

Mapping deep geothermal resources in Europe by European geological surveys using an adapted play-based exploration pyramid within the Horizon Europe co-founded GSEU Project

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The Pan EU Atlas of Sustainable GeoEnergy Capacities



Outlook

1. GSEU project. The Geological for Service for EUROPE
2. What has been done so far and what are the activities of GSEU in the Deep Geo
3. From the Play-based Exploration Pyramid concept to the GSEU approach for Deep Geo
4. Pan-EU Atlas of SGC. Deep geothermal. Published datasets Levels 00, 01, and 02
5. The role of geological surveys in geothermal development
6. Why is the information and knowledge on these issues important for Europe?
7. Accelerate EU, Plan - Creation of an EU-level geological database to accelerate geothermal energy.
8. Summary

1. GSEU project. The Geological for Service for EUROPE

GSEU is a UE Horizon Europe funded project (Coordination and Support Action) running between 2022-2027, lead by EuroGeoSurveys and 49 partners.

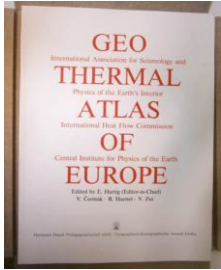
Main goal: to develop and make permanently available a **pan-European geological data infrastructure** and related information services for the sustainable and safe use of our subsurface and its resources.

Structured into different Areas of Expertise: Raw Materials, **GeoEnergy Resources**, Groundwater Resources, Coast and Sea, Geological modelling, EGDl.

A **Pan-European online Atlas of Sustainable GeoEnergy Capacities** (geothermal energy resources and subsurface storage capacities for sustainable energy carriers (hydrogen, heat and cold) and sequestration of CO₂), with harmonized and generalized maps and databases based on the evaluation and assessment of existing and new data and information.

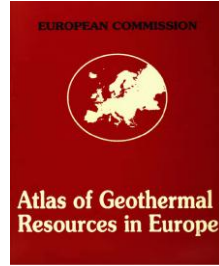
2. What has been done so far and what are the activities of GSEU in DG

Historic projects



Hurtig et al
(1992)

Hurter, S. J.
and Haenel,
R. (2002)



Atlas of Geothermal
Resources in Europe

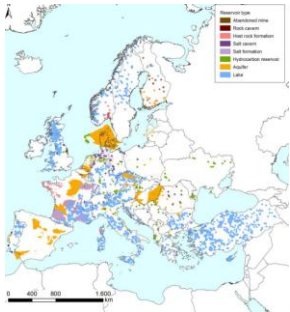
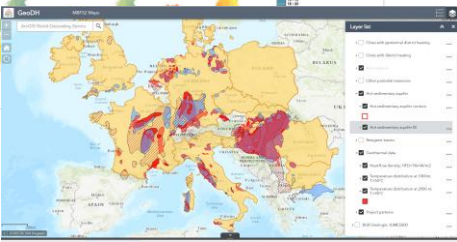


GEOELEC

2011-2013

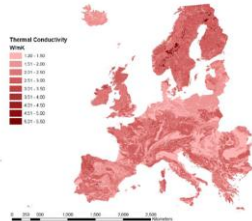


2011-2014



ESTMAP
Energy Storage Mapping And Planning

2015-2016



GEOCOND

2017-2021

GSEU's new **Pan-EU Atlas of SGC** takes as its starting point the information from previous EU projects in this topics, **updating, expanding and generating new** information oriented to the end user (for planning, decision-making aid)

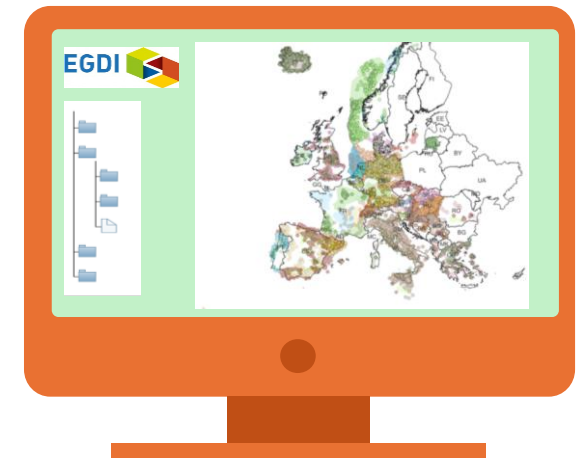
1) gathering previous information



3) Compilation and publication

2) Updating, expanding and **generating new layers** and guides

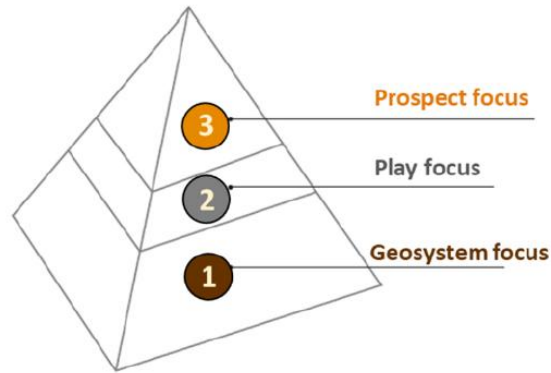
The future Pan EU Atlas of Sustainable GeoEnergy Capacities



3. From the Play-based Exploration Pyramid concept to the GSEU approach for DG

Play-based Exploration Pyramid concept

(adapted for geothermal, Moeck, 2020)



(Moeck, 2020, modified from Royal Dutch Shell, 2013)

(1) Geological system analysis as a whole

- Plate setting
- Tectonostratigraphic framework
- Geothermal Play identification and typing (Moeck, 2014)

(2) Play focus

- Play level identification (basic characterization)
- Summary of play maps (basic spatial delimitation)
- Prospect selection

