Pan-European Atlas of Sustainable Geo-Energy Capacities

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Geothermal energy & Underground storage inventory	
Online Pan-European Atlas of Sustainable Geo-Energy Capacities	
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Disclaimer

All the datasets included described in this document are collaborative products of 35 geological survey organizations across Europe, developed under the framework of the Pan-European Atlas of Sustainable Geo-Energy Capacities. These datasets are provided for informational purposes only and are intended to support exploration, research, planning, and decision-making related to sustainable Geo-Energy resources. While every effort has been made to ensure the accuracy and completeness of the data, it is provided 'as is' without any warranty, express or implied, including but not limited to warranties for a particular purpose. The contributing organizations and project partners assume no responsibility for errors, omissions, or inaccuracies in the dataset or for any consequences arising from its use. Users are advised to independently verify the data before relying on it for critical applications. The dataset may be subject to updates or modifications without prior notice. By accessing or using this dataset, users agree to hold harmless all contributing partners from any liability resulting from its use.

Acknowledgments

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Abbreviations	
BHT	Bottom Hole Temperature
CAES	Compressed Air Energy Storage
CCS	Carbon Capture and Storage
CD	Conduction-Dominated Geothermal Plays
CO_2	Carbon dioxide
CV	Convection-Dominated Geothermal Plays
DG-TWG	Deep Geothermal – Thematic Working Group
EC	Electrical Conductivity
EGDI	European Geological Data Infrastructure
ESRI	Environmental Systems Research Institute
EU	European Union
GPT	Geothermal Play Type
ID	Identification code
TDS	Total Dissolved Solids
TVD	True Vertical Depth
SGC	Sustainable Geo-Energy Capacities

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1. Introduction

In the framework of the Geological Service for Europe project (GSEU), the Geothermal energy & Underground storage inventory seeks to construct an online Pan-European Atlas of Sustainable Geo-Energy Capacities (Pan-European Atlas SGC) accessible through the European Geological Data Infrastructure (EGDI) platform (https://www.europe-geology.eu/data-tools/map-viewer/). It aims to provide harmonized Pan-European inventories, characterisations and knowledge of sustainable Geo-Energy carriers. The effort of the initial stage of this project have been focused on gathering and harmonizing transnational data to assess geological storage capacity and geothermal energy of subsurface in a frame of a decarbonized, sustainable and competitive European industry. The GSEU SGC Atlas aims to provide continuum and rigorous data across Europe regarding 1) Geological Storage (permanent CO_2 storage; temporal Hydrogen storage, and Compressed Air Energy Storage (CAES)), and 2) Geothermal energy including Low, Mid-Temperature/High Temperature Underground Thermal Energy Storage.

The Atlas aims to integrate data from historical projects and new appraisal and assessment activities to create impact on the following approaches:

- To improve alignment of cross-border Geo-Energy developments.
- To ensure access to future insights and updates on Geo-Energy resulting from national and European research.
- To accelerate the efficient and competitive uptake of clean and sustainable Geo-Energy and storage technologies.
- To improve planning, regulation and decision-making to enable responsible and effective uptake of Geo-Energy.

The current **version (V0.1)** of the Pan-European Atlas SGC provides a first version of the CO_2 storage potential (to be reviewed at 2026), and favourable areas for of deep geothermal prospection (geothermal plays), including mid and hight temperature thermal underground energy storage (to be completed at 2026). This information is structured in three main sections, listed as drop-down categories, which two of them contain multiple layers following this scheme:

Geo-Energy

GSEU – Pan-European Atlas of Sustainable Geo-Energy Capacities

- Boreholes and Wells
- Carbon Storage Potential
  - *CO_2 Storage Traps*
  - *CO_2 Storage Geological Units*
  - *CO_2 Storage Geological Formations*
- Geothermal Energy
  - *Thermal Springs*
  - *Favourable areas for Deep Geothermal Prospecting*

This document describes each of the sections and the layers included in the first version of the Pan-European Atlas SGC according to the main impacts of the GSEU project. All the datasets have been generated as a collaborative effort of 35 geological survey organizations across Europe, which may be subject to subsequent updates and/or modifications without prior notice.

2. Boreholes and Wells

The first section of the Pan-European Atlas SGC corresponds to a vector point layer containing the data of each Geo-Energy borehole, either onshore or offshore, gathered and harmonised by the 35 geological survey contributors.

This layer mainly supports the topics of CO_2 storage and Geothermal Energy, but also any other energy carrier even despite that is not described in the Atlas now. Some threshold constraints have been considered during the generation of this layer in relation to CO_2 storage and Deep Geothermal Energy purposes:

- All boreholes of at least 800 m of true vertical depth (TVD) may be considered. This criterion is usually used in the literature as the minimum depth for the transition zone at which CO_2 should be in a supercritical phase, making it favourable for CO_2 storage.
- All boreholes of at least 30 ºC may be considered. It is the minimum temperature threshold for Deep Geothermal purposes.

Exceptions for those constrains have been also considered: boreholes that do not fit the thresholds of depth and temperature but located in areas where geological and/or technical parameters are favourable for geological storage (CO_2, H_2, CAES) and/or Deep Geothermal purposes, have been also considered according to the expert knowledge of the whole contributors.

Table 1 summarises all the items included in the attribute table for each borehole and can be interactively checked in the Atlas visor (https://www.europe-geology.eu/data-tools/map-viewer/). Not all the fields have been filled in due to the lack of data (some of the boreholes were drilled more than a century ago), or due to confidentiality requirements from the data owners (these concerns, as well, to some sensitive attributes such as the point coordinates). Bottom Hole Temperature (BHT), TVD, geochemical measurements or borehole purpose are some of the main attributes included in this product.

Potential geological reservoirs identified in each borehole (single or multiple reservoirs) are indicated in the attribute table, including the main lithology facies, depth of the top reservoir, and type of carrier (for Carbon Storage purposes) or reservoir temperature.

All the points in the Pan-European Atlas SGC are displayed according to the True Vertical Depth (TVD) values in meters, considered as the total amount of drilled section. Blue points correspond to lower values and red ones to higher values of this attribute (cf. *Figure 1*).

Table 1: *Example and definition of the attributes for boreholes and well layer.*

Attribute in layer	**definition**	**Example**
ID	Unique identification code composed by the NUTS Level 2 code + word "well" + unique and consecutive number for each well starting from 001.	ES51_well_001
X_EPSG3035	X coordinates in meters based on the geographic reference system: EPSG:3035 ETRS89 / LAEA Europe (https://epsg.io/3035).	43624946.00
Y_EPSG3035	Y coordinates in based on the geographic reference system: EPSG:3035 ETRS89 / LAEA Europe (https://epsg.io/3035).	463454810.00
Well_name	Free text according to the original well name.	Amposta-1
Company	Organization related to well drilling.	SIPSA
Drill_year	Year of well drilling.	1995
Purpose	Purpose of well drilling.	Geothermal prospective
TVD	True vertical depth of the well in meters.	3200.50
BHT	Bottomhole temperature. The maximum temperature recorded at total depth, in ºC.	56.50
Gradient	Rate of increase in temperature per unit depth in the Earth. In ºC/km	25.40
Mean_sur_T	Annual mean air temperature of the drilling point, in ºC.	15.00
Topo_m (Elevation)	Topographic elevation of the drilling starting point in meters. Positive (onshore) / negative (offshore).	250.50
Geoch_TDS	Total dissolved solids in ppm.	445.25
Geoch_EC	Electrical conductivity of the fluid in µS/cm.	2500.00
Status	The current state of the well.	Active well
Database	Reference database if the well data is stored there.	Non-existent database
Metadata of source data	Link to metadata repository.	Non-existent metadata
Storage_R1	First reservoir for geo-energy storage indicating lithology, depth of top in meters and type of use.	Limestone/1800/CO_2 (include multiple vectors if needed, e.g. CO_2+H_2)
Geo_Res1	First geothermal reservoir indicating lithology, depth top of reservoir in meters and temperature in ºC.	Limestone/1800/65
Storage_R2	Second reservoir for geo-energy storage indicating lithology, depth of top in meters and type of vector.	Sandstone/2300/CO_2 (include multiple vectors if needed, e.g. CO_2+H_2)
Geo_Res2	Second geothermal reservoir indicating lithology, depth of top in meters and temperature in ºC.	Sandstone/2300/75

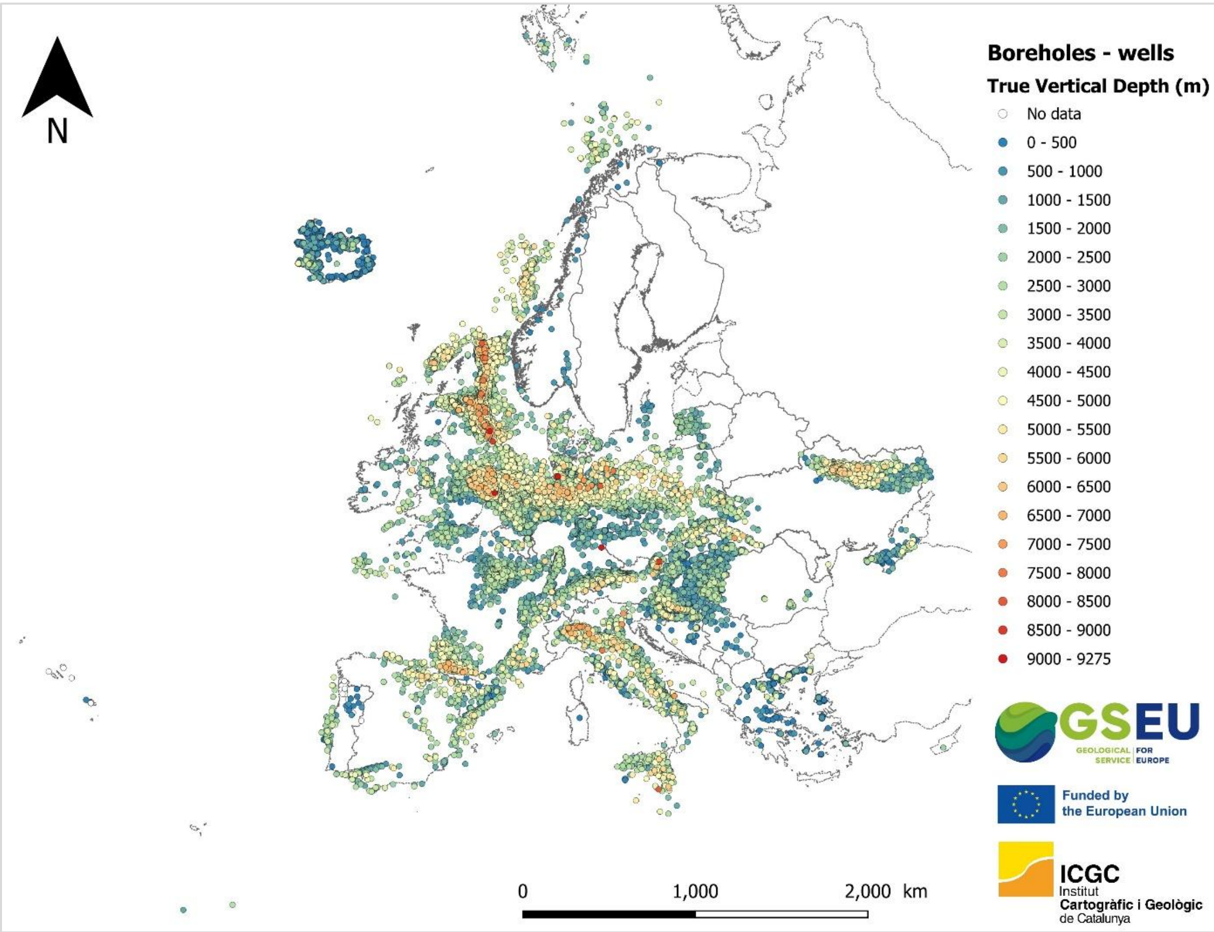

Figure 1: *Example of the borehole's visualization in the Pan-European Atlas SGC.*

How to cite this product:

GSEU Project (2025). Map of Geo-Energy Boreholes and Wells. Version 1.0. Access information on May 28th, 2025 [https://www.europe-geology.eu/data-tools/map-viewer/].

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3. Carbon Storage Potential

The second section of the Pan-European Atlas SGC corresponds to a group of layers conforming the Carbon or CO_2 storage purposes. Three different polygon vector layers have been constructed for this section and are linked together through a database relationship enabling a one-to-many relational database structure:

1) **Formation:** refers to the storage formation.
2) **Storage unit:** is defined as a part of a storage formation which meets the depth condition of more than 800 meters for CO_2 storage, and there can be one or more per formation.
3) **Trap:** is defined as the structural or stratigraphic fluid trap which has the potential to contain the fluid, and there can be one or more in each storage unit.

The database contains the high-level identified formations within each country that may have the potential for geological storage of CO_2. Within those formations are multiple storage units representing the area within the formation where CO_2 could be stored. Data can be added for multiple traps within each storage unit data representing geological closures for storage. The database allows the addition of detailed information for each formation, storage unit and trap to build as complete a picture as possible of the potential for geological storage within each of the European countries. In some cases, the database could be limited to one or two levels (formations and/or storage units) depending on the level of knowledge in the area. This is the same data structure followed by CO2Stop EU funded project 2012-2013 (fomer Pan-European Atlas of CO_2 storage potential).

The database was developed to suit display in a **Geographical Information System** (GIS) represented by **polygons,** the areas where storage potential may exist, and reflects the formations, units and traps within the database. It is worth noting that in some cases, the polygons are assumed where there is uncertainty over the extent of the geographical area with potential for storage, or where the data are confidential (CF).

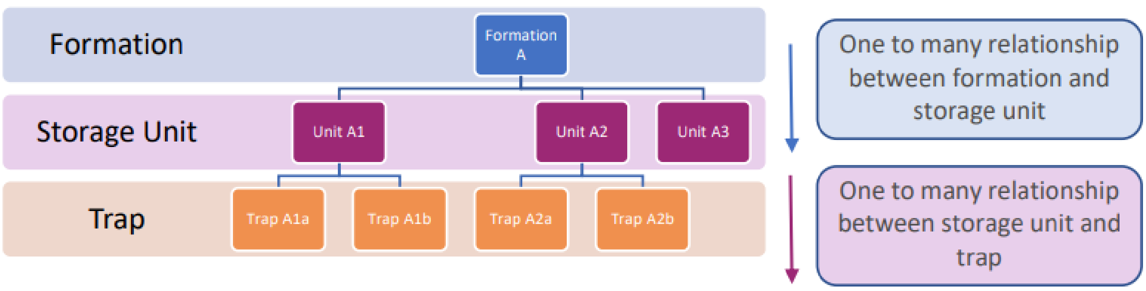


Figure 2: *Relational database (Courtesy of Hystories).*

In relation to data for depth to storage formation, it was decided to record two separate depths; median or average depth of the storage formation across its extent and the depth to the top of the formation. The median or average depth was recorded for CO2Stop and is adopted as it enables modelling of storage site behaviour. The decision to include the depth to top of the storage formation, in addition to the median depth, was based on its value in risk assessments and the depth to the crest of a hydrocarbon field is often published and in the public domain.

