Annual report on the RD&I activities and their impacts

Report on 2021/2022 RD&I activities

Deliverable number: (D.6.3)
Author(s): Philippe Dumas, Madeleine Constance
Author'(s') affiliation: EGEC
ISBN n°: 978-9979-68-539-5

Deep GEOTHERMAL IWG
SUPPORT UNIT

 This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [838814]

Contents

Introduction

The third and last Annual report presents the review of the year 2021 and first semester of 2022 RD&I activities and their impacts. This report outlines the new and ongoing RD&I projects to better understand the trends and the ongoing RD&I activities in the geothermal energy sector.

This analysis is part of the Task 6.1 that requires a Comprehensive Analysis of the RD&I Geothermal Panorama. The analysis of the RD&I activities is crucial in order to assess how the SET Plan related RD&I activities (detailed in the 8+2 IP fiches) and the targets of the Deep Geothermal Implementation Plan are executed.

Methodology

This report compiles the final results from Deliverables in **WP2-3-4** and data collection activities that were already started by the ETIP Deep Geothermal and the Geothermica. The basis of this report comprises the information from:

- **Member States level – non-exhaustive survey, highlight trends (D2.1, D4.5, GEOTHERMICA)**
- **Researchers**
- **Industry**

It reports data collected for the SET Plan during the annual reporting for the Steering Group in 2021 and 2022.

RD&I activities 2021/2022

ACTIVITIES AT PUBLIC LEVEL (NATIONAL AND EUROPEAN)

The following information is based on the inputs from the report D2.1, D4.5 and GEOTHERMICA.

Recent monitoring of public and private investments on EU geothermal energy R&I projects, enabled to observe the following.

On the basis of the overall 2017-2022 budget allocated, 286.9 M€ related to projects funded by transnational and national budgets. The public share is 131.1 M€. The EU funding is about 225 M€, of which 173.9 M€ as an EC contribution. The geothermal R&I funding distribution per country and per financing source (public, private), for the period 2017-2022, is observed in Figure 1.

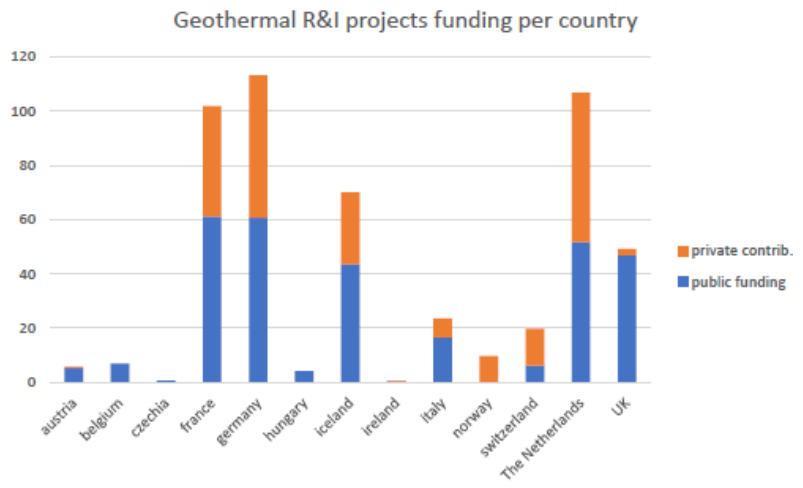


Figure 1- Geothermal R&I funding distribution per country and per financing source (2017-2022) (DG-IWG, 2020).

R&I funding programmes are drivers of private investments. Those R&I programmes and frameworks that co-finance public-private projects in variable ranges of technology readiness levels work as drivers for private initiative with impacts at a national level (Figure 2).

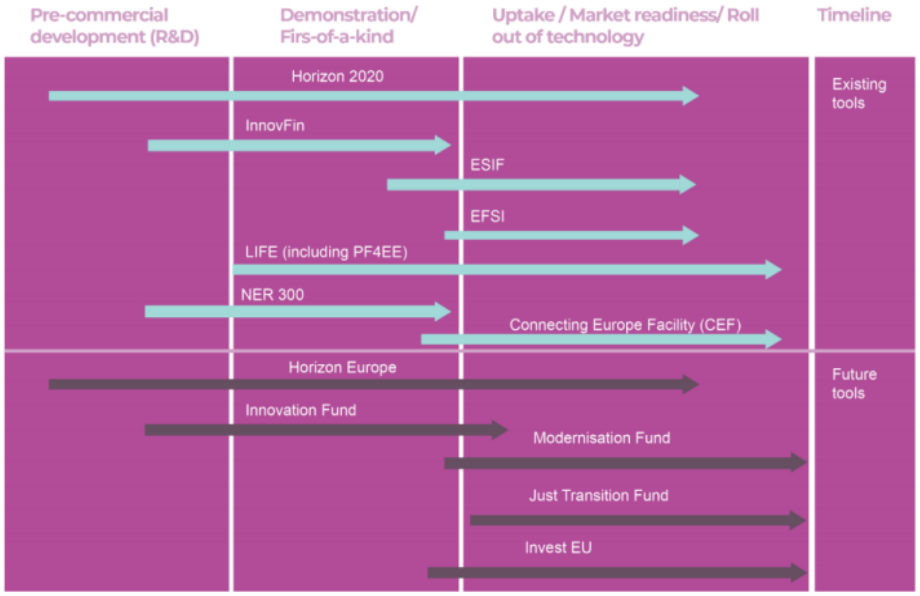


Figure 2: EU Programmes for renewable and low-Carbon innovation (In: DG-IWG Brochure (In: www.deepgeothermal-iwg.eu/)

Several R&I funding schemes or projects are implemented at national level. In the EU, countries like Germany and France should be referred. Outside the EU, Iceland and Switzerland are other relevant European players. The SET plan working group for deep geothermal energy identified a number of R&I activities as 'flagship':

a) geothermal heat in urban areas;
b) enhancement of conventional reservoirs and development of unconventional reservoirs;
c) integration of geothermal heat and power into the energy system and grid flexibility;
d) zero emissions power plants.