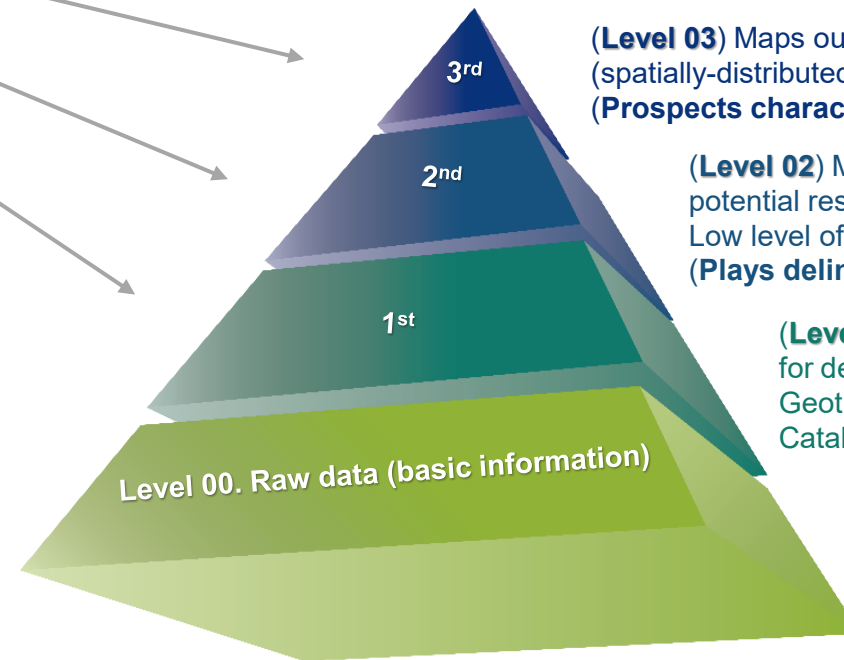
(3) Play level analysis in prospect area (local)

- Geophysical evaluation at prospect scale
- Geological (3D) model building
- Play execution activities

GSEU Pan-EU Atlas SGC (Deep Geothermal & MT/HT-ATES)

Concept based on Levels of knowledge

High knowledge / Low coverage



(Level 03) Maps outlining and assessing potential reservoirs (spatially-distributed). Medium-high level of characterization
(Prospects characterization at local scale)

(Level 02) Map of global scale outlining and assessing potential reservoirs for geothermal and MT/HT-ATES. Low level of characterization + Catalogue Sheets
(Plays delineation and assessment)

(Level 01) Map of favourable areas at EU scale for deep geothermal prospecting based on Geothermal Plays Types and MT/HT ATES + Catalogue Sheets
(GeoSystems Typing)

(Level 00) Boreholes & wells, thermal spring water data

Low knowledge / High coverage

3. From the Play-based Exploration Pyramid concept to the GSEU approach for DG

GSEU Pan-EU Atlas SGC (Deep Geothermal & MT/HT-ATES)

Concept based on Levels of knowledge

High knowledge / Low coverage

Classification of “Geothermal Plays Types”

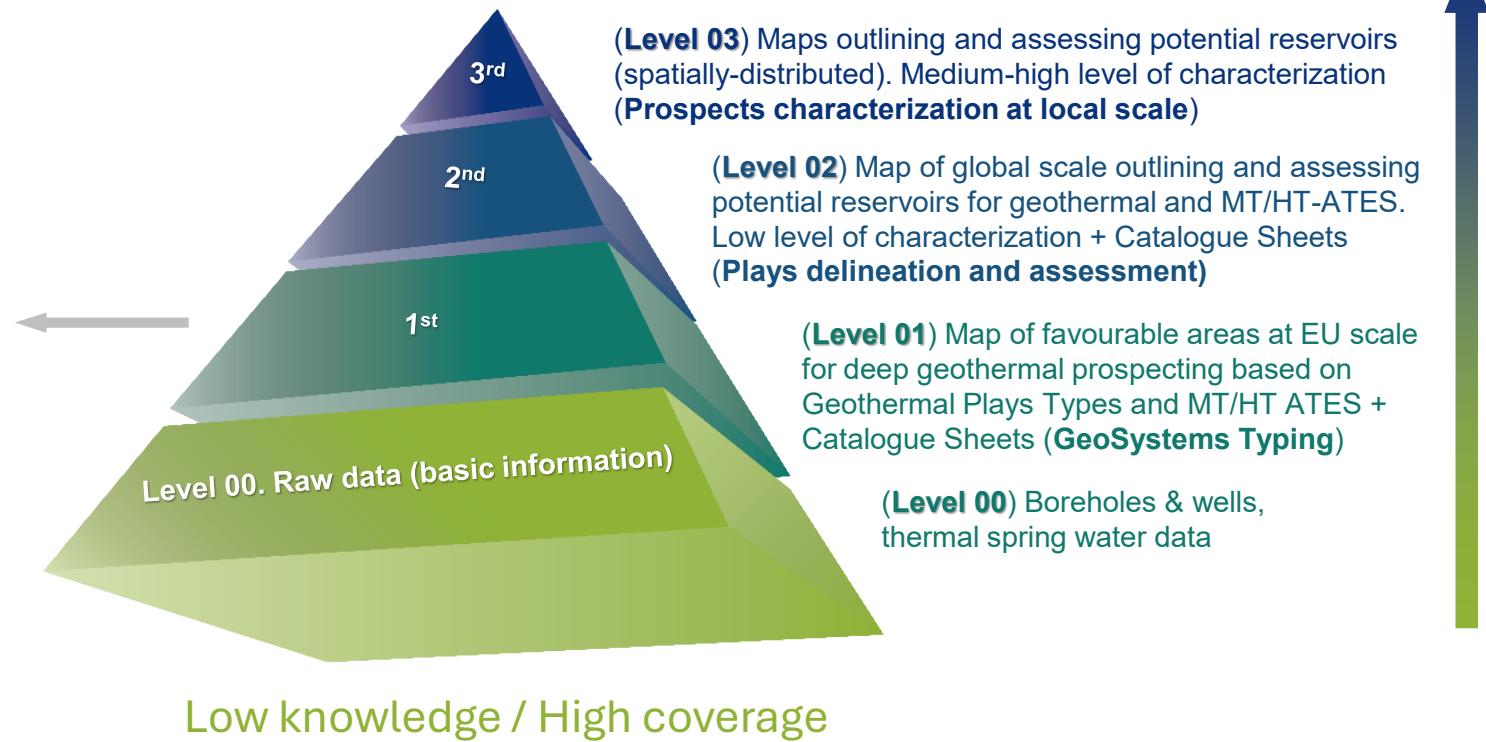
(Moeck, 2014, 2015; Moeck et al., 2019)

