Deep Geothermal Implementation Working Group stresses the relevance of two cross-cutting issues which are crucial for gaining more widespread support for all research and innovation actions while promoting non-technical barriers/enablers:

Knowledge transfer + training (including peer-to-peer learning and research infrastructures)

It is important that the EC demonstrates throughout Europe capacity building, industrial technology transfer and science & academic partnerships via know-how, with the shared goal to develop high quality, competitive and sustainable geothermal energy projects. This includes supporting the existing pan-European infrastructure of experimental test and monitoring facilities and infrastructures (Geo Energy Test Beds, GETB - see also https://www.epos-ip.org/data-services/community-services-tcs/geo-energytest-beds-low-carbon-energy) and making efficient and coordinated use of them. This cross-cutting action also aims at training and educating new geothermal professionals. Among the necessary actions, a key issue is represented by the cooperation between education and training institutes and companies, creating networks for education and training involving industrial platforms, universities and research centres. Further ideas are to develop courses on geothermal energy within existing university courses and to launch new courses; to absorb the workforce of declining industries; and to promote the mobility of workers in Europe. Support to these actions should be sought nationally, in H2020 (and subsequent framework programs) Concertation and Support Actions, and in existing EC programs or support of knowledge transfer and human mobility, such as (Marie Curie, Erasmus +, ERC grants).

Recommendation of an open-access policy to geothermal information (including standard exchange formats)

The scope of this cross-cutting action is to facilitate access to geothermal information at the European level via the development of an information platform, creation of standard and common data models at EU level. This should be achieved through progressive harmonization of national data to facilitate data discovery and mining. This is an important step to provide scientists, stakeholders, investors and geothermal developers with important information, and is also the basis for resource assessment and feasibility studies. Resources for this action should be mainly guaranteed by national geological services within European countries. A general commitment to open access to relevant data is recommended through a user-friendly interface with different levels for professionals and the general public seeking information. In the frame of the Geothermal ERA-NET the concept of a European Geothermal Information Platform was developed, and principal features suggested. Such a platform is envisaged as a web tool gathering data and knowledge from national and scientific providers in agreement with the European INSPIRE directive. The platform needs to be interoperable with other pan-European data platforms, e.g. EGDI. Activities include:

- Definition of standards (e.g. for database format, services which make automatic uses of data) and data models.
- Data preparation, harmonization and publication through national web-services.
- Development of the geothermal information platform, providing services for open-access data harvesting, data mining and data management (e.g. graphs, statistical tools etc.)

Continuing support to ERA-NET/GEOTHERMICA or the Horizon Europe Clean Energy Transition – Partnership (CET-P) though Concertation and Support Actions or other initiatives is recommended

Next Steps

The Deep Geothermal Implementation Working Group (IWG) is composed of representatives of relevant countries and stakeholders, representing both the industry and the academia. The IWG is responsible for revision of the Deep Geothermal IP. Throughout 2020 the Implementation Plan was revised.

All the actions of the Implementation Plan are crucial to meet the SET-Plan targets for geothermal energy listed in the relevant Declaration of Intent. To ensure their proper implementation, an estimated overall investment of €936.5m shall be mobilised, to be covered as follows:

- €456m coming from the industry (private funds - 49% of the total)
- €342m coming from national programmes (36.5% of the total)
- €138.5m coming from EU funds (14.5% of the total – from both NER 300 and Horizon 2020, including the ongoing Geothermica ERA NET project)

Of the 8 R&I activities identified, 4 are considered to be flagship. Common for these R&I activities are that interdisciplinary and intersectoral demonstration projects (flagship projects) are required for efficient implementation. Furthermore, 5 target projects with low initial TRL, hence requiring basic and/or fundamental research endeavours (R&I activities 2, 3, 4, 5 and 8 have initial TRLs between 3 and 4). R&I activity 5 is related to cross-cutting technologies necessary for several parts of the geothermal value chain. For the flagship projects, the TRL refers to the main technology, but sub-technologies on lower initial TRL related to the cross-cutting R&I activity 5 is necessary to exploit the potential of linking of more basic research to large demonstration projects. Finally, the main non-technological barriers to the development of deep geothermal, i.e. public acceptance, dissemination of best practices, coordination of geological risk mitigation methods and development of ad-hoc financial schemes, are targeted by separate, dedicated activities.

For these reasons, the proposed activities are characterised by different levels of maturity. Although the implementation of R&I activities as well as NTBE-A and NTBE-B, which are partially covered by the ongoing GEOTHERMICA ERA NET project, considerable extra efforts and funding will be required over the coming months and years to meet the goals of the Declaration of Intent. Continuous work on this IP is therefore expected.