DG-IWG priorities for RD&I actions

In 2020, the Implementation Working Group (IWG) on Deep Geothermal of the SET plan proposed an update of the Implementation Plan. The updated Deep Geothermal Implementation Plan includes the following priorities for RD&I actions in the deep geothermal sector:

1. Geothermal heat in urban areas
2. Integration of geothermal electricity and heating & cooling in the energy system responding to grid and network demands
3. Improvement of overall geothermal energy conversion performance for electricity and heating & cooling generation
4. Closed loop electric and heating & cooling plants integrated in the circular economy
5. Sustainable and efficient production technologies
6. Development and exploitation of geothermal resources in a wider range of geological settings
7. Advanced drilling/well completion techniques
8. Innovative exploration techniques for resource assessment and drilling target definition
9. Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions
10. Risk mitigation (financial/project)

These updated priorities cover a broad range of topics for the deep geothermal sectors and involve all segments of the deep geothermal value chain.

Across the different parts of the geothermal value chain, different types of actors are contributing with their own expertise and resources to advancing the priorities for research, development and innovation in the deep geothermal sectors, along the lines identified in the SET Plan Deep Geothermal Implementation Plan. For each priority, the scope is briefly described and the typology of actors implementing the SET Plan Deep Geothermal RD&I priorities is described.

GEOTHERMICA programme

Second Call - 2019

A second call, with the participation of new partners from the United States of America and Norway, was launched in 2019 with projects awarded by 2020. These projects started September 2020 and have continued to 2022 and therefore are reported here.

The objective of GEOTHERMICA's second call is to launch projects that accelerate the piloting, demonstration and validation of novel concepts of geothermal energy supply within the energy system and to identify paths to commercially viable deployment. Projects may also address oriented research that underpins novel concepts and paths to commercialisation.

Moreover, for the second call, GEOTHERMICA's consortium has broadened, with Norway and USA joining. GEOTHERMICA's weight and influence serves to accelerate the development of geothermal energy not only in Europe but, owing to the close alignment of research priorities and complementarity of skills and facilities, also increasingly globally.

Joint call Members

The budget available for Joint Call 2021 from each National Funding Agency is approximately 32million €. Joint Call Members are listed below in the table.

List of participants- Joint Call Members

Participants	**Funding Organisation (Program Owner / Program Manager)**	**Network**	Budget **M€**
Austria	Austrian Research Promotion Agency, **FFG**	SES	1.83
Wallonia	General Directorate of Territoire, Logement, Patrimoine, Energie**, SPW DG TLPE**	SES	0.6
Denmark	Energy Technology Development and Demonstration Program, **EUDP**	GEOTHERMICA	3.0
	Innovation Fund Denmark	SES	1.0
Germany	German Federal Ministry for Economic Affairs and Energy **BMWi** (geothermal)	GEOTHERMICA	2.5
	German Federal Ministry for Economic Affairs and Energy **BMWi** (solar-thermal)	GEOTHERMICA	1.0
	German Federal Ministry for Economic Affairs and Energy **BMWi** (CSP)	GEOTHERMICA	1.0
Hungary	National Research, Development and Innovation Office **NKFIH**	SES	0.2
Iceland	Icelandic Research Institute, **RANNIS**	GEOTHERMICA	0.5
Ireland	Geological Survey Ireland, **GSI**	GEOTHERMICA	0.3
	Sustainable Energy Authority of Ireland, **SEAI**	SES	0.5
Israel	Ministry of Energy Chief Scientist Office, **MoE-IL**	SES	0.6
Netherlands	Netherland Enterprise Agency, **RVO**	GEOTHERMICA	8.0
Norway	The Research Council of Norway, **RCN**	Both	1.0
Scotland	Scottish Enterprise, **SE**	SES	1.1
Sweden	Swedish Energy Agency, **SWEA**	SES	2.0
Switzerland	Swiss Federal Office of Energy, **DETEC - SFOE**	Both	3.5
Turkey	The Scientific and Technological Research Council of Turkey, **TÜBİTAK**	Both	0.75
USA	Department of Energy, **DOE**	GEOTHERMICA	3.3

In this second additional call, seven projects were funded, four as Type A- large trans-national demonstration projects with a total budget of €19 million; and three Type B- smaller trans-national research and innovation projects with a total budget of €5 million.

The total budget funding in this second additional joint call is around M€ 39 which 61% is supported by GEOTHERMICA Call 2 Consortium.

List of projects

1. DEEP
Objective: Innovation for de-risking enhanced geothermal energy projects**.** DEEP has a strong focus on optimization of monitoring and risk assessment procedures in order to reduce commercial costs to future projects.
Website: DEEP | Home (deepgeothermal.org)
Start year: 2020
End year: 2023
Budget/Funding (€ million): not available
Relevant activities addressed/targets achieved: R&I 6, 10

2. DEEPEN
Objective: De-risking exploration for geothermal plays in magmatic environments. The project aims to develop improved exploration methods and an improved framework for the joint interpretation of exploration data using the Play Fairway Analysis (PFA) methodology. Most geothermal resources, currently under production, belong to this play type. Improved understanding of subsurface conditions in these environments would improve the success rate of drilling and, thus, directly impact the economic viability of geothermal power projects through reduced drilling cost.
Website: DEEPEN (or.is)
Start year: 2020
End year: 2023
Budget/Funding (€ million): total cost € 3.658.928, geothermica financing - € 2.041.478, own financing - € 3.558.320
Relevant activities addressed/targets achieved: R&I 8, 10

3. TEST-CEM
Objective: Sustainable geothermal well cements for challenging thermos-mechanical conditions. The project aims to reduce risks associated with compromised well integrity, common for all geo-wells, and use recently gained insights in the field of materials to evaluate advanced cement systems in a wide temperature range (up to super-critical) and under thermal cycling.
Website: TEST-CEM Geothemral Energy Solutions (bnl.gov)
Start year: 2020
End year: 2023

Budget/Funding (€ million): not available
Relevant activities addressed/targets achieved: R&I 5, 10

4. SPINE

Objective: Stress profiling in EGS. SPINE is developing new tools for stress profiling in crystalline rock to estimate stimulation efficiency and seismicity related to subsurface heat exchangers' creation.
Website: Stress Profiling in Enhanced Geothermal Systems (SPINE) - RWTH AACHEN UNIVERSITY LIH - English (rwth-aachen.de)
Start year: 2020
End year: 2023
Budget/Funding (€ million): not available
Relevant activities addressed/targets achieved: R&I 6