Convection-Dominated Geothermal Plays (CV)

1	Volcanic field type	Plutonic type	Extensional domain type
2	Java-Kamojang	Larderello	Bradys (Basin and Range)
3	Magmatic arcs Mid oceanic ridges Hot spots	Young orogens Post-orogenic phase	Metamorphic core complexes Back-arc extension Pull-apart basins Intracontinental rifts
	Magma chamber, intrusion	Young intrusion+extension	Thinned crust → elevated heatflow
4	Active magmatism (volcanism)	Recent plutonism	Active extensional domain
5	← Convection dominated systems →		
6	← Fault controlled Magmatic →		

Conduction-Dominated Geothermal Plays (CD)

1	Intracratonic Basin Type	Orogenic Belt Type	Basement Type
2	Paris Basin	Unterhaching (Germany)	Habanero (Australia)
3	Intracratonic/Rift basins Passive margin basins	Fold-and-thrust belts Foreland basins	Intrusion in flat terrain Heat producing element rock
	Sedimentary aquifers Permeability/porosity with depth	Sedimentary aquifers Permeability/porosity with depth Fault and fracture zones	Hot intrusive rock (granite) Low porosity/low permeability Fault and fracture zones
4	hydrothermal	hydrothermal	petrothermal
5	← Conduction dominated systems →		
6	← Fault/fracture controlled Litho-/biofacies controlled →		



3. From the Play-based Exploration Pyramid concept to the GSEU approach for DG

GSEU Pan-EU Atlas SGC (Deep Geothermal & MT/HT-ATES)

Concept based on Levels of knowledge

High knowledge / Low coverage

(Level 03) Maps outlining and assessing potential reservoirs (spatially-distributed). Medium-high level of characterization (Prospects characterization at local scale)

(Level 02) Map of global scale outlining and assessing potential reservoirs for geothermal and MT/HT-ATES. Low level of characterization + Catalogue Sheets (Plays delineation and assessment)

(Level 01) Map of favourable areas at EU scale for deep geothermal prospecting based on Geothermal Plays Types and MT/HT-ATES + Catalogue Sheets (GeoSystems Typing)

(Level 00) Boreholes & wells, thermal spring water data

Level 00. Raw data (basic information)

Low knowledge / High coverage

Prospects
(at local scale)

Processed data
Level 3
Raster files
2/3D

Plays
(reservoirs)

Level 02

2D Vector file

Sheets catalogue of assessed reservoirs (Plays)

Boreholes
& Thermal
Springs

Geothermal
Play Types
regions

Level 00
Level 01

1D
2D Vector files

Sheets catalogue of Geothermal Play Types (GeoSystems)

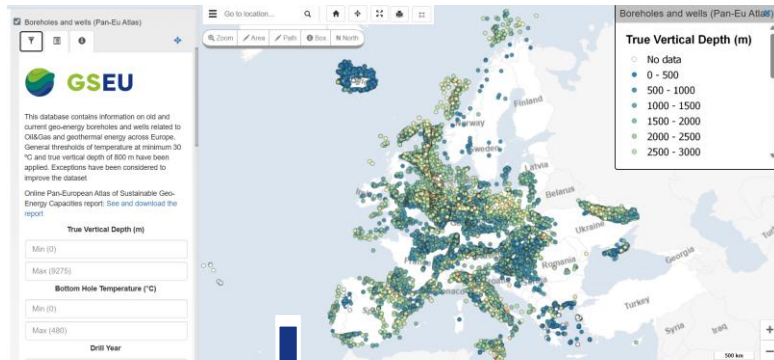
4. Pan-EU Atlas of SGC. Deep geothermal: Levels 00 and 01

Level 00

Boreholes and wells

(O&G, geothermal, mining, water resources...)

Data useful for Deep Geothermal and Geo Storage (CO₂, H₂, CAES, ATES) purposes

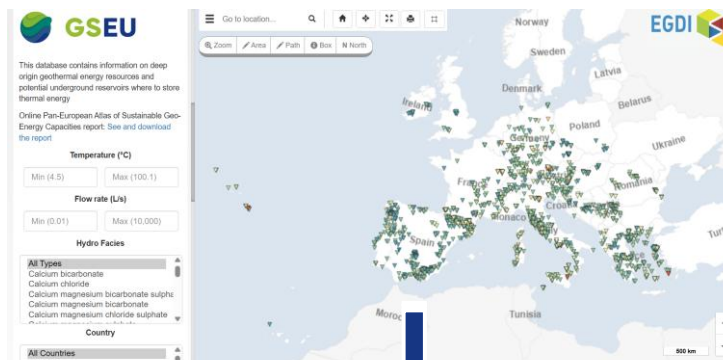


ID	K	V	V	V	Company	Province	Depth_m	Depth	Min_Sec_T	Temp_max	Secs_TC	Secs_C	Hydro	Structure
1	1917	014	014	014	ARIPAN	1917	014	014	014	014	014	014	014	014
2	2011	014	014	014	DUINPT	2011	014	014	014	014	014	014	014	014
3	1917	014	014	014	IMFP	1917	014	014	014	014	014	014	014	014
4	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
5	1917	014	014	014	CHEIRON	1917	014	014	014	014	014	014	014	014
6	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
7	1917	014	014	014	SMEL	1917	014	014	014	014	014	014	014	014
8	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
9	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
10	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
11	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
12	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
13	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
14	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
15	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
16	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
17	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
18	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
19	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
20	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
21	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
22	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
23	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014
24	1917	014	014	014	ADINA	1917	014	014	014	014	014	014	014	014