The identified potential synergies with several other IWGs are still relevant, namely:

- Carbon capture storage/use (use (CCS/U) (combining CCS/U with geothermal energy extraction; data availability for CO_2 saline equilibria at high pressures and temperature; reservoir modelling; equipment for drilling and NCG reinjection; …)
- Concentrated Solar Power (advanced Power Cycles, with specific reference to supercritical CO_2)
- Energy consumers (rebound effect of geothermal energy on non-dispatchable renewables, with significant effects on the cost of electricity)
- Integrated and flexible energy systems (grid dispatchability)

A Support Unit to the Deep Geothermal IWG has been created, with a financial support from the European Commission, to facilitate the execution/realisation of the Implementation Plan and to ensure that the DG-IWG will have sufficient data, tools and procedures in place for it to have well-grounded discussions and make strategic decisions to accelerate the uptake of geothermal energy in Europe in a productive way.

The workstreams of the Support Unite are three, namely:

- To provide the DG-IWG with relevant data about the IP execution, from the various stakeholder groups as well as providing strategy support for the DG-IWG in their decision-making process and actions;
- To promote and organise initiatives to mobilise the geothermal community to implement the actions identified in the implementation plan, e.g.: workshops, brokerages, consortium building and exploitation of RD&I results.
- To provide a secretariat for the DG-IWG to assist on administrative issues and strategy support

The IP will continue to be regularly revised in accordance with activity's executions and general development of the sector.

Ongoing and planned R&I Activities

In the following, prioritized research and innovation activities are identified and completed with a discussion on non-technical barriers and enablers.

A - GEOTHERMAL HEAT IN URBAN AREAS

R&I Activity A	**Targets: DOI 1, 3, 7 & NTBE A, B**
TRL at start: 4-5	**TRL at end: 7-9**
Total budget required: €73,3m	**Flagship: Yes**

Scope:

To enhance the European heat transition to renewable energy by providing geothermal based solutions for urban areas. To contribute to decarbonising energy use for heating and cooling in cities and to improve air quality.

Description:

Based on direct use of geothermal energy, the following must be achieved: demonstrate new heating concepts for urban areas and/converting conventional district heating networks of urban areas into renewable heating systems; enable the smart use of thermal grids with emphasis on flexible supply of resources, adapted to different source temperatures and varying demand; and position geothermal utilization (including underground storage) as a crucial pillar for the (heat) transition of the energy system. Activities include geothermal heat for industry and agriculture, underground thermal energy storage (UTES) including high-temperature storage, innovative and multiple uses for geothermal energy and side-products, balneological systems, and design and operation of geothermal doublets.

Several demonstration projects will showcase the broad potential of geothermal energy, providing an overall justification for a Flagship in terms of relevant contribution to conservation of energy resource and together with geothermal energy storage to a large-scale transition towards renewable heat in Europe. Integrated innovative concepts will be demonstrated including smart integration into the energy system (e.g. cascading, matching supply with demand, heat and cold exchange, using a LowEx approach which minimizes exergy losses by matching the energy quality of heat (or cold) demand and supply) and possible integration of other renewables in the geothermal heat supply.

Monitoring mechanism:

A subject should be decided for reporting at member states/EC level.

Progress will be reported with respect to deliverables of each specific project. Quantitative check on energy delivered to connected users with respect to targets declared in the flagship project.

Expected deliverables:	Timeline:
Portfolio (expected at least one per country involved) of Member state demonstration projects: number of realized project will be listed, pointing out best practices and successes. Minewater Heerlen, Greater Munich, Paris, Milan, Geneva, Bern …	2020 on
Examples of combining Renewable Technologies for a Renewable District Heating System, might include H2020 demonstration case.	2019 on

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, BE, CH, DE, FR, IT, NL, PT, EU	Dedicated industry investment (private funds)	€30m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €40.5m Italy: €0.7m
		Structural funds could play a role as well, based for example on the pilot experience in Tuscany, which builds on the interregional platform on energy
	GEOTHERMICA CFA	€8.5m of EU funds[1]
	LCE-17-2017 "Easier to install and more efficient geothermal systems for retrofitting buildings".	Projects, and relevant EU and private budget, to be announced in the first half of 2018

[1] Total GEOTHERMICA budget, relevant to various IP activities (see the rest of this document)

B INTEGRATION OF GEOTHERMAL HEAT AND POWER IN THE ENERGY SYSTEM AND GRID FLEXIBILITY

R&I Activity B	**Targets: DOI 6, 3 & NTBE B**
TRL at start: 7	**TRL at end: 9**
Total budget required: €11,5m	**Flagship: Yes**

