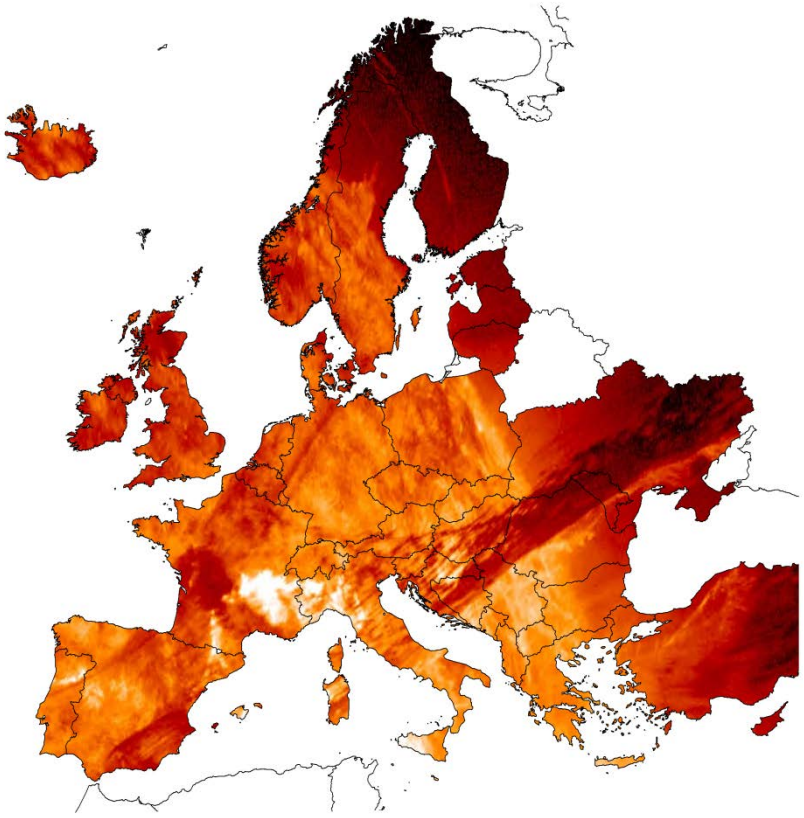

ESTMAP
D3.05: Country Energy Storage Evaluation

As part of EC Service Contract no.: ENER/C2/2014-640/S12.698827

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Table of Content

1. General Introduction

This documents provides a per country summary of all data sources, results and statistics (country data report). The overall background, approach and results of the subsurface and above ground data collection are described in report ESTMAP D3.04: Storage Data Collection.

1.1. Abbreviations

Common abbreviations for storage technologies used in the country data reports:

UGS:	Underground Natural Gas Storage
HES:	Hydrogen Storage
CAES:	Compressed Air Energy Storage
UTES:	Underground Thermal Energy Storage
PHS:	Pumped Hydro Storage

1.2. Country report structure

The country reports provide a generic structured and comparable overview of the energy storage potential. To this end the contents of the database are aggregated in the following maps, tables and graphs:

Provider Administration:

Mentions the names of the organisations responsible for providing the data, including contact persons and their relation to the ESTMAP project. Furthermore the date/version of data delivery is given.

Main Data Sources

Includes a table (nr. 1) describing the main data sources consulted by the data provider. Further details are contained in the database source description fields.

Storage Data Review

Main section describing the actual data collected and energy storage characterization. Includes the following items:

A brief country summary with a table (nr. 2) evaluating the key aspects and storage potential per reservoir type

A country map showing the location of collected subsurface and above ground reservoirs as well as existing and planned energy storage facilities (for definitions see report D3.05). Each map has the same legend as shown in Figure 1.2-1. The legend shows existing and/or planned facilities (energy storage plants) as black symbols. Reservoirs are shown as coloured areas or dots. Note that the facilities are connected to the electricity grid or local to national distribution networks. The full black circle (Natural gas) indicated Underground gas storage. The full black square is either a pumped hydro power or pumped hydro storage plant.

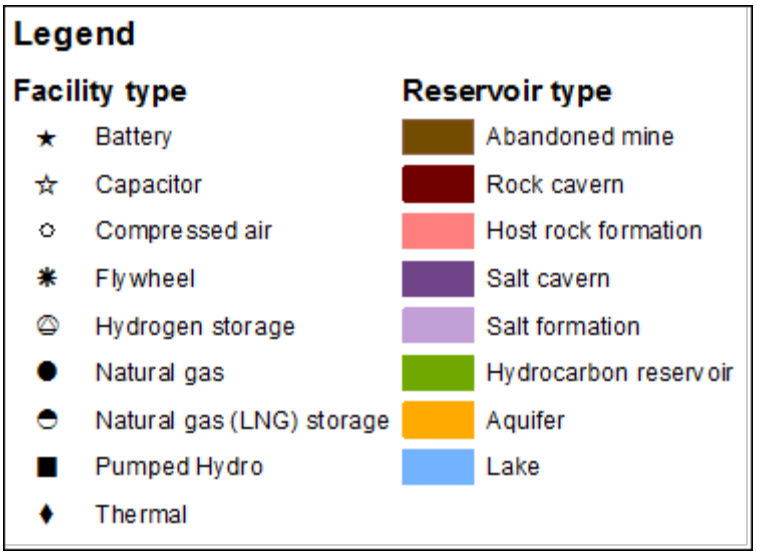

Figure 1.2-1: Legend for the country base maps

A frequency pie-chart showing the number of records for each reservoir type contained in the database. The size of the chart sections does not represent the size of the total capacity (e.g. a large regional aquifer covering hundreds of square kilometres may count as on entry, while there may also be many local-defined storage reservoirs in a smaller area, each of which is included as a separate record). The colours of the chart correspond to the colours of the map legend.

A bar chart characterizing the feasibility per technology in each reservoir type. Each bar shows the share of a certain technical feasibility category for a given reservoir type over the total number of reservoirs of that type (e.g. with a total of 50 aquifers in the database and 10 of them being suitable for thermal energy storage, the bar will show a 20% share). The total cumulated bar is always 100%. The feasibility categories are defined as follows:

- **Proven**: The reservoir has been developed for the given technology or a confirmed development plan is present.
- **Likely**[1]: Feasibility is technically considered probable. Either site-specific assessments have been carried out or concrete plans for development are presented. Note that the feasibility determination does not incorporate legal, economic and societal aspects.
- **Possibly**[1]: Feasibility is technically considered possible (based on regional quick scans, subsurface evaluations or technical assumptions). Suitability should however be confirmed by site-specific investigations. Note that the feasibility determination does not incorporate legal, economic and societal aspects.
- **Unknown/Maybe**: Feasibility determination is still pre-mature and suitability for the given energy storage technology is unknown/unconfirmed. Based on generic geological assumptions there may however be scope for further investigations to assess suitability.
- **Unlikely**: The potential for given technology is absent or very unlikely (considering the generic geological conditions).

[1] The suitability for Pumped Hydro Storage included in ESTMAP and as determined by the JRC-2013 assessment study, concerns “realisable potential” (i.e. a subset of the larger theoretical potential that is also discussed in the report but was not available to ESTMAP). In the context of the ESTMAP country evaluations in this report, suitability is labelled as “Probably” when the identified site is defined by two existing lakes (T1 in JRC-2013). Sites defined by one existing lake and one potential (new to be developed) lake, are labelled as “Possible”

Note that a proven and developed reservoir may still represent potential for other types of energy storage, regardless of whether the current function would allow this or not. This potential is regarded as a possibility from a (theoretical) geological/geographical point of view and as an option that could eventually be implemented after decommissioning the current storage development. Figure 1.2-2 shows an example of the feasibility characterization.

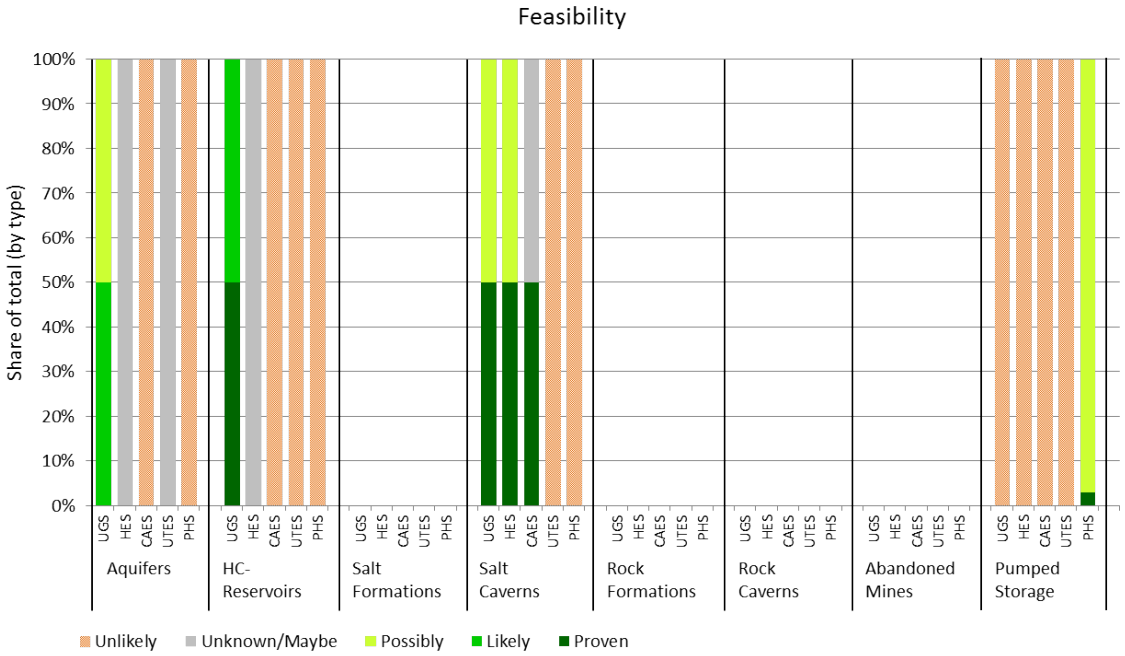

Figure 1.2-2: Example of a feasibility chart. The horizontal axis is subdivided into each of the main reservoir types. Each type is again subdivided into the storage technology categories. 50% of all hydrocarbon (HC) reservoirs have proven development for UGS while the other 50% are likely candidates. All HC reservoirs may theoretically be candidates for HES, but this is still mostly unknown/unconfirmed. According to the data provided, the hydrocarbon reservoirs are not considered candidates for CAES, UTES and PHS.

A bar chart characterizing the overall scale and maturity of assessment of each reservoir type. This attribute includes two aspects:

1. The **spatial definition** which can be either be
    a. "local", meaning that the reservoir represents a concrete asset or unit that can be evaluated or deployed for storage) or;
    b. "regional" (meaning that the reservoir represents a larger area or formation that cannot be used for storage as such but inside which there is scope for identifying site-specific (local) potential
2. The **maturity of assessment** which defines to what extent the suitability for any of the storage functions has been confirmed. The categories are "tested", "planned", "evaluated" and "indicative".

Based on these two aspects, the following assessment maturity categories are defined in the graphs:

- **Local tested**: The reservoir is local-defined and has been tested and considered proven for one or more storage technologies
- **Local planned**: The reservoir is local-defined. One or more storage technologies are planned in this reservoir, but deployment is not fully confirmed yet.
- **Local evaluated**: The reservoir is local-defined And considered a prospective target Suitability for one or more storage technologies on the basis of technical evaluation.

Suitability for deployment needs to be confirmed by on site investigations (including technical, economic and environmental assessment).

- **Local indicative**: The reservoir is local-defined. Although suitability for any storage technology is still very uncertain, quick scans and generic geological/geographical assumptions suggest that the reservoir is considered a potential target for further investigation of storage potential . There is no comprehensive assessment available (or known to the ESTMAP project) that has investigated the site-specific potential in further detail.
- **Regional tested**: The reservoir is regional defined and does not represent site-specific potential. The reservoir is however known to be successfully tested (proven development) for one of the storage technologies at one or more locations. As an example, a large regional-defined aquifer may be used for UGS a one location. This means that suitability is confirmed and tested at one location, but it is still unknown whether other parts of the aquifer are also suitable for UGS.
- **Regional planned**: The reservoir is regional defined and does not represent site-specific potential. There are however known plans to develop storage technologies at one or more locations. For other parts of the aquifer suitability for energy storage development may still be unknown.
- **Regional indicative**: The reservoir is regional defined and does not represent site-specific potential. Quick scans and generic geological/geographical assumptions suggest that the reservoir may comprise locations that are a potential target for further investigation of storage potential. There is no comprehensive assessment available (or known to the ESTMAP project) that has investigated the specific potential in further detail.

Each full bar in the graphs represents 100% of all reservoirs of the given type. The categories represent the share of the total number of reservoirs complying to the assessment level. (e.g. with a total of 50 aquifers in the database and 10 of them being regional-defined, the bar will show a 20% share).

Note that the assessment level in this graph does not relate to a specific storage technology. It just indicates the highest level that is known for any technology. Figure 1.2-3 shows an example of the feasibility characterization.

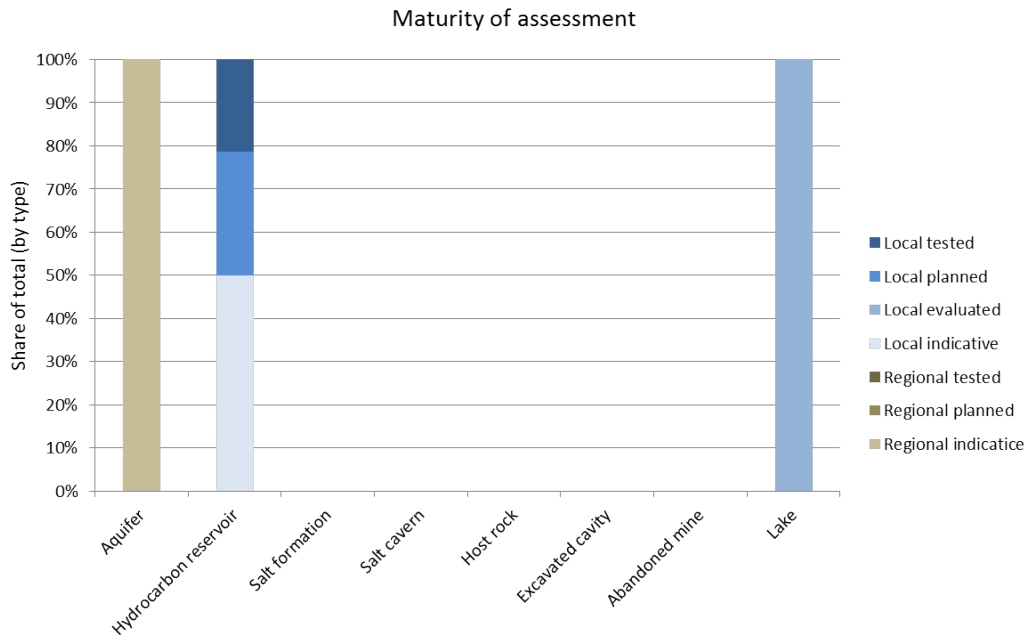

Figure 1.2-3: Example of an assessment level chart. In this case all aquifers represent indicative regional-defined potential. All HC reservoirs are local-defined, ~20% of them are already developed as storage and 30% of them are planned for storage. The potential of the remaining 50% is only indicative and would require further in depth evaluation in order to confirm feasibility for any storage technology.

A bar chart indicating the overall quality and comprehensiveness of capacity determination of each reservoir type. Like above, a distinction is made between local and regional-defined reservoirs, resulting in the following categories:

- **Local specific**: Capacity is determined for a local-defined reservoir. The determination directly relates to the concrete storage performance in terms of working volume (i.e. gas working volume, energy storage capacity).
- **Local approximate**: Capacity is determined for a local-defined reservoir. The determination approximates the storage performance and capacity through indirect indicators (e.g. total gas volume is provided; in which case further assumptions on cushion volume are needed to estimate the working volume).
- **Local indicative**: Capacities at local level are not specified yet but can be roughly estimated from global indicators such as the total rock or pore volume. Many parameters that could narrow down uncertainty are unknown or unconfirmed .
- **Regional indicative**: Determination of local-specified capacities is not possible. Regional reservoir parameters do however allow for estimation of gross rock or pore volumes across the entire reservoir outline (e.g. thickness x area).
- **None**: There are no reservoir parameters available that can be used to estimate storage capacity or performance.

Each full bar represents 100% of all reservoirs of the given type. The categories represent the share of the total number of reservoirs complying to the capacity determination level. (e.g. with a total of 50 aquifers in the database and 10 of them being regional-defined, the bar will show a 20% share).

Note that the capacity determination in this graph does not relate to a specific storage technology. It just indicates the most accurate level that is known for any technology. Figure 1.2-4 shows an example of the capacity determination.

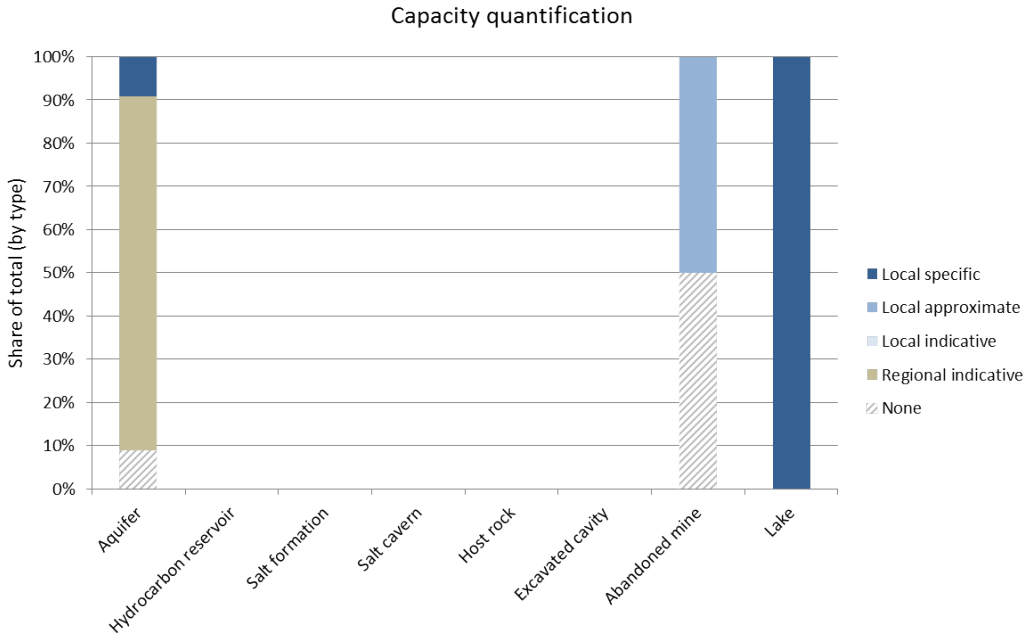

Figure 1.2-4: Example of a capacity determination level chart. In this case for ~80% of all aquifers a rough gross volume estimation is possible without any possibilities to estimate capacities at a local level. ~10% is local-defined with specific operational capacity (working volumes) given. ~10% lacks any parameters to perform any kind of volume determination.

2. Europe Grand Total Overview

This chapter provides a general overview of the energy storage data collection results for all of Europe. Details are described in Chapter 3.

2.1. Energy Storage Data Sources

The map in Figure 2.1-1 gives an overview of the key subsurface data providers. For most countries a national partner was subcontracted. For Germany, Ireland, Serbia and Slovakia public internet and literature sources where consulted by the consortium members. For Cyprus, Iceland, Luxembourg, Malta, Macedonia, Moldavia, Montenegro and Switzerland no sources where found.