Attribute table

Thermal springs

(Natural outflow water 5°C higher than the mean air annual temperature)



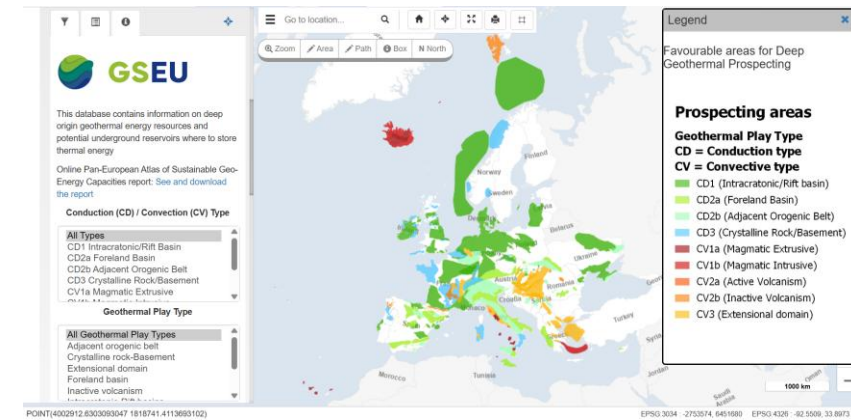
ID	K	V	V	V	SpringName	Flow_rate	TEMP	No_Thermal	Hydro	Secs_TC	Secs_C	Hydro_Faci	Database	Structure
1	1917	014	014	014	A RABDA	30	21	No Thermal	Hydro	1917	014	014	014	014
2	1917	014	014	014	AGUAS DE MANZOS	30	19	No Thermal	Hydro	1917	014	014	014	014
3	1917	014	014	014	AGUAS DE ACOGADA	0	16	No Thermal	Hydro	1917	014	014	014	014
4	1917	014	014	014	AGUAS FORTESITAS	0	19	No Thermal	Hydro	1917	014	014	014	014
5	1917	014	014	014	AGUASANTA	1	12	No Thermal	Hydro	1917	014	014	014	014
6	1917	014	014	014	BALNEARIO BRUES	460	27	Thermal	Hydro	1917	014	014	014	014
7	1917	014	014	014	BALNEARIO CALDAS	80	12	No Thermal	Hydro	1917	014	014	014	014
8	1917	014	014	014	BALNEARIO CALDAS	80	47	Thermal	Hydro	1917	014	014	014	014
9	1917	014	014	014	BALNEARIO DAXLA	700	48	Thermal	Hydro	1917	014	014	014	014
10	1917	014	014	014	BALNEARIO DE ARZOBISPO	2100	42	Thermal	Hydro	1917	014	014	014	014
11	1917	014	014	014	BALNEARIO DE BARRA	1200	28	Thermal	Hydro	1917	014	014	014	014
12	1917	014	014	014	BALNEARIO DE CABALLERO	400	27	Thermal	Hydro	1917	014	014	014	014
13	1917	014	014	014	BALNEARIO DE LANTAS	460	36	Thermal	Hydro	1917	014	014	014	014
14	1917	014	014	014	BALNEARIO DE LA TOJA	240	42	Thermal	Hydro	1917	014	014	014	014
15	1917	014	014	014	BALNEARIO DE LAUS	1000	30	Thermal	Hydro	1917	014	014	014	014
16	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
17	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
18	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
19	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
20	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
21	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
22	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
23	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014
24	1917	014	014	014	BALNEARIO DE LAUS	1000	30	No Thermal	Hydro	1917	014	014	014	014

Attribute table

Level 01

Geothermal Plays Types at Pan-EU scale

(Favourable geological settings for geothermal exploration)



Catalogue of accessible factsheets of Geothermal Play Type across EU containing the description



Attribute table

4. Pan-EU Atlas of SGC. Deep geothermal: Levels 00 and 01

Version v1.0 Pan-EU Atlas (April 2025)

Version v2.0 Pan-EU Atlas (May 2026) **update!**

(Level 00) **Boreholes & wells, thermal spring water data**

(Level 01) **Map of favourable prospecting areas at EU scale + Catalogue Sheets**



55.117 boreholes & wells

376 SHEETS describing the "Geothermal Plays Types" across EU

GSEU

This database contains information on deep origin geothermal energy resources and potential underground reservoirs where to store thermal energy

Online Pan-European Atlas of Sustainable Geo-Energy Capacities report: [See and download the report](#)

Conduction (CD) / Convection (CV) Type

- All Types
- CD1 Intracratonic/Rift Basin
- CD2a Foreland Basin
- CD2b Adjacent Orogenic Belt
- CD3 Crystalline Rock/Basement
- CV1a Magmatic Extrusive

Geothermal Play Type

- All Geothermal Play Types
- Adjacent orogenic belt
- Crystalline rock-Basement
- Extensional domain
- Foreland basin
- Inactive volcanism

Legend

- Boreholes and wells (Pan-Eu Atlas)
- Thermal Springs
- Favourable areas for Deep Geothermal Prospecting
- Prospecting areas**
- Geothermal Play Type**
- CD = Conduction type**
- CV = Convective type**
- CD1 (Intracratonic/Rift basin)
- CD2a (Foreland Basin)
- CD2b (Adjacent Orogenic Belt)
- CD3 (Crystalline Rock/Basement)
- CV1a (Magmatic Extrusive)
- CV1b (Magmatic Intrusive)
- CV2a (Active Volcanism)
- CV2b (Inactive Volcanism)