Scope:

Integration of flexible generation from geothermal power in the energy sector

Description:

Demonstrate the technical and economic feasibility of responding to commands from a grid or network operator, at any time, to increase or decrease output ramp up and down. Demonstrating the automatic generation control (load following / ride-through capabilities to grid specifications) and ancillary services of geothermal power plants. Addressing flexible heating and cooling and electricity supply from binary cycles and EGS plants, including coupling with renewable energy sources; addressing specific problems of geothermal power production in isolated energy networks (islands). Geothermal energy storage integrated with district heating networks and dedicated equipment (heat pumps, ORC turbo-expanders, and heat exchanger networks, with hot and cold reservoirs able to cover variable demand of heating, cooling and electricity.

Activities will include impact on the development of transmission and distribution infrastructure and the interplay with other flexibility options (e.g. demand-side management and storage), and test on dispatchability. Furthermore, the flexible generation should be able to provide additional services to the grid such as peak power, role in electricity balancing/reserve market.

Monitoring mechanism:

H2020 and GEOTHERMICA project monitoring Annual round-check on advances made in operational flexibility of geothermal plants connected to the electric grid and heating and cooling networks with different technologies.

Expected deliverables:	Timeline:
Tests demonstrating automatic generation control (load following / ride-through capabilities to grid specifications)	2019-22
Demonstrations of load following in binary cycles coupled to RES	2019-2022

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, CH, IS, IT, PT, TR, EU	Dedicated industry investment (private funds)	€10m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €1.5m

C IMPROVEMENT OF OVERALL GEOTHERMAL ENERGY CONVERSION PERFORMANCE FOR ELECTRICITY AND HEATING & COOLING GENERATION

R&I Activity C	**Targets: DOI 3, 2 & NTBE A**
TRL at start: 5-6	**TRL at end: 7-8**
Total budget required: €21m	**Flagship: No**

Scope:

To improve the overall conversion efficiency and reduce the cost of geothermal energy utilization, developing an EU technology solution with a perspective to become a worldwide standard.

The overall geothermal energy conversion efficiency will be improved by the development of higher performance power plants, including binary cycle power plants, able to supply heat and electric power.

Description:

This action shall focus on specific components with considerable potential for an increase of system efficiency e.g. design of improved heat exchangers and pumps, selection of materials, new working fluids with very small GWP (Global Warming Potential), increase in expander efficiency, improved efficiency of the cooling system by enhancement of the air-cooler condenser and matching to the cycle, or avoiding the dumping of useful heat into the environment by promoting the low-enthalpy industrial use of the circulating fluid. Utilizing high temperature (> 175 ° C) and high content of Non-Condensable Gases (>2%), geothermal fluids through a binary power plant can solve some of the material challenges. Bottoming/hybridization of existing or new power plants and development of new cycle concepts is also of interest.

In order to cope with fluctuations of heat demand, flexible supply units are necessary that are not designed for one specific optimal condition, but in a way that maximizes the use of the heat source. Such systems should also consider hybridization with various sources of renewable heat, such as biomass or solar thermal. Technical solutions should be tested, and their applicability demonstrated, promoting the flexible use of the geothermal heat source depending on demand (electricity and heat). This implies an optimization of partial load behaviour and flexible control strategies for the operation of the whole system. Activities are also directed to facilitating the direct use of heat for industry and/or municipality by finding new innovative and multiple uses for the geothermal resource.

Monitoring mechanism:

Annual round-check on advances in performance of energy conversion including information on new plants (commissioned or under construction) in the partner' countries involved in these activities.

Benchmarking with respect to specific project deliverables and reference plants.

Expected deliverables:	Timeline:
General performance improvement of systems that enable the generation of electricity and heating and cooling from geothermal energy resources with medium and low enthalpy, including double flash and complex/hybrid cycle systems, organic Rankine Cycles (ORC), Kalina and supercritical CO_2 cycles.	2022
Improving efficiency of surface systems equipment/components: heat recovery equipment, turbines for power only and for combined heat & power generation, cooling generation (via heat absorption)	2022

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, FR, IT, FR, IS, PT, TR, EU	Dedicated industry investment (private funds)	€15m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €4.5m Italy: €1.5m
	LC-SC3-RES-12-2018: Demonstrate highly performant renewable technologies for heat and power generation and their integration in the EU's energy system National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	€8-10m – shared with Grid Flexibility demonstration)- Research from private manufacturers Cooperation with other energy sectors Support potential involvement of private research.