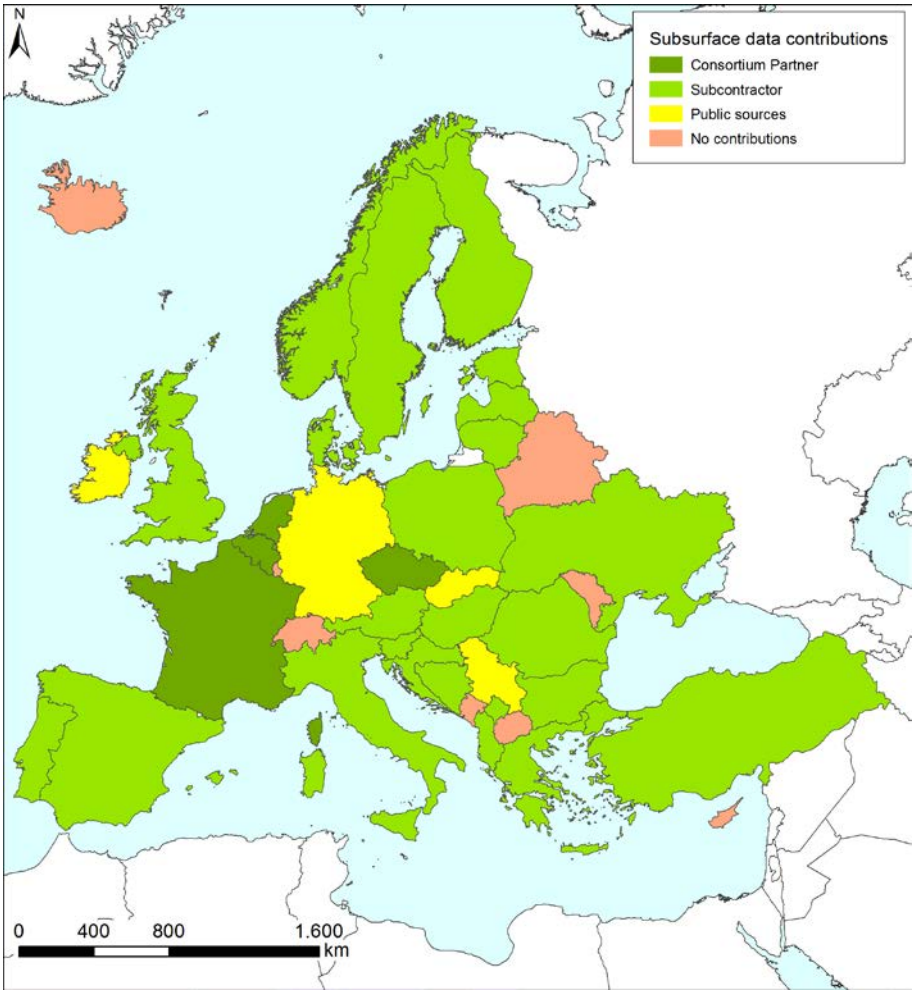

Figure 2.1-1: Overview of subsurface data providers and sources consulted in ESTMAP

Figure 2.1-2 shows the available sources for lake data (pumped hydro storage). Data from most countries were available from https://setis.ec.europa.eu/node/3910. Albania, Bulgaria, the Former Yugoslavian Republic Of Macedonia (FYROM) Iceland, Kosovo, Montenegro, Serbia, Slovakia, Spain and Switzerland are included in the JRC-2013 assessment, but the data were not publicly available to ESTMAP. Belarus, Estonia, Latvia, Lithuania, Luxembourg, Moldavia and Ukraine have not been assessed. No potential for PHS was identified in the Netherlands and Denmark (low, flat areas).

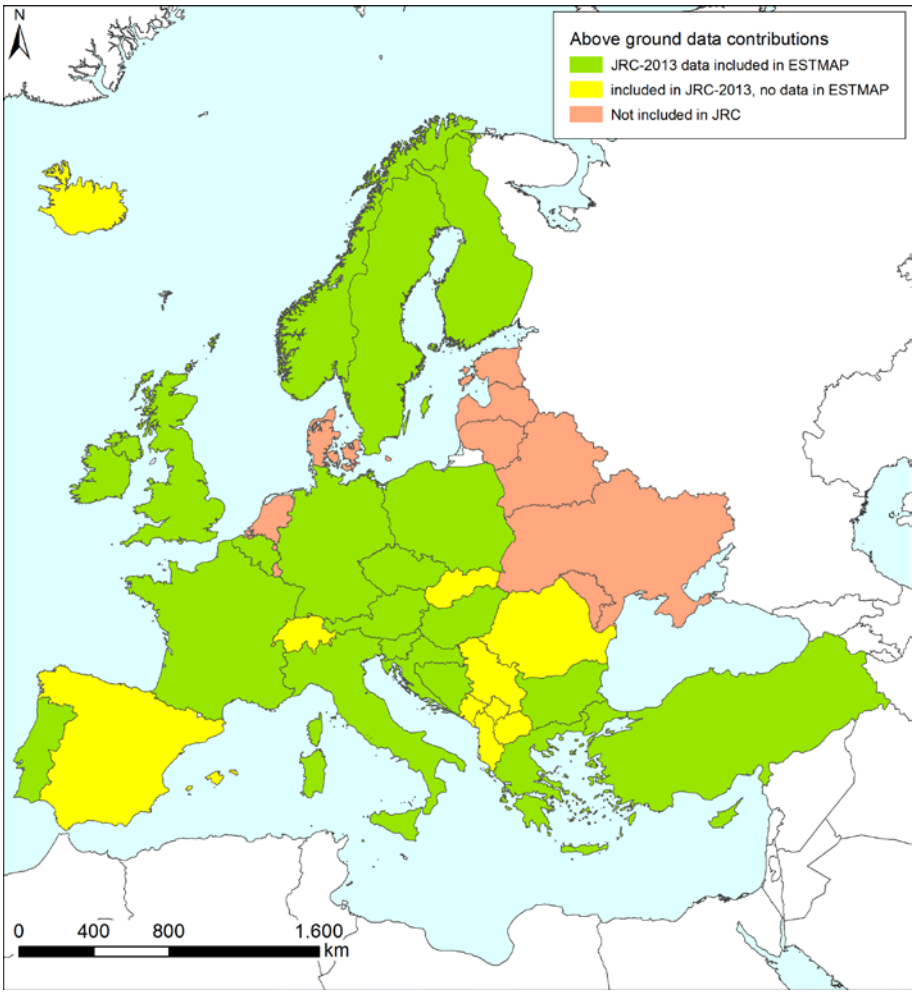

Figure 2.1-2: Overview of PHS-assessment data available to ESTMAP (from JRC-2013)

2.2. EU data summary

Figure 2.2-1 - Figure 2.2-12 show the maps, grand totals and statistics for reservoirs collected in ESTMAP (subsurface and above ground domain).

Lakes for pumped hydro storage are the most frequent reservoir type in the database (~ two thirds of the total dataset, see Figure 2.2-1). The countries with most realisable potential sites (> 100, Figure 2.2-2) are the UK, France, Germany, Norway, Italy Turkey, Spain and Switzerland (for the last two no public data were available to ESTMAP and therefore represented with value 0 in Figure 2.2-2). All sites include estimated operational capacity indicators including lake volumes, elevation differences and energy storage capacities (Figure 2.2-11). Sites are either defined as two existing nearby (<10 km) lakes or as one existing lake with a nearby (<10 km) option to develop a new lake. Theoretical potential (distances > 10 km, limited elevation differences, surface restrictions, etc.) is not included (data is reported in JRC-2013, but not publicly available).

Aquifers are a common and widely distributed reservoir type across Europe (Figure 2.2-3). About half of the sites in ESTMAP have defined site-specific potential (Figure 2.2-11). For these entries, there is in many cases a relatively good indication of capacity available (e.g. total or working gas volume, thermal energy storage capacity, Figure 2.2-12). The other half concerns regional formations without definitions of site-specific potential and capacities. Particularly in this case,

capacity estimations are mostly lacking, or are specified to a very limited extent (area-thickness). These aquifers can be regarded as focus areas for further investigation and confirmation of realisable potential (regional and site-specific subsurface evaluations). The key target storage technology for aquifers is UGS (most common existing development option, Figure 2.2-10) with UTES as a second most occurring technology. Often HES is mentioned as a scope for further investigation on the basis of generic geological criteria. Besides energy storage, the aquifers are often also targets for CO_2 storage.

Storage potential in **hydrocarbon reservoirs** is also widely distributed with most sites being identified in the Netherlands, Germany, Poland and Austria (Figure 2.2-4). The dominant storage technology is UGS (>30% is either developed or planned for development, Figure 2.2-10). HES is considered a good alternative but the suitability strongly relies on the sealing capacity (a major scope of investigation and research for this technology). Almost half of the sites have relatively good indications of capacity available (e.g. total or working gas volume, Figure 2.2-12). The other half is lacking capacity specifications, which is probably due to confidentiality issues.

Salt formations and associated **salt caverns** are in particular key targets for UGS, HES and CAES (Figure 2.2-10). The overall good suitability lies in the possibility to specifically engineer caverns for the storage purpose, the options for scaling-up the storage capacity (i.e. multiple caverns), the very good sealing capacity of salt and the possibility to achieve very high input/output rates. The downside is that the potential for developing salt caverns strongly relies on local subsurface conditions (a.o. presence of sufficiently thick, homogeneous salt formations of appropriate quality, within depth range of ~300 – 2000m) that are less widely distributed across Europe. Especially in Germany there are many salt structures which have been identified (Figure 2.2-5) after comprehensive regional mapping and assessment studies. UGS is the technology that has been most commonly implemented up to now (Figure 2.2-10). Database entries are mostly local-defined and include, in most cases, good capacity indications (gas working volumes, cavern volumes, Figure 2.2-12). The regional-defined formations still depend on further identification and confirmation of suitable sites.

Rock formations and **rock caverns** are only sparsely defined as suitable options for energy storage across Europe (Figure 2.2-7 and Figure 2.2-8). One reason might be that the development of rock caverns is costly and sometimes technically challenging and that the evaluation of this potential is still lacking or pre-mature. As exception, data from Norway includes many rock formations which are used for UTES (Figure 2.2-10). Associated capacities are mostly well defined (thermal energy storage capacity, Figure 2.2-12). Rock caverns are occasionally developed for UGS. Depending on the natural subsurface conditions, there might be scope to perform further regional subsurface evaluations and extend the current potential included in ESTMAP.

Abandoned mines are considered potential candidates for energy storage in several countries, with Czech Republic and Finland on the top with regard to provided amount of data (Figure 2.2-9). The overall level of assessment is still very pre-mature (suitability is theoretically assumed and has to be confirmed by further subsurface assessment, Figure 2.2-11). Parameters for capacity estimation are mostly lacking (Figure 2.2-12). Mines are mainly considered for UTES development (there are two known existing operational sites in Europe, Figure 2.2-10).

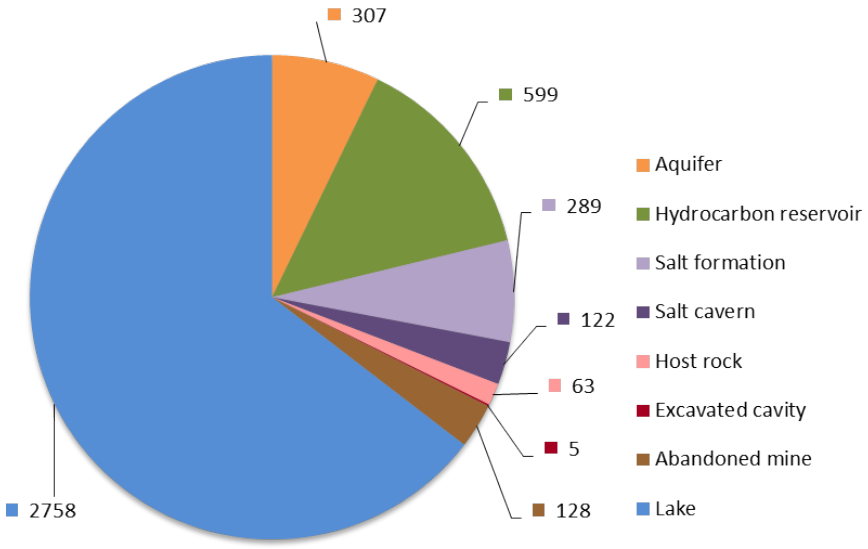

Figure 2.2-1: Number of energy storage reservoir types contained in the database (entire database)

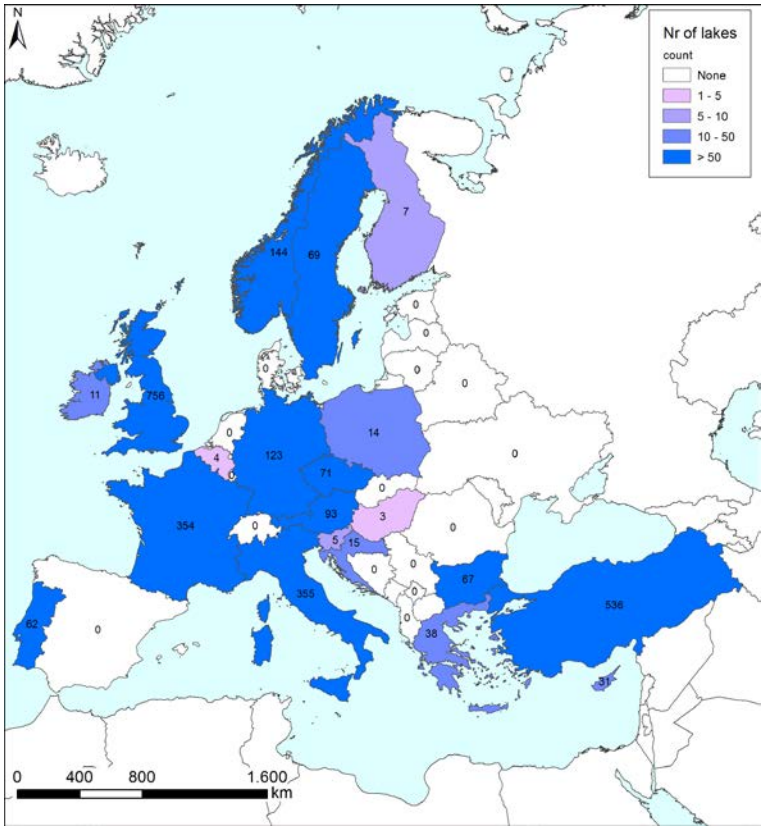

Figure 2.2-2: Number of above ground lakes (for pumped hydro storage) per country included in the ESTMAP database

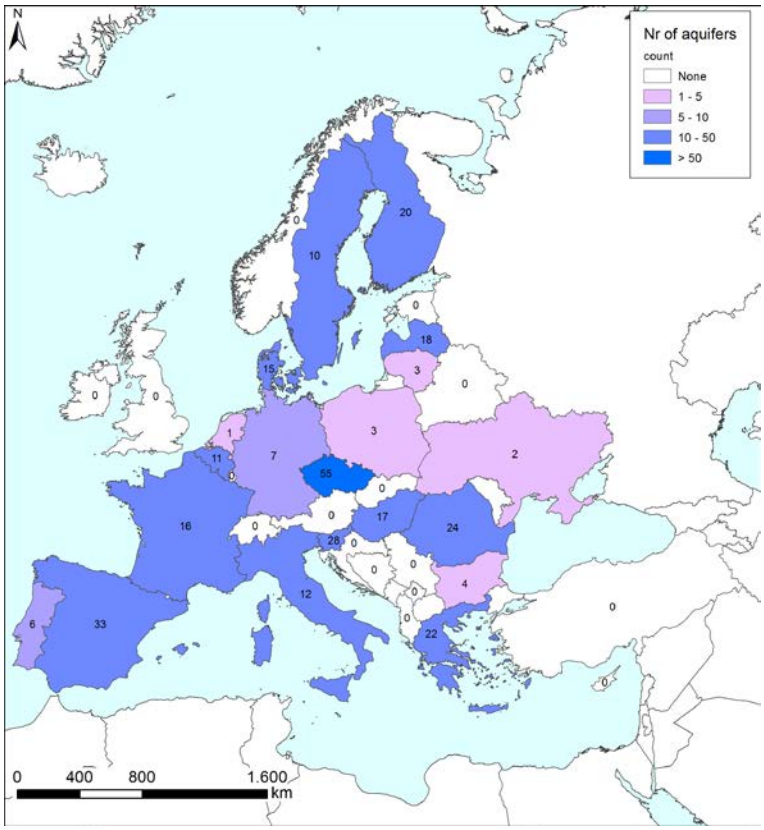

Figure 2.2-3: Number of subsurface aquifers per country included in the ESTMAP database

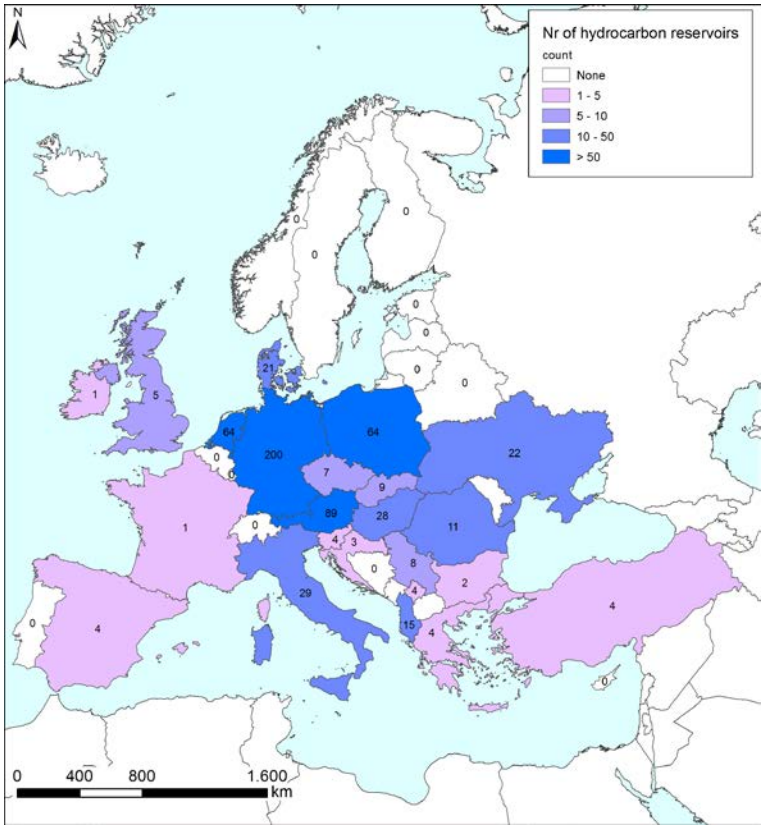

Figure 2.2-4: Number of subsurface hydrocarbon reservoirs per country included in the ESTMAP database

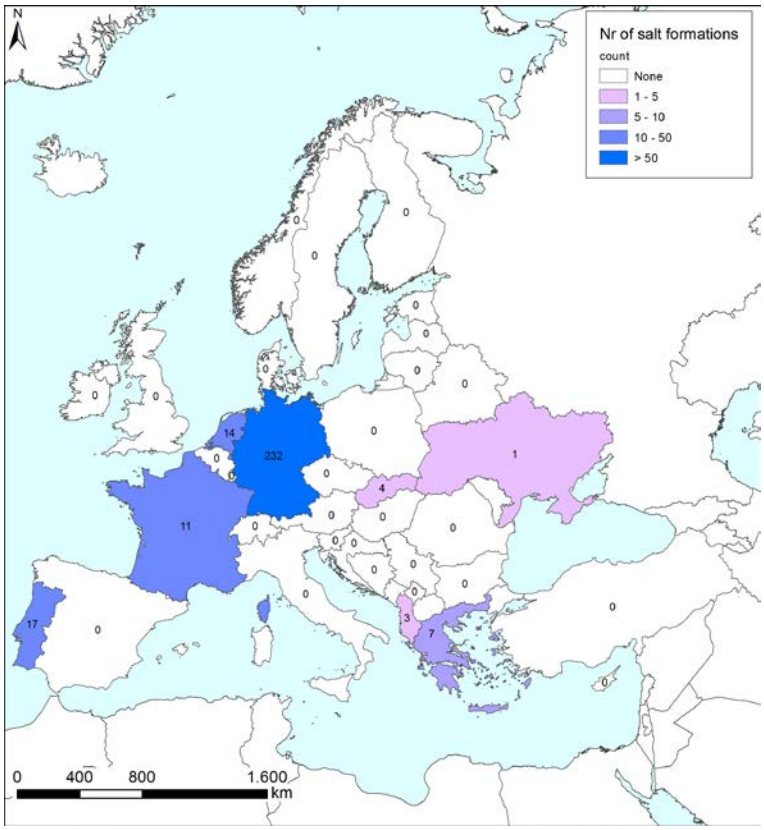

Figure 2.2-5: Number of subsurface salt formations per country included in the ESTMAP database