5. RESULT

Objective: Enhancing reservoirs in urban development: smart wells and reservoir development. The main objective is to demonstrate the potential for increased performance by 30-100% of major (marginal) reservoirs for heating in urban areas in the northern EU.
Website: not available
Start year: 2020
End year: 2023
Budget/Funding (€ million): not available
Relevant activities addressed/targets achieved: R&I 1

6. SEE4GEO

Objective: Seismoelectric effects for geothermal resource assessment and monitoring. The project aim is to perform a fully integrated approach to assess the potential of utilization Seismic Electric Effects (SEE) for exploration and development of geothermal systems, by creating a SEE numerical package to be used for improved subsurface tomography, supported and validated by laboratory experiments
Website: SEE4GEO -Seismoelectric Effects for Geothermal Resources Assessment and Monitoring - Norce (norceresearch.no)
Start year: 2020
End year: 2023
Budget/Funding (€ million): Total budget: 2.500.000 NOK
Relevant activities addressed/targets achieved: R&I 8

7. GRE-GEO

Objective: The GRE-GEO (glass fiber reinforced epoxy casing for geothermal application) project will develop a new well completion strategy that aims to establish a corrosion-resistant alternative to decrease the development and production costs of geothermal energy while avoiding extra investments.
Website: https://www.gre-geo.org/
Start year: 2020
End year: 2023

Budget/Funding (€ million): not available
Relevant activities addressed/targets achieved: R&I 3, 7

According to the above data, the majority of the funds were directed to R&I priority actions 8, 6 and 10; innovative exploration techniques, exploitation of geothermal resources in wider geological settings, and risk mitigation (finance/projects). This fact underlines the necessity for further improvement in exploration techniques, since investing in exploration generally leads to a reduction of the subsurface unit technical cost because of higher certainty regarding the resource; its location/depth, spatial extent, location of inflow and outflow zones and so on. Hence, there is a relationship between exploration and field development phases and their respective costs.

Furthermore, projects that focus on exploitation of geothermal resources in a wider range of geological settings are critical to enabling geothermal deployment at large scale in view of a significant market penetration, and expansion of the global application of geothermal energy for wide scale decarbonisation of heating, cooling, and power generation. Finally, de-risking geothermal development is essential for reducing the high capital costs of geothermal projects, and driving private investment in the sector for increased deployment.

Joint Call' 2021

On the 31st of May 2021, the GEOTHERMICA Era-Net, in cooperation with the network Joint Programming Platform Smart Energy Systems (JPP SES), launched a joint call for proposals for transnational projects. Consortia were currently invited to Stage 2 to submit their project's full proposals concepts by 31 January 2022. The expected start date for projects is September 2022.

This Joint Call' 2021 seeks to accelerate the heating and cooling transition by bringing together national and regional programmes aimed at energy system integration and technological progress in the various heating and/or cooling technologies, with a strong presence but not limited to geothermal energy technologies.

The Joint Call is a two-stage process asking in stage 1 for pre-proposals and stage 2 for full project proposals with a budget allocated at approximately €32,5 million.

Clean Energy Transition Partnership (CET Partnership)

CET Partnership is a multilateral and strategic partnership of national and regional research, development and innovation (RDI) programmes in European Member States and Associated Countries aiming to boost and accelerate the energy transition and to support the implementation of the European Strategic Energy Technology Plan (SET Plan).

The CET Partnership enables **50** national and regional RTDI programme owners and managers from **30 countries** to align their priorities, pool national budgets of **210 Mill EUR** for two joint calls in 2022 and 2023, as well as to implement annual joint calls from 2022 to 2027.

The CET Partnership Joint Call 2022 is the first annual co-funded call under the CET Partnership and is co-funded by the European Commission under the Horizon Europe Partnership scheme.

The CET Partnership Joint Call 2022 is a 2 stage call structured around 11 Call modules provided by the TRIs. It is due to be launched in September 2022.

Case study of a national R&I funding programme: Sweden

The Swedish Energy Agency Research and Innovation Program Termo

The Swedish Energy Agency's Research and Innovation Program Termo has a purpose to contribute to the development of heating and cooling for the energy systems of the future. It is about utilizing energy resources, resource-efficient use and interaction with other energy carriers. The program includes both the technical system and market players, the rules of the game that surround the system and the interaction between them. In addition, the program contribute to strengthening Swedish competitiveness through skills building and innovations for jobs and climate, including export opportunities for Swedish business.
The program runs until 31 December 2024 and has a budget of SEK 260 million for the years 2018 - 2024. The program includes three research, development and innovation areas:

- Heating and cooling solutions for future users and local communities
- Efficient utilization of renewable and recycled heat and cooling
- Mission-oriented approach for effective interaction in heating and cooling: business models, organization, regulations, instruments, technology, etc.

TERMO Program have the following impact targets 2030:
Energy Resources- Energy for heating and cooling consists of recycled and renewable energy. Excess heat from various sectors is utilized and benefits society with following sub-goals:

- Knowledge, models and methods for efficient utilization of heating and cooling resources have been developed through e.g.
  - Low temperature systems
  - District heating and cooling technology
  - Heat pump technology
  - Geothermal solutions
- New methods and tools to increase the use of excess heat have been developed and demonstrated
- New alternatives and strategies for reducing greenhouse gas emissions have been developed.

Interaction in Energy System- Interaction between heating and cooling and other energy carriers contributes to a resource- and cost-efficient energy system as well as a secure energy supply with following sub-goals:

- New innovative solutions for flexible control of heating, cooling and electricity production as well as storage of heat and cooling have been developed and demonstrated.
- Solutions where the electricity and heating systems work together in order to contribute to balancing the electricity system and secure energy supply have been developed.
- Digital solutions have been developed to facilitate efficient interaction between different resources, storage and energy carriers.