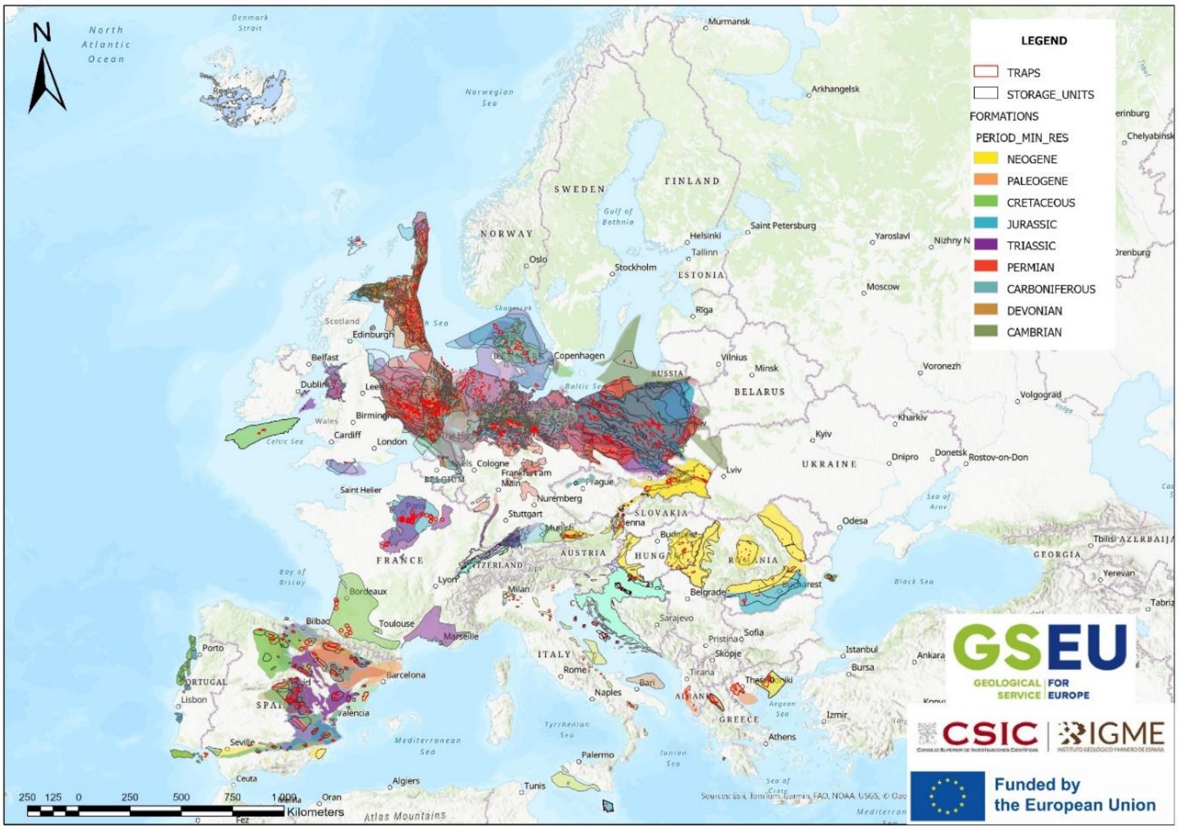


Figure 3: *Example of the formations, storage units and traps visualization in the Pan-European Atlas SGC.*

3.1. Defining geological features of interest

The database accommodates the heterogeneity and confidentiality of data by offering the possibility to define large areas where there are porous rocks (formations), areas where there are porous rocks at suitable depth (units) and identified closures with storage potential (traps).

Storage formation is defined as a mappable body of rock that is continuous in the subsurface and which is both porous and permeable. It is usually a defined geological formation within the recognised national chrono-stratigraphy.

Storage unit delineates the parts of the storage formation that lie at depths greater than 800 m and which are covered by an effective cap rock. Storage unit information can also be used to highlight areas where storage potential is expected but traps cannot be defined owing to data confidentiality, or lack of available data.

Storage traps are the most important geological features, as these represent the areas where the most data are available and highlight a tangible opportunity to carry out further investigation to verify the storage potential. Storage traps are defined as structural or stratigraphic traps which have the potential to retain CO_2 within them, e.g. domes in saline water-bearing parts of the reservoir rock that are completely sealed by cap rocks, or proven oil and gas fields. If the traps are 'stacked' and separated by thicknesses of impermeable rock, then these traps should be identified separately since depth is an important parameter for estimating storage capacity.

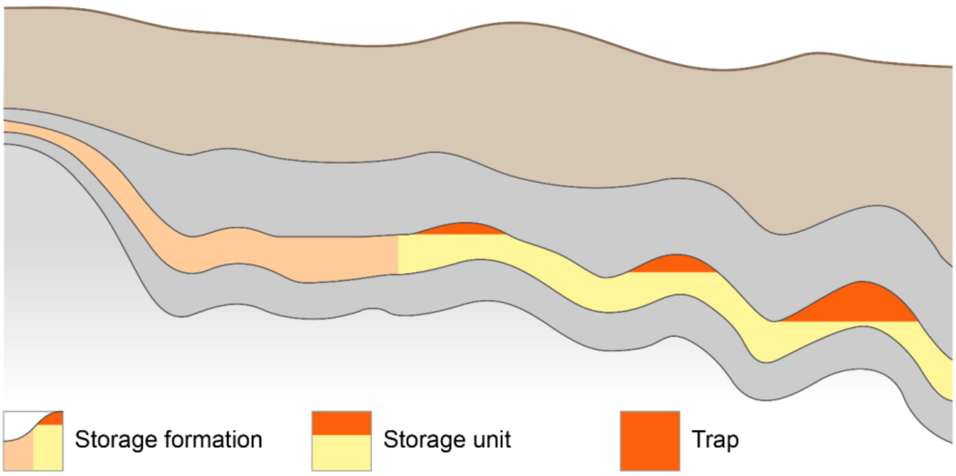


Figure 4: *Illustration of storage formation, unit and trap in the database (Courtesy of Hystories).*

3.2. Compiling the data from CO2Stop and Hystories as the starting point for GSEU

The GSEU project builds on the work of the CO2Stop and Hystories (https://hystories.eu/) EU funded projects. CO2Stop contained potential CO_2 storage formations, units and traps. Hystories contained potential hydrogen storage formations, units and traps. Since the Hystories database built on the CO2Stop database and maintained the same structure, similar attribute fields, and the formation, unit and trap ID numbers were preserved, it was possible to merge the databases to generate v0 of the GSEU Access database. The following steps were undertaken

- A copy of the Hystories data was taken as a text file from the Hystories WebGIS
- The Hystories data was imported, using FME, into the Hystories database structure
- Since some columns were removed during Hystories, these were added back directly from the CO2Stop database, based on the columns required in the word document.
- The CO2Stop tables were then imported using an Access query to populate the new 'CO2Stop' columns into the Hystories database where the id's matched. This generated the GSEU database.
- The Access data entry tables were then updated to reflect the merged database and new data entry features and/or dictionaries were added
- The database was then split by country to allow partners to work on a local copy of the GSEU database.

3.3. CO_2 storage capacity

The CO_2 storage capacity estimation approach depends on the level of knowledge and open to a expert opinion. Taking into account the level of (low) maturity in most cases, it was proposed storage capacity estimation based on theoretical (volumetric or static) CO_2 storage estimation but keeping the option to other approaches if they are accepted by international community and properly referenced. It was considered a priority to apply same approach (and capacity estimation calculation) at national level and at Pan-European Atlas; that is, those countries with national CO_2 storage potential calculation have provided the same values. The estimated capacity had been accompanied by an SRL which indicates the level of maturity for each estimation.

Both, capacity estimation and SRL are defined for traps. Only, if a storage unit is provided with no traps, a regional estimation of capacity and/or SRL is acepted.

A consistent and published methodology was proposed to calculate theoretical CO_2 storage capacity, following the same approach used in CO2Stop for both saline aquifers and hydrocarbon fields which are described belong.

For this Version 1 of the Pan-European Atlas of SGC (April 2025), it is included capacity estimation for those existing national atlas. For final version (2026), capacity estimation will be included for all countries.

3.3.1.Deep saline aquifers

Several methods were proposed to obtain a storage capacity estimate method for saline formations. The method used had been chosen depending on the level of knowledge and available data on a given structure.

- **Connected pore volume and storage efficiency (Method 1)**
  The approach for storage capacity estimation in deep saline aquifers follows both theoretical and effective storage capacity by applying a storage efficiency factor (capacity coefficient). The efficiency factor includes the cumulative effects of trap heterogeneity, CO_2 buoyancy and sweep efficiency, but no values or range of values are given as the factor is site-specific and needs to be determined through numerical simulations and/or field work. However, in absence of data, the 2022 reviewed CO2 SCREEN tool[1], developed by NETL (National Energy Technology Laboratory) of US Department of Energy, provides a set of Efficient factors (Sef) estimated by numerical simulations for different depositional environments.

  Deep saline aquifer: $M_{CO2} = A * h * NG * \Phi * \rho_{CO2} * S_{ef}$

  where:
  M_{CO2}: regional "bulk" storage capacity
  A: area of regional aquifer/ trap
  h: average height of regional aquifer / trap
  NG: average net to gross ratio of regional aquifer

[1] https://edx.netl.doe.gov/dataset/co2-screen (tool) and https://edx.netl.doe.gov/carbonstorage (report)

Φ: average reservoir porosity of regional aquifer (best estimate)
ρ_{CO2} : CO_2 density at reservoir conditions
S_{ef} : storage efficiency factor (for bulk volume of regional aquifer)- in case of no other data, it was proposed 2%.

If the knowledge and level of detail exists at trap level, storage capacity estimates volume in traps, where the buoyant CO_2 can be safely retained. It was emphasized here that storage capacity in saline formations is not only limited by the pressure increase that could be sustained by the formation and the allowable pressure increase, but also by the traps where CO_2 collects after injection. In a high-level regional screening study, proving the existence of suitable traps and the location of injection sites may be deferred to a later and more detailed subsurface characterization. The volume of CO_2 that is derived from the connected volume and assumed pressure increase must nevertheless be stored in a structure that will retain the CO_2. The smaller of these two volumes (CO_2 volume from pressure increase, trap volume) defines the total storage volume.

Comparison of the methodologies proposed by the CSLF Task Force and the USDOE Capacity and Fairways Subgroup indicates several analogies and differences (Bachu, 2008) based of the defined CO2Stop methodology, it must be keeping in mind to be agreed:

1) Only volumetric (static) storage of CO_2 in free phase is considered (no CO_2 in solution);
2) USDOE Capacity and Fairways Subgroup does not limit the volumetric trapping in deep saline aquifers only to stratigraphic and structural traps; rather the entire aquifer is considered;
3) The effect of irreducible water saturation is included in the efficiency factor Sef through the pore-scale displacement efficiency;
4) Recommended to use an average CO_2 density at in-situ conditions rather than minimum and maximum values.

- **Connected pore volume and pressure increase (Method 2)**

A more reliable estimate of the storage capacity of a saline formation can be obtained, when the level of knowledge allows an estimate of the allowable pressure increase to be made. Combined with the compressibility of the fluids and rock, the storage capacity estimate is derived from Frailey (2007):

$$M_{CO2} = A * h * NG * \Phi * \rho_{CO2} * \Delta P * (\beta_r + \beta_f)$$

where:
ΔP: the pressures increase (relative to the initial pressure)
β_r and β_f : compressibility of the matrix and compressibility of the fluid, respectively.

- **Capacity estimate from detailed site characterisation study (Method 3)**

A site characterisation study is one of the elements required for a storage licence application. In such a study all available data on the storage formation is collected to model the static and dynamic behaviour of the formation. This estimated storage capacity is based on all available data and on detailed modelling of the dynamic behaviour of the storage formation.

- **Capacity estimate from injection tests (Method 4)**

The most reliable storage capacity estimate is obtained from an injection test, or from a prolonged injection period. A test injection will demonstrate not only the feasible injection rates, but, when the injection is continued for a sufficiently long time, will also show the size of the connected volume. An injection test is one of the last activities, prior to starting an injection and storage project.

3.3.2. Hydrocarbon fields

For hydrocarbon fields, the method proposed here is the same as that used to obtain the storage capacity estimates that are in the EU GeoCapacity and CO2Stop database. Two methods are described:

- **CSLF method for hydrocarbon field storage capacity (Method 1)**
  The calculation of CO_2 storage capacity in hydrocarbon fields uses the methodology described by Bachu et al. (2007):

  Gas field: $M_{CO2} = \rho_{CO2} * Rf * (1-F_{ig}) * OGIP * Bg$
  Oil field: $M_{CO2} = \rho_{CO2} * (Rf * OOIP * Bo - V_{iw} + V_{pw})$

  Where:
  - M_{CO2}: hydrocarbon field storage capacity
  - ρ_{CO2}: CO_2 density at reservoir conditions (best estimate)
  - Rf: Recovery factor
  - F_{ig}: fraction of injected gas
  - OGIP: original gas in place (at surface conditions)
  - Bg: gas formation volume factor << 1
  - OOIP: original oil in place (at surface conditions)
  - Bo: oil formation volume factor > 1
  - Viw: volume of injected water
  - Vpw: volume of produced water

- **Alternative method for hydrocarbon field storage capacity (Method 2)**
  An alternative formulation can be used, in cases where not all of the above parameters are available (Schuppers et al., 2003):

  $$M_{CO2} = \rho_{CO2} * UR_p * B$$

  where:
  M_{CO2}: hydrocarbon field storage capacity
  ρ_{CO2}: CO_2 density at reservoir conditions (best estimate)
  URp: proven ultimate recoverable oil or gas
  B: oil or gas formation volume factor in this last expression,

  The methodology used for hydrocarbon fields yield theoretical storage capacity according to the methodology described by CSLF. To reach effective storage capacity CSLF introduce a number of capacity coefficients representing mobility, buoyancy, heterogeneity, water saturation and aquifer strength, respectively and all reducing the storage capacity. However, there are very few studies and methodologies for estimating the values of these capacity coefficients and hence we have chosen not to distinguish between theoretical and effective storage capacity for hydrocarbon fields.