Details

Boreholes and wells (Pan-Eu Atlas) New window

Thermal Springs New window

Favourable areas for Deep Geothermal Prospecting New window

Go to	Geothermalplaycode	Geothermalplayname	Geographicalallocation	Geographicalcountry	Geographicalregion	Conductionconvectiontype	Geothermalplaytype	Platetectonicsetting	Geologicshabitat	Geologiccontrols	Descriptionofgeothermalplay	Metadatasourcedata	Contr
FR_CD3_006	Link...	Armorican massif	FRH0, FRD1, FRG0, FR13	France	Bretagne (FRH0), Basse-Normandie (FRD1), Pays de la Loire (FRG0), Poitou-Charentes (FR13)	CD3	Crystalline rock-Basement	Heat producing element in rock-Hot intrusive rock	Hydrothermal-petrothermal	Fault-lithology controlled	The CD3 Armorican massif is a basement domain composed of two orogenic events, the Cadomian orogeny in the north and the Variscan orogeny. It is composed of carboniferous	BRGA	

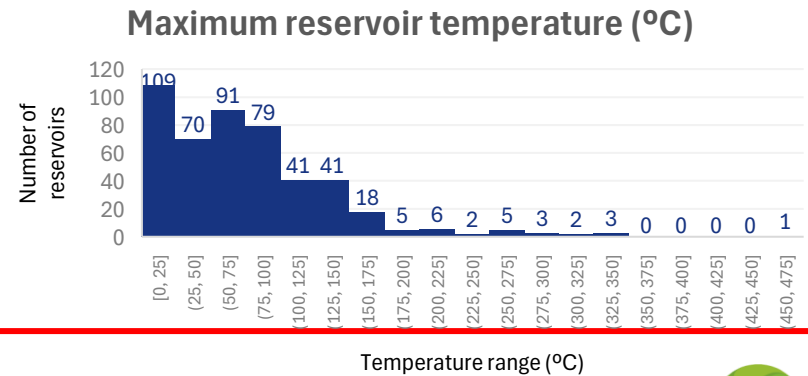
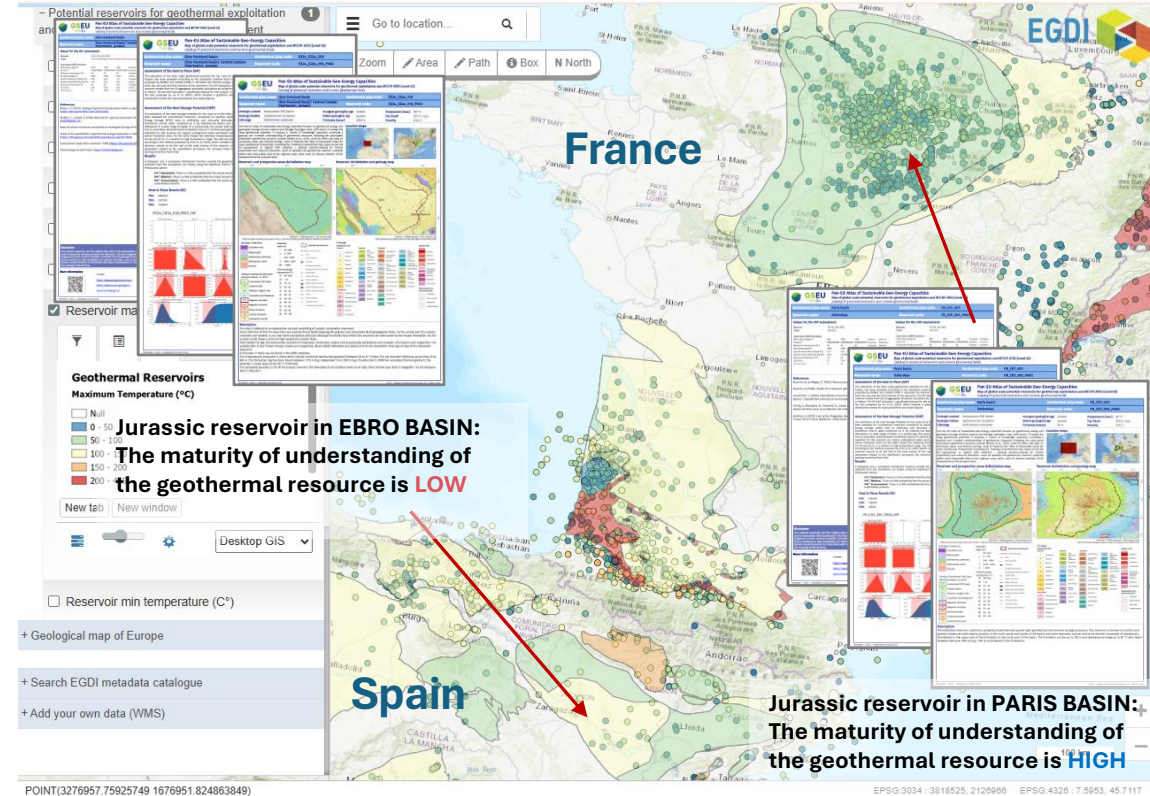
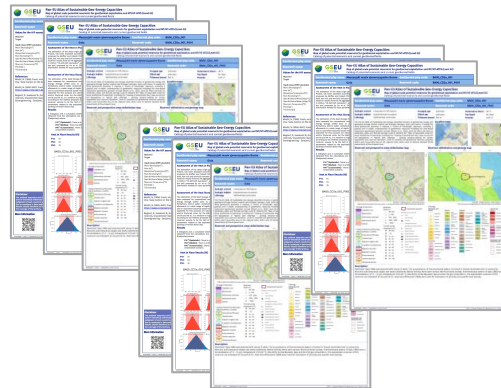
<https://maps.europe-geology.eu/>

4. Pan-EU Atlas of SGC. Deep geothermal: Levels 02

(Level 02) Map of Identified and Broadly Assessed Potential Natural Reservoirs for Deep Geothermal Energy and MT/HT ATEs across Europe – v1.0 (May 2026).