D CLOSED LOOP ELECTRIC AND HEATING & COOLING PLANTS INTEGRATED IN THE CIRCULAR ECONOMY

R&I Activity D	**Targets: DOI 2, 3 & NTBE B**
TRL at start: 5-6	**TRL at end: 6-7**
Total budget required: €123.4m	**Flagship: Yes**

Scope:

Demonstrating the feasibility of closed-loop power plants by the application of the total reinjection of the geothermal fluids including the capture of non-condensable gases (Zero emission plants), to eliminate waste and ensure long term stability of the geothermal resources.

Description:

Zero emission plants and capture, storage and reinjection schemes for the development and exploitation of geothermal reservoirs with high content of CO2 and/or other harmful non-condensable gases (NCGs) will be .demonstrated.

The feasibility and reliability of closed-loop reinjection will be validated for high temperature (> 175° C) and high content of NCGs (>5%) geothermal fluids, Systems for capture and re-injection or use of chemical compounds associated with produced geothermal fluids will be developed.

NCGs are often present in geothermal brines and may contain contaminants requiring chemical processing. Depending on reservoir conditions (thermodynamics and composition, including saline equilibria) the challenge can in some cases be addressed avoiding flashing of the resource, or maintaining a high flash pressure, possibly using hybrid solutions. Solutions for complete reinjection into the reservoir are targeted, with NCGs in gaseous or liquid state. These solutions imply correct matching to the power cycle and development of new equipment (compressors, pumps, intercoolers, mixing nozzles, and possibly refrigeration equipment). Research will deal both with whole process optimization, and new equipment. The first plants of this type are expected within 2025 and may represent a worldwide flagship, with relevant market fallouts for many countries (IT, TR, IS, Kenya…).

Monitoring mechanism:

Annual checks on advances. Every year information on new plants (realized or under construction) will be gathered in partner countries involved in these activities.

Benchmarking with respect to specific project deliverables. The information collected every year will be organized in a report taking into account the initial baseline and also data coming from countries not represented in the TWG.

Quantitative check on power connected with respect to targets declared in the flagship project.

Expected deliverables:	Timeline:
Lab and field tests demonstrating possibility of full reinjection in test circuits and/or geothermal reservoirs with different resource conditions	2020
Pilot/demonstrative geothermal plants to experiment high-performance closed loop technologies	2025

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, FR, IS, IT, PT, TR, EU	Dedicated industry investment (private funds)	An industrial project is under authorization procedure in Italy, for an expected investment of €40m (5 MW_{el} demonstration pilot).
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €7.5m Italy: €0.4m Turkey: €0.5m
	LC-SC3-RES-13-2018: Demonstrate solutions that significantly reduce the cost of renewable power generation (Type of action: R&IA)	€15-20m (contribution from the EU expected per proposal)
	LC-SC3-RES-12-2018: Demonstrate highlyperformant renewable technologies for heat and power generation and their integration in the EU's energy system (Type of action: R&IA)	€15-20m (contribution from the EU expected per proposal)
	Geothermae NER 300 project in Croatia	€15m *The private contribution can be estimated as being roughly 4 times as high as the NER 300 one.*

E METHODS, PROCESSES, EQUIPMENT AND MATERIALS TO ENSURE THE STEADY AVAILABILITY OF THE GEOTHERMAL RESOURCES AND IMPROVE THE PERFORMANCE OF THE OPERATING FACILITIES

R&I Activity E	**Targets: DOI 3, 2, 1 & NTBE A**
TRL at start: 3-4 (Methods); 5 (Equipment); 4 (Materials)	**TRL at end: 6 (Methods); 9 (Equipment); 6 (Materials)**
Total budget required: €25.6m	**Flagship: No**

Scope:

Developing new methods, processes, equipment and materials suitable to solve problems commonly encountered in geothermal resources development and exploitation (e.g. corrosion and scaling) for low and high temperatures and reduce the power demand of operating facilities through the application of advanced well architectures and innovative technologies and materials decreasing the overall cost of a geothermal project.

Description:

The major advantage of geothermal energy over other renewable energy sources is the time and site independent availability of the geothermal resource. To use this advantage, the operational availability of geothermal energy installations and the subsurface system must be stable on a high level. Sustainable and reliable production from deep geothermal resources is associated with various challenges, mainly related to the high temperature, high pressure environment, and geothermal fluid composition as well as dynamic reservoir response to stimulation and/or fluid production/reinjection. The materials and equipment required need to cope with hostile and aggressive reservoir environments and thermochemical fluid properties; the goal is to improve equipment reliability and to increase the plant utilization factor. Developing materials and/or methods and/or equipment such as pumps and heat exchangers for the application in all parts of a geothermal plant to minimize operational issues related to high temperatures, scaling, corrosion, and gas content. Development and utilization of machine learning technology in analysis of geothermal data has significant potential in improving exploitation and operation of geothermal systems. Improved monitoring, simulation technology and methods to better understand the coupled processes during reservoir stimulation and/or fluid production/reinjection of the reservoir are important to ensure stable operating conditions, improved performance and mitigation of risk.