3.4. Storage Readiness Level (SRL)

The European Commission Communication (2024) on industrial carbon management strategy requires that "*each potential storage site will be labelled according to its 'storage readiness level' and matched with public data to speed up the work to identify and assess the storage capacities.* SRL is an attribute to be included as new attribute on GSEU CO_2 Atlas.

CO_2 Storage Readiness Levels (Akhurst et al. 2021) are presented to communicate CO_2 storage site technical appraisal, Carbon Capture and Storage (CCS) project planning and permitting activities that have been completed, and what remains to be completed for a CO_2 storage site to become operational. The framework is based on the experience of site planning in the UK, The Netherlands and site operation in Norway to 2021 and applied to more than 700 sites. It extends and complements the industry commercial project development classification to encompass sites at lower levels of understanding, data availability and interpretation. Flexibility within the framework allows communication of the level of understanding of all prospective sites and enables comparison of sites in different permitting jurisdictions. Application of standardised levels informs the duration of permitting and resources invested to achieve contingent storage resource

SRLs are a **qualitative appraisal,** not a quantitative measure, since each site will have its own specific characteristics, including aspects such as, history of investigation, ownership, availability of CO_2, national policy and regulation.

There are no 'hard boundaries' between the levels and a degree of overlap of activities exists, this flexibility enables application and comparison of sites within a national portfolio and in different permitting jurisdictions. Advice from industry stakeholders has ensured consistency of the SRL framework, as a high-level communication tool, with the industry resource classification and commercial storage project viability (SPE, 2017). The SRL framework extends the commercial classification which does not assess the lower levels of appraisal although consistent terminology is used, where they are equivalent. The SRLs framework encompasses prospective sites from first-pass assessment at SRL 1, theoretical capacity at SRL 2, and introduces an initial storage project concept and risk reduction at SRL 3. There will have been completion of sufficient risk-assessment-led desktop study to apply for an exploration permit, if needed, for sites at SRL 4 and all technical containment, capacity and injectivity risks are reduced or mitigated at SRL 5. The SRLs framework is consistent and complementary with the commercial project development classification. A site at SRL 6, where a site is integrated into a feasible CCS project concept, is 'discovered', equivalent to and also termed the same 'contingent storage resource' as the commercial storage project classification. All CCS project planning will have been completed, sufficient to apply for or award of a storage permit, for sites at SRL 7. At SRL 8 a storage permit has been issued and the investment decision to construct and operate the site for a CCS project has been made. At SRL 9 the site is operational as a component of an integrated CCS project.

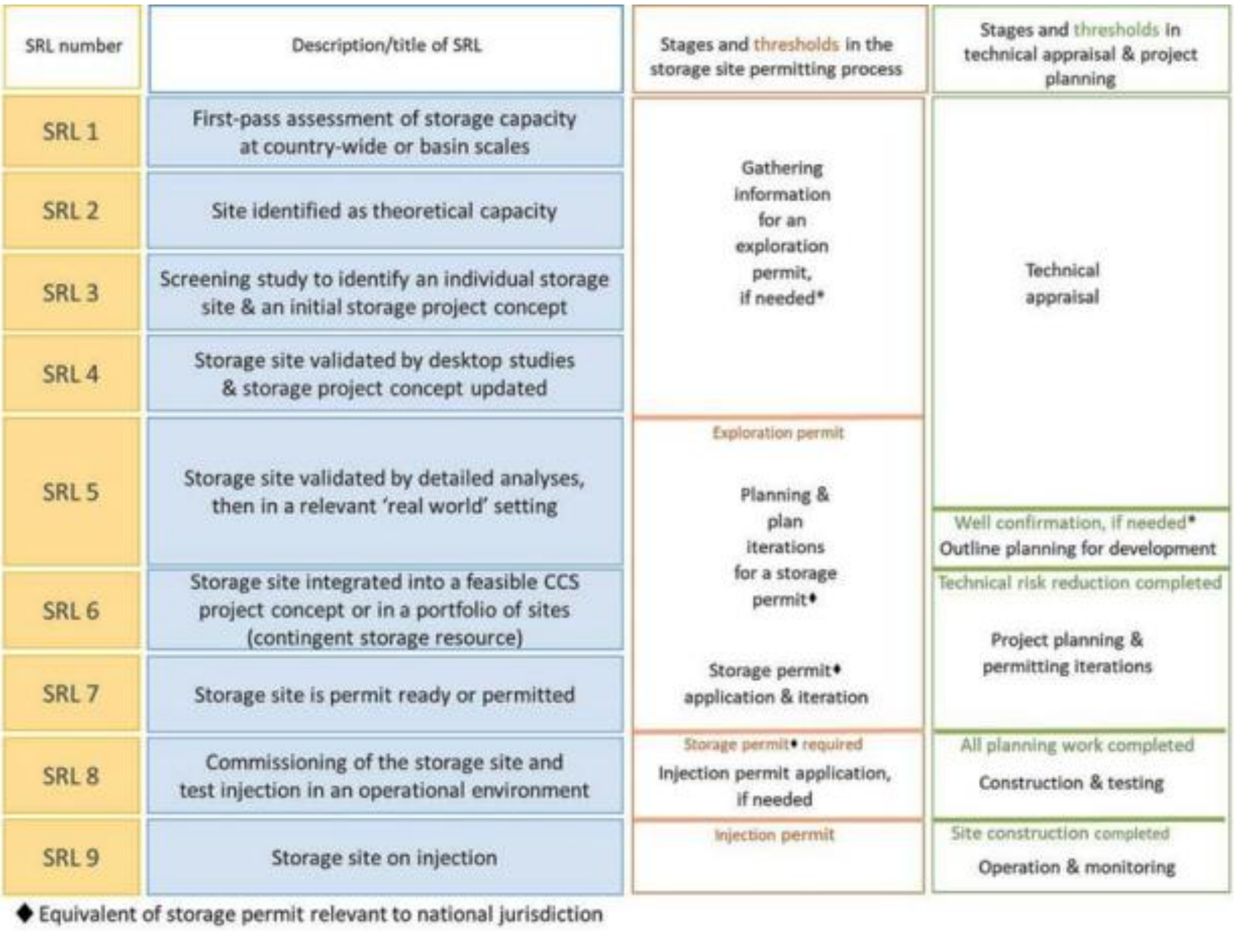


Figure 5: *Storage readiness level (SRL) framework, stages and thresholds in the storage site permitting process (brown) and storage technical appraisal and planning (green). *An exploration permit or well confirmation may not be needed for re-use of a hydrocarbon field from Akhurst et al. (2021)*

Although there is flexibility in the qualitative SRLs framework, the site regulatory stages and the supporting technical appraisal and project planning activities, defines thresholds illustrated in Fig. 3 . During appraisal of a storage site, the results of detailed investigations may reveal characteristics that make it unsuitable for the planned storage project. The site will remain at the SRL achieved at that point but flagged as 'development on hold'. The site data and findings of the characterisation investigations will remain available until needed by a storage project with a matching required capacity. Communication of a storage site's technical appraisal, project planning and permitting is conveyed to stakeholders regardless of scale, whether considered at national, depositional basin, regional or local extent. However, the standardised approach and flexibility accommodated by the SRLs framework allows comparison of like-with-like regardless of scale for decision making, e.g. : site selection by an operator in the proximity of a CO_2 capture project; strategic development of a national storage resource; governmental planning of CO_2 emissions reduction.

The activities that are likely to have been undertaken, from initial capacity assessment to project operation, for each SRL is summarised in *Table 2Table 1*.

Table 2: *Descriptive title and activities that are likely to have been undertaken, from initial capacity assessment to project operation, by Storage Readiness Level (SRL). EIA, Environmental Impact Assessment.*

SRL	Descriptive title	Activities at each SRL
SRL 1	First pass assessment of storage capacity at country-wide or basin scales	At SRL 1 an appraisal to identify the CO_2 storage potential has been completed, as a first pass assessment, although this potential may not have been fully quantified. Characteristics suitable for CO_2 storage have been identified within a country or region.
SRL 2	Site identified as theoretical capacity	At SRL 2 there has been systematic mapping of the storage potential of a whole region, country or jurisdiction's potential storage resource. A consistent and referenced methodology will have been followed and applied.
SRL 3	Screening study to identify an individual storage site and initial storage project concept	At SRL 3 a screening study will have been completed, achieved after a ranking exercise based on the storage site's expected performance against a set or subset of geological, technical, economic and geographical criteria. An initial project concept will have been outlined and a CO_2 storage site may have been identified, either individually or as a group of sites, as having high potential for storage. Any major risks to containment and capacity will have been identified.
SRL 4	Storage site validated by desktop studies and storage project concept updated	At SRL 4 a detailed desktop characterisation of the storage site will have been completed to validate the selection as potentially suitable for storage. For a site to qualify for SRL 4 it will have an initial static geological model or conceptual geological model. Available site-specific data will have been interpreted. There is sufficient information for preparation of an exploration licence application and submission to the relevant authority, if needed.
SRL 5a 5b 5c	Storage site validated, firstly by detailed analysis, then in a relevant 'real world' setting	At SRL 5a detailed risk assessment-led investigations and risk reduction activities required to inform a storage permit application specific to a given site based on existing information will have been completed. At SRL 5b new data is acquired, where needed, to assure the storage site, this may include direct evidence of the storage strata in a 'real world' setting and to inform an EIA. At SRL 5c all storage site data will have been acquired, analysed and technical appraisal completed to reduce or mitigate storage risks sufficient for a storage permit application.
SRL 6	Storage site integrated into a feasible CCS	At SRL 6 a storage site will have been integrated into a feasible CCS project or a portfolio of sites. The assured storage capacity will have been defined. An EIA will have been completed. All concerns

	project concept or portfolio of sites (contingent storage resource)	regarding subsurface containment, migration and capacity to store CO_2 for a project will have been addressed.
SRL 7	Storage site is permit ready or permitted	At SRL 7 all of the CCS project planning work, based on the technical appraisal and as required for a storage permit application, will have been completed. An application for a CO_2 storage permit has been either submitted to the Competent Authority and permitted or is ready to be submitted.
SRL 8	Commissioning of the storage site and test injection at the site	At SRL 8 the storage permit has been issued and the investment decision to operate the site for a CCS project has been made. All legal and practical activities needed to implement site commissioning have been completed and the storage site has been tested in an operational environment.
SRL 9	Storage site on injection	At SRL 9 the site is operational as a component of an integrated CCS project.

3.5. Attributes represented in the layers

3.5.1. Attributes of formation level

At "Formation level" the attributes are listed in *Table 3*. The database from CO2Stop was reviewed and some attributes have been renamed (yellow) or added (green). Attributes shown in black are assigned by database.

Table 3: *Attributes of the Formations level.*

GSEU Name of Attribute	Type	Description	CO2Stop	Hystories
OBJECTID	Long Integer	Required for ArcGIS	OBJECTID	OBJECTID
FORMATION_ID	Text	Unique ID of the formation (automatically generated by Access)	FORMATION_ID	FORMATION_ID
FORMATION_NAME	Text	Name of the Formation	FORMATION_NAME	FORMATION_NAME
NO_STORE_UNITS	Number	Number of storage units	NO_STORE_UNITS	NO_STORE_UNITS
NO_DAUGHTER_UNITS	Number	Number of trap units	NO_DAUGHTER_UNITS	NO_DAUGHTER_UNITS
ASSESS_UNIT_TYPE	Text	Assessment Unit type - options are saline Aquifer with or without hydrocarbon fields	ASSESS_UNIT_TYPE	ASSESS_UNIT_TYPE
PERIOD_MIN_RES	Text	Youngest Period of storage formation	PERIOD_MIN	PERIOD_MIN_RES
PERIOD_MAX_RES	Text	Oldest Period of formation	PERIOD_MAX	PERIOD_MAX_RES
AGE_MIN_RES	Text	Youngest chronostratigraphy of storage formation	AGE_MIN	AGE_MIN_RES

AGE_MAX_RES	Text	Oldest chronostratigraphy of storage formation	AGE_MAX	AGE_MAX_RES
STRAT_GROUP_RES	Text	Stratigraphic Unit Group of storage formation	STRAT_GROUP	STRAT_GROUP_RES
STRAT_FORMATION_RES	Text	Stratigraphic Unit formation of storage formation	STRAT_FORMATION	STRAT_FORMATION_RES
LITHOLOGY_RES	Text	predominant lithology of storage formation	LITHOLOGY	LITHOLOGY_RES
GEOGRAPHIC_AREA	Text	Area of geological formation	GEOGRAPHIC_AREA	GEOGRAPHIC_AREA
GEOLOGICAL_BASIN	Text	Geological basin	GEOLOGICAL_BASIN	GEOLOGICAL_BASIN
ON_OFFSHOR	Text	Is the formation onshore or offshore (if both, label as wherever the majority of the formation lies – onshore or offshore)	ON_OFFSHOR	ON_OFFSHOR
REP_THICK_RES	Long Integer	Representative thickness of storage formation (m)	REP_THICK	REP_THICK_RES
REP_POR	Long Integer	Representative Porosity of storage formation decimal %	REP_POR	REP_POR
SEAL	Text	Name of most widespread primary seal for the storage formation	SEAL	SEAL
REP_THICK_SEAL	Number	Representative thickness of seal (m)		REP_THICK_SEAL
REMARKS	REMARKS	Any other relevant information	REMARKS	REMARKS
COUNTRY	Text	Country where the formation located	COUNTRY	COUNTRY
COUNTRYCODE	Text	International code of country	COUNTRYCODE	COUNTRYCODE
X_DD	*Double*	*X co-ord sin decimal degrees (WGS84)*	*X_DD*	*X_DD*
Y_DD	*Double*	*y co-ord in decimal degrees (WGS84)*	*Y_DD*	*Y_DD*
X	Double	X coordinates in any given projection	X	X
Y	Double	y coordinates in any given projection	Y	Y
Projection_Info	Text	Details of projection used for X and Y coords	Projection_Info	Projection_Info
X_GIS	Double	X coordinates from the Hystories web GIS and new entries in EPSG: 4326		X_GIS
Y_GIS	Double	y coordinates from the Hystories web GIS and new entries, in EPSG: 4326		Y_GIS
Projection_Info_HYST	Text	Details of projection used for X_GIS and Y_GIS coords (must be in: WGS84 LL EPSG 4326)		Projection_Info_HYST
Date_Entered	Date/Time	Date the data was entered		Date_Entered
HYST_OR_CO2	Text	Project when this was updated ie Hystories, CO2Stop or GSEU		HYST_OR_CO2

3.5.2. Attributes of storage unit level

Once a formation is defined, storage units are those areas within it at a **depth greater than 800 metres from surface**. for each storage unit, the attributes collected are listed in *Table 4*.