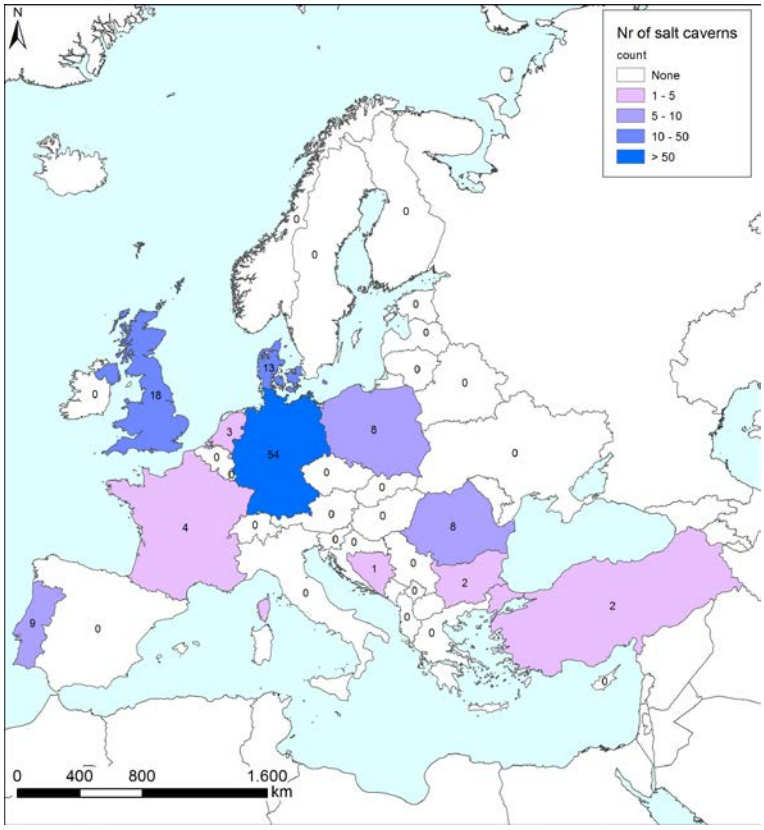

Figure 2.2-6: Number of subsurface salt caverns per country included in the ESTMAP database

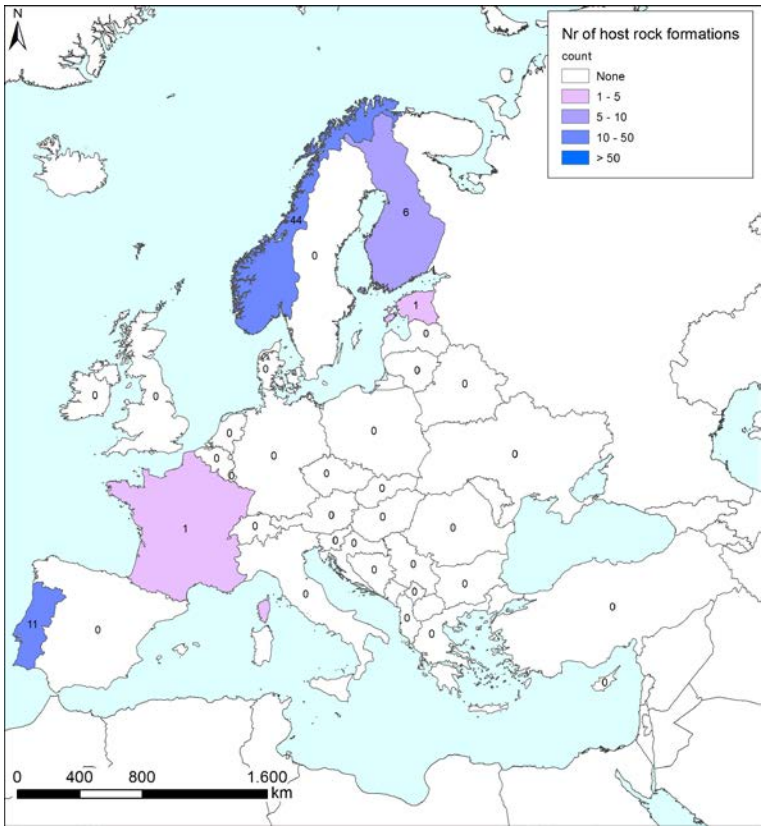

Figure 2.2-7: Number of subsurface host rock formations per country included in the ESTMAP database

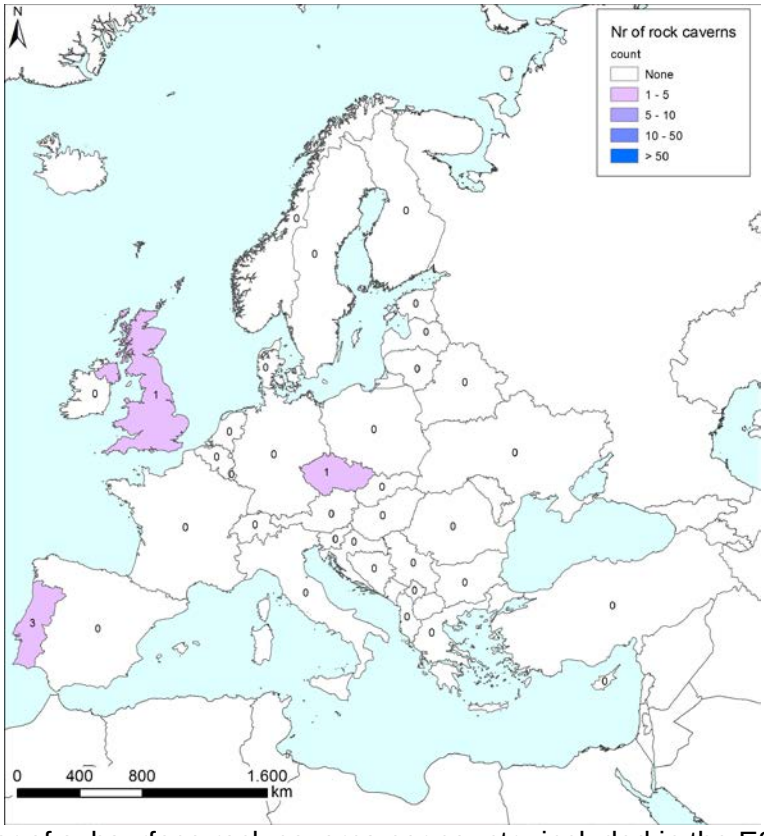

Figure 2.2-8: Number of subsurface rock caverns per country included in the ESTMAP database

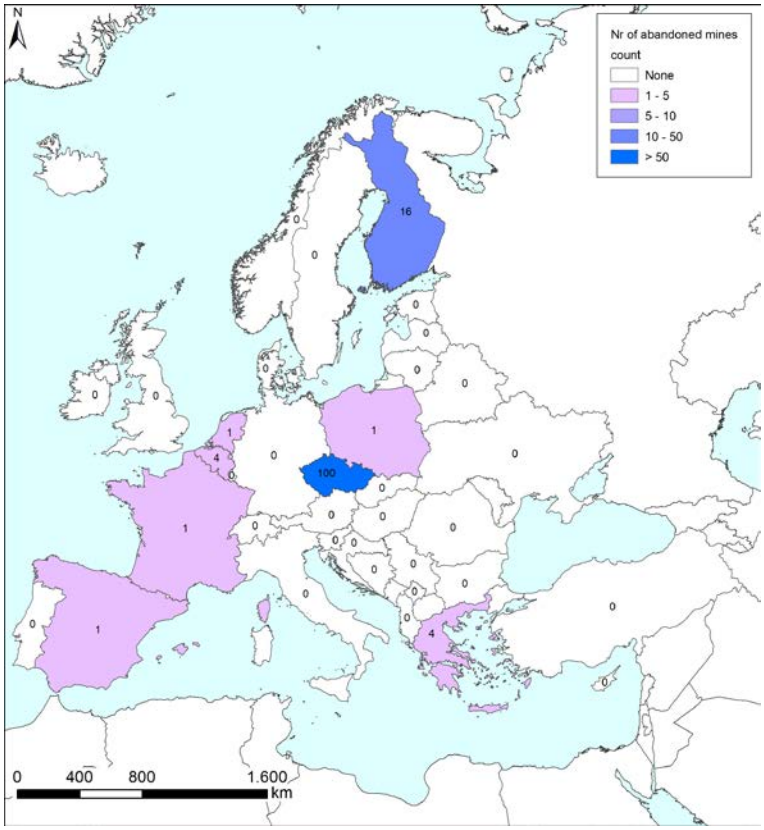

Figure 2.2-9: Number of subsurface abandoned mines per country included in the ESTMAP database

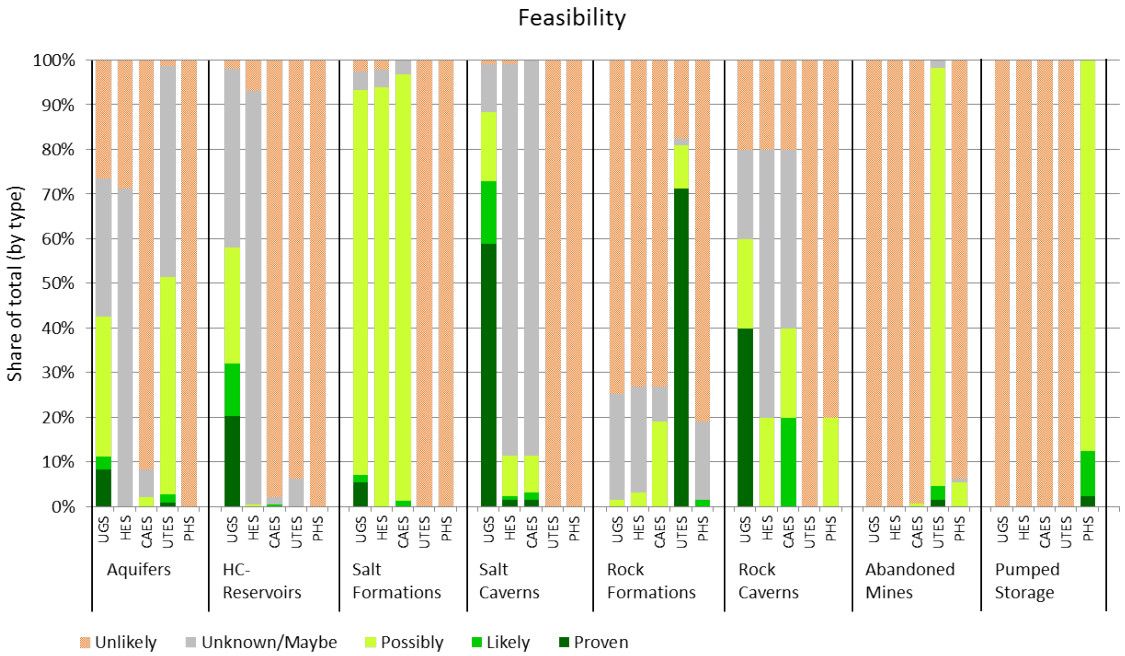

Figure 2.2-10: Feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type (entire database) . Classes are explained in Paragraph 1.2

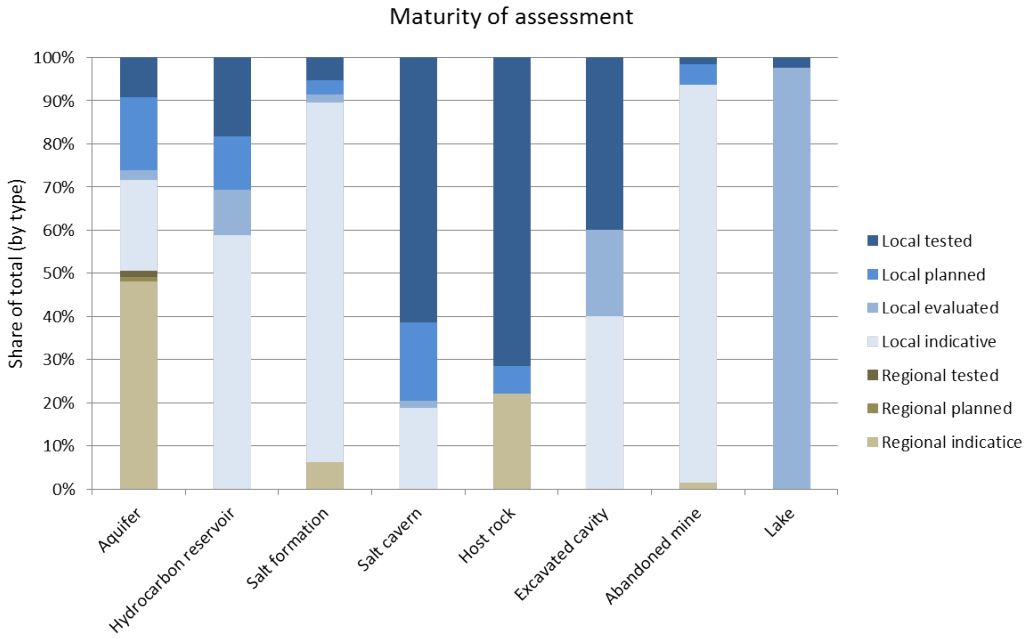

Figure 2.2-11: Maturity of assessment for each reservoir category (entire database) . Classes are explained in Paragraph 1.2

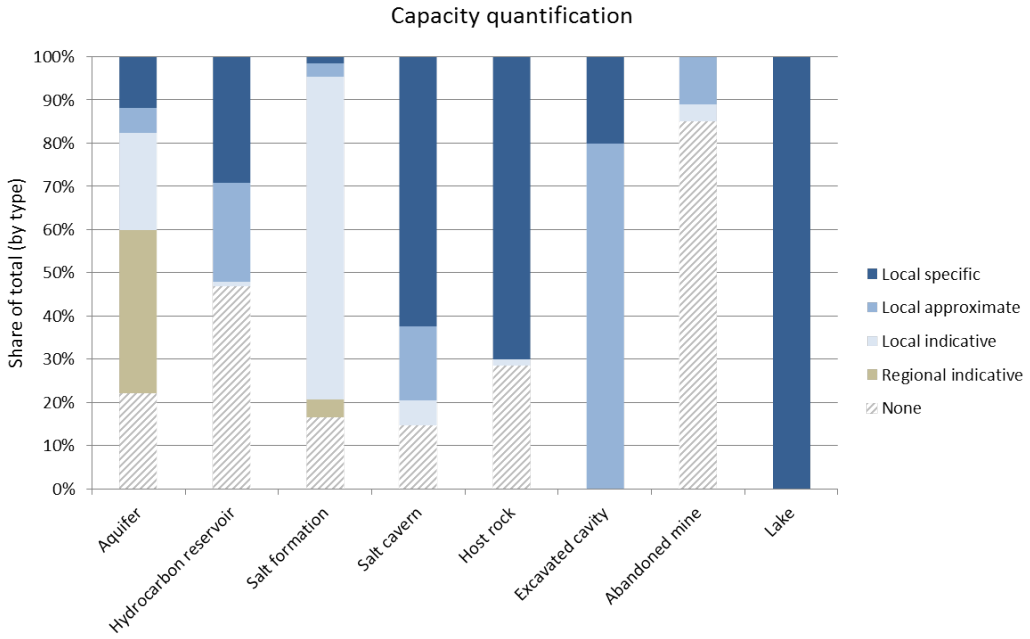

Figure 2.2-12: Quality of capacity determination for each reservoir category (entire database) . Classes are explained in Paragraph 1.2

3. Country Data Reports

In the following paragraphs the data and energy storage potential are discussed for each country.

3.1. Albania

3.1.1. Provider administration

Main providing organisations subsurface storage information:

AGS – Albanian Geological Survey
Subcontractor
Contact Person: Dr. Arben Pambuku

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.1.2. Main data sources

Table 3.1-1: List of common sources used

Source name / URL	Description	Version / Date
National Agency of National Resources	Literature sources	2015-
Albanian Geological Survey	Literature sources	April 2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.1.3. Storage Data Review Albania

The only reservoir types obtained for Albania are hydrocarbon fields (oil, gas and mixed) and some salt formations. Reservoirs are local-defined with approximate capacity determinations (total volumes). All hydrocarbon fields and one salt structure are already planned for UGS development. Besides these reservoirs, no further information regarding additional future geological potential was available to ESTMAP. More broadly oriented and in-depth geological evaluation may eventually reveal this (e.g. aquifers). Albania was not included in the JRC-2013 pumped hydro storage assessment, but considering the hilly to mountainous landscape this potential is expected to be present.