Monitoring mechanism:

Checking of deliverables for each specific project with respect to advancement plan.

Expected deliverables:	Timeline:
Status report on improvement of operational availability in the Geothermal sector	2022
Demonstration of major innovations that bring operational availability to a higher level (e.g. pump, heat exchanger, materials)	2030

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, DE, IS, IT, NL, PT, EU	Dedicated industry investment (private funds)	€10m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €4.5m Italy: €1.5m
	LC-SC3-RES-12-2018: Demonstrate highly performant renewable technologies for heat and power generation and their integration in the EU's energy system National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	€8-10m – shared with Grid Flexibility demonstration)- Research from private manufacturers Cooperation with other energy sectors Support potential involvement of private research.
	GEOTHERMICA CFA	€8.5m of EU funds
	LC-SC3-RES-1-2019: Developing the next generation of renewable energy technologies	€2-5m

F DEVELOPMENT AND EXPLOITATION OF GEOTHERMAL RESOURCES IN A WIDER RANGE OF GEOLOGICAL SETTINGS

R&I Activity F	**Targets: DOI 3, 2 & NTBE A**
TRL at start: 4	**TRL at end: 8**
Total budget required: €382.5 m	**Flagship: Yes**

Scope:

Demonstration of innovative methods and techniques for reservoir development and exploitation in a wider range of geological settings, including complex and/or untested geological conditions.

Description:

This action covers the development and demonstration of energy efficient, environmentally sound and economically viable generation of electricity, and/or heating and cooling from geothermal resources and the integration in a flexible energy supply and delivery system. New geological environments which require additional reservoir performance improvement techniques shall be developed for the geothermal use, fostering an unprecedented development of geothermal energy at European level (including Member States with low-quality or presently absent resources). Environmental impacts assessment and mitigation measures (e.g. Induced seismicity, aeriform emissions, landscape footprint, chemical products) will be an integrated part of all development and exploitation. The expected outcome will be geothermal energy in a form that can be widely deployed and competitively priced, underpinned with reduced capital, operational and maintenance costs.

Monitoring mechanism:

Annual round-check on advancement. Every year new information on plants will be gathered (realized or under construction) in countries involved in this activity. Benchmarking with respect to deliverables. The information collected every year will be organized in a report which also accounts for the initial baseline and captures data from countries not directly involved in this activity or current TWG composition. Quantitative check on electricity/heat targets declared in the flagship project. A particular focus will be on activities in connection with flagship projects and the implementation of monitoring systems.

Expected deliverables:	Timeline:
Portfolio of existing/planned projects Soultz, Deep EGS, Hungary, Mol, Gardanne	2020
1 plant=10 MW_{el}-20MW_{th}	2022
1 plant=20 MW_{el}-40MW_{th}	2025

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, CH, DE, FR, IS, IT, PT, EU	Dedicated industry investment (private funds)	€30m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €33m
	LCE 18 2017 EGS in different geological conditions	€8-10m
	LC-SC3-RES-12-2018: Demonstrate highly performant renewable technologies for heat and power generation and their integration in the EU's energy system	€8-10m – shared with Grid Flexibility demonstration
	LC-SC3-RES-13-2018: Deep geothermal demonstration of cost efficient technologies to limit emissions and/or to condense and re-inject gases	€15-20m
	LC-SC3-RES-14-2019: Develop a better understanding of the chemical and physical properties of geothermal fluids (including hot and super-hot fluids)	€3-5m
	South Hungarian EGS Demonstration NER 300 project in Hungary	€39m
	GEOSTRAS NER 300 project in France and Germany	€17m *The private contribution can be estimated as being roughly 4 times as high as the NER 300 one.*

G ADVANCED DRILLING/WELL COMPLETION TECHNIQUES

R&I Activity G	**Targets: DOI 3, 5**
TRL at start: 5 (improvement), 4 (novel)	**TRL at end:7 (improvement), 6 (novel)**
Total budget required: €52.1m	**Flagship: No**

Scope:

Reduction in drilling/well completion costs leading to reduced cost of energy (€/MWh) in anticipation of the steady increase of number of deep geothermal projects; and applications of advanced exploration techniques able to increase the drilling success rate;