Table 4: *Attributes of the Storage Units level.*

Name of Attribute GSEU	Type	Description	CO2Stop	Hystories
OBJECTID	Long Integer	A unique identifier for each feature record within the dataset generated by ArcGIS	OBJECTID	OBJECTID
FORMATION_ID	Text	Foreign key - Unique ID of the formation	FORMATION_ID	FORMATION_ID
STORAGE_UNIT_ID	Text	Unique storage unit id (auto populated)	STORAGE_UNIT_ID	STORAGE_UNIT_ID
STORAGE_UNIT_NAME	Text	Name of the storage unit	STORAGE_UNIT_NAME	STORAGE_UNIT_NAM E
ASSESS_UNIT_TYPE	Text	Assessment of Unit type – Drop down list (Saline Aquifer with or without hydrocarbon fields)	ASSESS_UNIT_TYPE	ASSESS_UNIT_TYPE
PERIOD_MIN_RES	Text	Youngest period of storage unit	PERIOD_MIN	PERIOD_MIN_RES
PERIOD_MAX_RES	Text	Oldest period of formation	PERIOD_MAX	PERIOD_MAX_RES
AGE_MIN_RES	Text	Youngest chronostratigraphy age of storage unit	AGE_MIN	AGE_MIN_RES
AGE_MAX_RES	Text	Oldest chronostratigraphy of storage unit	AGE_MAX	AGE_MAX_RES
LITHOLOGY_RES	Text	Predominant lithology of storage unit	LITHOLOGY	LITHOLOGY_RES
WATER_DEPTH	Long Integer	Mean average water depth (m)	WATER_DEPTH	WATER_DEPTH
ON_OFFSHOR	Text	Is the unit onshore or offshore (if both, label as wherever the majority of the unit lies – onshore or offshore)		ON_OFFSHOR
SUBSURF_INTERF	Text	Interference with other uses of subsurface	SUBSURF_INTERF	SUBSURF_INTERF
SURF_ISSUES	Text	Any surface issues	SURF_ISSUES	SURF_ISSUES
EST_STORECAP_MIN	Double	Minimum estimated CO_2 storage capacity (Mt)	EST_STORECAP_MIN	
EST_STORECAP_MEAN	Double	Mean estimated CO_2 storage capacity (Mt)	EST_STORECAP_MEAN	
EST_STORECAP_MAX	Double	Maximum estimated CO_2 storage capacity (Mt)	EST_STORECAP_MAX	
CAP_EST_METHOD	Text	Method used to estimate the storage capacity Drop down (Volumetric with storage efficiency, from detailed site characterisation study, replacement of hydrocarbons, Monte Carlo simulations)	CAP_EST_METHOD	
PEER_REVIEW_REF	Text	Provide peer reviewed public reference for the capacity method		
GROSS_THICK_MIN_RES	Double	Minimum Height / thickness of the storage unit (m)	GROSS_THICK_MIN	GROSS_THICK_MIN_ RES
GROSS_THICK_MEAN_RES	Double	Mean Height / thickness of the storage unit (m)	GROSS_THICK_MEAN	GROSS_THICK_MEAN _RES

GROSS_THICK_MAX_RES	Double	Maximum Height / thickness of the storage unit (m)	GROSS_THICK_MAX	GROSS_THICK_MAX_RES
DEPTH_MIN_RES	Double	Minimum Depth of storage unit (m)	DEPTH_MIN	DEPTH_MIN_RES
DEPTH_MEAN_RES	Double	Mean Depth of storage unit (m)	DEPTH_MEAN	DEPTH_MEAN_RES
DEPTH_MAX_RES	Double	Maximum Depth of storage unit (m)	DEPTH_MAX	DEPTH_MAX_RES
DEPTH_TOP_MIN	Double	Depth to highest point of storage unit (that buoyant fluid could theoretically reach)		DEPTH_TOP_MIN
PRESSURE_MIN	Double	Minimum current pressure of storage unit (bar)	PRESSURE_MIN	PRESSURE_MIN
PRESSURE_MEAN	Double	Mean current pressure of storage unit (bar)	PRESSURE_MEAN	PRESSURE_MEAN
PRESSURE_MAX	Double	Maximum current pressure of storage unit (bar)	PRESSURE_MAX	PRESSURE_MAX
MAX_PRESSURE_MIN	Double	Minimum maximum allowable pressure of formation after CO_2 injection (bar)	MAX_PRESSURE_MIN	
MAX_PRESSURE_MEAN	Double	Mean maximum allowable pressure of storage unit after CO_2 injection (bar)	MAX_PRESSURE_MEAN	
MAX_PRESSURE_MAX	Double	Maximum allowable pressure of storage unit after CO_2 injection(bar)	MAX_PRESSURE_MAX	
TEMP_C_MIN	Double	Minimum temperature (c)	TEMP_C_MIN	TEMP_C_MIN
TEMP_C_MEAN	Double	Mean temperature (c)	TEMP_C_MEAN	TEMP_C_MEAN
TEMP_C_MAX	Double	Maximum temperature (c)	TEMP_C_MAX	TEMP_C_MAX
PERM_MIN	Double	Minimum effective permeability mD	PERM_MIN	PERM_MIN
PERM_MEAN	Double	Mean effective permeability mD	PERM_MEAN	PERM_MEAN
PERM_MAX	Double	Maximum effective permeability mD	PERM_MAX	PERM_MAX
POROSITY_MIN	Double	Minimum porosity decimal %	POROSITY_MIN	POROSITY_MIN
POROSITY_MEAN	Double	Mean porosity decimal %	POROSITY_MEAN	POROSITY_MEAN
POROSITY_MAX	Double	Maximum porosity decimal %	POROSITY_MAX	POROSITY_MAX
FIELD_EXTENT_MIN	Double	Minimum areal extent of the storage unit (km^2)	FIELD_EXTENT_MIN	
FIELD_EXTENT_MEAN	Double	Mean areal extent of the storage unit (km^2)	FIELD_EXTENT_MEAN	FIELD_EXTENT_MEAN
FIELD_EXTENT_MAX	Double	Maximum areal extent of the storage unit (km^2)	FIELD_EXTENT_MAX	
VERT_NET_GROSS_MIN	Double	Minimum vertical net-gross (%)	VERT_NET_GROSS_MIN	VERT_NET_GROSS_MIN
VERT_NET_GROSS_MEAN	Double	Mean vertical net-gross (%)	VERT_NET_GROSS_MEAN	VERT_NET_GROSS_MEAN
VERT_NET_GROSS_MAX	Double	Maximum vertical net-gross (%)	VERT_NET_GROSS_MAX	VERT_NET_GROSS_MAX
COMPROCK_MIN	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MIN	
COMPROCK_MEAN	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MEAN	
COMPROCK_MAX	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MAX	
COMPFLUID_MIN	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MIN	

COMPFLUID_MEAN	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MEAN	
COMPFLUID_MAX	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MAX	
SALINITY_BRINE	Double	Total dissolved solids (g/l)	SALINITY_BRINE	SALINITY_BRINE
STATUS	Text	Status: i.e. producing, not producing etc	STATUS	STATUS
Not required for GSEU but field remains in the database		*Sulphates in Rock or Fluid of Reservoir*		*SULPHATES_RES*
Not required for GSEU but field remains in the database		*Iron in rock or Fluid of Reservoir*		*IRON_RES*
CO2_RES	Text	CO_2 in fluid of reservoir		CO2_RES
CO2_DENSIT	Double	Calculated using separate spreadsheet	CO2_DENSIT	
NO_AQUIF_DAUGHT		Number of Aquifer traps in the database		NO_AQUIF_DAUGHT
NO_HC_DAUGHT		Number of HC traps in the database		NO_HC_DAUGHT
SRL	Double	Storage Readiness Level (see Akhurst et al 2021 paper		
SEAL	Text	Name of most widespread primary seal for the storage unit	SEAL	SEAL
PRIM_SEAL_OVERLIE	Text	Does primary seal directly overlie assessment unit (yes/no)		PRIM_SEAL_OVERLIE
MIN_SEAL_THICK	Double	Minimum primary seal thickness (m)		MIN_SEAL_THICK
Not required for GSEU but field remains in the database		*Sulphates in Rock or Fluid of seal*		*SULPHATES_SEAL*
Not required for GSEU but field remains in the database		*Iron in rock or Fluid of seal*		*IRON_SEAL*
PERIOD_MIN_SEAL	Text	Youngest period of storage unit		PERIOD_MIN_SEAL
PERIOD_MAX_SEAL	Text	Oldest period of storage unit		PERIOD_MAX_SEAL
AGE_MIN_SEAL	Text	Youngest chronostratigraphy of storage unit		AGE_MIN_SEAL
AGE_MAX_SEAL	Text	Oldest chronostratigraphy of storage unit		AGE_MAX_SEAL
LITHOLOGY_SEAL	Text	predominant lithology of seal		LITHOLOGY_SEAL
FAULT_DEN	Double	Number of faults that cut top storage unit	FAULT_DEN	FAULT_DEN
FAULT_THR_OVERBURDEN	Double	Number of faults that cut the top storage unit and top seal	VERT_EXTENT_FAULT	FAULT_THR_OVERBURDEN
AVE_FAULT_THR	Double	Average fault throw (m)	AVE_FAULT_THR	AVE_FAULT_THR
MAX_FAULT_THR_RES	Double	Max fault throw at top storage unit (m)	MAX_FAULT_THR_RES	MAX_FAULT_THR_RES
RISK_LAT_MIGR	Text	Risk of lateral migration out of unit of assessment (low/medium/high)	RISK_LAT_MIGR	RISK_LAT_MIGR
AVE_DIP_UNIT	Double	Average dip of unit of assessment (degrees)	AVE_DIP_UNIT	AVE_DIP_UNIT
SUSCEPT_RES_DAM	Text	Susceptibility of storage unit to damage when injecting fluids (low/medium/high)	SUSCEPT_RES_DAM	SUSCEPT_RES_DAM
Not required for GSEU but field remains in the database		*mineralogy of the storage unit*	*RES_MIN*	*RES_MINERAL*

Not required for GSEU but field remains in the database		*Faults in the seal*		*FAULT_IN_SEAL*
VERT_STRAT_COMPART	Text	Vertical storage unit compartmentalisation is flow barriers (e.g. faults expected to be sealing)	VERT_STRAT_COMPART	VERT_STRAT_COMPART
HOR_STRAT_COMPART	Text	Horizontal storage unit compartmentalisation (eg mudstone stringers)	HOR_STRAT_COMPART	HOR_STRAT_COMPART
Not required for GSEU but field remains in the database		*Fault Comparmentalisation of the Storage Unit*		*FAULT_COMPART*
ADVERSE_DIAG	Text	Risk of adverse diagenesis (capture any diagenetic features that might adversely affect rock quality, e.g. fibrous illite)	ADVERSE_DIAG	
SEAL_OTHER	Text	Secondary or other seal names	SEAL_OTHER	SEAL_OTHER
NO_WELLS_PENETR	Double	Number of existing wells penetrating the storage unit	NO_WELLS_PENETR	NO_WELLS_PENETR
WELL_VINT	Text	Well vintage	WELL_VINT	WELL_VINT
NO_ADAND_WELL_PENETR	Double	Number of abandoned wells penetrating storage unit	NO_ADAND_WELL_PENETR	NO_ADAND_WELL_PENETR
AGE_OLD_WELL	Double	Age of oldest abandoned well	AGE_OLD_WELL	AGE_OLD_WELL
VINT_PLAT	Text	Vintage production platform or site	VINT_PLAT	VINT_PLAT
SEISMIC	Text	Seismic available e.g. Full 3D seismic coverage, few 2D lines	SEISMIC	SEISMIC
WELLS	Text	Wells available (e.g. Wells through unit with logs)	WELLS	WELLS
MODELS	Text	Models available (e.g. regional model, site model)	MODELS	MODELS
STATUS_RESEARCH	Text	Status of the research on the unit	STATUS_RESEARCH	STATUS_RESEARCH
REMARKS	Text	Text field to add comments	REMARKS	REMARKS
COUNTRY	Text		COUNTRY	COUNTRY
COUNTRYCODE	Text		COUNTRYCODE	COUNTRYCODE
LAMBERT_E	*Double*	*Eastings in Lambert projection*	*LAMBERT_E*	*LAMBERT_E*
LAMBERT_N	*Double*	*Northings in Lambert projection*	*LAMBERT_N*	*LAMBERT_N*
X_DD	*Double*	*X co-ord sin decimal degrees (WGS84)*	*X_DD*	*X_DD*
Y_DD	*Double*	*y co-ord in decimal degrees (WGS84)*	*Y_DD*	*Y_DD*
X	Double	X coordinates in any given projection	X	X
Y	Double	y coordinates in any given projection	Y	Y
Projection_Info	Text	Details of projection used for X and Y coords	Projection_Info	Projection_Info
X_GIS	Double	X coordinates from the Hystories web GIS and new entries in EPSG: 4326		X_GIS
Y_GIS	Double	y coordinates from the Hystories web GIS and new entries, in EPSG: 4326		Y_GIS

Projection_Info_HYST	Text	Details of projection used for X_GIS and Y_GIS coords (must be in: WGS84 LL EPSG 4326)		Projection_Info_HYST
Date_Entered	Date/Time	Date the data was entered (automatically populated by the database)		Date_Entered
HYST_OR_CO2	Text	Project when this was updated ie Hystories, CO2Stop or GSEU		HYST_OR_CO2

3.5.3. Attributes of trap level

The final level of knowledge refers to a structural or stratigraphic trap with the potential to contain or trap fluids. For each storage unit identified, where traps are identified, the following attributes were compiled, as listed in *Table* 5.