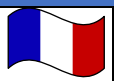
Resource Efficient Use- Heating and cooling are used in a resource-efficient way with minimal environmental impact. Users benefit from competitive prices in local markets with following sub-goals:

- Valuation methods and solutions for flexible heating and cooling as well as thermal storage in order to promote resource-efficient use have been developed
- From the perspective of users and prosumers, new solutions and methods have been developed for increased comfort, flexible use and own production
- Through digital solutions, methods and tools have been developed to increase energy exchange between different users, prosumers and producers.

OnGoing R&I Projects per country in Geothermica Era-NET

The main results obtained from the SU-DG-IWG survey submitted by the Member-States and Associated Countries are presented in the tables below. The SU-DG-IWG survey tool was developed to identify "R&I Projects in Course" for geothermal energy development by countries. Table 2 "Ongoing Geothermal R&I Projects by Country" and Table 3 "Ongoing Geothermal R&I Projects 2020 by Country" summarise the ERA-net Geothermica R&I projects and the Horizon 2020 R&I projects of the countries that answered the SU-DG-IWG questionnaire. The analysis of table 1 "OnGoing Geothermica Energy R&I Projects per Country" results in 7 countries and 2 regions involved in different ERA-NET Geothermica R&I projects, namely the Member States **France**, **Germany**, Ireland, **Netherlands**, **Italy** and, outside of the EU, **Iceland**, **Switzerland** , **USA** and **Norway**. The projects are currently in progress, having started in September 2020 and due to end in 2023. The countries participating in ERA-NET Geothermica share many common interests, however, their involvement in the different projects differs according to their own interests from focal areas for geothermal development, their energy market development, their geopotential for energy use, and the energy policy implemented for geothermal energy.

Table 1 **-** Ongoing Geothermica Energy R&I Projects per Country

Member-State/Region	Ongoing GEOTHERMICA Energy R&I Projects per Country								
									
DEEP	✓	✓		✓	✓	✓	✓		✓
DEEPEN	✓	✓	✓			✓	✓	✓	
TEST-CEM	✓				✓		✓	✓	
RESULT			✓	✓	✓				
SPINE		✓				✓	✓		

SEE4GEO	✓						✓	✓	
GRE-GEO		✓			✓	✓			

OnGoing H2020/Horizon Europe R&I Projects per Country

Horizon Europe

Horizon Europe is the new EU framework programme for research and innovation for the period 2021 until 2027, which succeeds Horizon 2020.
It has a slightly different structure than its predecessor and a larger budget (the European Commission is proposing a total budget of €100 billion for 2021-2027). In keeping with the design of its predecessor, Horizon Europe is divided into three main pillars:

- Excellent Science;
- Global Challenges;
- European Industrial Competitiveness

The 2021-2027 programme will also five mission areas: adaptation to climate change including societal transformation, cancer, climate-neutral and smart cities, healthy oceans, seas, coastal and inland waters, soil health and food. Each mission will have a dedicated mission board and assembly.

The European Commission has recently launched new calls for projects under Horizon Europe's Work Programme for 2021-2022.
EU funding of EUR 99 million in total is now available for Energy with a deadline of 27 October 2022.

Regarding ongoing European research projects, the analysis of table 2 "H2020 OnGoing R&I Projects per Country", results in results in 24 countries and 7 regions across 22 Horizon 2020 projects funded within this reporting period, namely Member States: Italy, France, Germany, Spain, Netherlands and, outside the EU, Iceland, UK and Norway. On the other hand, the absence of a response from some countries may be related to the geothermal market conditions of the country to engage in R&I projects, according to the objectives of the projects. This identification allowed to provide the degree of development and to present the main involvement of the Member States involved in the different projects for the development of geothermal energy as one of the main sources of renewable energy for their energy market.

Table 2- Ongoing Horizon 2020 R&I Projects per country.

H2020 Ongoing R&I Projects Per Country	Member-State																														
EASYGO	✓		✓				✓					✓																			
GEOPRO		✓	✓	✓					✓		✓	✓	✓																		
GEOTHERMICA	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓													
REFLECT	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓							
GEO4CIVHIC	✓	✓	✓		✓	✓		✓				✓		✓	✓										✓						
MEET		✓	✓	✓										✓										✓							
GEOUS			✓																				✓		✓						

GECO	✓	✓	✓	✓		✓	✓		✓		✓		✓																		
GEOFIT	✓	✓	✓		✓	✓	✓							✓													✓	✓	✓			
GEOSMART	✓	✓	✓	✓					✓		✓		✓	✓																	
GEOHEX	✓	✓		✓					✓		✓				✓															✓		
GEO-DRILL	✓	✓	✓	✓		✓			✓		✓																				
CROWDTHERMAL	✓		✓	✓		✓	✓	✓					✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓						✓	✓
THERM		✓																													
EVOTRAP			✓																												
MAPSI											✓																				

DEEPU	✓		✓		✓																										
OPTIDRILL			✓	✓			✓		✓																						
ORCHYD		✓						✓	✓	✓	✓																				
ARMISTICE						✓																									
MODERATE									✓																						
IMPROVE	✓	✓	✓	✓	✓	✓			✓																						

ACTIVITIES OF THE RESEARCH COMMUNITY

During the year 2021, these focus mostly on the set of the research and innovation (R&I) priorities for deep geothermal energy actions described in the Geothermal Implementation Plan and on the mobilisation of the research community by its realisation (Task 3.2 of the project). The following information is based on the inputs from report D3.5.

EERA GE is an active and flexible group focused on the SET-Plan actions and taking a pro-active role in fulfilling the EU CET aims. SU-DG-IWG does not see any points that necessarily need to be implemented or corrected to strengthen the input of EERA GE to the IP Deep Geothermal.

Table 3 shows the EERA and non-EERA research organisations participating in the H2020 projects running in January 2022. The listed projects are dealing with deep geothermal or cross-cutting activities including aspects of deep geothermal research. 10 of the 24 projects include EERA GE and non-EERA GE organisations, 12 projects include only non-EERA GE research institutions (3 of them are one participant projects). The industry project partners are not included in the Table. In only 6 projects the EU13 are represented.