- 540 geothermal reservoirs identified across the European Union (v1.0); further expansion planned.
- 358 reservoirs (66%) assessed using HIP and HSP methodologies.
- Mapped attributes: max/min temperature, top/bottom depth, max/min thickness, average porosity, and lithology.
- Downloadable 3–4-page factsheets with maps, assessments, and references.

540 SHEETS describing the “Broadly Assessed Potential Natural Reservoirs for Deep Geothermal Energy and MT/HT ATEs ” across EU



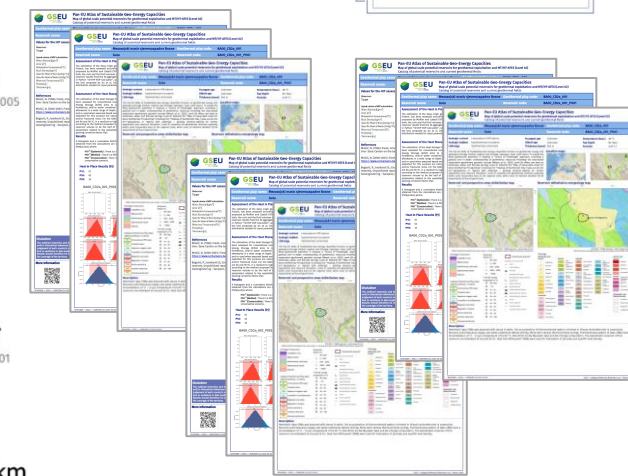
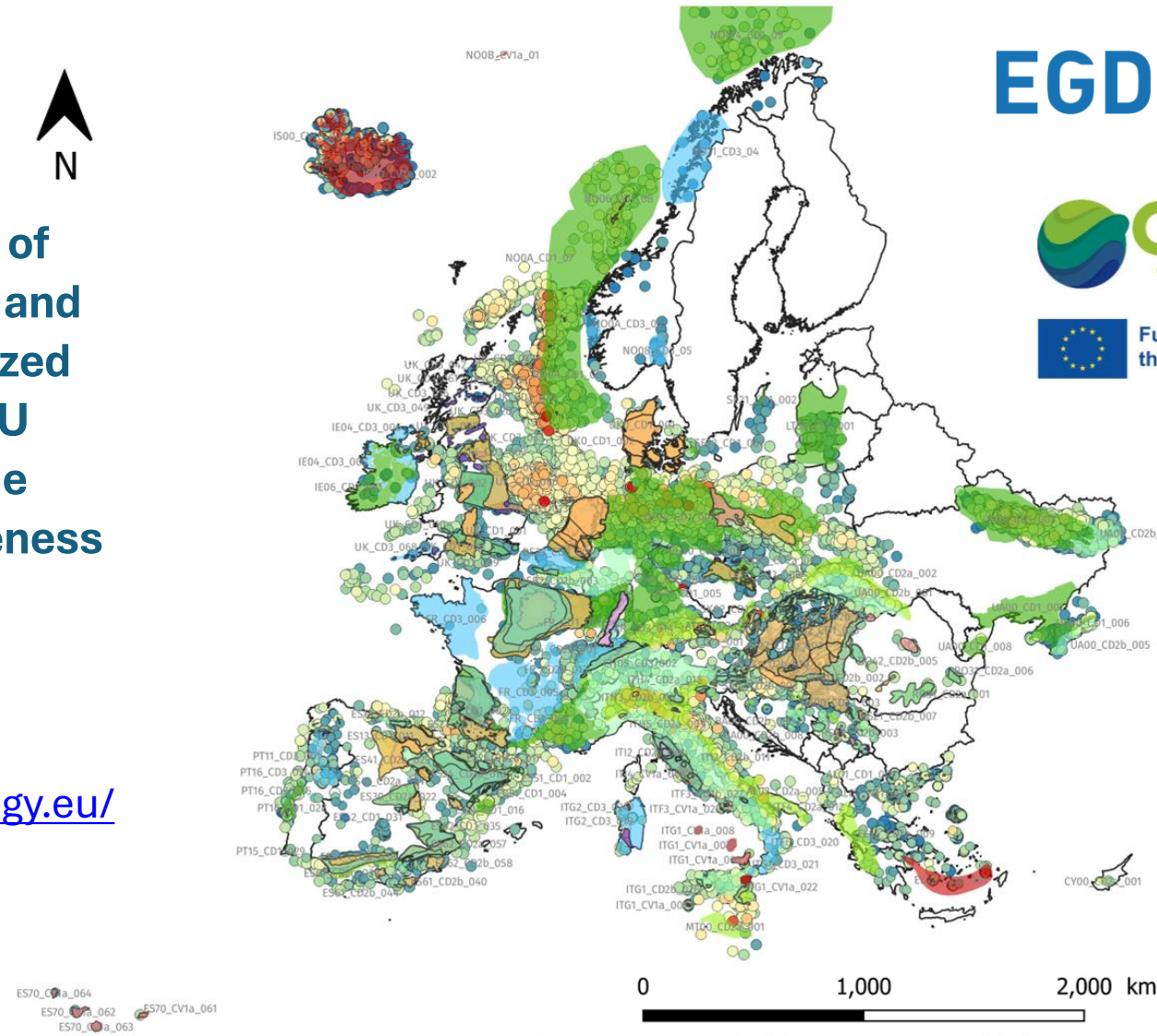
Histograms for attributes