Table 5: *Attributes of the traps level.*

Name of Attribute GSEU	Type	Description	CO2Stop	Hystories
OBJECTID	Long Integer		OBJECTID	OBJECTID
STORAGE_UNIT_ID	Text	Foreign key - Unique ID of the storage unit	STORAGE_UNIT_ID	STORAGE_UNIT_ID
TRAP_ID	Text	Unique id of the trap	TRAP_ID	TRAP_ID
TRAP_NAME	Text	Name of the trap	TRAP_NAME	TRAP_NAME
OPERATOR	Text	Field/site operator name		OPERATOR
OWNERSHIP	Text	E.g. Private company/state owned etc		OWNERSHIP
LICENCE	Text	Licence owner, type, date		LICENCE
ASSESS_UNIT_TYPE	Text	Storage unit type - drop down list saline aquifer with or without hydrocarbon fields	ASSESS_UNIT_TYPE	ASSESS_UNIT_TYPE
AVAILABLE	Text	Could this site be developed for CO_2 storage? Yes/no/possibly		AVAILABLE
CURRENT_DEV	Text	Eg operating oil field, abandoned, gas storage, none		CURRENT_DEV
PLANNED_DEV	Text	Eg gas storage, H2 storage, gas production, none		PLANNED_DEV
EXPLORATION	Text	Has site exploration started? Yes/no/possibly		EXPLORATION
STORAGE_DEVELOPED	Text	Has storage (gas, CO_2, H_2) storage site been developed - ie is it up and running? Yes/no/possibly		STORAGE_DEVELOPED
END_YEAR	Double	Planned year of site closure (including for oil extraction/gas storage etc)		END_YEAR
PERIOD_MIN_RES	Text	Youngest period of trap	PERIOD_MIN	PERIOD_MIN_RES

PERIOD_MAX_RES	Text	Oldest period of trap rock	PERIOD_MAX	PERIOD_MAX_RES
AGE_MIN_RES	Text	Youngest chronostratigraphy of trap rock	AGE_MIN	AGE_MIN_RES
AGE_MAX_RES	Text	Oldest chronostratigraphy of trap rock	AGE_MAX	AGE_MAX_RES
LITHOLOGY_RES	Text	predominant lithology of trap rock	LITHOLOGY	LITHOLOGY_RES
BOUNDARIES	Text	Drop down list – open, closed, partially open. Aim is to understand pressure constraints, if boundaries are closed, then pressure buildup will be quicker		
WATER_DEPTH	Long Integer	Mean average water depth (m)	WATER_DEPTH	WATER_DEPTH
ON_OFFSHOR	Text	Is the unit onshore or offshore (if both, label as wherever the majority of the unit lies – onshore or offshore)		ON_OFFSHOR
ENV_DEP_RES	Text	Primary environment of deposition of trap rock Eg. Desert		ENV_DEP_RES
RES_MINERAL	Text	mineralogy of the trap rock	RES_MIN	RES_MINERAL
SUBSURF_INTERF	Text	Interference with other uses of subsurface eg gas storage planned, drinking water aquifers above	SUBSURF_INTERF	SUBSURF_INTERF
SURF_ISSUES	Text	Any surface issues	SURF_ISSUES	SURF_ISSUES
EST_STORECAP_MIN	Double	Minimum estimated CO_2 storage capacity (Mt) – aquifer daughter unit only	EST_STORECAP_MIN	
EST_STORECAP_MEAN	Double	Mean estimated CO_2 storage capacity (Mt) – aquifer daughter unit only	EST_STORECAP_MEAN	
EST_STORECAP_MAX	Double	Maximum estimated CO_2 storage capacity (Mt) – aquifer daughter unit only	EST_STORECAP_MAX	
CAP_EST_METHOD	Text	Method used to estimate the storage capacity	CAP_EST_METHOD	
PEER_REVIEW_REF	Text	Provide peer reviewed public reference for the capacity method		
GROSS_THICK_MIN_RES	Double	Minimum Height / thickness of the trap (m)	GROSS_THICK_MIN	GROSS_THICK_MIN_RES
GROSS_THICK_MEAN_RES	Double	Mean Height / thickness of the trap (m)	GROSS_THICK_MEAN	GROSS_THICK_MEAN_RES

GROSS_THICK_MAX_RES	Double	Maximum Height / thickness of the trap (m)	GROSS_THICK_MAX	GROSS_THICK_MAX_RES
DEPTH_MIN_RES	Double	Minimum Depth of the trap (m)	DEPTH_MIN	DEPTH_MIN_RES
DEPTH_MEAN_RES	Double	Mean Depth of the trap (m)	DEPTH_MEAN	DEPTH_MEAN_RES
DEPTH_MAX_RES	Double	Maximum Depth of the trap (m)	DEPTH_MAX	DEPTH_MAX_RES
DEPTH_TOP_MIN	Double	Depth to crest of trap in trap (m) (used to support risk assessment)		DEPTH_TOP_MIN
PRESSURE_MIN	Double	Minimum Current Pressure of trap (bar) (at the minimum average depth of reservoir)	PRESSURE_MIN	PRESSURE_MIN
PRESSURE _MEAN	Double	Mean Current Pressure of trap (bar) (at the mean average depth of reservoir)	PRESSURE_MEAN	PRESSURE _MEAN
PRESSURE _MAX	Double	Maximum Current Pressure of trap (bar) (at the maximum average depth of trap)	PRESSURE_MAX	PRESSURE _MAX
MAX_PRESSURE_MIN	Double	Minimum Maximum allowable pressure of trap after CO_2 injection (bar)	MAX_PRESSURE_MIN	
MAX_PRESSURE_MEAN	Double	Mean Maximum allowable pressure of trap after CO_2 injection (bar)	MAX_PRESSURE_MEAN	
MAX_PRESSURE_MAX	Double	Maximum Maximum allowable pressure of trap after CO_2 injection(bar)	MAX_PRESSURE_MAX	
TEMP_C_MIN	Double	Minimum Temperature (°C) (at the average depth of trap)	TEMP_C_MIN	TEMP_C_MIN
TEMP_C_MEAN	Double	Mean temperature (°C) (at the average depth of trap)	TEMP_C_MEAN	TEMP_C_MEAN
TEMP_C_MAX	Double	Maximum temperature (°C) (at the average depth of trap)	TEMP_C_MAX	TEMP_C_MAX
PERM_MIN	Double	Minimum effective permeability mD	PERM_MIN	PERM_MIN
PERM_MEAN	Double	Mean effective permeability mD	PERM_MEAN	PERM_MEAN
PERM_MAX	Double	Maximum effective permeability mD	PERM_MAX	PERM_MAX
POROSITY_MIN	Double	Minimum porosity (decimal %)	POROSITY_MIN	POROSITY_MIN
POROSITY_MEAN	Double	Mean porosity (decimal %)	POROSITY_MEAN	POROSITY_MEAN
POROSITY_MAX	Double	Maximum porosity (decimal %)	POROSITY_MAX	POROSITY_MAX
FIELD_EXTENT_MIN	Double	Minimum Areal Extent of the trap (km2)	FIELD_EXTENT_MIN	
FIELD_EXTENT_MEAN	Double	Mean Areal Extent of trap (km2)	FIELD_EXTENT_MEAN	FIELD_EXTENT_MEAN
FIELD_EXTENT_MAX	Double	Maximum Areal Extent of the trap (km2)	FIELD_EXTENT_MAX	
VERT_NET_GROSS_MINN	Double	Minimum vertical net:gross (decimal %)	VERT_NET_GROSS_MINN	VERT_NET_GROSS_MINN
VERT_NET_GROSS_MEAN	Double	Mean vertical net:gross (decimal %)	VERT_NET_GROSS_MEAN	VERT_NET_GROSS_MEAN
VERT_NET_GROSS_MAX	Double	Maximum vertical net:gross (decimal %)	VERT_NET_GROSS_MAX	VERT_NET_GROSS_MAX
COMPROCK_MIN	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MIN	
COMPROCK_MEAN	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MEAN	
COMPROCK_MAX	Double	Rock compressibility (1/Pa) - default = 5.00E -5	COMPROCK_MAX	

COMPFLUID_MIN	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MIN	
COMPFLUID_MEAN	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MEAN	
COMPFLUID_MAX	Double	Fluid compressibility (1/Pa) default = 1.00E -4	COMPFLUID_MAX	
FLUID_FILL	Text	Fluid fill of trap, Eg fresh water, gas		FLUID_FILL
SALINITY_BRINE	Double	Total dissolved solids (g/l)	SALINITY_BRINE	SALINITY_BRINE
Not required for GSEU but field remains in the database		*Sulphates in Rock or Fluid of Reservoir*		*SULPHATES_RES*
Not required for GSEU but field remains in the database		*E.g. pyrite nodules or H2S in reservoir*		*SULPHATES_RES_DETAIL*
Not required for GSEU but field remains in the database		*Iron in Rock or Fluid of Reservoir*		*IRON_RES*
Not required for GSEU but field remains in the database		*E.g. iron nodules in reservoir, iron stained sandstone*		*IRON_RES_DETAIL*
CO2_RES	Text	CO_2 in Fluid of Reservoir Text - Yes/no		CO2_RES
CO2_RES_DETAIL	Text	Eg CO_2 in oil		CO2_RES_DETAIL
CO2_DENSITY	Double	Calculated using separate spreadsheet	CO2_DENSIT	
STATUS	Text	Status i.e. producing, not producing etc - HC daughter units only	STATUS	STATUS
CONNECTIVITY	Text	Connectivity to rest of storage unit (yes / no) - aquifer daughter unit only	CONNECTIVITY	CONNECTIVITY
MIN_UR_GAS	Double	Minimum ultimate recovery gas (bcm - billion m3) - hydrocarbon traps only	MIN_UR_GAS	MIN_UR_GAS
MEAN_UR_GAS	Double	Mean ultimate recovery gas (bcm - billion m3) - hydrocarbon traps only	MEAN_UR_GAS	MEAN_UR_GAS
MAX_UR_GAS	Double	Maximum ultimate recovery gas (bcm - billion m3) - hydrocarbon traps only	MAX_UR_GAS	MAX_UR_GAS
MIN_UR_OIL	Double	Minimum ultimate recover oil (MMcm) - hydrocarbon traps only	MIN_UR_OIL	MIN_UR_OIL
MEAN_UR_OIL	Double	Mean ultimate recover oil (MMcm) - hydrocarbon traps only	MEAN_UR_OIL	MEAN_UR_OIL
MAX_UR_OIL	Double	Maximum ultimate recovery oil (MMcm) - hydrocarbon traps only	MAX_UR_OIL	MAX_UR_OIL
FVF_OIL	Double	Oil Formation Volume Factor (Rcm / scm) - hydrocarbon traps only	FVF_OIL	FVF_OIL
FVF_GAS	Double	Gas Formation Volume Factor (Rcm / scm) - hydrocarbon traps only	FVF_GAS	FVF_GAS
DISCOV_YR	Double	Discovery year - hydrocarbon fields only	DISCOV_YR	DISCOV_YR
FIRST_YR_PROD	Double	First year of production - hydrocarbon fields only	FIRST_YR_PROD	FIRST_YR_PROD
LAST_YR_PROD	Double	Last year of production - hydrocarbon fields only	LAST_YR_PROD	LAST_YR_PROD
SRL	Double	Storage Readiness Level		

SEAL	Text	Name of most widespread primary seal for the storage unit	SEAL	SEAL
PRIM_SEAL_OVERLIE	Text	Does primary seal directly overlie assessment unit (yes/no)		PRIM_SEAL_OVERLIE
PERIOD_MIN_SEAL	Text	Minimum period of seal formation		PERIOD_MIN_SEAL
PERIOD_MAX_SEAL	Text	Maximum period of formation		PERIOD_MAX_SEAL
CHRONSTRAT_MIN_SEAL	Text	Minimum age of seal formation		AGE_MIN_SEAL
CHRONSTRAT _MAX_SEAL	Text	Maximum age of seal formation		AGE_MAX_SEAL
ENV_DEP_SEAL	Text	Primary environment of deposition of seal Eg. Deep sea		ENV_DEP_SEAL
LITHOLOGY_SEAL	Text	predominant lithology of rock		LITHOLOGY_SEAL
SEAL_MINERAL	Text	mineralogy of the seal rock		SEAL_MINERAL
Not required for GSEU but field remains in the database		*Sulphates in Seal*		*SULPHATES_SEAL*
Not required for GSEU but field remains in the database		*Iron in Seal*		*IRON_SEAL*
MIN_SEAL_THICK	Double	Minimum primary seal thickness (m)	MIN_SEAL_THICK	MIN_SEAL_THICK
FAULT_DEN	Double	Number of faults that cut top of storage formation into seal formation k	FAULT_DEN	FAULT_DEN
FAULT_THR_OVERBURDEN	Text	Presence of faults that cut the top storage formation and primary seal formation (Drop down list, Faults present, displacement greater than thickness of the seal; No faults cut the entire primary seal etc)	VERT_EXTENT_FAULT	FAULT_THR_OVERBURD EN
AVE_FAULT_THR	Double	Average fault throw (m)	AVE_FAULT_THR	AVE_FAULT_THR
MAX_FAULT_THR_RES	Double	Max fault throw in primary seal at top storage formation (m)	MAX_FAULT_THR_RES	MAX_FAULT_THR_RES
RISK_LAT_MIGR	Text	Risk of lateral migration out of unit of assessment (low/medium/high)	RISK_LAT_MIGR	RISK_LAT_MIGR
AVE_DIP_UNIT	Double	Average dip of unit of assessment (degrees)	AVE_DIP_UNIT	AVE_DIP_UNIT
SUSCEPT_RES_DAM	Text	Susceptibility of trap rock to damage when fluids are injected (low/medium/high)	SUSCEPT_RES_DAM	SUSCEPT_RES_DAM
VERT_STRAT_COMPART	Text	Comment field to note vertical reservoir compartmentalisation (e.g. by geological faults)	VERT_STRAT_COMPAR T	VERT_STRAT_COMPART
HOR_STRAT_COMPART	Text	Comment field to note horizontal storage formation compartmentalisation (eg shale stringers)	HOR_STRAT_COMPAR T	HOR_STRAT_COMPART
Not required for GSEU but field remains in the database		*Fault compartmentalisation in reservoir (yes/no)*		*FAULT_COMPART*
ADVERSE_DIAG	Text	Risk of adverse diagenesis (capture any diagenetic features that might adversely	ADVERSE_DIAG	