Table 3 - EERA and non-EERA research organisations participating in the H2020 projects running in January 2022

Project name	Website or short description	EERA GE members	Non-EERA GE members
GECO	https://geco-h2020.eu/	Iceland Geosurvey (ISOR, IS) Institutt For Energiteknikk (IFE, NO)	University of Iceland (UI, IS) Centro De Investigación De Recursos Y Consumos Energético (CIRCE, GR) Middle East Technical University (METU, TR) Consiglio Nazionale Delle Ricerche (CNR, IT) Fraunhofer-Einrichtung Für Energieinfrastrukturen Und Geothermie (Fraunhofer-LEG, DE) United Kingdom Research and Innovation (UKRI, UK) Centre National De La Recherche Scientifique (CNRS, FR)
Geo-Drill	https://cordis.europa.eu/project/id/815319		University of Iceland (UI, IS) Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung Ev (DE)

			Hochschule Bochum (DE)
GeoHex	https://cordis.europa.eu/project/id/851917		Nyskopunarmidstod Islands (IS) University of Leicester (UK) University of Iceland (UI, IS) Universitatea Politehnica din Bucuresti (RO)
GEOPRO	https://cordis.europa.eu/project/id/851816	Eidgenoessische Technische Hochschule Zuerich (CH)	University of Iceland (UI, IS) Centre National De La Recherche Scientifique (CNRS, FR) Norges Teknisk-Naturvitenskapelige Universitet (NTNU, NO)
GeoSmart	https://www.geosmartproject.eu/		University of Iceland (UI, IS) VITO (BE) Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung Ev (DE) Middle East Technical University (METU, TR)
GEoUs	https://cordis.europa.eu/project/id/856670		Technical University of Ostrava (CZ) Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung Ev (DE)
REFLECT	https://cordis.europa.eu/project/id/850626	Technische Universiteit Delft (NL) Institutt For Energiteknikk (IFE, NO) Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek (TNO, NL) Izmir Institute of Technology (TR)	Bureau de Recherches Geologiques et Minieres (FR) Universite de Neuchatel (CH) United Kingdom Research and Innovation (UKRI, UK) Miskolci Egyetem (HU)
SU-DG-IWG	https://cordis.europa.eu/project/id/838814/en	Karlsruher Institut fuer Technologie (DE)	
GeoERA	GeoERA – Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe | GeoERA Project | H2020 | CORDIS |	Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek (TNO, NL) Bureau de Recherches Geologiques et Minieres (FR) British Geological Survey (UK)	Ceska Geologicka Sluzba (CZ) Geological Survey of Denmark and Greenland (DK) Polish Geological Institute (PL) Instituto Geológico y Minero de España (ES) Geološki zavod Slovenije (SI) Institut Cartogràfic i Geològic de Catalunya (ES) Hrvatski Geološki Institute (HR) Sveriges Geologiska Undersökning (SE)

	European Commission (europa.eu)	Geological Survey Ireland (IS) Laboratorio Nacional de Energia e Geologia I.P (PT)	Institutul Geologic al Romaniei (RO) Geological Survey of Ireland (IE)
ENeRAG	Excellency Network Building for Comprehensive Research and Assessment of Geofluids | ENeRAG Project | H2020 | CORDIS | European Commission (europa.eu)	Universita Degli Studi di Milano (IT)	Eotvos Lorand Tudomanyegyetem (HU) Geological Survey of Finland (FI)
GEoREST	predictinG EaRthquakES induced by fluid injecTion | GEoREST Project | H2020 | CORDIS | European Commission (europa.eu)		Agencia Estatal Consejo Superior de Investigaciones Cientificas (ES)
GEOPRO	Accurate Geofluid Properties as key to Geothermal Process Optimisation | GEOPRO Project | H2020 | CORDIS | European Commission (europa.eu)	Eidgenoessische Technische Hochschule Zuerich (CH)	University of Iceland (UI, IS) Centre National De La Recherche Scientifique (CNRS, FR) Norges Teknisk-Naturvitenskapelige Universitet (NTNU, NO) Universitaet zu Koeln (DE)
GeoTwinn	Strengthening research in the Croatian Geological Survey: Geoscience-Twinning to develop state-of-the-art subsurface modelling capability and scientific impact | GeoTwinn Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)		Hrvatski Geološki Institute (HR) United Kingdom Research and Innovation (UKRI, UK) Geological Survey of Denmark and Greenland (DK)
HyStorIES	Hydrogen Storage In European Subsurface | HyStorIES Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)		Montanuniversitaet Leoben (AT) Instytut Gospodarki Surowcami Mineralnymi i Energia PAN (PL)
LEAP-RE	Long-Term Joint European Union - African Union Research and Innovation Partnership on Renewable Energy	French Geological Survey (BRGM, FR) Italian National Research Council (CNR, IT) Helmholtz Centre Potsdam - GFZ German	Deutsches Zentrum für Luft- und Raumfahrt (DE) Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung Ev (DE) Forschungszentrum Jülich (DE)

		Research Centre for Geosciences (GFZ, DE) NORCE-Norwegian Research Centre (NO) National Laboratory for Energy and Geology (PT) Poliotecnico di Milano (IT) Lorraine University (FR) Utrecht University (NL)	Loughborough University (UK) LUT University (FI)
PRD-Trigger	Precipitation triggered rock dynamics: the missing mesoscopic link | PRD-Trigger Project | H2020 | CORDIS | European Commission (europa.eu)		Centre National De La Recherche Scientifique (CNRS, FR)
REGEN-BY-2	Next REnewable multi-GENeration technology enabled by TWO-phase fluids machines | REGEN-BY-2 Project | H2020 | CORDIS | European Commission (europa.eu)		Universita di Pisa (IT) Centre National De La Recherche Scientifique (CNRS, FR) Ethnicon Metsovion Polytechnion (GR) Universite de Liege (BE)
EASYGO	Efficiency and Safety in Geothermal Operations | EASYGO Project | H2020 | CORDIS | European Commission (europa.eu)	Eidgenoessische Technische Hochschule Zuerich (CH) Technische Universiteit Delft (NL) Poliotecnico di Milano (IT)	Rheinisch-Westfaelische Technische Hochschule Aachen (DE)
ORCHYD	Project - Orchyd, Novel Drilling Technology Combining Hydro-Jet and Percussion for ROP Improvement in deep geothermal drilling | ORCHYD Project | H2020 | CORDIS | European Commission (europa.eu)	SINTEF AS (NO)	University of Piraeus Research Center (GR)
OptiDrill	OPTIDRILL - Fraunhofer IEG, Optimisation of Geothermal Drilling Operation with Machine Learning | OptiDrill Project | H2020 | CORDIS |		Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung Ev (DE) United Kingdom Research and Innovation (UKRI, UK)