Table 3.1-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Main reservoir type for Albania. Local-defined with approximate capacity determination (total gas volume). All sites are already planned for UGS and theoretically may represent alternative potential for HES	Confirm operational UGS capacities and performance. Investigate and assess alternative potential including HES. Regional exploration may reveal other trapped structures.
Salt formations and caverns	Three local-defined salt formations[2] with approximate capacity determination (estimated total gas volume). One site is already planned for UGS, others unknown are unknown. May represent additional potential for HES and CAES.	Confirm local suitability for cavern development and storage. Mature capacity and performance determinations. Investigate and assess HES and CAES potential. Regional mapping to reveal additional prospective sites.
Host rock, caverns, mines	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Albania was included in the JRC-2013 assessment report, but these data were not publicly available. Albania has relatively good realisable potential for PHS development including options based on two existing nearby lakes.	Include PHS assessment data once publicly available

[2] Reservoir type of two salt formations near Peshkopi is ambiguous (originally entered as depleted reservoir, but lithology suggests it is a salt formation)

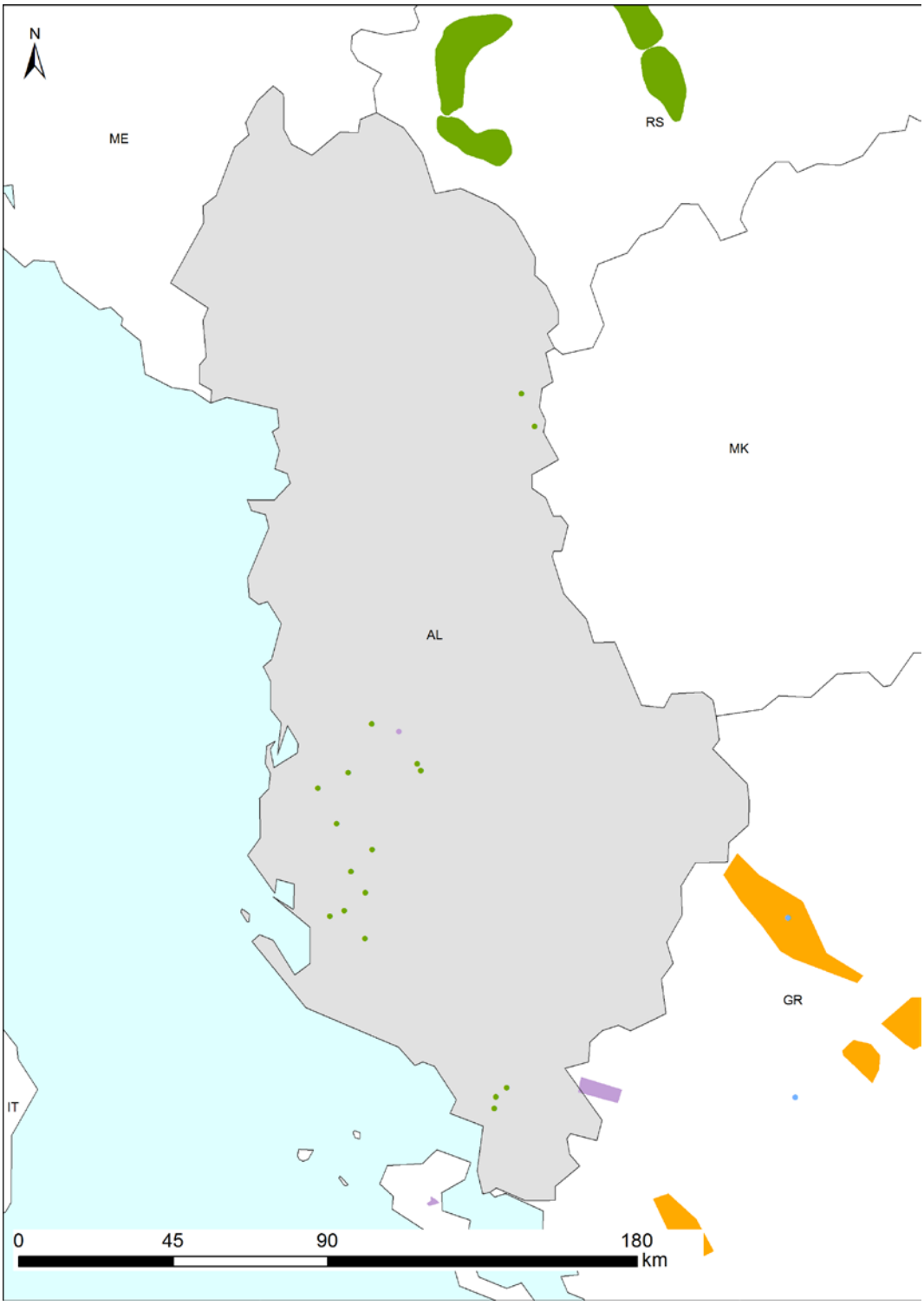

Figure 3.1-1: Albania - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

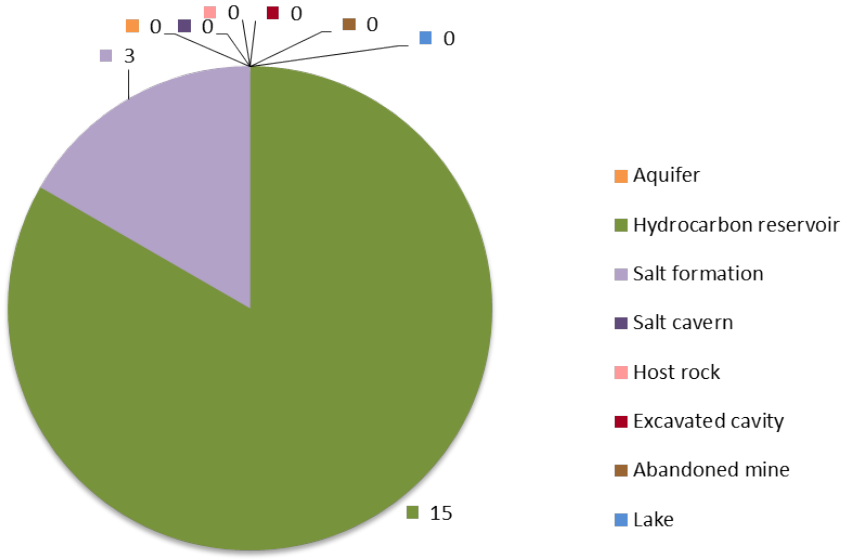

Figure 3.1-2: Albania - Summary of energy storage reservoir types contained in the database

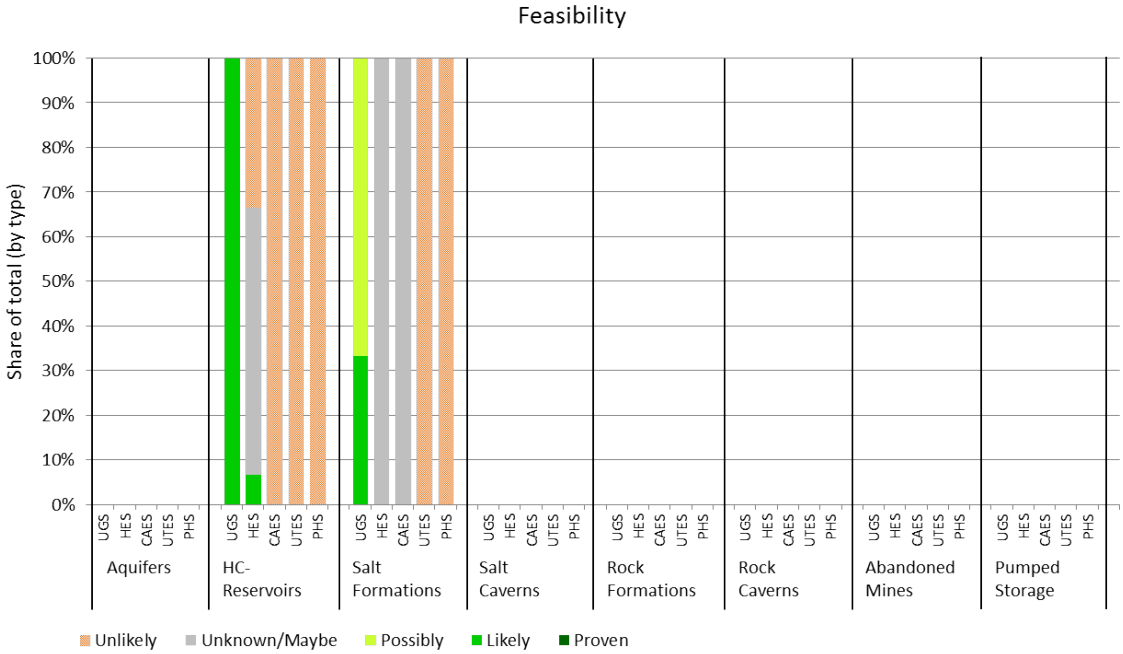

Figure 3.1-3: Albania - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

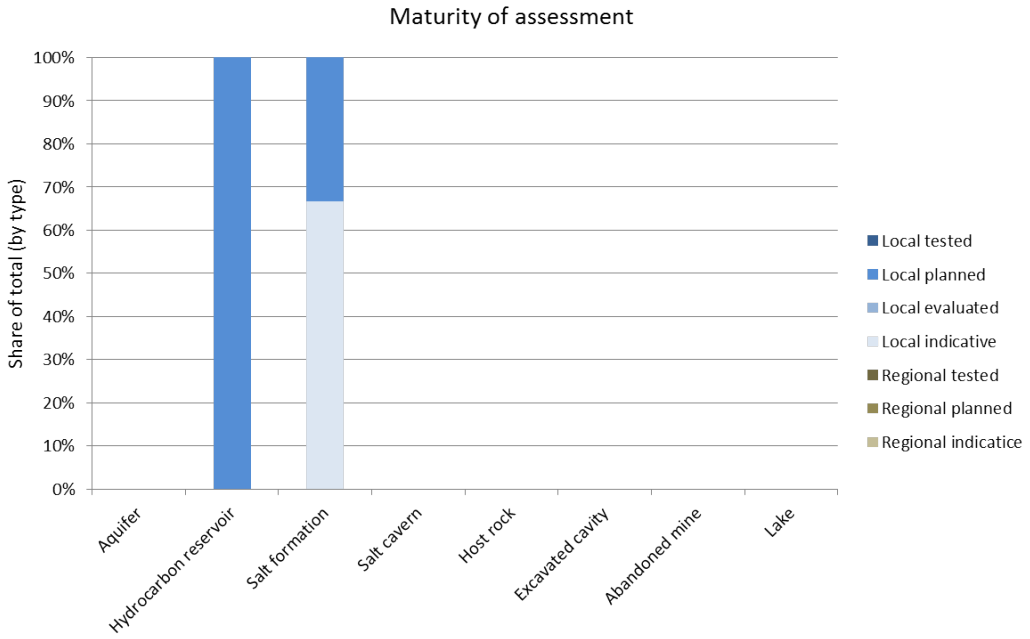

Figure 3.1-4: Albania - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

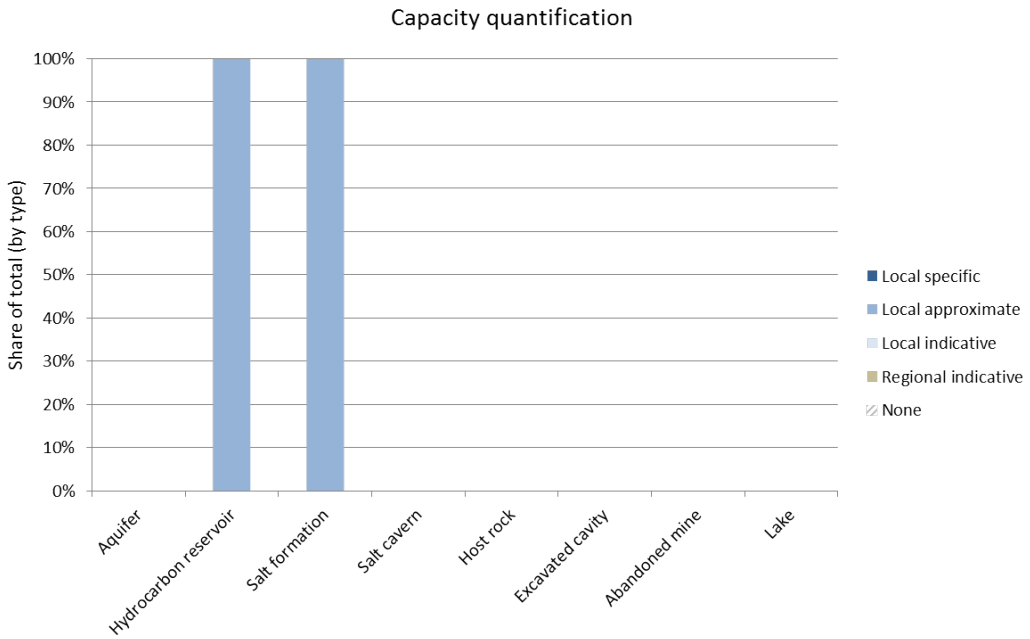

Figure 3.1-5: Albania - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.2. Austria

3.2.1. Provider administration

Main providing organisations subsurface storage information:

GBA – Geologische Bundesanstalt Austria
Subcontractor
Contact Person: Piotr Lipiarski

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.2.2. Main data sources

Table 3.2-1: List of common sources used

Source name / URL	Description	Version / Date
Austrian Mining Yearbook	Reporting of hydrocarbon reserves and resources	2014-
Scharf & Clemens 2006 / Welkenhuysen 2015	Literature sources	2006 / 2015
OMV HP	Operator website	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.2.3. Storage Data Review Austria

The Austrian dataset only considers hydrocarbon reservoirs for subsurface energy storage (key potential for UGS), which are found in the northern and north-eastern region of the country (alpine foreland basin). Potential for storing and generating electrical power is predominantly present and developed in abundant above ground pumped hydro lakes the western and southern regions of the country. Both reservoir types include already developed storages and future potential for new energy storages where the hydrocarbon reservoirs may also represent alternative potential for HES. Additional energy storage potential may be present in other reservoir types, including aquifers and host rock caverns. At the time of the ESTMAP project these potentials were however not available or considered mature enough to be included.

Table 3.2-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Aquifers are however expected to be present in Austria (being part of the Pannonian sedimentary basin)	Investigate scope for further identification of energy potential (e.g. thermal)
Hydrocarbon reservoirs	Abundant in the N and NE parts of Austria. Nine out of 89 are already developed as UGS and have operational capacities (working volumes) defined. The rest may represent future potential for UGS with approximate capacities defined by total gas volumes (suitability to be confirmed). In theory these reservoirs represent alternative options for HES while CAES has not been considered yet.	Confirm suitability for UGS development of undeveloped reservoirs and assess expected operational capacities and performance. Investigate and assess alternative potential including HES. Regional exploration may reveal other trapped structures.
Salt formations and caverns	No entries available in ESTMAP. Some salt formations are mined for mineral resources. Storage potential has not been identified. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Abundant realisable potential for pumped hydro storage is present in Austria (mainly SW and W parts of the country), including options based on two existing nearby lakes. Eight out of 93 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

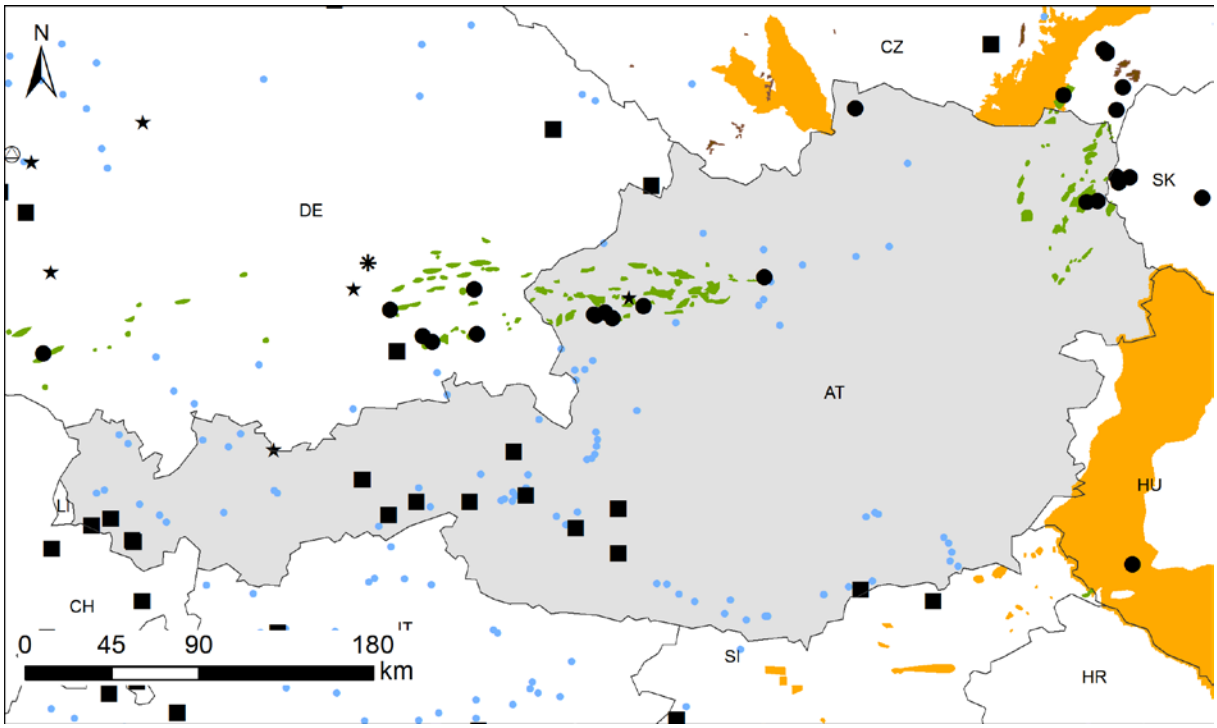

Figure 3.2-1: Austria - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

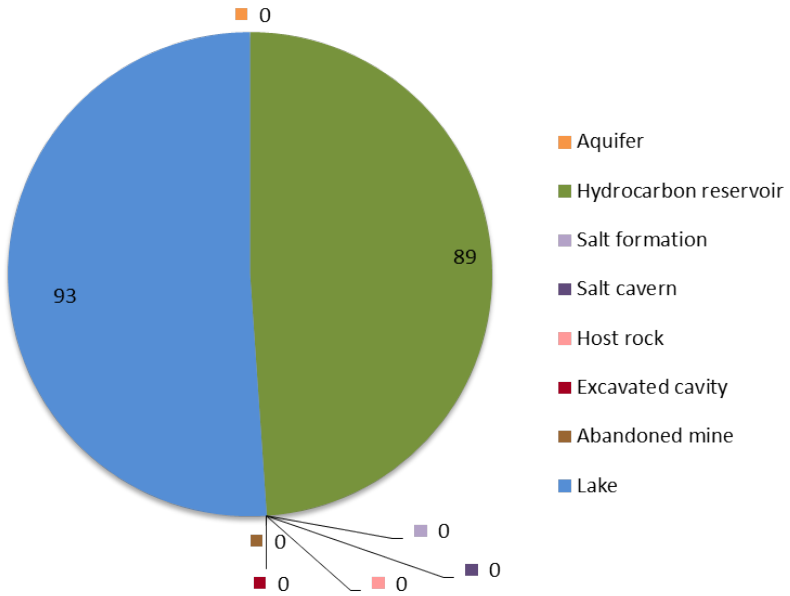

Figure 3.2-2: Austria - Summary of energy storage reservoir types contained in the database