		affect storage formation quality, e.g. fibrous illite)		
Not required for GSEU but field remains in the database		*Faulting in the seal (yes/no)*		*FAULT_IN_SEAL*
SEAL_OTHER	Text	Secondary or other seal names	SEAL_OTHER	SEAL_OTHER
NO_WELLS_PENETR	Double	Number of existing wells penetrating the storage unit	NO_WELLS_PENETR	NO_WELLS_PENETR
WELL_VINT	Text	Well vintage	WELL_VINT	WELL_VINT
ANNUAL_PRODUCTION_RATE	Double	Annual production rate (oil/gas extraction in mmbl/year or mmscf/year - hydrocarbon traps only, data for whole field		ANNUAL_PRODUCTION_RATE
WELL_FLOW_RATE	Text	Well flow rate (oil/gas extraction in mmbl/day or mmcf/d - if field is oil/gas)		WELL_FLOW_RATE
NO_ADAND_WELL_PENETR	Double	Number of abandoned wells penetrating storage unit	NO_ADAND_WELL_PENETR	NO_ADAND_WELL_PENETR
AGE_OLD_WELL	Double	Age of oldest abandoned well	AGE_OLD_WELL	AGE_OLD_WELL
VINT_PLAT	Text	Vintage production platform or site	VINT_PLAT	VINT_PLAT
SEISMIC	Text	Seismic available	SEISMIC	SEISMIC
WELLS	Text	Wells available	WELLS	WELLS
MODELS	Text	Models available	MODELS	MODELS
STATUS_RESEARCH	Text	Status of the research on the unit, describes stages of site investigation before any industrial operations	STATUS_RESEARCH	STATUS_RESEARCH
DATA_SOURCE	Text	Data source		DATA_SOURCE
DATA_QUALITY	Text	Data quality and confidence (excellent, good, fair, poor, low)		DATA_QUALITY
REMARKS	Text	Any additional information – e.g. average porosity for oilfield given, polygons not available, trap crosses country boundaries, seal thickness estimated from one well, seismic data held by private companies and not released, saline aquifer used for gas storage, field contains oil and gas, 2% H_2S present etc)	REMARKS	REMARKS
COUNTRY	Text		COUNTRY	COUNTRY
COUNTRYCODE	Text		COUNTRYCODE	COUNTRYCODE
LAMBERT_E	*Double*	*Eastings in Lambert projection*	*LAMBERT_E*	*LAMBERT_E*
LAMBERT_N	*Double*	*Northings in Lambert projection*	*LAMBERT_N*	*LAMBERT_N*
X_DD	*Double*	*X co-ord sin decimal degrees (WGS84)*	*X_DD*	*X_DD*
Y_DD	*Double*	*y co-ord in decimal degrees (WGS84)*	*Y_DD*	*Y_DD*
X	Double	X coordinates in any given projection	X	X
Y	Double	y coordinates in any given projection	Y	Y
Projection_Info	Text	Details of projection used for X and Y coords	Projection_Info	Projection_Info

X_GIS	Double	X coordinates from the Hystories web GIS and new entries in EPSG: 4326		X_GIS
Y_GIS	Double	y coordinates from the Hystories web GIS and new entries, in EPSG: 4326		Y_GIS
Projection_Info_HYST	Text	Details of projection used for X_GIS and Y_GIS coords (must be in: WGS84 LL EPSG 4326)		Projection_Info_HYST
Date_Entered	Date/Time	Date the data was entered		Date_Entered
HYST_OR_CO2	Text	Project when this was updated ie Hystories, CO2Stop or GSEU		HYST_OR_CO2

How to cite this product:
GSEU Project (2025). Map of CO_2 storage potential areas (formation, units and traps) at the EU-scale. Version 1.0. Access information on April 1st, 2025 [https://www.europe-geology.eu/data-tools/map-viewer/].

4. Deep Geothermal Energy Potential

The third section of the **Pan-European Atlas of Sustainable GeoEnergy Capabilities** corresponds to the group of layers that define the objectives for **deep geothermal potential**.

4.1. Defining the deep geothermal approach

The information structure planned under the **GSEU** concept for the **Pan-European Atlas of SGC** is based on information levels structured according to a modified version of a **play-based geothermal exploration approach** (Moeck, 2020) (cf.*Figure 6*) which was already adapted from the hydrocarbon industry. This approach organizes information from **geosystems or geothermal play types** regions at the Pan-European scale, to **plays or reservoirs** at large to medium scales, and finally to **prospects** at a small scale within any geothermal system.

Information Levels:

- **Level 00** – Natural Thermal Water Springs (and Boreholes and Wells)
- **Level 01** –Favourable areas at the EU-scale for Deep Geothermal prospecting (Geothermal Play Types).
- **Level 02** – Potential reservoirs evaluated on a global scale for deep geothermal energy and MT/HT-ATES (play delineation and assessment)
- **Level 03** – Assessed spatially distributed potential reservoirs, with a medium-high level of characterization (prospect characterization at the local scale), based on previous EU projects.

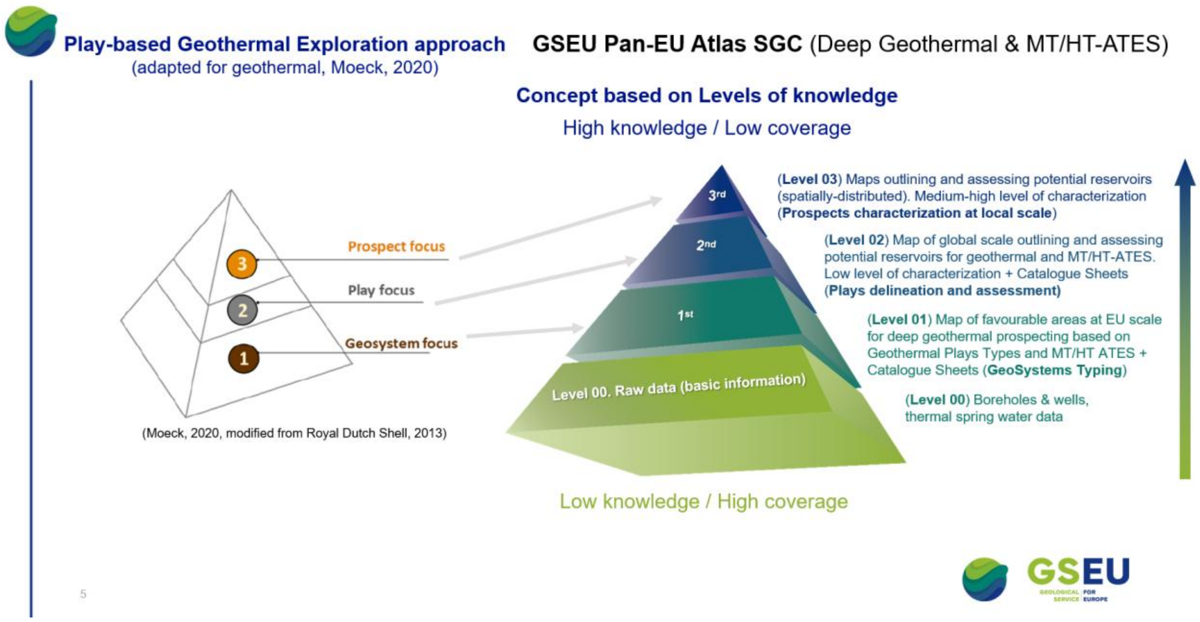


Figure 6: *Play-based Exploration Pyramid (Moeck, 2020) applied to the GSEU approach for DG*

4.2. The datasets included on this version 1 (May 2025)

The current version 1 of the SGC Pan-European Atlas (March 2025), includes, at this stage, the following new layers:

1) **Level 00: Natural Thermal Water Springs** (+ Boreholes and Wells, already presented in the chapter 2**)**

2) **Level 01. Favourable Areas for Deep Geothermal Prospecting:** provide a new harmonized and generalized distribution Map of favourable prospecting areas to take advantage of deep geothermal energy in EU based on identification of geothermal play types - including standardized qualitative attributes (description of potential reservoirs and uses) with the aim of achieving the maximum coverage across EU for the Pan-European Atlas SGC + a collection of sheets describing individually each polygon (downloadable)

4.3. Natural Thermal Water Springs

This layer contains the natural thermal springs associated to deep-origin geothermal energy resources. The main threshold constrain for this layer is the temperature of outflowing water. According to the agreed limit values, it must be at least, 5 ºC above the mean air temperature of the geographical region where measured.

Table 6 summarises all the items included in the attribute table of the layer for each thermal spring and can be interactively checked in the Atlas visor (https://www.europe-geology.eu/data-tools/map-viewer/). Not all the fields have been filled in due to the lack of data. Temperature, geochemical values or related structures are some of the main attributes included in this product.

All the points in the Pan-European Atlas SGC are displayed according to the measured temperature (ºC) in the outflowing point. Blue points correspond to lower values and red ones to higher values of this attribute (cf.*Figure 7Figure 6).*

Table 6: *Example and definition of the attributes for thermal springs layer.*

Attribute in layer	**definition**	**Example**
ID	Unique identification code composed by the NUTS Level 2 code + word “spring” + unique and consecutive number for each well starting from 001.	ES51_spring_001
X_EPSG3035	X coordinates in meters based on the geographic reference system: EPSG:3035 ETRS89 / LAEA Europe (https://epsg.io/3035).	43624946.00
Y_EPSG3035	Y coordinates in based on the geographic reference system: EPSG:3035 ETRS89 / LAEA Europe (https://epsg.io/3035).	463454810.00
SpringName	Free text according to the original well name.	Manantial Codina
Flow_rate	Average steady-state flow rate in L/s.	0.75
Temp	The maximum measured temperature recorded, in ºC.	56.50
Thermal water	To specify if the spring is legally designated as thermal water	Thermal water / No thermal water
Geoch_TDS	Total dissolved solids in ppm.	445.25
Geoch_EC	Electrical conductivity of the fluid in µS/cm.	2500.00
Hydro_faci	Hydrogeochemical facies description following the Piper diagram facies classification.	Sodium-bicarbonate
Database	Reference database if the well data is stored there.	https://www.data.gov.uk/dataset/96c70ac5-945c-4f2c-9b55-c14c3da85918/spring-index
Metadata of source data	Link to metadata repository.	
Structure	If known, the relation to a large-scale structure	Extensional fault

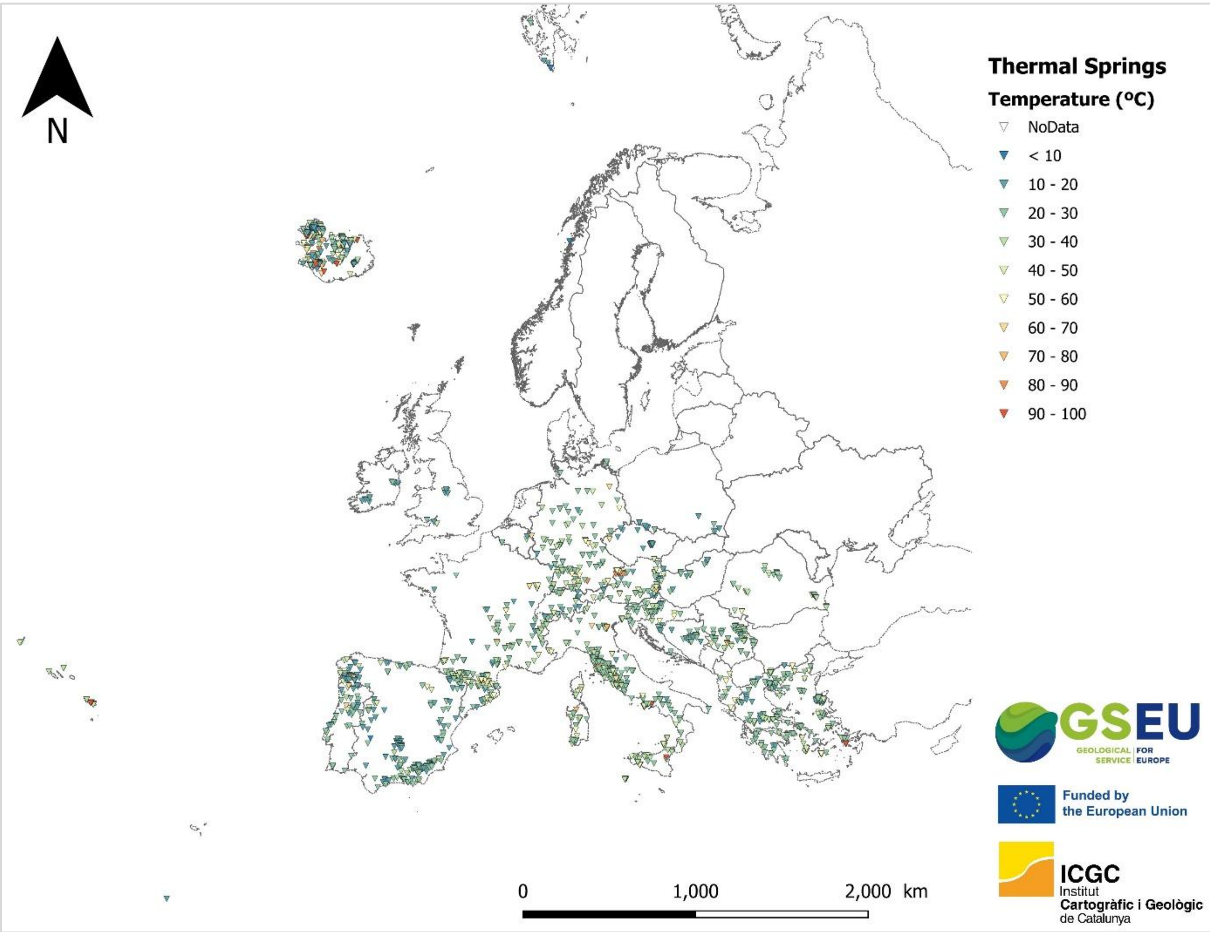


Figure 7: *Example of the thermal spring's visualization in the Pan-European Atlas SGC*

How to cite this product:

GSEU Project (2025). Map of natural Thermal Water Springs. Version 1.0. Access information on May 28th, 2025 [https://www.europe-geology.eu/data-tools/map-viewer/].

Terms of Use / License:

4.4. Favourable Areas for Deep Geothermal Prospecting (Geothermal Play Types)

This layer encompasses the concept of Geothermal Play Types (GPT), which was firstly proposed by Inga Moeck (2014) as a result of the expertise and experience acquired from the Oil & Gas industry. It refers to the characterization and classification of the natural geothermal energy systems mainly based on the type of heat transport and the effects of geological controls and structural setting. The main aim is to identify areas with favourable geologic conditions to potentially host deep-origin geothermal resources.