<https://maps.europe-geology.eu/>

4. Pan-EU Atlas of SGC. Deep geothermal

The GSEU's PanEU-Atlas of SGC provide information and knowledge in a standardized and harmonized way at EU level, so it will support the dissemination, the awareness and the development of Europe's geothermal energy sector

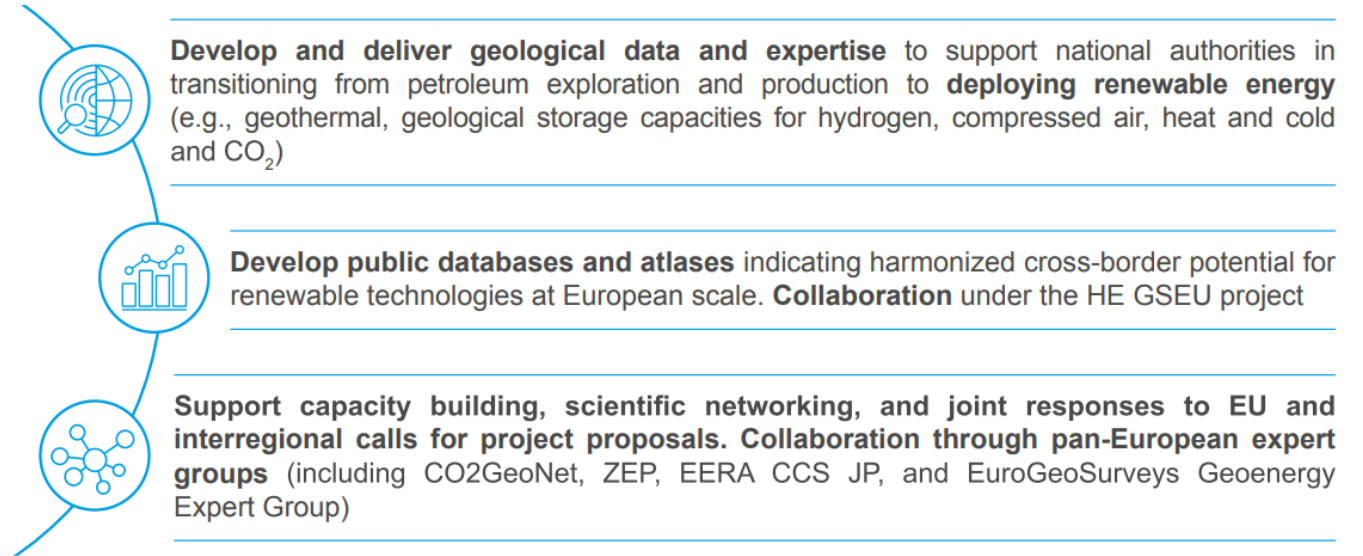
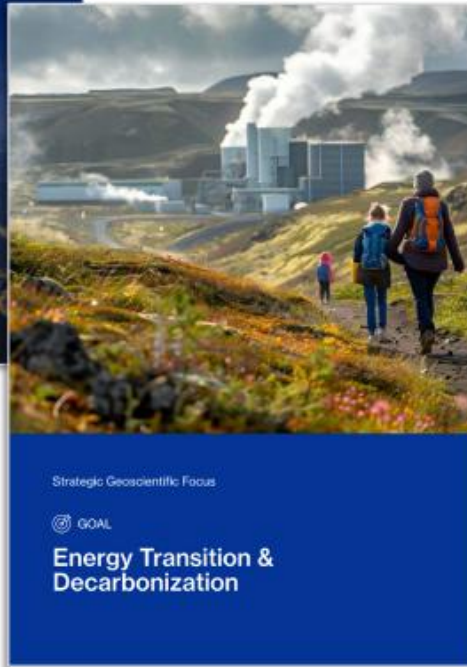
<https://maps.europe-geology.eu/>



5. The role of geological surveys in geothermal development



The EuroGeoSurveys ten-year SRIA



GOAL: Energy Transition & Decarbonization

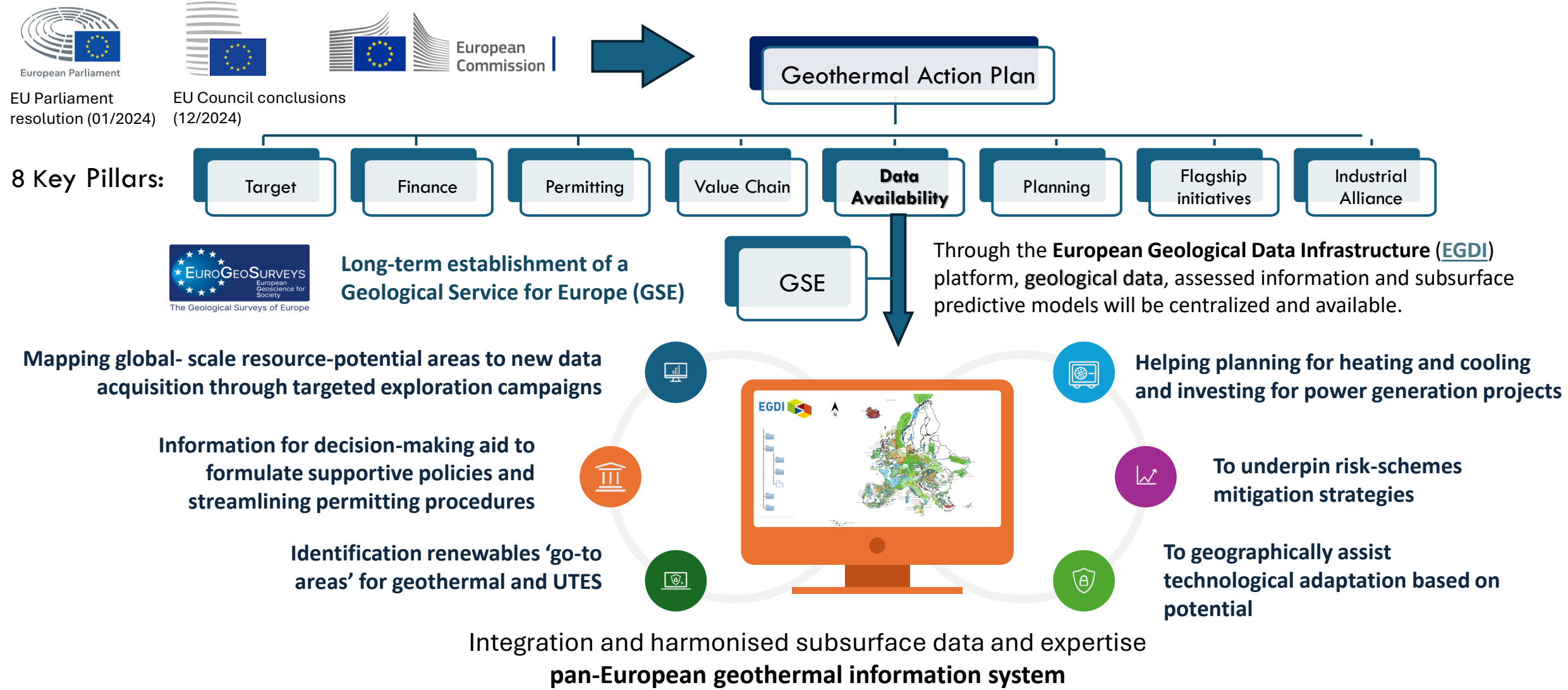
- **Priority ETD1 - Develop and deploy “Pan-EU Information and Decision Support Systems” to accelerate deployment of geothermal systems; with different topics**
- **Fit-for-purpose digital geological data, for techno-economical evaluations, for de-risking schemes, etc.**