Demonstrate concepts that can significantly reduce drilling/well completion costs (reduce drilling time and non-productive time, reduce costs, mitigate risks) or enhance reservoir performance (including directional and horizontal multilateral drilling). The target is to reduce cost of geothermal energy by reducing cost for drilling and underground installations by at least 25% compared to the situation today

Description:

Well construction represents a major share of the necessary investment in geothermal projects. Hence, reductions in specific well cost (€/MWh) will substantially influence the overall economics of a deep geothermal plant. To increase the economic viability of a geothermal development, advanced drilling technologies, currently not used in geothermal well construction, have to be adapted and optimized for the specific project requirements. Implementation of advanced technologies includes, but is not limited to, process automatization, drilling fluids to compensate unwanted loss of circulation zones as well as improved cementing procedures and well cladding, and stimulation methods improvement for deep wells. Risk assessment and lifetime analysis of the new technologies and approaches must be part of the work. Innovative system to avoid/reduce the discharge of geothermal fluid into the environment while drilling and flow tests will be considered. Horizontal - multilateral wells clusters in various geological formations will be also considered. Targeted (e.g. compact and lightweight) equipment and techniques for drilling and well completion in urban areas is another challenge in this area. Increased technology transfer from the oil and gas industry on horizontal well drilling and completion is needed. The proposed procedures should result in a significant reduction of overall costs over the lifetime of the installations.

New methods for drilling and well completion in the various geological formations relevant for geothermal energy with the potential to accelerate the process, reducing costs and risks shall be tested in realistic settings. Such methods include percussive drilling for deep/hot wells (fluid hammers etc.) and non-mechanical drilling method development (such as laser, plasma, hydrothermal flame drilling). Benchmark testing in boreholes should be attempted. The efforts will be directed to demanding environments (e.g. >5000 m depth and T>250ºC) and all relevant geological formations.

Monitoring mechanism:

Annual round-check on advances: Information will be gathered on new operating wells in partner countries involved in these activities Benchmarking with respect to specific project deliverables.

The information collected every year will be organized in a report with reference to the initial baseline and also including data from countries not directly involved in this activity (i.e. countries not represented in the IWG).

Expected deliverables:	Timeline:
Developed (new) and demonstrated concepts that significantly reduce drilling/well completion costs (reduce drilling time, reduce costs, or mitigate risks) or enhance reservoir performance	2022
New technologies (non-mechanical methods) will be ready for testing at the real scale in deep wells. Reduction in drill time or nonproductive time ~20% by 2025 with the potential to reduce by 50% in 2040	2022

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, CH, DE, IS, IT, NL, PT, EU	Dedicated industry investment (private funds)	€20m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €30m
	GEOTHERMICA CFA	€8.5m of EU funds
	LC-SC3-RES-11-2018: Developing solution to reduce the cost and increase performance of renewable technologies	€8-10m

H INNOVATIVE EXPLORATION TECHNIQUES FOR RESOURCE ASSESSMENT AND DRILLING TARGET DEFINITION

R&I Activity H	**Targets: DOI 3, 4**
TRL at start: 5-6	**TRL at end: 7-8**
Total budget required: €49m	**Flagship: No**

Scope:

Demonstrate the technical and economic ability of innovative exploration approaches and tools to increase the precision for resource assessment, target definition of exploratory drilling and prediction of long-term reservoir performance.

Moving beyond the state of the art by demonstrating the application of new tools, developing new approaches and taking advantage of improved software and computing power, the drilling success will be increased by 20% in 2025 and 50% in 2030 thereby reducing the exploration costs.

Description:

To ensure a reliable pre-drilling assessment of geothermal resources, high resolution exploration methods and approaches are essential to minimize exploration risks. This will be achieved by

- **a)** The development and application of new tools and techniques coupled with innovative modelling techniques, increasing measurement precision and applying faster analysis of acquired data to achieve a feasible model of the reservoir.
- **b)** The update and improvement of state-of-the-art exploration techniques and methods to reduce the average cost for exploration while increasing the drilling success rate. Such progress must address in increasing detail the geological complexity of resources and increasing target depths.

Monitoring mechanism:

Annual round-check on advancement. Each year information will be gathered on new wells in the partner countries involved in these activities

Benchmarking with respect to specific project deliverables in terms of unit finding cost. The information collected every year will be organized in a report taking into account the initial baseline and also data coming from countries not directly involved in this activity (i.e. countries not represented in the IWG).