	European Commission (europa.eu)		
EXCITE	Electron and X-ray microscopy Community for structural and chemical Imaging Techniques for Earth materials | EXCITE Project | H2020 | CORDIS | European Commission (europa.eu)	Utrecht University (NL) The Belgian Research Alliance (BERA/VITO) Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences (GFZ, DE) Technische Universiteit Delft (NL)	Universidad de Granada (ES) Centre National De La Recherche Scientifique (CNRS, FR) Universitetet i Oslo (NO) Universidade da Beira Interior (PT) Universite Grenoble Alpes (FR) Universite De Pau et des Pays De L'adour (FR) Istituto Nazionale di Geofisica e Vulcanologia (IT) Norges Teknisk-Naturvitenskapelige Universitet (NTNU, NO) The University of Edinburgh (UK)
MaPSI	Mathematical and Numerical Modelling of Process-Structure Interaction in Fractured Geothermal Systems | MaPSI Project | H2020 | CORDIS | European Commission (europa.eu)	Universitetet i Bergen (NO)	
ARMISTICE	Analysis and Risk Mitigation measures for Induced Seismicity in supercriTICal gEothermal systems | ARMISTICE Project | H2020 | CORDIS | European Commission (europa.eu)		Agencia Estatal Consejo Superior de Investigaciones Cientificas (ES)
MODERATE	Magma Outgassing During Eruptions and Geothermal Exploration | MODERATE Project | H2020 | CORDIS | European Commission (europa.eu)		The University of Liverpool (UK)

ACTIVITIES OF PRIVATE ACTORS

The following information is based on the inputs from the report D4.5 and the EGEC 2021 Market Report.

As highlighted in D4.5, private financing is leading the investments race in R&I on the European level. According to the European Commission's Report on the progress of clean energy competitiveness, the EU has invested in recent years an average of nearly **EUR 20 billion a year on clean energy R&I** prioritised by the Energy Union :

- EU funds contribution - 6%
- Public funding from national governments accounts - 17%
- **business contribution estimated - 77%**

Despite this fact, according to the 2021 report on the State of the Energy Union, the EU **private sector experienced a 7% reduction in overall energy R&I spending**. R&I investment in the activities set out in the European Strategic Energy Technology Plan, agreed between Member States, industry, the research community and the Commission, represents only 15% of the estimated needs up to 2030.

The most relevant technological developments within the geothermal industry in 2021:

Innovation in geothermal power plant development
The geothermal project in Geretsried is now seeing an update by Canadian technology company Eavor Technologies. The project saw two drilling campaigns in the past that did not produce the necessary results for further successful development in 2013 and 2017. Now, with its technology of a closed-loop system, Eavor is targeting to extract the good heat resource discovered in the earlier drilling campaigns.The approval process via the Mining Office South with the government of Upper Bavaria is in the decisive phase. If everything goes as the investors and operators hope, construction of the first well is to begin in spring 2022. A total of four so-called loops, each with two boreholes, are planned.

In the Kirchstockach geothermal plant, city utility SWM decide to convert from an initial only power plant, to the co-production of geothermal heat from the plant for local district heating. A special feature of Garching an der Alz geothermal plant in Bavaria, is the type of cooling, which, on the basis of continuous water cooling, enables significantly more efficient production processes and can thus convert more energy from the thermal water into electricity while at the same time using less electricity. So far, all existing German systems have run with air condensers.

Heating and Colling systems
The year 2021 marks the commissioning of new geothermal district heating and cooling in 9 different European countries, among which 3 are far from traditional geothermal district heating and cooling markets (Finland, Cyprus and Norway), materialising the geographical diversification of geothermal heating and cooling uses. Moreover, two systems are district

cooling geothermal systems – or at least include some cooling capacity – which is another signal towards the role geothermal projects are going to play in an energy system where renewable cooling is an increasingly valuable resource.

Table 4 - Ruggero Bertani – European Geothermal Innovation Award 2021 finalists

Company	Project	Location: country	Topic
Baker Hughes	Corrosion Resistant Podded Electrical Submersible Pump & Completion System	Netherlands	Geothermal production wells in the Netherlands are susceptible to corrosion along the wellbore due to high salinity contents in the well fluid leading to very expensive workovers on a regular basis. Baker Hughes Artificial Lift Systems has partnered with ECW Geomanagement BV (ECW) to design, develop and successfully execute an industry-first well completion that allows geothermal production to continue, and the casing to be protected against both localized and general corrosion. The completion includes an ESP deployed on production tubing, pressure sealed within a pod, and set in a custom completion system that also allows for deep corrosion inhibitor injection.
BBT SE - BrennerBasis Tunnel - Galleria di Base del Brennero	Smart Flowing - A geoexchangers prototype installed at the Brenner Base Tunnel	Italy	Smart Flowing, tailored for tunnels excavated by TBM (Tunnel Boring Machine), is a geoexchangers prototype consists in a modular horizontal closed-loop system located into the central drain formed by the invert elements of the exploratory tunnel's lining inside the Brenner Base Tunnel. The system consists of seven modules for a total length of 10.5 m and about 90 m of absorber pipes installed in contact with the lower invert segment, submerged by the water drained by the mountain tunnel and enclosed by the upper invert segment. Smart Flowing can be categorised into the closed-loop system family of horizontal collectors
Celsius Energy	Celsius Energy System	France	The Celsius Energy system is an innovative ground source heat pump system consisting of three main elements: 1) A closed-loop geothermal energy exchanger, with Ushaped probes arranged in a pyramid-shape pattern to minimize its surface footprint; 2) A heat pump allowing simultaneous supply of heating and cooling; 3) A digital control system, minimizing electricity consumption and guaranteeing system performance by optimizing the use of the subsurface and of