It focusses on geoscientific data, information, and knowledge of the subsurface to address EU and global challenges




EU Geothermal Action Plan

6. Why is the information and knowledge on these issues important for Europe?



7. The PanEU Atlas of SGC in the framework of the new “AccelerateEU Plan”

The key role of the GSEU geothermal DDBB

- The European Commission launched the **AccelerateEU Plan** on 22 April 2026, recognizing geothermal energy as essential for EU energy security, economic resilience, and climate action
 - The plan highlights geothermal energy as a versatile renewable source for electricity, heating, and cooling that can replace imported fossil fuels with clean and affordable energy
 - The **AccelerateEU Plan** outlines a series of measures that, among them: **creating an EU-level database of geological data** focused to speed-up the deployment of geothermal energy projects across the whole of the EU
- 
- This underlines the strategic importance of the **Pan-EU Atlas of GSEU database** structure and the need to secure its long-term maintenance, together with its continuous enrichment with new data



The screenshot shows the European Commission website with the following elements:

- Logo of the European Commission and the text "European Commission".
- Language selector set to "EN" and a search bar.
- Navigation menu: Energy, Climate change, Environment.
- Sub-navigation menu: Energy.
- Breadcrumbs: Home > Strategy > AccelerateEU to strengthen EU energy resilience.
- Page title: AccelerateEU to strengthen EU energy resilience.
- Text: "The Communication AccelerateEU addresses the EU's rising energy costs amid volatile fossil fuel markets and aims to accelerate the clean energy transition and strengthen our energy resilience."
- Map of Europe showing geothermal resource distribution with various colored markers and regions labeled (e.g., SWEDEN, FINLAND, NORWAY, BELARUS, UKRAINE).
- EGDI logo in the top right corner of the map.
- Map controls: Go to location..., Zoom, Area, Path, Box, N North.
- Map title: GSEU.
- Map description: "This database contains information on deep origin geothermal energy resources and potential underground reservoirs where to store thermal energy." and "Online Pan-European Atlas of Sustainable Geo-Energy Capacities report: See and download the report".
- Filters on the left sidebar:
 - Conduction (CD) / Convection (CV) Type: All Types, CD1 Intracratonic/Rift Basin, CD2a Foreland Basin, CD2b Adjacent Orogenic Belt, CD3 Crystalline Rock/Basement, CV1a Magmatic Extrusive.
 - Geothermal Play Type: All Geothermal Play Types, Adjacent orogenic belt, Crystalline rock-Basement, Extensional domain, Foreland basin, Inactive volcanism.
 - Plate Tectonic Setting: All Plate Tectonic Settings, Active magmatism, Convergent margins-Post-orogenic phase, Fault-fracture zones, Fold-and-thrust belts, Foreland basins.
 - Geologic Habitat: All Geologic Habitats, Active extensional domain, Active magmatism.
- Map coordinates: POINT(2129248.958910366 3548219.725957965) and EPSG:3034 : 5675750, 2217605 EPSG:4326 : 31.0146, 44.2585.

8. Summary

The **GSEU** project:

- Creates the base structure for the **Pan-European Atlas for Sustainable GeoEnergy Capacities**. The deep geothermal part It is based on an adapted Play-based Explorariion pyramid concepts.
- The **Pan EU Atlas for SGC** published into EGD I complements, expand and update the coverage provided by previous EU projects, whose geographic scope was only partial, or the data are not updated and was not harmonized.
- It will be further developed in the future within the framework of a permanent **Geological Survey for Europe, incorporating also information from other relevant past EU-funded R+I projects**
- The broader vision is for EGD I to become the European reference infrastructure for geothermal data sharing and preservation, supporting geothermal deployment through harmonized and standarized datasets, improved subsurface knowledge, and pan-European information and decision-support services developed together with the European geothermal community, a *European Investment Opportunities Atlas for Geothermal Energy*



Thank you for your attention!

Dr. Ignasi Herms

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EuroGeoSurveys

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Institut Cartogràfic i Geològic de Catalunya (ICGC)

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