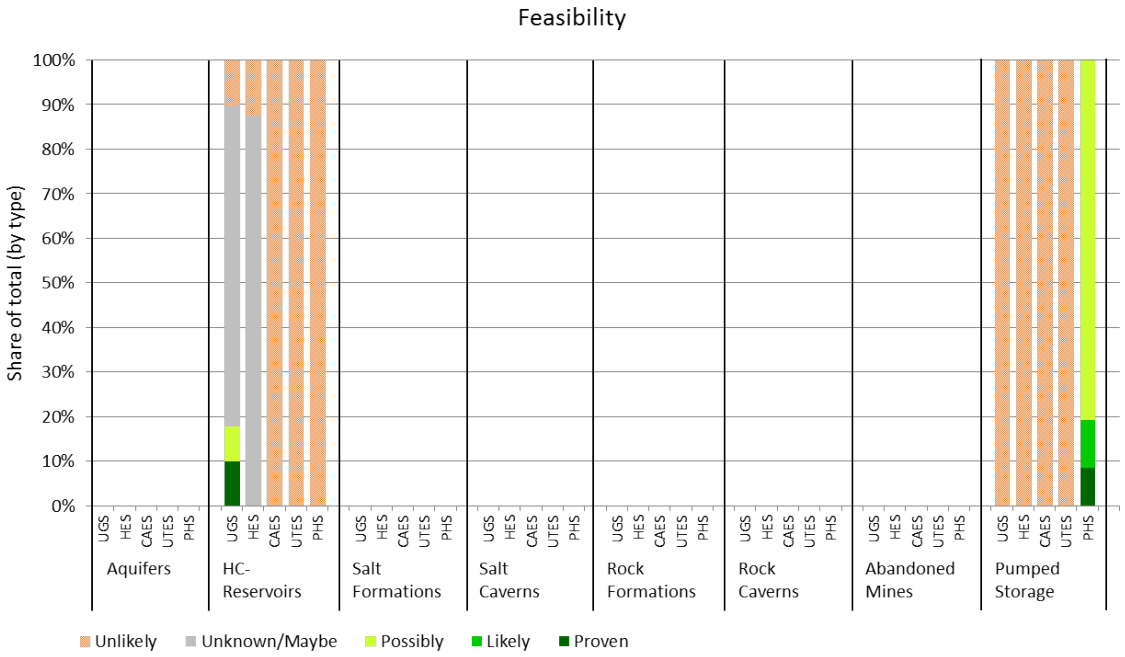

Figure 3.2-3: Austria - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

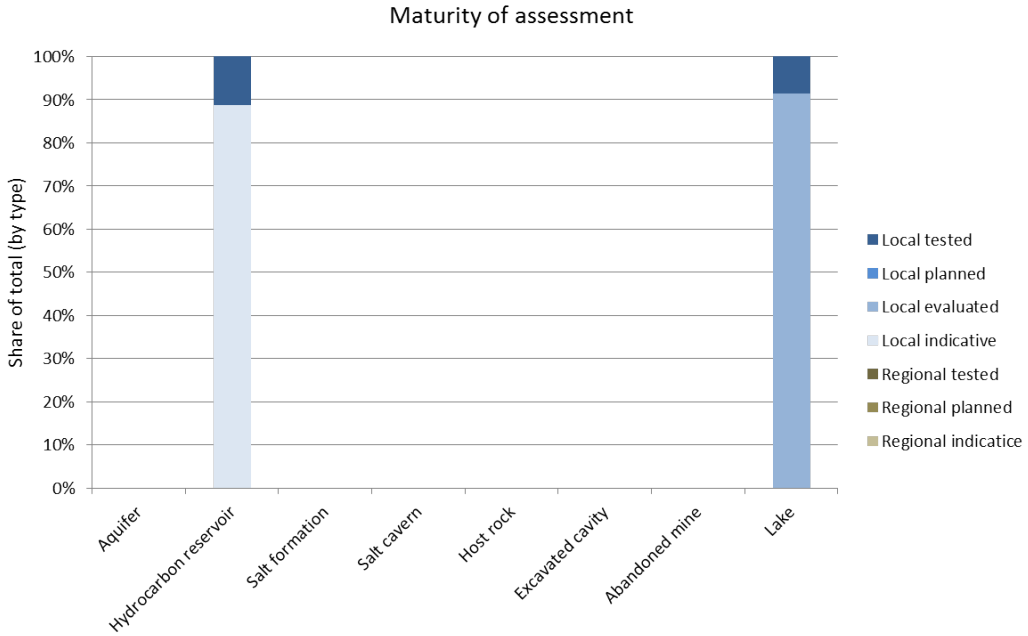

Figure 3.2-4: Austria - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

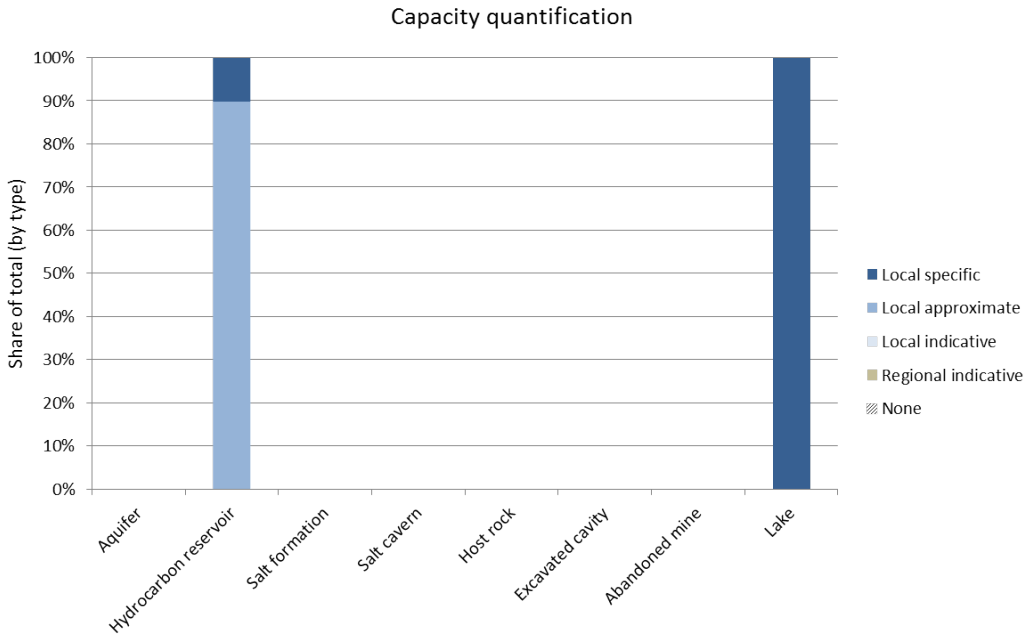

Figure 3.2-5: Austria - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.3. Belgium

3.3.1. Provider administration

Main providing organisations subsurface storage information:

VITO NV
ESTMAP Consortium Partner
Contact Person: David Lagrou

GSB – Royal Belgian Institute of Natural Sciences, Geological Survey of Belgium
Subcontractor
Contact Person: Estelle Petitclerc

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.3.2. Main data sources

Table 3.3-1: List of common sources used

Source name / URL	Description	Version / Date
Various technical reports at VITO	Literature sources, based on assumptions and scattered data	
Various geological data and studies from GSB	Literature, Quick scan, sources, based on assumptions and scattered data	
Report: Développement de la plate-forme Géothermique de la Wallonie" 2011	Literature source	2011
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.3.3. Storage Data Review Belgium

Large parts of Belgium are characterized by regional-defined storage potential in aquifers and mining areas. Main storage technology scope is UTES. One operational UGS is included. Substantial efforts will be needed to further mature and confirm location specific subsurface potential. Above ground pumped hydro storage potential is limited.

Table 3.3-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Aquifers represent the main scope for energy storage. The existing potential is mainly regional-defined and lacking definition of location-specific feasibility and capacities. One local-defined site has been developed for UGS. For the other entries, the primary indicated potential is UTES.	Identification of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Hydrocarbon reservoirs	No entries available in ESTMAP. Belgium has no active oil or gas development.	No scope for future investigation.
Salt formations and caverns	No entries available in ESTMAP. Belgium has no salt formations that allow for development of suitable caverns.	No scope for future investigation.
Host rock, caverns, mines	Several mining areas are regional-defined as theoretical potential. Little information is available to confirm feasibility and capacity. Yet the mines are considered a target for UTES. Three abandoned mines are local-defined, two of which have further matured feasibility and capacity determinations.	Identification of location-specific potential, confirmation of suitability for UTES, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type (e.g. CAES).
Lakes	Belgium has limited realisable potential for PHS development based on one existing and one potential (to be developed) lake. The ESTMAP database included information of two developed hydro power sites. Few additional theoretical options with two lakes or >10km lake separation exist but these are not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

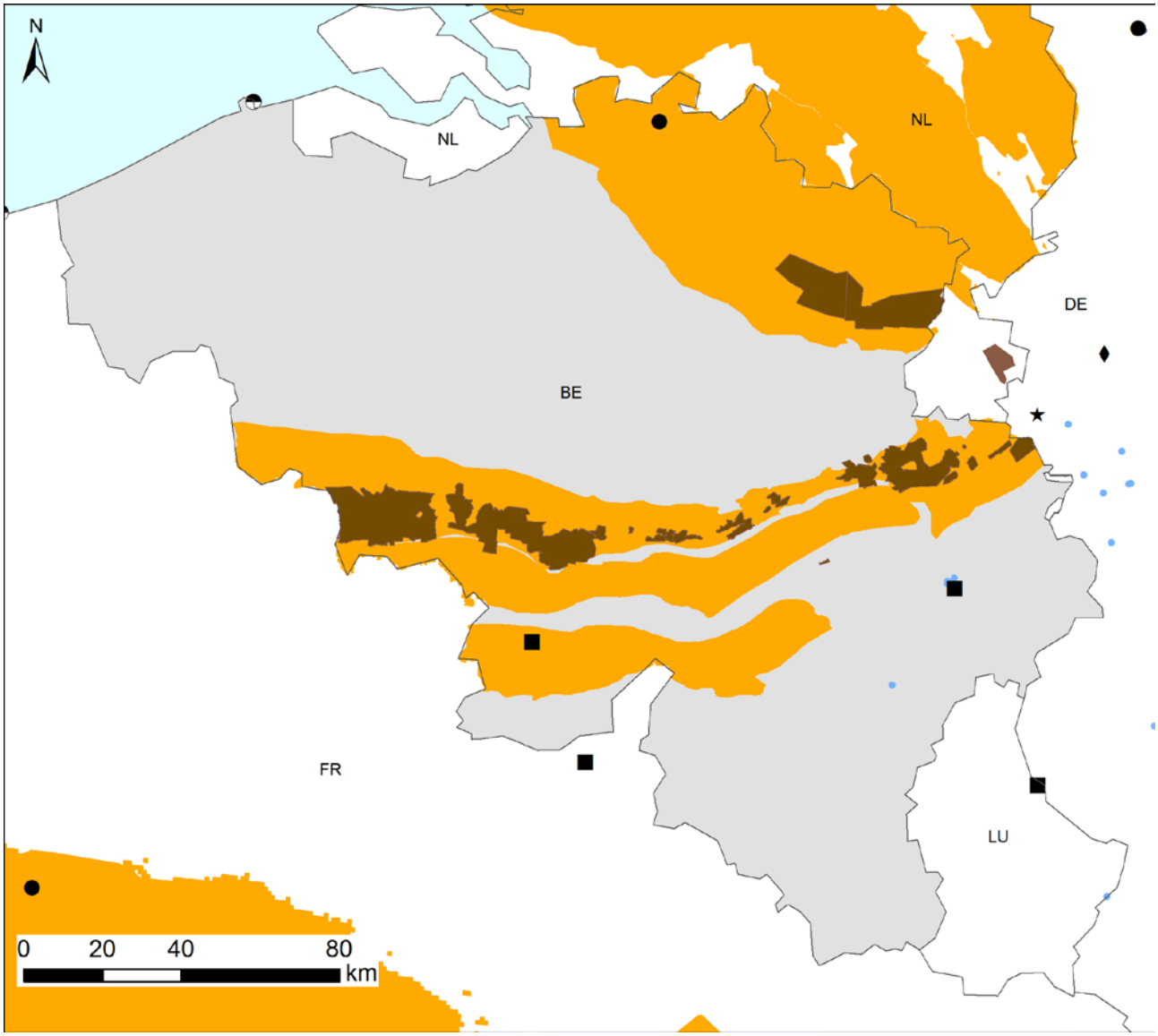

Figure 3.3-1: Belgium - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

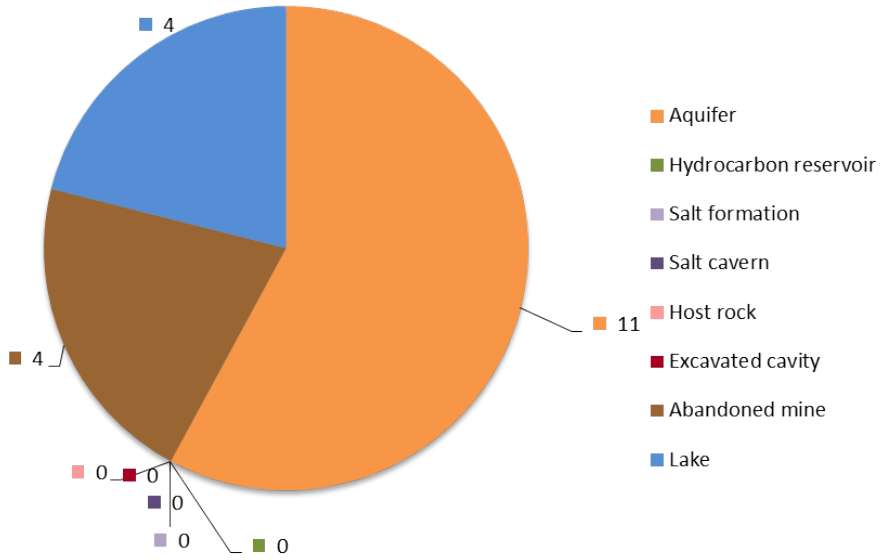

Figure 3.3-2: Belgium - Summary of energy storage reservoir types contained in the database

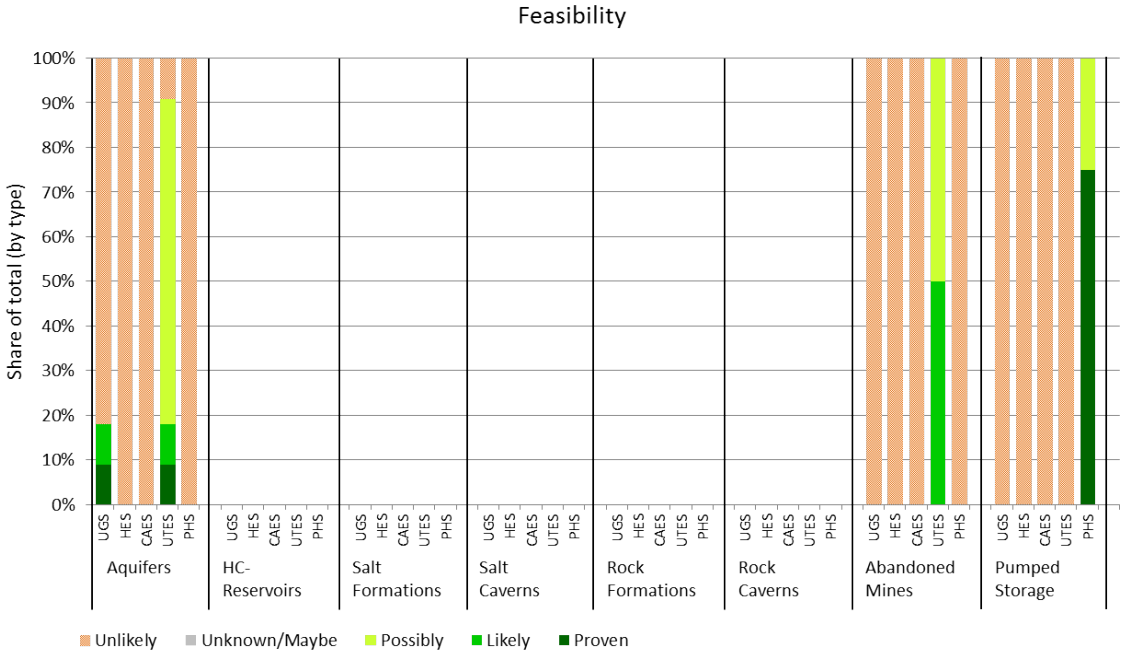

Figure 3.3-3: Belgium - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

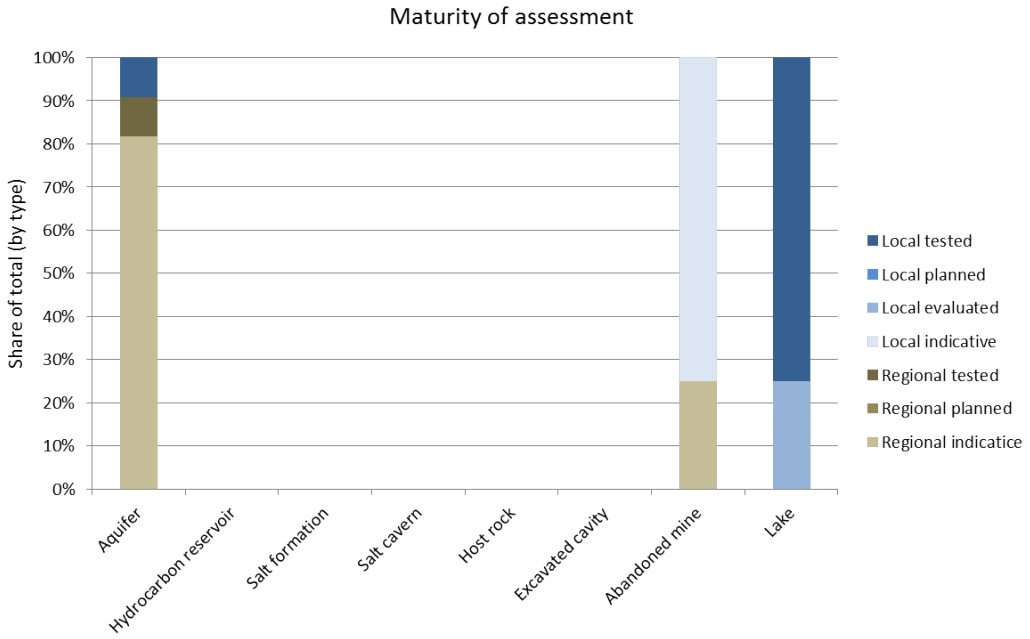

Figure 3.3-4: Belgium - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

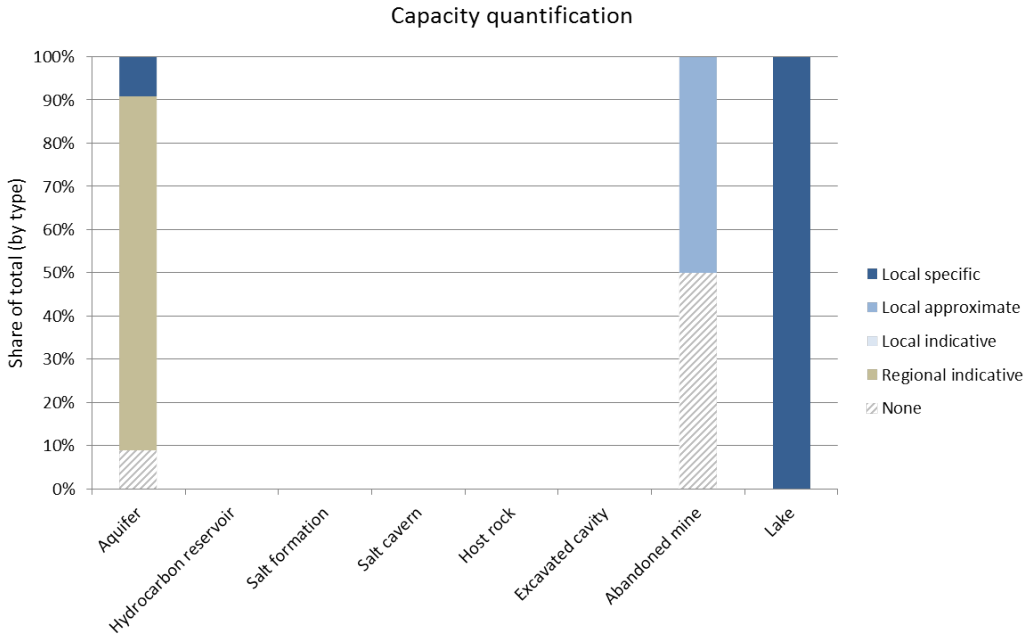

Figure 3.3-5: Belgium - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.4. Bosnia-Herzegovina

3.4.1. Provider administration

Main providing organisations subsurface storage information:

UNTZ– University of Tuzla
Subcontractor
Contact Person: Sanel Nuhanovic

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.4.2. Main data sources

Table 3.4-1: List of common sources used

Source name / URL	Description	Version / Date
Operator: Salt mine Tuzla, copartnership Tuzla	Technical documentation of salt pit "Tetima" Tuzla	

3.4.3. Storage Data Review Bosnia-Herzegovina

The energy storage potential for Bosnia and Herzegovina in ESTMAP is limited to only one currently producing salt mine near Tuzla. Caverns are likely to represent potential for UGS, HES and CAES. The data provider has also indicated potential for oil storage and heat storage. Bosnia and Herzegovina was not included in the JRC-2013 pumped hydro storage assessment, but considering the hilly to mountainous landscape this potential is expected to be present. No hydro pumped hydro storage development is known to exist.