			heat pumps, coupled to the building in real time. The first Celsius Energy installation is located in Clamart, France. It has achieved reducing CO2 emissions by 90% and operating costs by 40%. Video overviews are available at http://youtu.be/v4ptE-9WExo and http://youtu.be/n6Bzo2-TL2g
Comsof Heat, for their partnership with University of North Dakota and Reykjavik University	Mandaree, North Dakota: A Case Study on Oil and Gas Well Conversion to Geothermal District Heating Systems for Rural Communities	Belgium	This scoping study sought to repurpose two of the many oil and gas wells found on the Fort Berthold Indian Reservation for geothermal district heating. The plan would provide heating for more than 200 structures and a 4km2 greenhouse in a rural Native American community of North Dakota. Providing low-carbon energy alternatives to individual propane heating systems would reduce energy poverty by delivering This scoping study sought to repurpose two of the many oil and gas wells found on the Fort Berthold Indian Reservation for geothermal district heating. The plan would provide heating for more than 200 structures and a 4km2 greenhouse in a rural Native American community of North Dakota. Providing low-carbon energy alternatives to individual propane heating systems would reduce energy poverty by delivering
Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG	Energy concept for geothermal cooling and heating	Germany	The project outline describes the innovative integration of an absorption heat pump into a system of heat grids, allowing the heat from geothermally driven high-temperature heat grids to be used year-round to provide low-temperature heating or cooling.
Full-Metal-Power	Full-Metal-Power	Netherlands	Full-Metal-Power brings to reality the "Holy Grail" of PDM Drilling motor power sections. Through a specialized process of removing metal through Electrochemical Machining we are able to produce a stator and rotor with such accuracy that we have eliminated the need for elastomers.
Getech Group plc	Heat Seeker	United Kingdom (UK)	Heat Seeker (R) is an integrated approach to geothermal exploration and development that combines geoscience data, energy demand, and infrastructure information (including competing and complementary energy sources, both conventional and renewable) on a common geospatial platform early in the exploration and development life cycle to focus on opportunities with the lowest technical risk and highest potential social and financial

			return to maximize investment efficiency, decarbonization, and deployment speed.
GRE GEO Consortium / Geothermica	GRE GEO - Glass Fiber Reinforced Epoxy Casing System for Geothermal Application	Germany	The GRE-GEO (glass fiber reinforced epoxy casing for geothermal application) project is developing a new well completion strategy that aims to establish a corrosionresistant alternative to the conventional steel casings, increasing the reliability and lifespan of the casing system, while avoiding extra investments for workover operations. Corrosion and scaling significantly reduce the lifespan of traditionally used steel casing systems, the primary function of which is to guarantee the wellbore integrity. Consequently, workover procedures are forced earlier than expected, and becoming a substantial financial burden. In contrast, Glass fiber casings (GRE) do provide a much-desired alternative as this material is corrosion resistant.
Helmholtz Centre Potsdam	Fluxtec	Germany	Gas emissions at the Earth's surface are fingerprints of deep geothermal resources. Area-wide information on emission rates and chemical composition provide reliable data on the fluid circulation in reservoirs and help to reduce the high exploration risks in geothermal projects. We have developed innovative workflows (TRL 8-9) for the systematic analysis of gases (e.g. CO2, CH4) rising along permeable zones to the surface. In addition, we demonstrated that long-term monitoring of gas emissions is a useful approach to understand changes in reservoirs due to exploitation (TRL 7- 8). In 2021, the start-up project fluxtec was launched by Anna Jentsch and Egbert Jolie with the goal to become an international service provider for gas analytics.
Izmir Institute of Technology	Capture and using CO2 as an inhibitor in geothermal power plant	Turkey	Scaling is a serious issue for geothermal power plants since it remarkably decreases the harvesting of energy. For the cleaning of metal silicate scaling, the reduction of pH by CO2 has been an effective solution. In this project, CO2 gas is injected to the geothermal system to prevent the formation of metal silicate scaling which have employed in the Tuzla Geothermal Power Plant (TGPP) in Turkey for pH modification. With this study, the application of other inhibitors in TGPP system has ended. The use of CO2 provides serious contributions both environmentally and economically. It will be implemented in many power plants

MS Energy Solutions Ltd	WeHEAT Systems - Wells for Heat Exchanger Advanced Technologies	Hungary	The WeHEAT technology developed by MS Energy Solutions Ltd. is a deep borehole heat producing system that can also be implemented in already drilled wells, therefore to reduce the CAPEX significantly, and to get rid of P&A costs for the o&g industry. Its greatest advantage is that it produces geothermal energy without extraction of formation water. It is a fully closed system that allows direct heat use for users living in the vicinity of the well through geothermal heat recovery. No emission, no OPEX, cheap sustainable green energy. Installed in an already drilled well the capacity can be as high as 900kW of heat energy, drilling a specific well for a WeHEAT System can produce electricity too.
OGLombardia	TO PROTECT AND HEAT	Italy	The Project is a new method for heating and cooling buildings, with a low enthalpy geothermal system, which is implemented simultaneously with the attenuation of vibrations induced in the structures by seismic phenomena. It aims to provide low enthalpy geothermal energy and simultaneously protect buildings and structures from earthquakes.
Perryman Technologies Research	Geothermal Lithium Extraction	France	Full Spectrum Solar© Thermal Utilizing IXED & ultrasonics solar thermal powered separation chlorides & precipitation of Li2CO3 from geothermal brine with H2O recovery. The aim of the main processes are as follows: (1) the EID method is used to maximize the separation of magnesium and lithium from the brine to obtain a low Mg/Li anolyte; (2) removing the multivalent ions (e.g., Mg2+, Ca2+, and SO4 2−) from the obtained anolyte via the NF method; (3) concentrating the permeate flow produced by NF with the RO method (we could use forced rapid evaporation here); (4) further increasing the lithium concentration by evaporation(we could use forced rapid evaporation here); (5) precipitating Li2CO3 by adding Na2CO3(Sodium Carbonate).
Private	Heat extraction from dry hot wells	Italy	The project is aimed to extract energy from the dry, hot wells, that normally are dug, by mistake, when a geothermal field is developed. The idea is to increase the internal surface of the well, making it deeper and digging several sloping branch from its bottom, fill it with an high boiling temperature not polluting liquid, like molten salts, to fill every cracks in the well wall and to allow heat movement by convection, and finally