Figure 8 represents a summary of the two main types of Geothermal Play Types firstly published in 2014 according to the type of heat transport and classified as follows:

1) Convection-Dominated Geothermal Plays (CV)
2) Conduction-Dominated Geothermal Plays (CD)

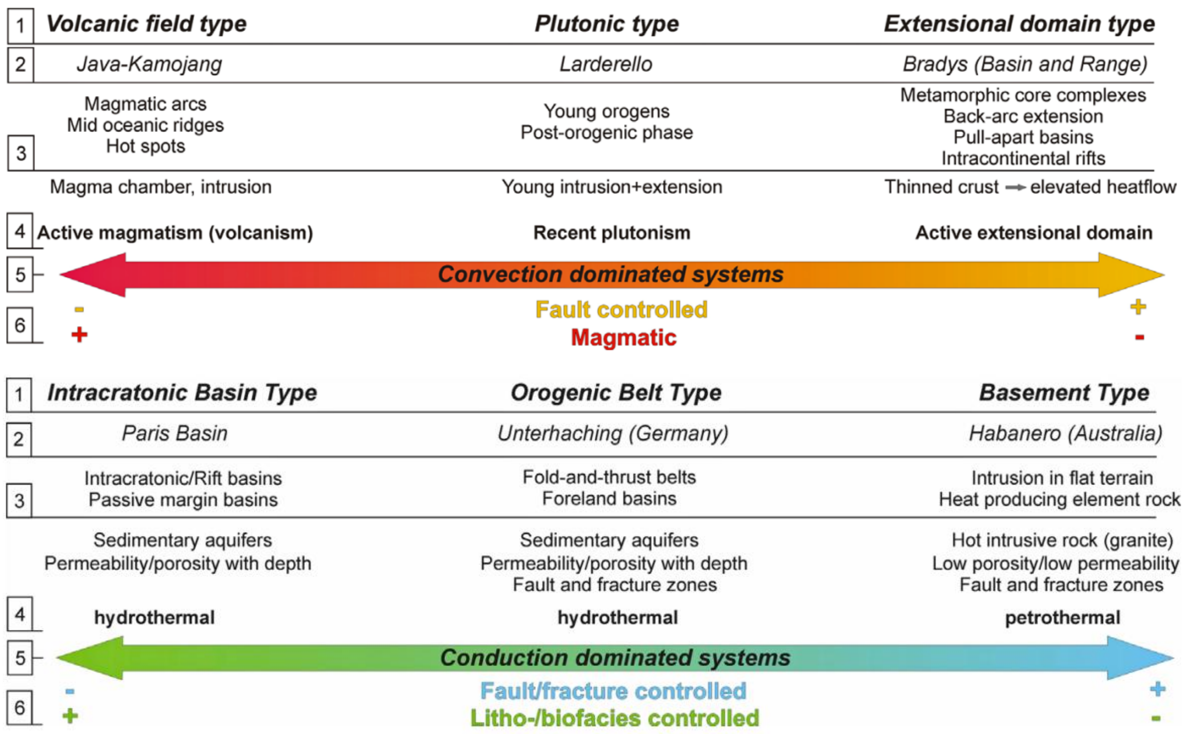


Figure 8: *Geothermal play classification from Moeck, I. (2014).*

This classification (cf. *Figure 8*) was slightly updated and published in a second paper (Moeck, I. & Beardsmore, G., 2014), where new subcategories of convective Geothermal Play Types were proposed and described. Indeed, in Moeck, I. et al., (2019) two new subcategories were proposed for the conductive CD2 Geothermal Play Type (CD2a - Foreland Basin; CD2b - Adjacent Orogenic Belt).

Type			Geologic Setting	Heat Source	Dominant Heat Transport Mechanism
Convection Dominated	CV-1: Magmatic	CV-1a: Extrusive	Magmatic Arcs, Mid Oceanic Ridges, Hot Spots	Active Volcanism, Shallow Magma Chamber	Magmatic-hydrothermal Circulation
		CV-1b: Intrusive	Magmatic Arcs, Mid Oceanic Ridges, Hot Spots	Active Volcanism, Shallow Magma Chamber	Magmatic-hydrothermal Circulation, Fault Controlled
	CV-2: Plutonic	CV-2a: Recent or Active Volcanism	Convergent Margins with Recent Plutonism (< 3 Ma), Young Orogens, Post-orogenic Phase	Young Intrusion+Extension, Felsic Pluton	Magmatic-hydrothermal Circulation, Fault Controlled
		CV-2b: Inactive Volcanism	Convergent Margins with Recent Plutonism (< 3 Ma), Young Orogens, Post-orogenic Phase	Young Intrusion+Extension, Felsic Pluton, Heat Producing Element in Rock	Hydrothermal Circulation, Fault Controlled
	CV-3: Extensional Domain		Metamorphic Core Complexes, Back-arc Extension, Pull-apart Basins, Intracontinental Rifts	Thinned Crust+Elevated Heatflow, Recent Extensional Domains	Fault Controlled, Hydrothermal Circulation
Conduction Dominated	CD-1: Intracratonic Basin		Intracratonic/Rift Basins, Passive Margin Basins	Lithospheric Thinning and Subsidence	Litho/Biofacies Controlled
	CD-2: Orogenic Belt		Foreland Basins within Fold-and-thrust Belts	Crustal Loading and Subsidence Adjacent to Thickened Crust	Fault/Fracture Controlled, Litho/Biofacies Controlled
	CD-3: Crystalline Rock - Basement		Intrusion in Flat Terrain	Heat Producing Element in Rock, Hot Intrusive Rock	Hot Dry Rock, Fault/Fracture Controlled

Figure 9: *Geothermal play classification from DARLINGe Interreg Project, Basic concepts of deep geothermal Energy (2017), based on Moeck, I. & Beardsmore, G., (2014).*

The layer development process was based on the preparation and collection of interpreted data by the partners by country, followed by a harmonization phase and subsequent compilation of the polygons for each geothermal play type across EU (cf. *Figure 9*) according to Moeck's (2014) classification. The interpretation carried out by the partners to establish the geothermal context considered all available information, including geological mapping, geophysical data, borehole and well measurements, the location of hot springs, and previous models, among others. The classification includes some examples and provides restrictions as a guide for its application in real-life cases.

The version 1 considers some information provided referring the potential areas for off-shore geothermal power generation (several areas off the northern coast of Norway and eastern Malta). More information in this regard will be added in next updates.

The white space in between polygons usually refers to the lack of exploration data to legitimate its classification into a group. The acquisition of new data may lead to the classification of white areas into new Geothermal Play Types in subsequent updates of the Atlas.

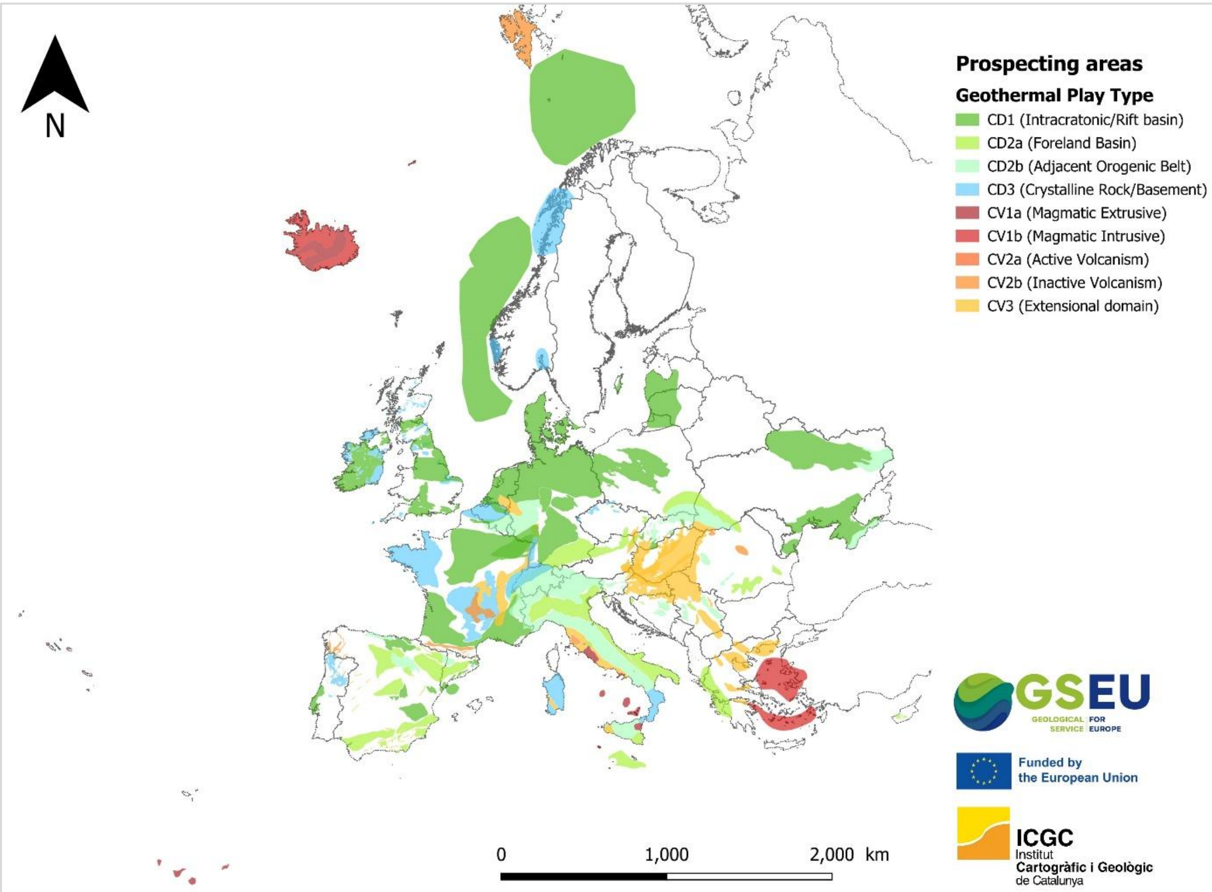
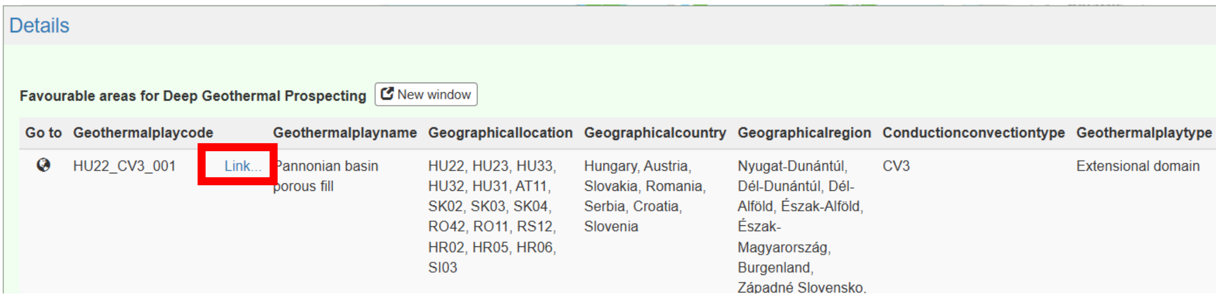


Figure 10: *Example of the Geothermal Play Types' visualization in the Pan-European Atlas SGC.*

All the items included in the attribute table of the layer for each Geothermal Play Type can be interactively checked in the Atlas visor (https://www.europe-geology.eu/data-tools/map-viewer/). The attributes have been selected from the classification of Geothermal Play Types according to the best suitable option in any geothermal and geological system.

Each polygon of this layer has been described, including the main potential reservoirs of deep-origin geothermal resources and other relevant data that supports the classification of the polygon. This information is, indeed, compiled and presented in a Factsheet accessible through the link in the attribute table of the layer in the EGDI visor (***Error! No s'ha trobat l'origen de la referència.Error! No s'ha trobat l'origen de la referència.Error! No s'ha trobat l'origen de la referència.****Figure 11*) as shown in *Figure 12*.



Details

Favourable areas for Deep Geothermal Prospecting New window

Go to	Geothermalplaycode		Geothermalplayname	Geographicallocation	Geographicalcountry	Geographicalregion	Conductionconvectiontype	Geothermalplaytype
	HU22_CV3_001	Link...	Pannonian basin porous fill	HU22, HU23, HU33, HU32, HU31, AT11, SK02, SK03, SK04, RO42, RO11, RS12, HR02, HR05, HR06, SI03	Hungary, Austria, Slovakia, Romania, Serbia, Croatia, Slovenia	Nyugat-Dunántúl, Dél-Dunántúl, Dél-Alföld, Észak-Alföld, Észak-Magyarország, Burgenland, Západné Slovensko,	CV3	Extensional domain

***Figure 11**: Example of the attribute table of a polygon in the EGDI visor. The link is in second position (red square).*

GSEU GEOLOGICAL SERVICE FOR EUROPE

Pan-EU Atlas of Sustainable Geo-Energy Capacities

Map of favourable areas at the EU-scale for deep geothermal prospecting (Level 01)

Catalog of Geothermal Play Types

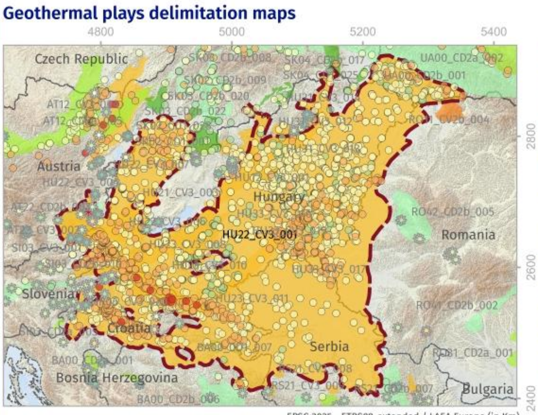
Geothermal play name: **Pannonian basin porous fill** **Geothermal play code:** **HU22_CV3_001**

Plate tectonic setting Thinned crust, Back-arc extension
Geothermal play type Extensional domain
Geologic habitat Hydrothermal circulation
Geologic controls Litho/biofacies controlled
Main heat transport mechanism Convection
Conduction convection type CV3

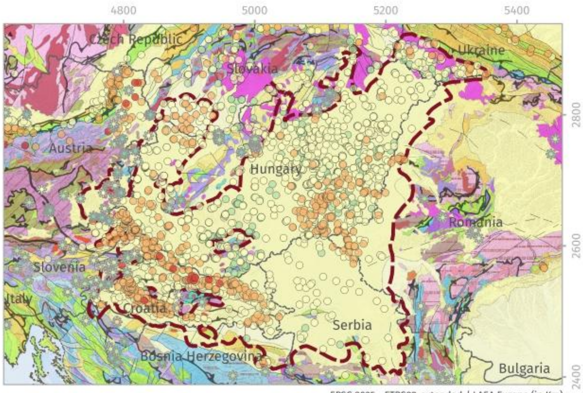
The Pan-EU Atlas of Sustainable Geo-Energy Capacities focuses on geothermal energy and geological storage (Carbon Capture and Storage, hydrogen, heat, cold) topics. To assess the deep geothermal potential, it employs a "Levels of Knowledge" approach, providing a gradual and in-depth understanding of geothermal resources following the play-based exploration geothermal pyramid concept (Moeck et al., 2020). Level 00 offers raw data on boreholes, wells, and thermal springs. Level 01 features the **"Map of Favourable Areas for Deep Geothermal Prospecting"** providing the **"Catalog of Geothermal Play Types across the EU"**—geosystems or regions with potential — guiding decision-making for further exploration and resource allocation. Level 02 assesses the geothermal reservoir potential within each Favourable Area at the regional scale, while Level 03 delivers detailed 2D/3D assessments at the prospect level.