Table 3.4-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential in this reservoir type
Hydrocarbon reservoirs	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential in this reservoir type
Salt formations and caverns	One main salt production site included in ESTMAP which is likely to represent potential for UGS, HES and CAES. Estimates for specific operational capacities (working gas volumes) are provided for all three options.	Confirm local suitability for cavern development and storage and further mature capacity and performance determinations. Regional mapping might reveal additional prospective sites in salt formations.
Host rock, caverns, mines	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Bosnia and Herzegovina was included in the JRC-2013 assessment report, but these data were not publicly available. Bosnia and Herzegovina has potential for PHS, but only very limited regarding the option of two existing lakes.	Include PHS assessment data once publicly available

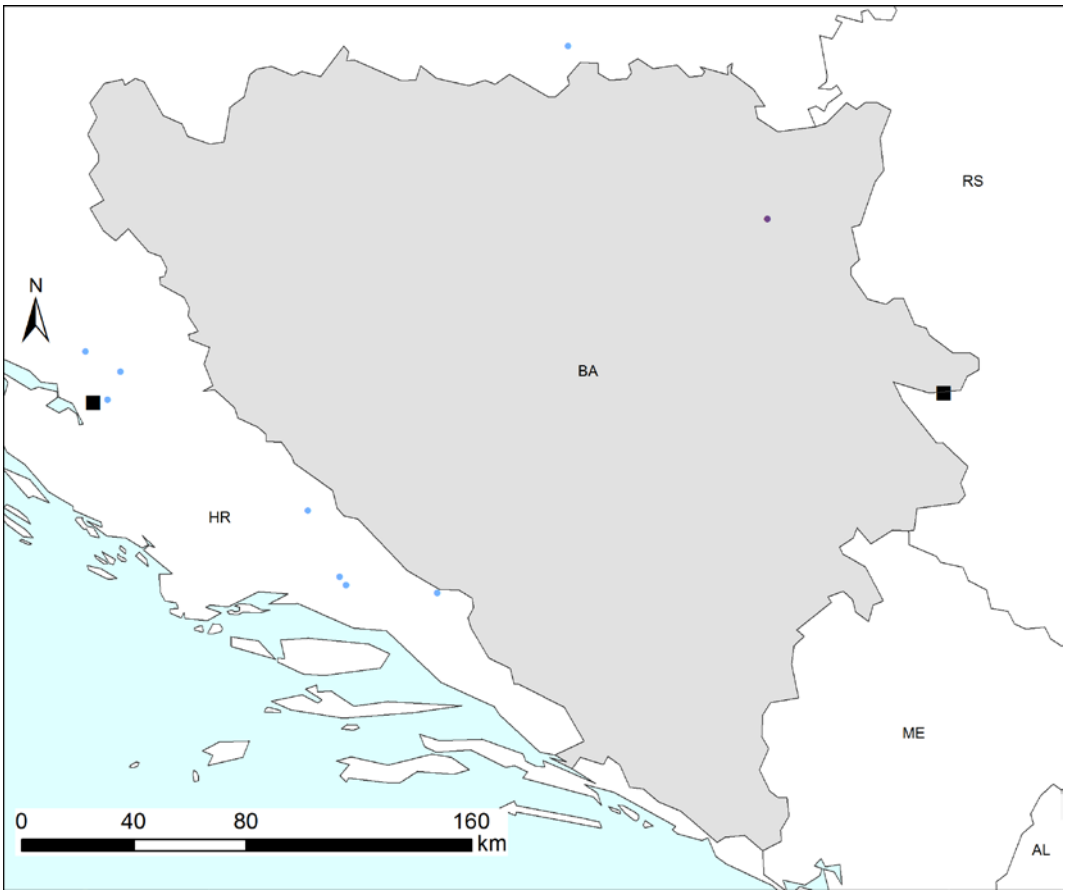

Figure 3.4-1: Bosnia-Herzegovina - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

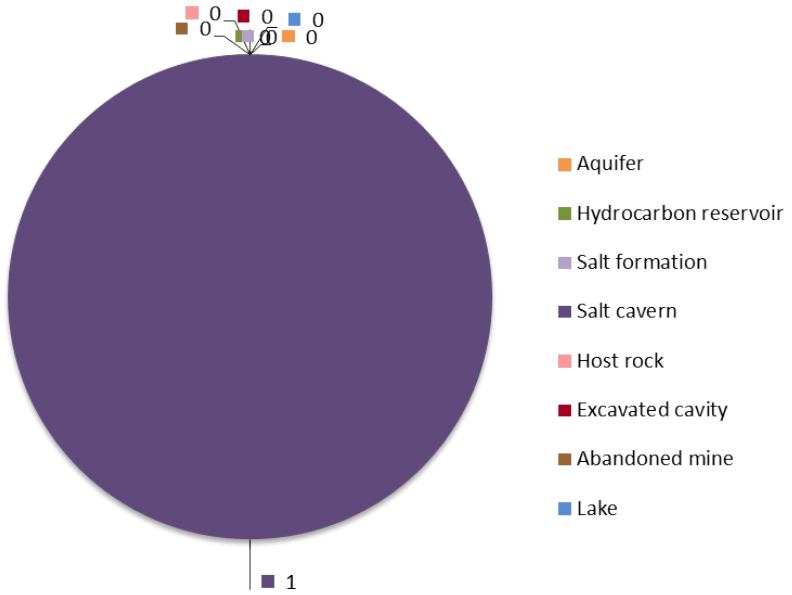

Figure 3.4-2: Bosnia-Herzegovina - Summary of energy storage reservoir types contained in the database

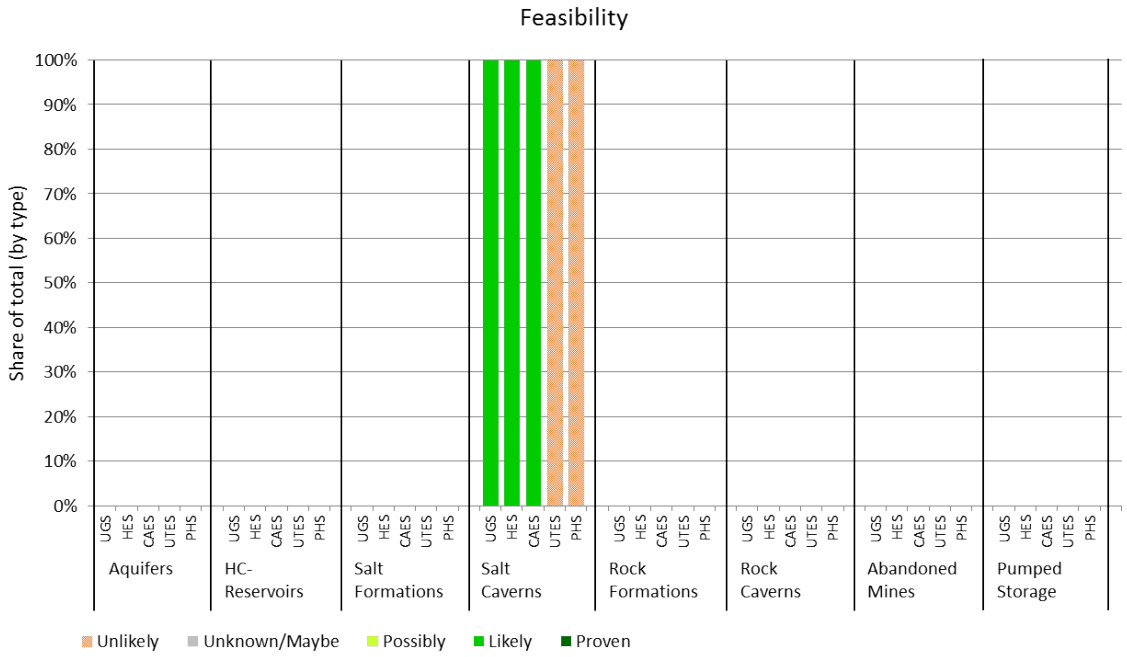

Figure 3.4-3: Bosnia-Herzegovina - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

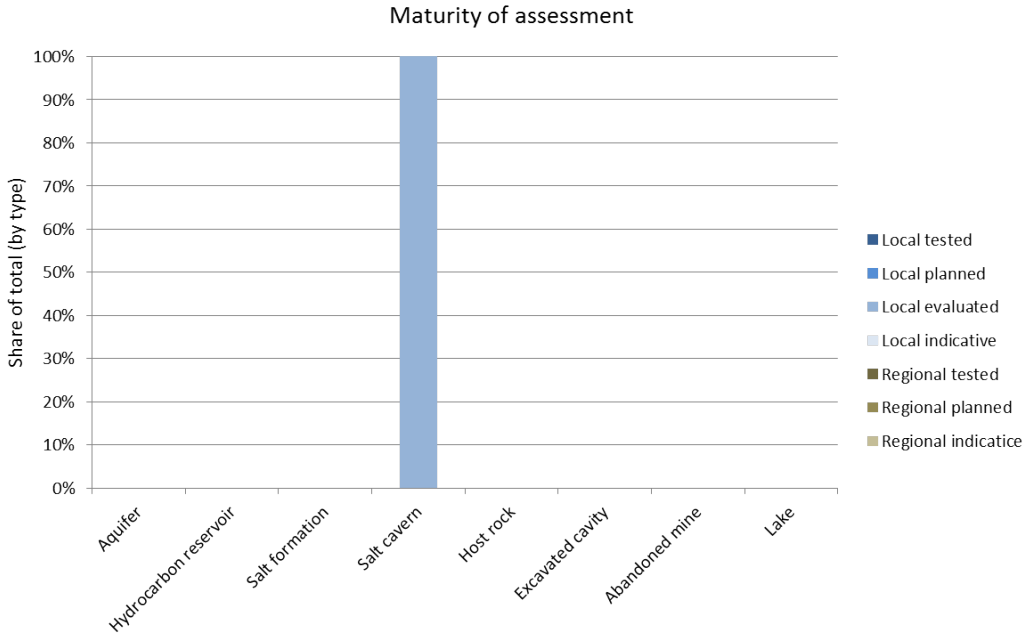

Figure 3.4-4: Bosnia-Herzegovina - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

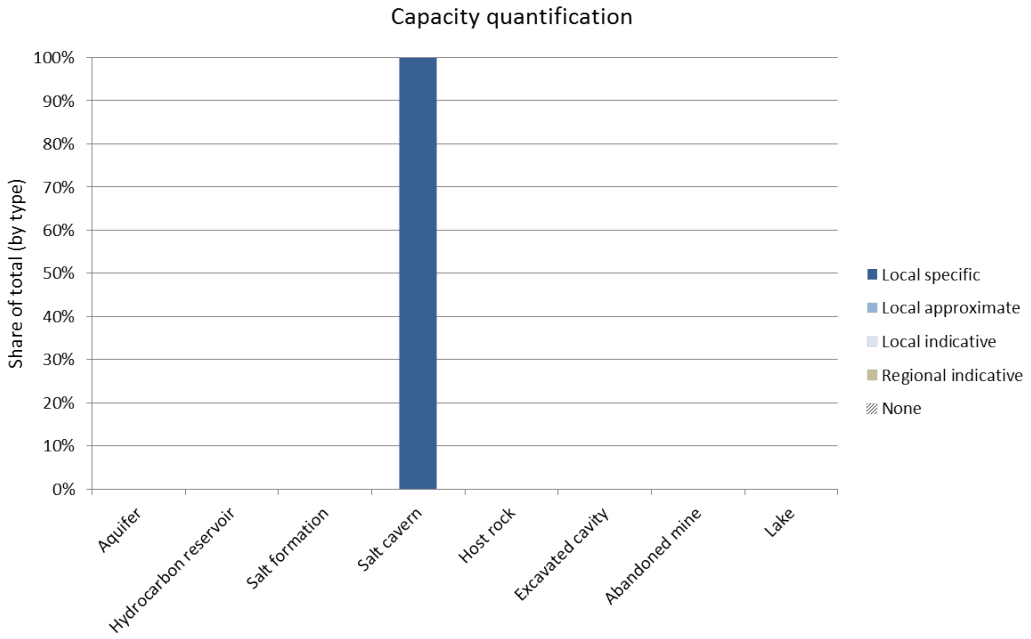

Figure 3.4-5: Bosnia-Herzegovina - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.5. Bulgaria

3.5.1. Provider administration

Main providing organisations subsurface storage information:

GGF – Sofia University
Subcontractor
Contact Person: Prof. Dr. Georgi Georgiev

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.5.2. Main data sources

Table 3.5-1: List of common sources used

Source name / URL	Description	Version / Date
Various surveying and operator Reports	Literature sources	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.5.3. Storage Data Review Bulgaria

Energy storage potential in Bulgaria is mostly defined in pumped storage lakes (PHS). Only few subsurface sites are included, almost all of which are already either developed or planned for energy storage. Capacity parameters are well specified but no GIS information regarding the geographical extent is available (only centre points). There may be scope for future geological research to reveal more prospective sites (e.g. regional mapping of aquifers).

Table 3.5-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Four aquifer sites are included as potential storage sites for UGS, HES or UTES. From these UGS appears the be the main target technology. The aquifers are regional-defined but the exact extent is unknown as more detailed geographical data were unavailable to ESTMAP. Estimations for local-defined working gas volumes are provided.	Improve geological definition of the aquifers in ESTMAP. Further identification and Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate additional potential in this reservoir type (geological mapping and reconnaissance).
Hydrocarbon reservoirs	Two hydrocarbon reservoirs are included in ESTMAP, one of which is developed as UGS and the other being planned for UGS expansion. Feasibility is locally determined and characterized by concrete operational capacities (gas working volumes). In theory both sites could also represent potential for HES but this is still unconfirmed. No additional storage potential is foreseen in this type of reservoir.	No or limited scope for future investigation, depending on future exploration activities..
Salt formations and caverns	Two nearby caverns are considered potential targets for UGS, HES or CAES (one being actively produced for salt). For one of the caverns the feasibility is confirmed. The other has indicated feasibility. Capacities are specified at operational level (expected gas working volumes). It is unknown whether Bulgaria houses more salt formations that could be represent scope for future storage assessment.	Further identification and Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate additional potential in this reservoir type (geological mapping and reconnaissance).
Host rock, caverns, mines	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Bulgaria has abundant realisable potential for pumped hydro storage, which is predominantly based on one existing and one (to be developed) lake. Two out of 67 sites in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

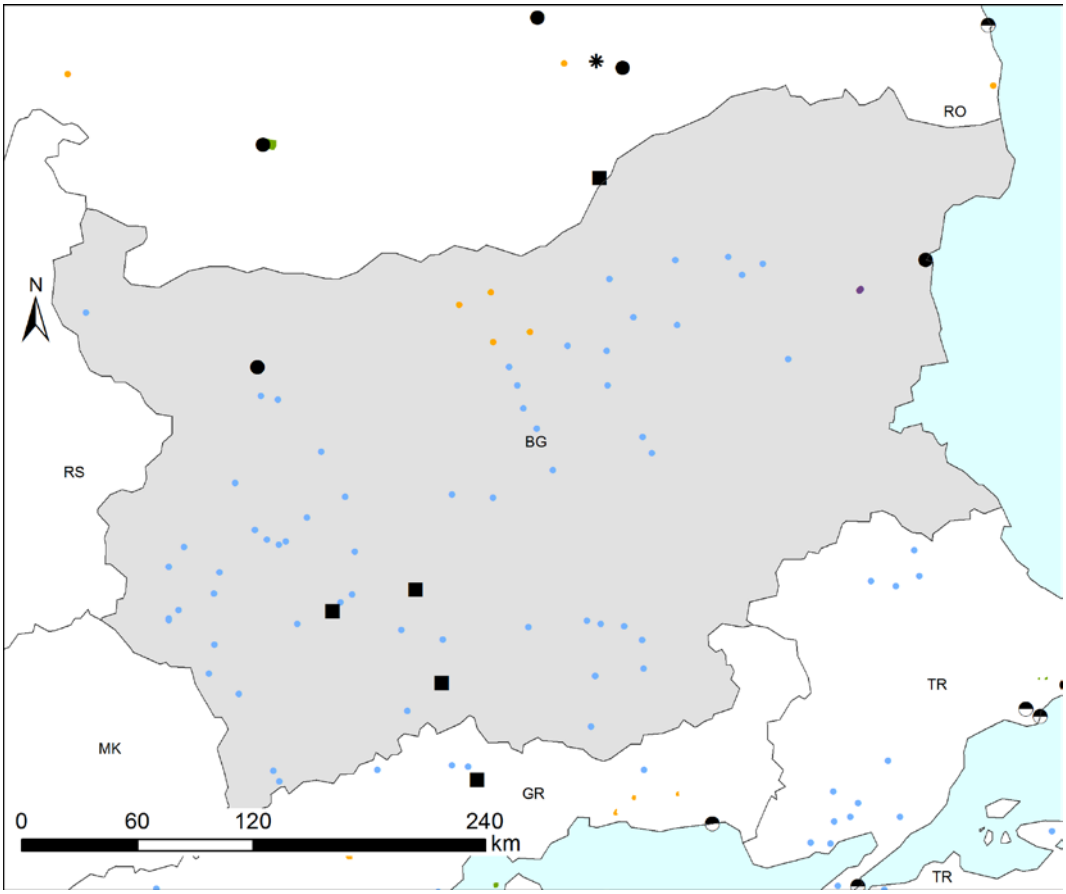

Figure 3.5-1: Bulgaria - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

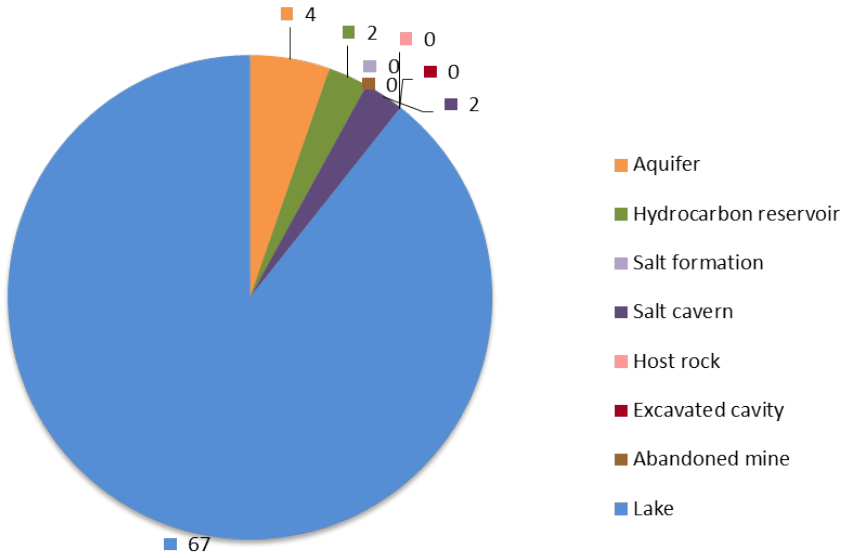

Figure 3.5-2: Bulgaria - Summary of energy storage reservoir types contained in the database