			insert into the liquid filled well an heat exchanger, to produce underground super heated water, that will be then sent to a flash steam turbine.
Storengy Deutschland GmbH	targeo - green heat for municipalities	Germany	According to a study conducted www.ifeu.de in 2017, around 40 % of the building stock is economically viable for hat pumps today, the double by 2050. With targeo, we offer municipal utilities and other regional heat transition players a software-supported consulting approach in which we identify technically feasible and economically suitable potential for ground-source heat pumps in a region. For this purpose, we superimpose different building and geothermal data and create an interactive map in which the technical suitability, the business case and the possible CO2 savings are shown for each building. Results are presented in digital twins which are basis of energy strategy definition of many market participants.
TERMOLINE Romania	Energy recovery system from thermally used geothermal	Romania	The project "Energy recovery system from thermally used geothermal water" consisting of a container equipped with geothermal probes where geothermal wastewater (used to heat buildings, pools, aquapark) is collected. It is primary energy source for GSHP working in tandem with hybrid HyHP (brine/air-to-water). HyHP are one of the novelties of the system: thermally used water does not have a constant regime as GSHP uses it as primary energy source. The air-to-water circuit of HyHP uses air a constantly available heat/cold source. When the wastewater in the container cools below 5°C, GSHP stop but the HyHP switches to air-to-water mode and continues to supply heat until of the water collected in the container will reach a designed temperature.

NEW PROJECTS STARTED IN 2021/2022

Project name (min. > € 1 mln)	Website or short description	Start year	End year	Budget / Funding (EUR million)	Relevant activities addressed/ targets achieved
GEOTHERMICA					
DEEP	DEEP | Home (deepgeothermal.org)	2020	2023		6, 10
DEEPEN	DEEPEN (or.is)	2020	2023	Total cost € 3.658.928, geothermica financing € 2.041.478, own financing € 3.558.320	8, 10
TEST-CEM	TEST-CEM Geothemral Energy Solutions (bnl.gov)	2020	2023		5, 10
RESULT	Enhancing reservoirs in urban development: smart wells and reservoir development. The main objective is to demonstrate the potential for increased performance by 30-100% of major (marginal) reservoirs for heating in urban areas in the northern EU.	2020	2023		1
SPINE	Stress Profiling in Enhanced Geothermal Systems (SPINE) - RWTH AACHEN UNIVERSITY LIH - English (rwth-aachen.de)	2020	2023		6
SEE4GEO	SEE4GEO -Seismoelectric Effects for Geothermal Resources Assessment and Monitoring - Norce (norceresearch.no)	2020	2023	255100,00	8
GRE-GEO	https://www.gre-geo.org/	2020	2023		3, 7
Horizon 2020					
MaPSI	https://cordis.europa.eu/project/id/101002507	2021	2026	€ 2 000 000	5

				EU contribution: € 2 000 000	
DeepU	https://cordis.europa.eu/project/id/101046937	2022	2025	€ 3 092 880,70 EU contribution: € 2 994 267,50	6, 8
OptiDrill	Optimisation of Geothermal Drilling Operation with Machine Learning | OptiDrill Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)	2021	2023	EU contribution: € 3 985 302,50	7
ORCHYD	Novel Drilling Technology Combining Hydro-Jet and Percussion for ROP Improvement in deep geothermal drilling | ORCHYD Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)	2021	2023	EU contribution: € 3 999 945	7
ARMISTICE	Analysis and Risk Mitigation measures for Induced Seismicity in supercriTICal gEothermal systems | ARMISTICE Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)	2021	2023	Total cost € 160 932,48 EU contribution: € 160 932,48	10, 6
MODERATE	Magma Outgassing During Eruptions and Geothermal Exploration | MODERATE Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)	2021	2026	Overall budget € 2 821 036 EU contribution: € 2 821 036	8, 10
IMPROVE	Innovative Multi-disciPlinary European Research training netwOrk on VolcanoEs | IMPROVE Project | Fact Sheet | H2020 | CORDIS | European Commission (europa.eu)	2021	2025	Total cost € 4 043 158,20 EU contribution: € 4 043 158,20	8

FINANCIAL CONTRIBUTION PER RD&I ACTIVITIES

Breakdown and comparison of approximate total funding (that includes EU, national and private) in 3 years for geothermal energy projects according to the R&I activities set by the IWG DG

List of Research and Innovation Activities	DG IWG	Funding 2019 (EUR million)	Funding 2020 (EUR million)	Funding 2021 (EUR million)
Geothermal heat in urban areas	R&I Activity 1	14.6	25.8	na
Materials, methods and equipment to improve operational availability (high temperatures, corrosion, scaling)	R&I Activity 2	6.5	12.1	na
Enhancement of reservoir (conventional and unconventional);	R&I Activity 3	/	9.1	na
Improvement of performance (conversion to electricity and direct use of heat)	R&I Activity 4	6.5	4.3	na
Exploration techniques (including resource prediction and exploratory drilling)	R&I Activity 5	26.8	18.5	na
Advanced drilling/well completion techniques	R&I Activity 6	1.3	23.5	na
Integration of geothermal heat and power in the energy system and grid flexibility	R&I Activity 7	6.5	16.7	na
Zero emissions power plants	R&I Activity 8	/	5.4	na
Increasing awareness of local communities and involvement of stakeholders in sustainable geothermal solutions	9: NTBE-A	4.4	1.8	na
Risk mitigation (financial/project)	10: NTBE.B	1.1	/	na
TOTAL		**67.7**	**117.2**	

Table above represents the comparison of the approximate total amount of diverse funding sources (EU, national programmes, and private finance) for geothermal energy projects in 2019, 2020 and 2021. The amounts were categorised according to each Research and Innovation Activity that was set in the updated Implementation Plan of the DG IWG.

According to the funding data in 2019 and 2020, majority of funds were directed to technologies and projects that are supporting R&I Activities 1 (Geothermal heat in urban areas) and 5 (Exploration techniques including resource prediction and exploratory drilling). This fact underlines the need of geothermal heating supply in urban areas as well as the necessity for further improvement in exploration techniques that will lead to more geothermal energy supply.

Data for 2021 are not yet fully available, especially the projects supported by Geothermica.