Expected deliverables:	Timeline:
Improved subsurface images, cost reduction, higher resolution, faster results	2022
Develop and apply new generation exploration techniques	2024

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, CH, DE, FR, IS, IT, PT, EU	Dedicated industry investment (private funds)	€15m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €22.5m Italy: €0.4m
	GEOTHERMICA CFA	€8.5m
	LC-SC3-RES-11-2018: Developing solutions to reduce the cost and increase performance of renewable technologies	€8-10m

NTBE - INCREASING AWARENESS OF LOCAL COMMUNITIES AND INVOLVEMENT OF STAKEHOLDERS IN SUSTAINABLE GEOTHERMAL SOLUTIONS

NTBE-A	**Targets: NTBE A & NTBE B**
TRL at start: not applicable	**TRL at end: not applicable**
Total budget required: €21m	**Flagship: No**

Scope:

A: Public acceptance: improve community perceptions about non-condensable gas emissions, microseismicity, stimulation, and other environmental effects. Coordination of national and regional regulatory oversight practices for health, safety and environmental aspects of geothermal projects.

B: Best practices for managing health, safety and environmental aspects of geothermal projects. Seismic monitoring and mapping of seismic events, guidelines for stimulation indicators in order to prevent surface impacts.

Description:

To address environmental and social concerns that pose barriers limiting the contribution of geothermal energy to the energy mix, the challenge is to assess the nature of public concerns and the elements that influence individual and group perceptions of geothermal installations, to increase the understanding of the socio-economic dimension of geothermal energy, and, where needed, to promote change in community responses to new and existing geothermal installations.

Different technologies and possible technological solutions, for reducing environmental effects and enhance societal benefits, including reinjection of incondensable gases in deep geothermal plants, and seismicity control, are key elements of the socio-environmental assessment. Risk management strategies and adequate technology selection, for example induced seismicity or emission reduction should be addressed.

A greater commitment of local communities in decision-making processes on the development of geothermal energy (on new plants, new technologies adopted, new scientific and technical results, etc.) should be considered a priority in any geothermal enhancement strategy. To this goal, new activities for engaging people and to share with them both benefits and reliable information are inescapable.

Monitoring mechanism:

Annual surveys that monitor changes in perception of people. Periodical (i.e. annual) information will be gathered about the perception of local communities in regard to near-by geothermal plants (built or under construction).

Benchmarking with respect to deliverables. The information collected (from surveys, media, public reporting, etc.) every year will be organized in a report taking into account the initial situation and also capturing data coming from countries not directly involved in this activity (i.e. countries not represented in the TWG)

Expected deliverables:	Timeline:
Guidelines/Best Practice documents for environmental performance of geothermal projects	2022
Guidelines for correct monitoring and mapping of seismic events	2025
Compendium of national and regional practices related to concessions	2025
Participative social methodologies implemented in geothermal sites or regions to improve social acceptability of deployment of geo-plants. New pilot projects testing participative methodologies for socially responsible market uptake of DG	2022

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, FR, IS, IT, PT, EU	Dedicated industry investment (private funds)	€1m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €4.5m Italy: €8m
	GEOTHERMICA CFA	€8.5m of EU funds
	LC-SC3-CC-1-2018-2019-2020: Social Sciences and Humanities (SSH) aspects of the CleanEnergy Transition Type of Action: R&IA	€1-3m (contribution from the EU expected per proposal)
	LC-SC3-EE-1-2018-2019-2020: Decarbonisation of the EU building stock: innovative approaches and affordable solutions changing the market for buildings renovation Type of action: R&IA	€3-4m (contribution from the EU expected per proposal)
	LC-SC3-RES-27-2018-2019-2020: Market Uptake support Type of Action: CSA	€1-3m (contribution from the EU expected per proposal)

NTBE B - RISK MITIGATION (FINANCIAL/PROJECT)

NTBE-B	**Targets: DOI 3, 1 & NTBE A**
TRL at start: not applicable	**TRL at end: not applicable**
Total budget required: €177m	**Flagship: No**

Scope:

Coordination of national geological risk mitigation methods and financial schemes (e.g. exploration grants, geothermal guarantee schemes).

Description:

Risk mitigation is crucial for widespread deployment of geothermal energy. The Netherlands, France, or Switzerland are examples of European countries that offer geothermal guarantee schemes. The schemes differ widely in the rationale, set-up, financing, coverage, procedural aspects, mode of pay-out, fee structure and so on. The activity will collate good practices (worth replicating) and lessons learnt. Advanced approaches and guidelines on how to address and quantify exploration risk, and financial tools that help mitigate such risks will be developed and paths towards a Europe-wide system will be explored (additional stakeholder consultation, creation of a «task force / working group», development of European concepts).