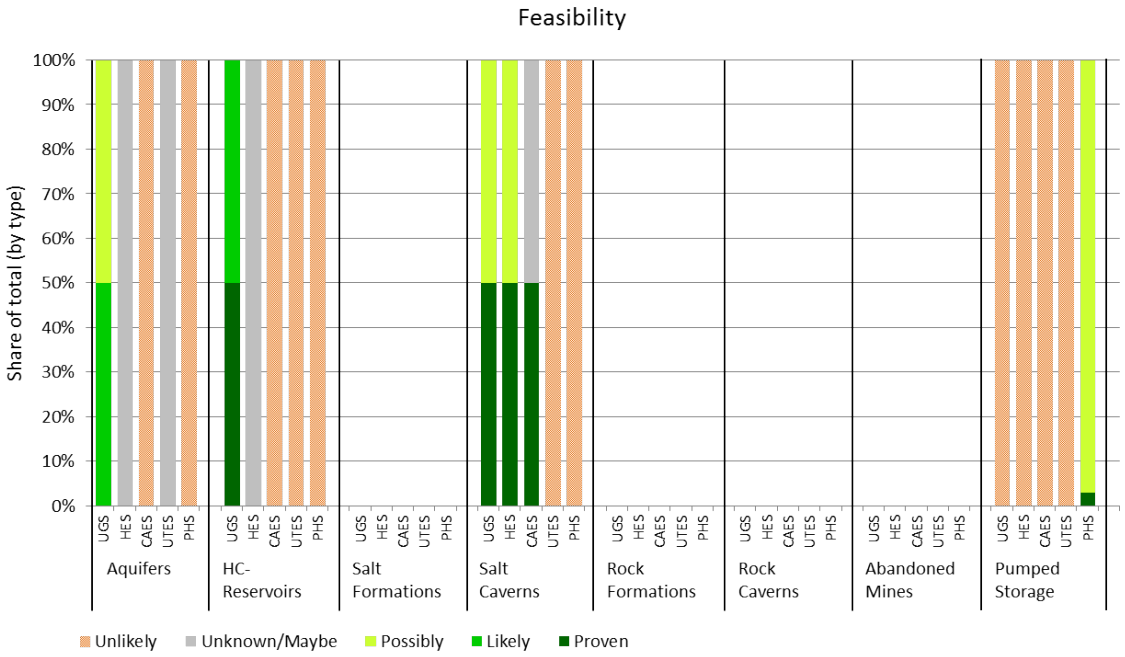

Figure 3.5-3: Bulgaria - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

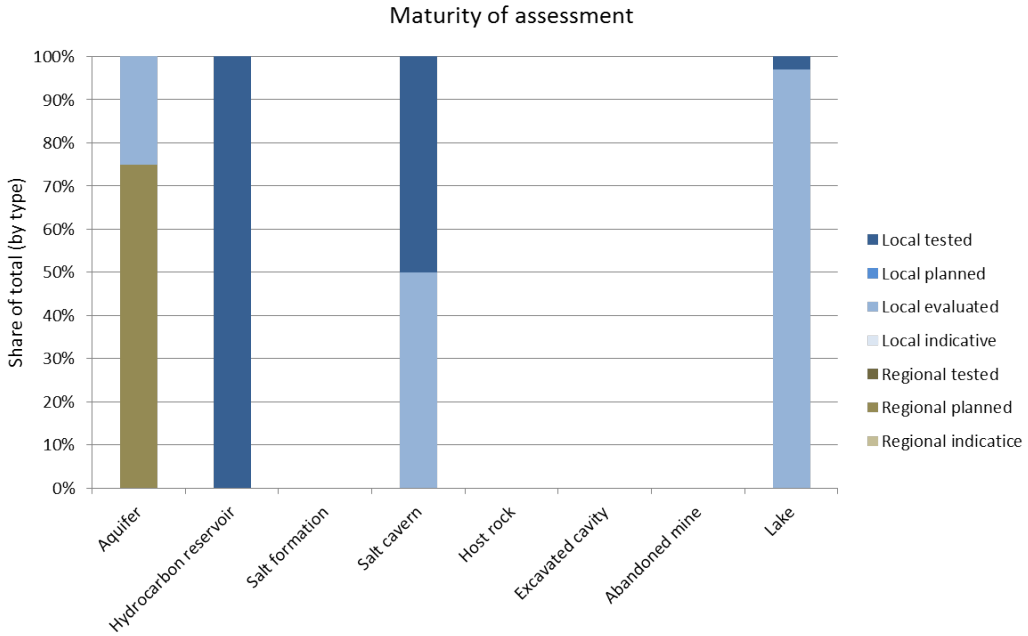

Figure 3.5-4: Bulgaria - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

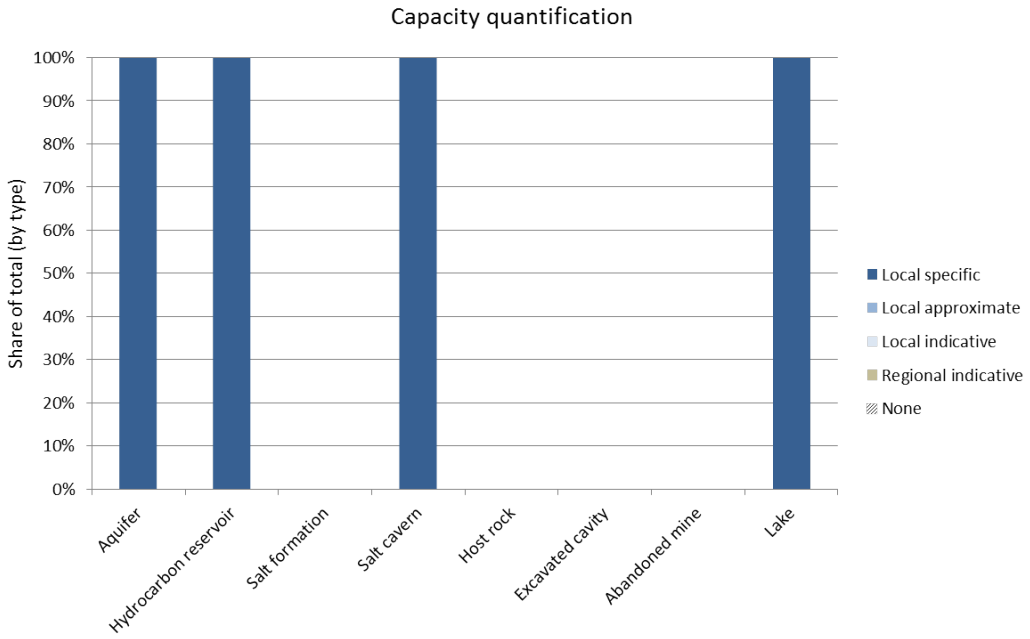

Figure 3.5-5: Bulgaria - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.6. Croatia

3.6.1. Provider administration

Main providing organisations subsurface storage information:

University in Zagreb
Subcontractor
Contact Person: Dr. Domagoj Vulin

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.6.2. Main data sources

Table 3.6-1: List of common sources used

Source name / URL	Description	Version / Date
Vulin, D., 2010: "Modeliranje termodinamičkih i petrofizičkih parametara za geološko skladištenje ugljičnog dioksida", eng.: "Modeling Thermodynamic and Petrophysical Parameters for Geological Storage of Carbon Dioxide",	Publication on CO_2 assessment	2010
PSP d.o.o. official web site ; Strategija gospodarenja mineralnim sirovinama: www.psp.hr	National strategy for exploitation of mineral resources	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.6.3. Storage Data Review Croatia

The currently known subsurface storage potential for Croatia is limited to UGS in hydrocarbon reservoirs. There is reasonable potential for PHS in above ground lakes. There is probably scope for investigating additional future potential through geological mapping and assessment.

Table 3.6-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential is considered present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Three local-defined hydrocarbon reservoirs are included, one of which has been developed as UGS and the other two of which are intended for UGS development. Direct working gas volume determinations are provided for all sites. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is currently unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	No entries available in ESTMAP. As far as known Croatia does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Croatia has moderate realisable potential for pumped hydro storage, all of which is based on one existing and one (to be developed) potential lake. Two out of 13 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

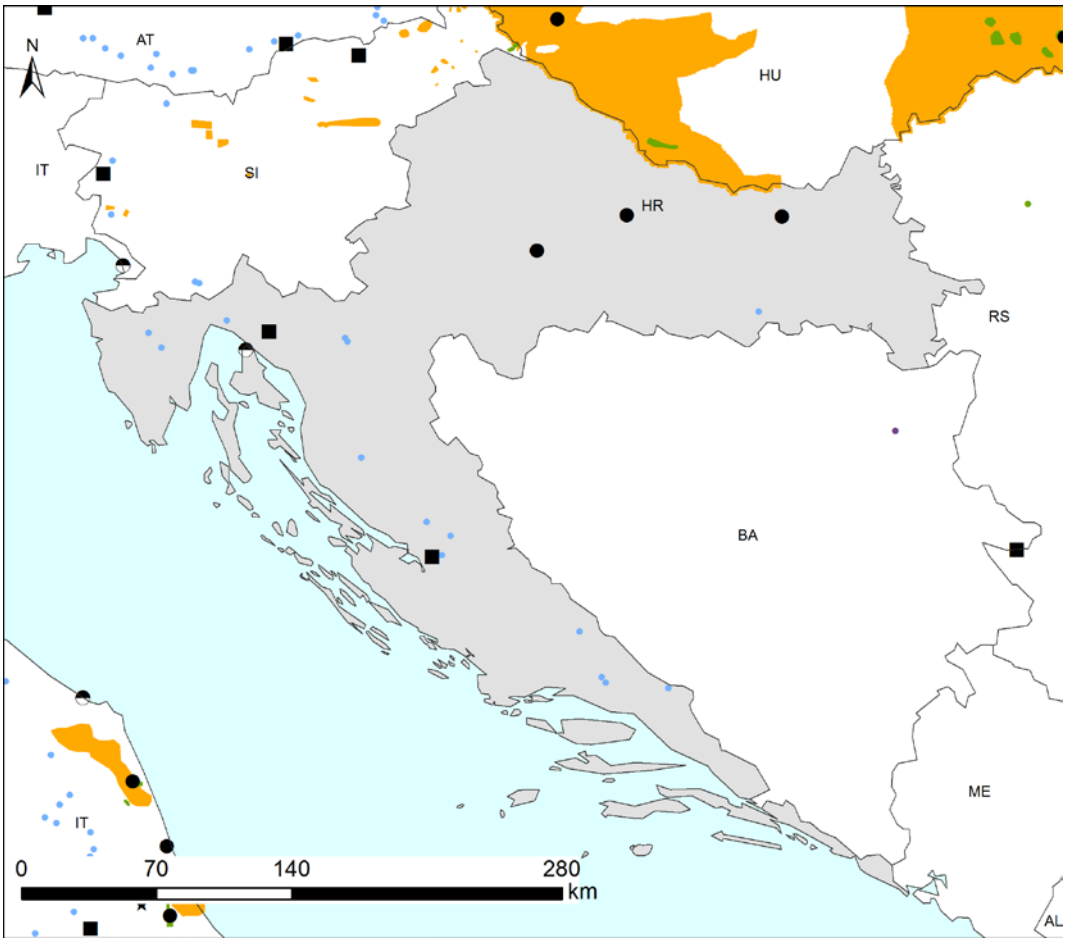

Figure 3.6-1: Croatia- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

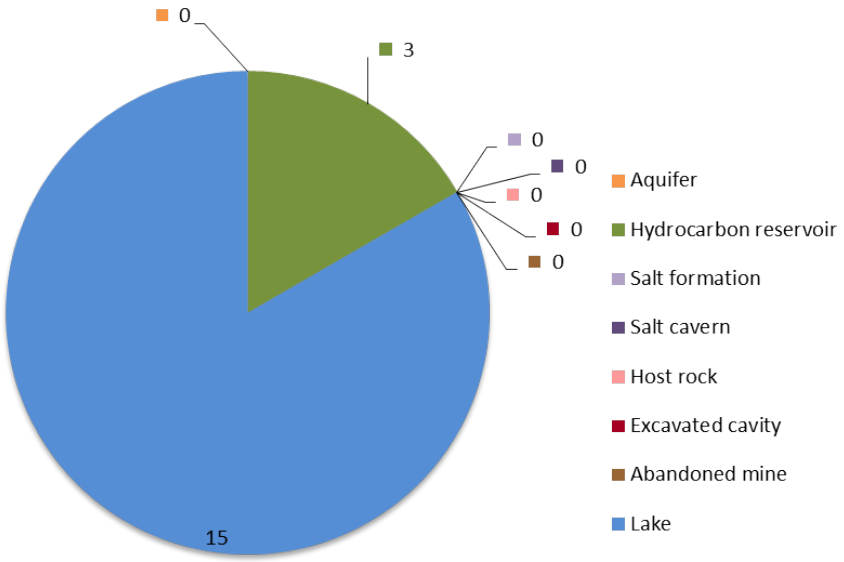

Figure 3.6-2: Croatia - Summary of energy storage reservoir types contained in the database

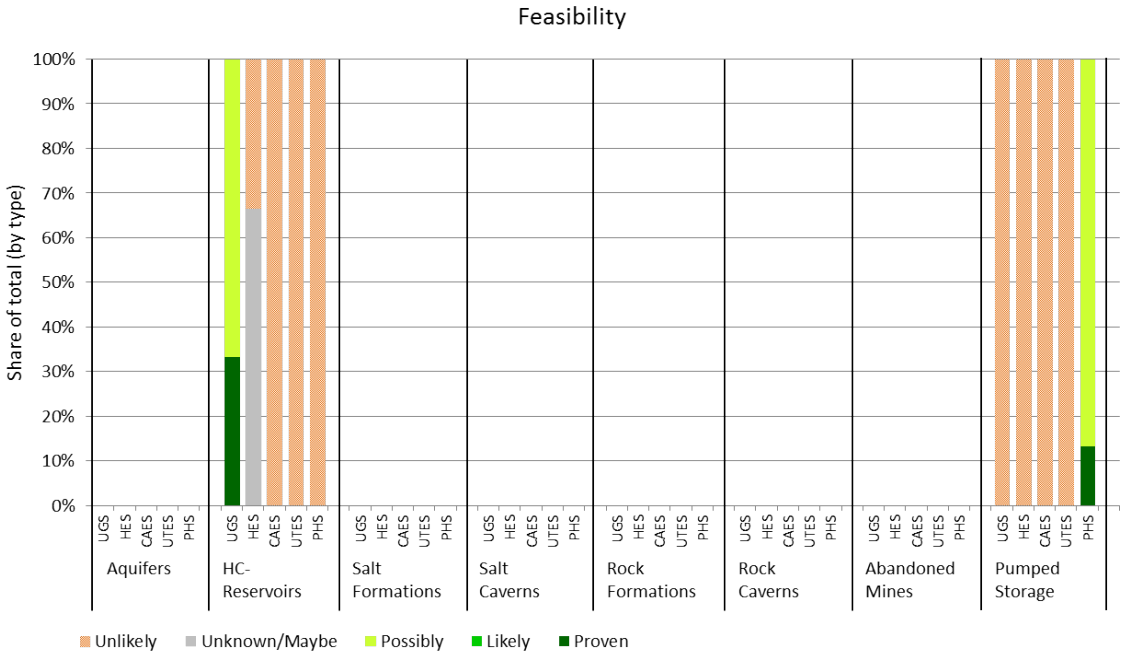

Figure 3.6-3: Croatia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

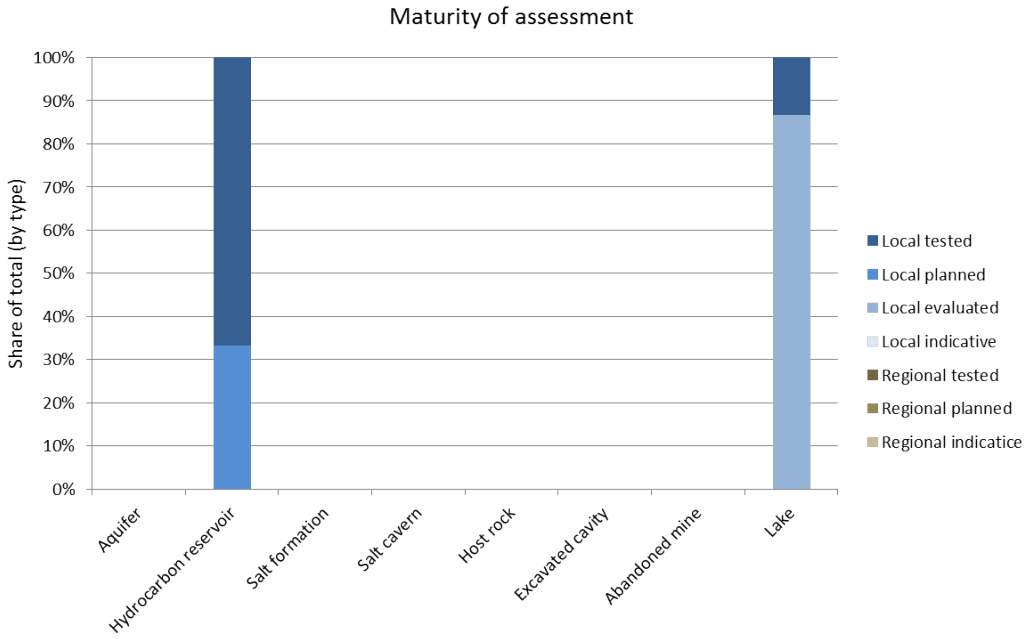

Figure 3.6-4: Croatia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

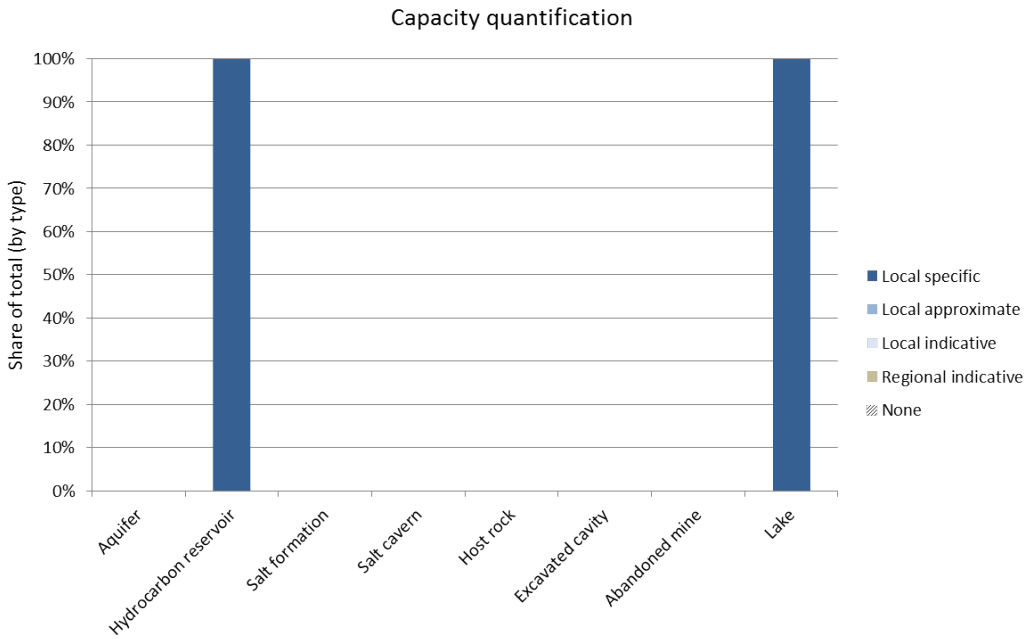

Figure 3.6-5: Croatia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.7. Cyprus

3.7.1. Provider administration

Main providing organisations subsurface storage information:

No provider

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.7.2. Main data sources

Table 3.7-1: List of common sources used

Source name / URL	Description	Version / Date
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.7.3. Storage Data Review Cyprus

Subsurface energy storage potential for Cyprus is still undefined in ESTMAP (no data provided or found in public sources). Potential for pumped hydro storage seems extensive, but no operational development is known to exist.