Location maps

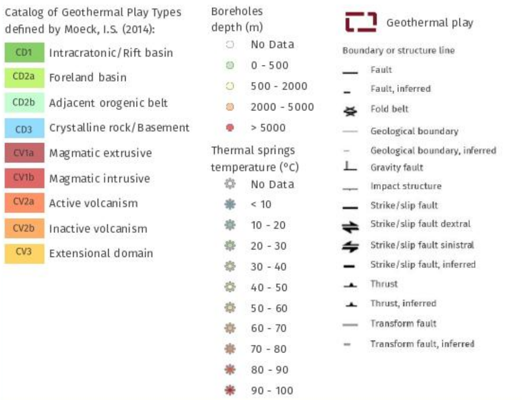

Geothermal plays delimitation maps

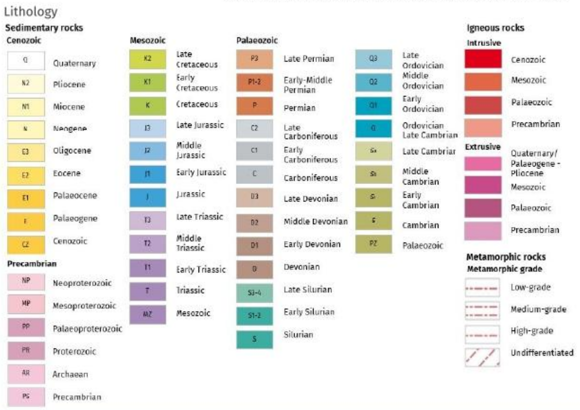


EPSG:3035 - ETRS89-extended / LAEA Europe (in Km)
EMODnet Bathymetry World Base Layer version 1. GGS Geo Consultancy (2021): EMODnet Bathymetry consortium



EPSG:3035 - ETRS89-extended / LAEA Europe (in Km)
1:5M International Geological Map of Europe and Adjacent Areas (IGME 5000)





Description

Basin fill sediments represent the forward accretion sediment packages that deposited during the gradual fill up of the Lake Pannon during Late Miocene and Early Pliocene, originated in the surrounding uplifting Alpine and Carpathian Mountain belts. The resulting siliciclastic sequences with low thermal conductivity (the "Pannonian" sedimentary succession) can be as thick as several thousand meters in the deepest sub-basins. This play consists of the upper part of the Pannonian sedimentary sequences down to a depth of about 2.000 m b.g.l., which is characterized by a gravity driven regional groundwater flow system recharged from precipitation.

The main reservoirs are:
- The Zagyva and Újfalu sandstones, characterized by large to very large permeability values, with limited interbeddings of poorly permeable muds and other fine-grained beds.

In general, the temperature distribution shows a good correlation with sediment thickness ranging on average from 50–60 °C at areas with sediment thickness up to 1.000 m, and displays the highest values of 100–120 °C in the centres of the deepest sub-basins where sediment thickness is over 2.000 m.
- In Austria the Styrian Basin is the largest Neogene basin, which represents the orogen-basin transition zone. Miocene Sarmat and Baden sediments in a range of 470-2.020 m b.g.l. Miocene Karpatian basal conglomerates in a range of 1.200-2.200m.
- In Slovakia the Danube Basin central depression: Pannonian and Pontian sands, sandstones, gravels, conglomerates, at top depth: 200 - 2.900 m b.g.l. and modeled temperatures of 17 - 135 °C. In the Horné Strháre - Trenč Graben primary reservoirs are Miocene sands, gravels and sandstone equivalents, at top depth: 60 - 1.800 m b.g.l. with modeled reservoir temperature of 16 - 85 °C. Reservoirs are stratified, hydraulic connection is questionable. In the Moldavská kotlina Basin identified reservoirs are in Badenian, Sarmatian and Panonian sands and sandstones, at top depth: 10 - 1.550 m b.g.l. and modeled temperature of 12 - 144 °C, stratified and questionable vertical connectivity. Existence of deep reservoirs of Mesozoic basement (Mid Triassic) is inferred

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GSEU v.1.0 - March, 2025

Pan-EU Atlas of Sustainable Geo-Energy Capacities

Map of favourable areas at the EU-scale for deep geothermal prospecting (Level 01)

Catalog of Geothermal Play Types

Geothermal play name: Pannonian basin porous fill **Geothermal play code:** HU22_CV3_001

Description

by analogy. Maximum sampled wellhead temperature: 37 °C.
- In Serbia the depth of Neogene sediments are 0.4-3.3 km, except Mt. Fruška Gora and Mt. Vršačke planine. The identified potential reservoirs are Pontian sandstone and sand (porous rocks) which extend from the surface up to 2.000 m b.g.l. in the northern-east part of the Pannonian basin, while the thickness of these sediment at the south Banat is 500 m and at the northern-west part of Bačka is 300 m. The groundwater temperature is up to 82 °C and the geothermal gradient is 4.5-6.2 °C/100 m.
- The Croatian part of the PBS can be subdivided into Mura, Drava, Sava and Slavonija-Srijem Depressions, plus smaller Bjelovar, Hrvatsko zagorje, Karlovac and Požega subdepressios. Basin fill is a succession of predominantly siliciclastic rocks (sandstones and marls in different thicknesses and proportions in diverse (sub)depressions), and some biocalcarenites, all with significant potential for thermal water production. Thickness of basin fill reaches up to 5.500 m in the Mura and 7.000 m in Drava depression. Due to thinned crust and high geothermal gradients at such depths high temperatures are present (up to 200 °C in depocenters).
- Basin fill sediments in NE Slovenia are siliciclastic succession with the greatest potential for thermal water production. They consist of Mura Formation – delta front and delta plain sediments (corespond to The Zagyva and Újfalu Fms in Hungary) which are highly permeable with loose sandy aquifer layers with good connectivity and regional interconnection. The alluvial gravely Ptuj-Grad Formation contains lukewarm water, as thermal and cold drinking water. The Goričko, Slovenske gorice and Haloze Hills are recharge areas for the regional flow and cross-border thermal water, flow is mainly from Slovenia to Hungary. The maximum depth of interest is up to 2 km but mostly layers up to 1.5 km are tapped, yielding water with 60-65 ºC and flow rates max. about 25 l/s per a well.
- In Ukraine Neogene Molassa type basin is subdivided into two domains: Mukachevo basin on west and Solotvyno basin on east. Basin fill thickness do not exceed 4 km of Neogene sediments. The region has widely spreaded faults of pull-apart basin origin. Heat flow density vary between 80 and 130 mw/m2 with significant anomalies, controlled by geological settings. Deep horizons are underexplored, so reservoir temperature and water flow rates uncertain.

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More Information

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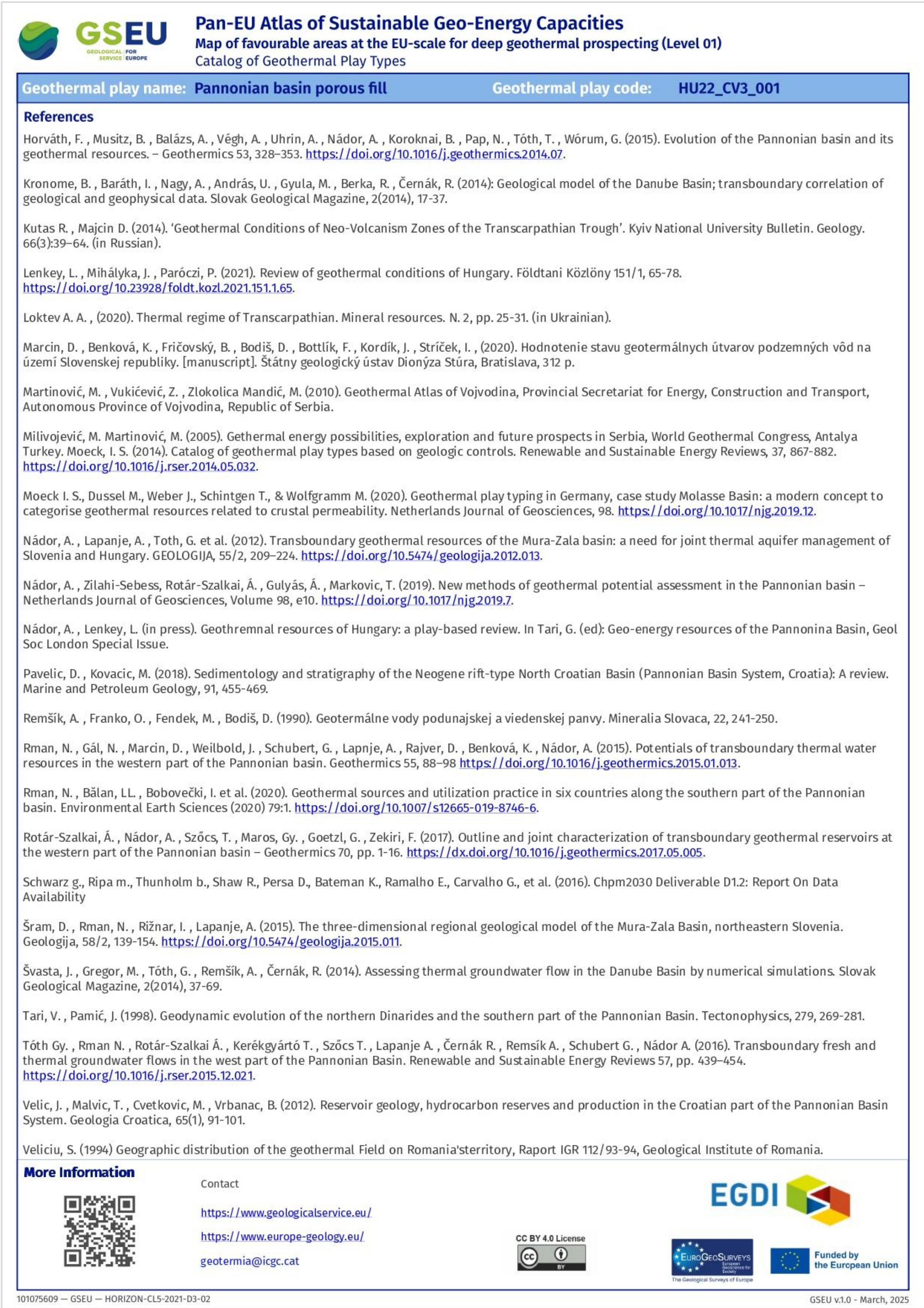

Pan-EU Atlas of Sustainable Geo-Energy Capacities
Map of favourable areas at the EU-scale for deep geothermal prospecting (Level 01)
Catalog of Geothermal Play Types

Geothermal play name:	Pannonian basin porous fill	Geothermal play code:	HU22_CV3_001

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Figure 12: *Example of a Factsheet from a geothermal play in Hungary.*

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6. Annex

WP3 consortium partners			
ID	**Partner Name**	**Acronym**	**Country**
2	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	Netherlands
3	Sherbimi Gjeologjik Shqiptar	AGS	Albania
5	Bureau de Recherches Géologiques et Minières	BRGM	France
6	British Geological Survey	BGS	UK
7	Ministry for Finance and Employment	MFE	Malta
8	Hrvatski Geološki Institut Croatian Geological Survey	HGI-CGS	Croatia
9	Institut Royal des Sciences Naturelles de Belgique	RBINS-GSB	Belgium
10	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	PGI-NRI	Poland
11	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain
12	Česká Geologická Služba	CGS	Czechia
13	Department of Environment, Climate and Communications - Geological Survey Ireland	GSI	Ireland
14	Agencia Estatal Consejo Superior de Investigaciones Científicas. Instituto Geológico y Minero de España	CSIC-IGME	Spain
15	Bundesanstalt für Geowissenschaften und Rohstoffe	BGR	Germany
16	Geološki zavod Slovenije	GeoZS	Slovenia
18	Federalni Zavod za Geologiju Sarajevo	FZZG	Bosnia and Herzegovina
19	Istituto Superiore per la Protezione e la Ricerca Ambientale	ISPRA	Italy

20	Regione Umbria	RU	Italy
22	Institute of Geological Sciences National Academy of Sciences of Ukraine	IGS	Ukraine
24	Ukrainian Association of Geologists	UAG	Ukraine
26	Geological Survey of Serbia	GZS	Serbia
27	Ministry of Agriculture, Rural Development and Environment of Cyprus	GSD	Cyprus
28	Norges Geologiske Undersøkelse	NGU	Norway
30	Sveriges Geologiska Undersökning	SGU	Sweden
31	Geological Survey of Denmark and Greenland	GEUS	Denmark
33	Magyar Bányászati és Földtani Szolgálat	MBFSZ	Hungary
34	Office fédéral de topographie	SWISSTOPO	Switzerland
35	Elliniki Archi Geologikon kai Metalleftikon Erevnon	HSGME	Greece
36	Laboratório Nacional de Energia e Geología I.P.	LNEG	Portugal
37	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos	LGT	Lithuania
38	GeoSphere Austria (previous Geologische Bundesanstalt)	GSA (previous GBA)	Austria
39	Service Géologique de Luxembourg	SGL	Luxembourg
43	Štátny Geologický ústav Dionýza Štúra	SGUDS	Slovakia
46	Íslenskar Orkurannsóknir	ISOR	Iceland
-	Geological Survey of the Republic of North Macedonia	GSNM	North-Macedonia