Monitoring mechanism:

Via monitoring of national policy instruments; at EGRIF level via EGEC.

Expected deliverables:	Timeline:
Improved national and/or European project risk mitigation schemes	2025

Party/Parties	Implementation Instruments	Indicative financing contribution
Industry, CH, FR, IT, NL, PT, EU	Dedicated industry investment (private funds)	€1m
	National funding programs (incl. public & private contributions) possibly combined in bi- or multilateral projects.	Germany, Portugal, Switzerland, Netherlands, France and Iceland (all involved in GEOTHERMICA – cumulative allocation): €176m (due to the presence of financial instruments) *EEA grants could also play a role. Furthermore, a European Geothermal Risk Insurance Fund (EGRIF) could be conceived, as proposed by GEOELEC*
	LC-SC3-RES-27-2018-2019-2020: Market Uptake support Type of Action: CSA	€1-3m

International Cooperation

N.	Title	Short description	DOI /NTBE LINK
1	GEMex	International Cooperation with Mexico on geothermal energy. The GEMex project is a Cooperation in Geothermal energy research Europe-Mexico for development of Enhanced Geothermal Systems and Superhot Geothermal Systems. Co funded by EC.	DOI A C
2	IEA-Geothermal TCP	The International Energy Agency's Geothermal Technology Collaboration Program or IEA Geothermal, provides an important framework for wide-ranging international cooperation in geothermal R&D. Efforts concentrate on encouraging, supporting and advancing the sustainable development and use of geothermal energy worldwide both for power generation and direct-heat applications.	DOI A C E
3	GGDP	The Global Geothermal Development Plan (GGDP) is an ambitious initiative by the World Bank's Energy Sector Management Assistance Program (ESMAP) and other multilateral and bilateral development partners to transform the energy sector of developing countries by scaling up the use of geothermal power. The GGDP differs from previous efforts in that it focuses on the primary obstacle to geothermal expansion: the cost and risk of exploratory drilling.	NTBE A
4	Global Geothermal Alliance	Global Geothermal Alliance, coordinated by IRENA, is a platform for enhanced dialogue and knowledge-sharing within the constituency as well as for coordinated action to increase the share of installed geothermal electricity and heat generation worldwide.	Transverse
5	GEOTHERMICA	GEOTHERMICA combines financial resources and knowhow of 17 geothermal energy research and innovation programme owners and managers from 14 European countries and their regions. Together with financial support from the European Commission GEOTHERMICA launches joint projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to commercial large-scale implementation. GEOTHERMICA regularly calls for innovative demonstration projects and technology development projects that accelerate geothermal energy deployment.	Transverse

6	EERA Geothermal	EERA Geothermal is a Joint Programme in the European Energy Research Alliance (EERA) that provides research to • expand the type, number and size of geothermal resources suitable for increasing power and heat generation; • improve efficiency, sustainability and flexibility in production of geothermal resources; and • improve integration of geothermal heat and power in the energy system. EERA Geothermal incorporates experiences from several plants in operation under different geological environments. Combining the forces of the major European geothermal R&D institutions and considering the strategic goals of the SET-Plan, EERA Geothermal aims at facilitating a significant acceleration of the development for providing reliable and highly efficient technology for the use of deep geothermal resources for heat and power. This is done through integration and coordination activities, knowledge sharing and sharing of facilities. EERA Geothermal has 37 research institutions across Europe as Full or Associate Participants and has organised its work in eight sub-programmes.	Transverse
7	ETIP Deep Geothermal	The ETIP-DG (European Technology & Innovation Platform on Deep Geothermal) is an open stakeholder group, endorsed by the European Commission under the Strategic Energy Technology Plan (SET-Plan), with the overarching objective to enable deep geothermal technology to proliferate and reach its full potential everywhere in Europe. The primary objective is overall cost reduction, including social, environmental, and technological costs. The ETIP-DG brings together representatives from industry, academia, research centres, and sectoral associations, covering the entire deep geothermal energy exploration, production, and utilization value chain.	Transverse

Contacts

Deep Geothermal IWG Chair:

Gunter Siddiqi (gunter.siddiqi@bfe.admin.ch)

Deep Geothermal IWG Vice-chairs:

Gerdi Breembroek (gerdi.breembroek@rvo.nl)

Inga Berre (inga.berre@uib.no)

Fausto Batini (fausto.batini@magmaenergyitalia.it)

Support unit

Harpa Pétursdóttir (harpa.petursdottir@os.is)

Hjalti Páll Ingólfsson (hpi@georg.cluster.is)