Table 3.7-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP (no data provider).	Check whether there is future scope to investigate potential for this reservoir type
Hydrocarbon reservoirs	No entries available in ESTMAP (no data provider).	Check whether there is future scope to investigate potential for this reservoir type
Salt formations and caverns	No entries available in ESTMAP (no data provider).	Check whether there is future scope to investigate potential for this reservoir type
Host rock, caverns, mines	No entries available in ESTMAP (no data provider).	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Cyprus has abundant realisable potential for pumped hydro storage, including options based on two existing nearby lakes. None of these appears to be developed yet. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

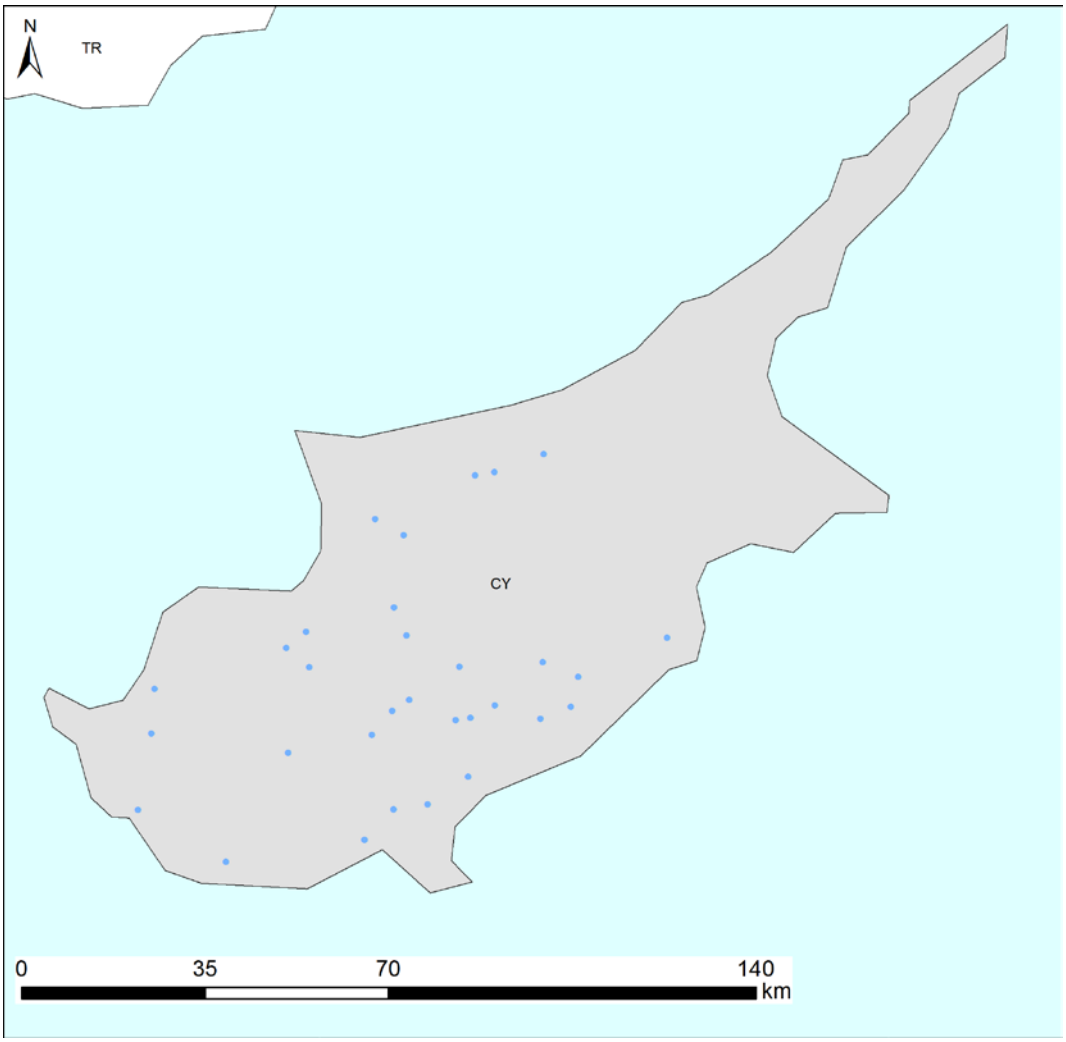

Figure 3.7-1: Cyprus - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

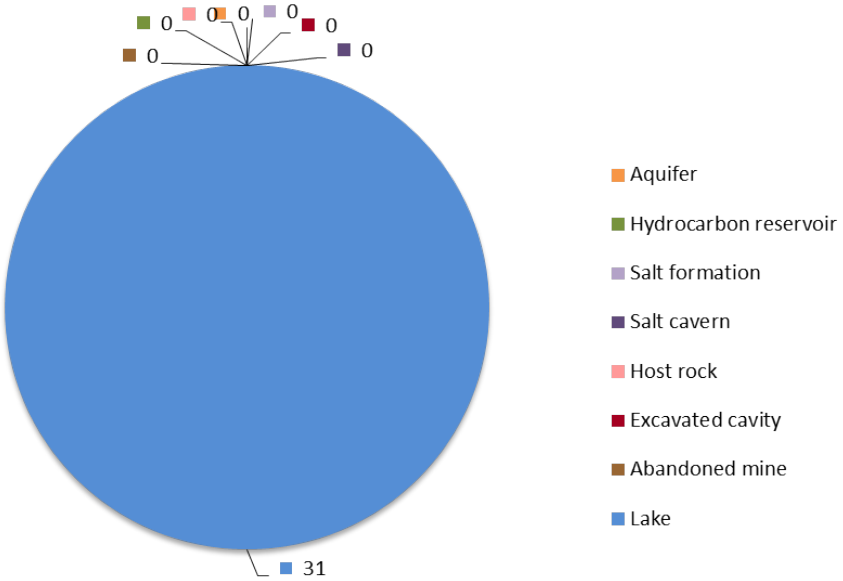

Figure 3.7-2: Cyprus - Summary of energy storage reservoir types contained in the database

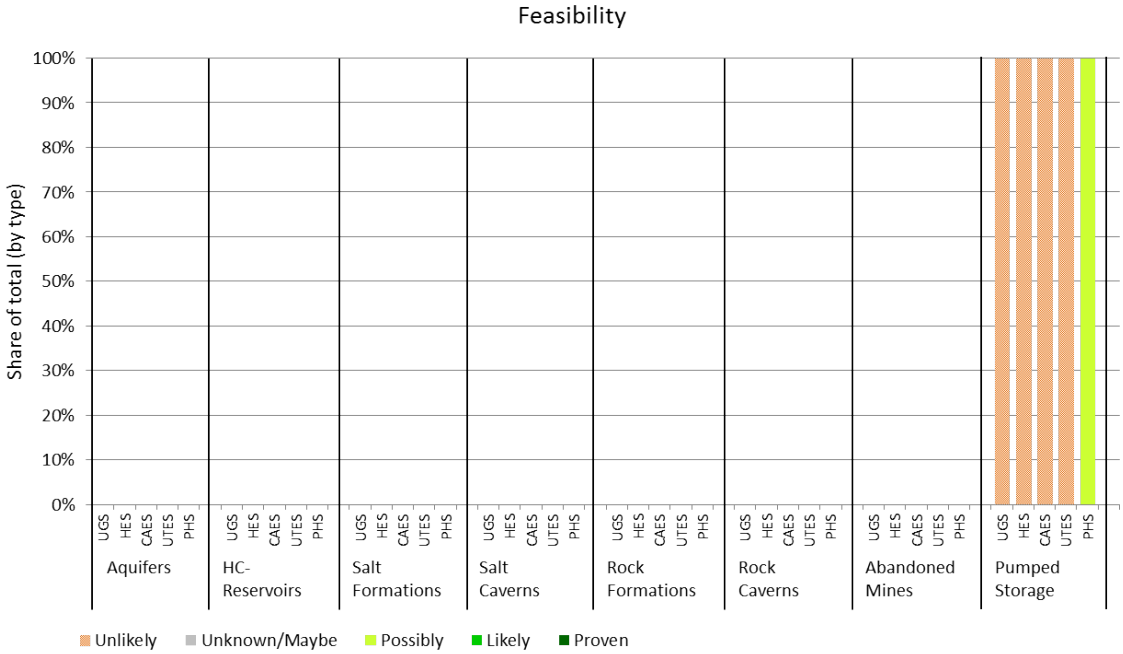

Figure 3.7-3: Cyprus - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

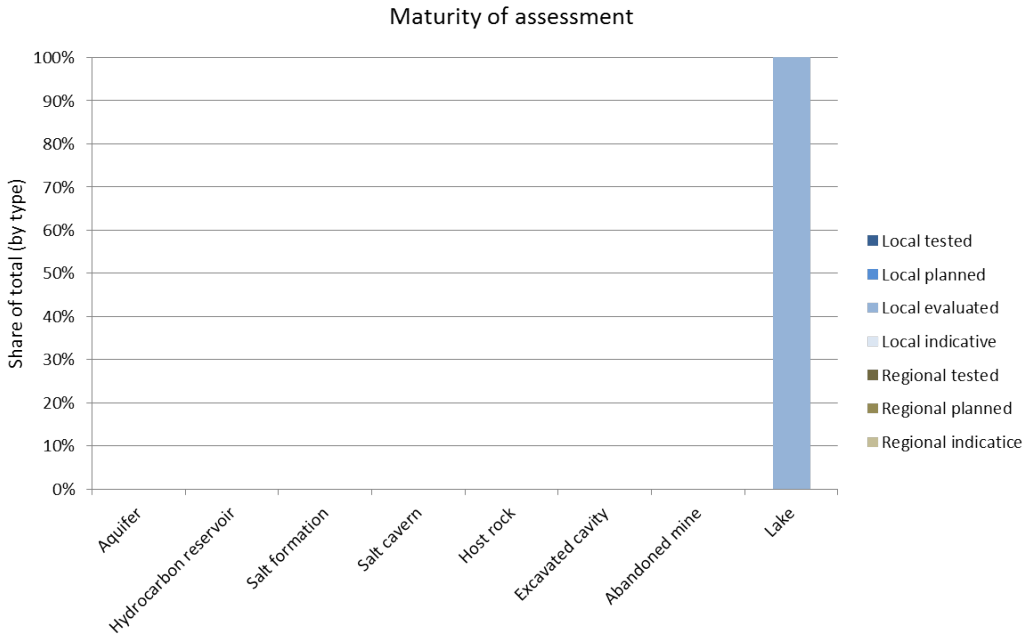

Figure 3.7-4: Cyprus - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

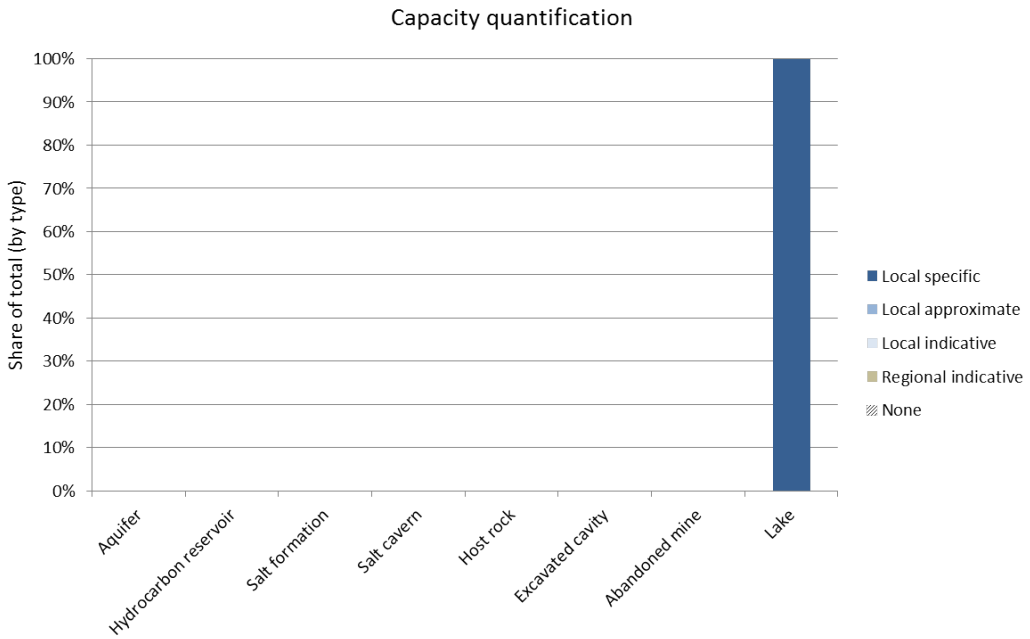

Figure 3.7-5: Cyprus - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.8. Czech Republic

3.8.1. Provider administration

Main providing organisations subsurface storage information:

CGS – Czech Geological Survey
ESTMAP Consortium Partner
Contact Person: Jan Holecek

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.8.2. Main data sources

Table 3.8-1: List of common sources used

Source name / URL	Description	Version / Date
Czech Geological Survey Data Archives	No further source details available	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.8.3. Storage Data Review Czech Republic

Subsurface storage potential in the Czech Republic is mainly defined in abandoned mines and regional aquifers. Feasibilities and capacity determinations are still unconfirmed and technically immature. Some developed UGS sites in hydrocarbon reservoirs and one rock cavern are included as well. There is good and local-defined potential for above ground pumped hydro storage across the entire country.

Table 3.8-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Potential for UTES in aquifers is regional-defined and extends over a large part of the country. Feasibilities are still theoretical (regional indicative) and largely unconfirmed. Very limited information regarding storage capacities is available. One local-defined site has been developed as UGS (in the past for city gas, meaning it should be suitable for HES as well).	Target aquifers are regionally in view, but substantial efforts are needed to define and confirm local-specific potential and estimate capacities.
Hydrocarbon reservoirs	Seven hydrocarbon fields are tested and developed as UGS. Reservoir capacities are approximated from total gas volumes. The reservoirs are in theory also suitable for HES, but this has not been confirmed.	No or very limited scope for future investigation.
Salt formations and caverns	No entries available in ESTMAP. The Czech Republic does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation.
Host rock, caverns, mines	An extensive dataset on local-defined abandoned mines is available to ESTMAP. These mines are considered a main target for UTES. Feasibilities are still theoretical (local indicative) and unconfirmed. Very limited information regarding storage capacities is available. There is one rock cavern that has been developed for UGS (operational capacities provided) and that could in theory also host HES and CAES. Further potential in host rock formations has not been assessed.	Substantial efforts are needed to define and confirm local-specific potential in the abandoned mines and to estimate capacities. Check whether there is future scope to investigate potential in host rock formations.
Lakes	The Czech Republic has abundant realisable potential for pumped hydro storage, including options based on two existing nearby lakes. Two out of 71 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

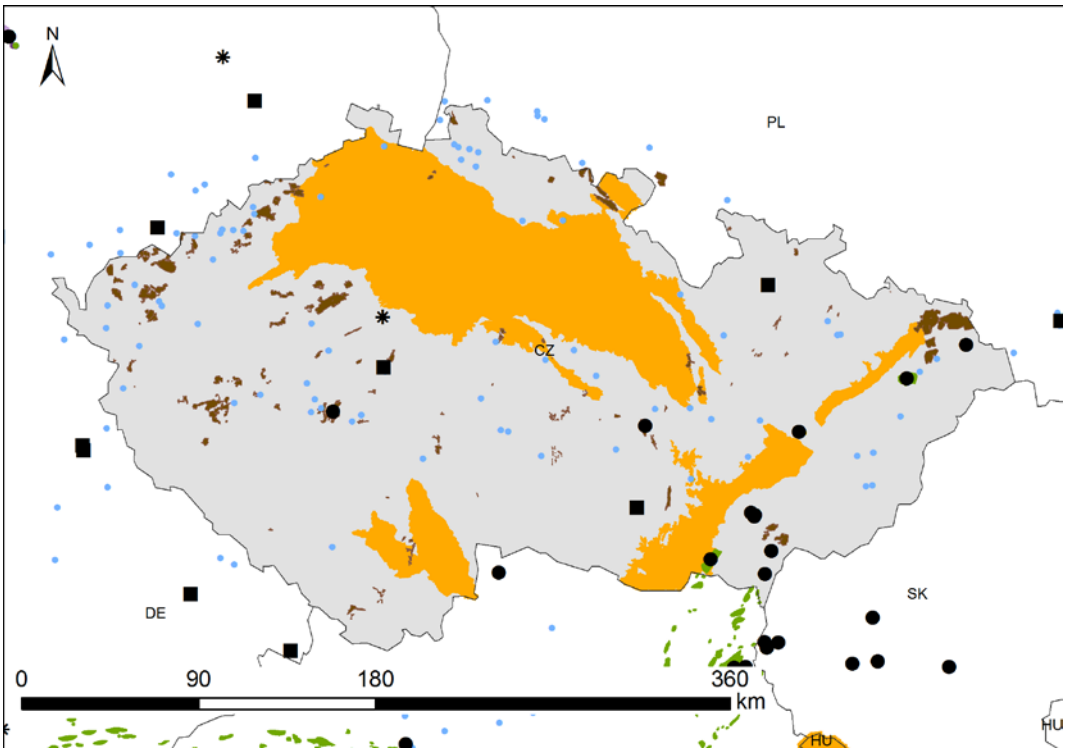

Figure 3.8-1: Czech Republic - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

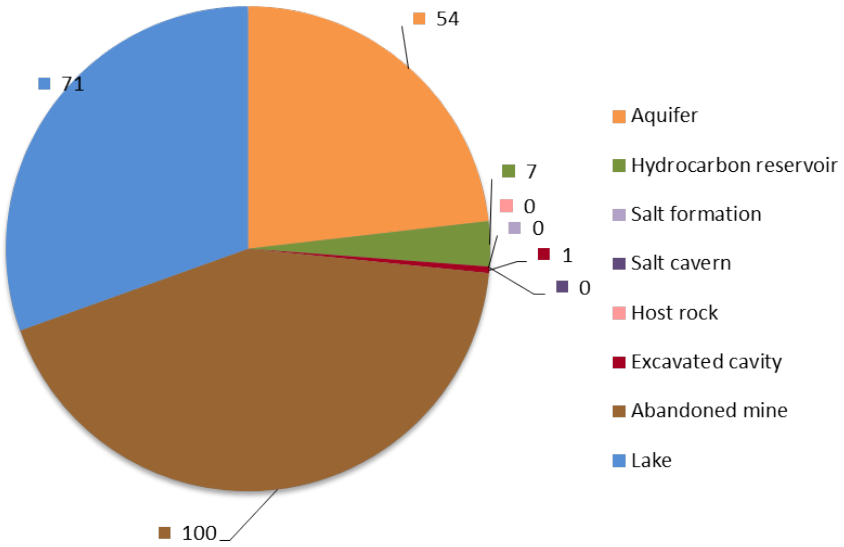

Figure 3.8-2: Czech Republic - Summary of energy storage reservoir types contained in the database

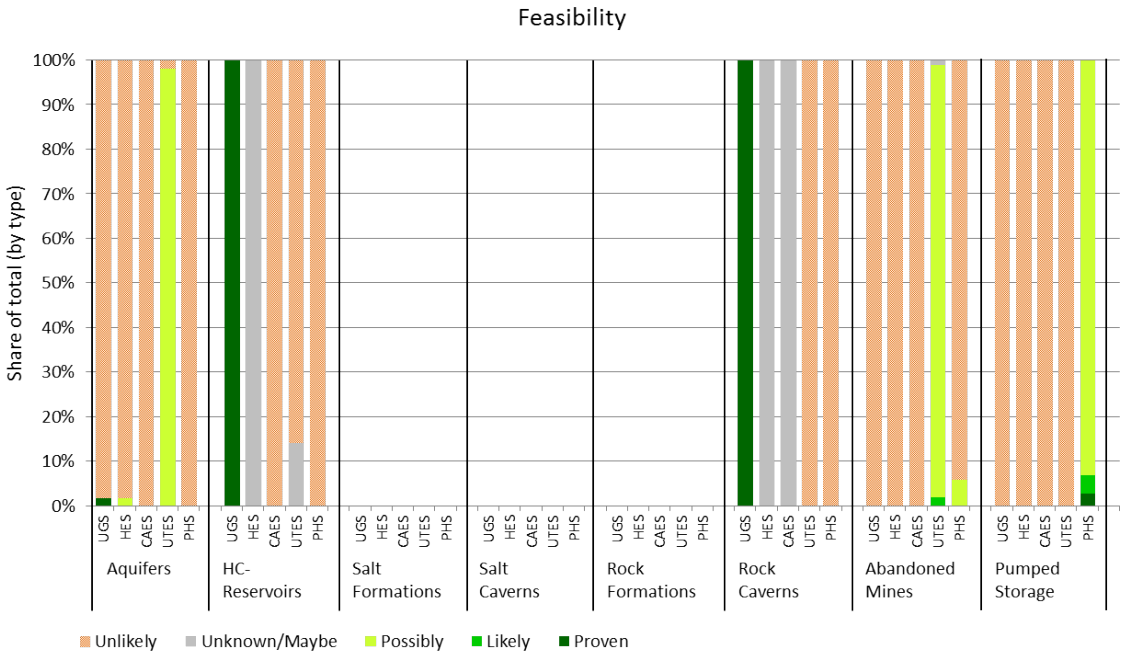

Figure 3.8-3: Czech Republic - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

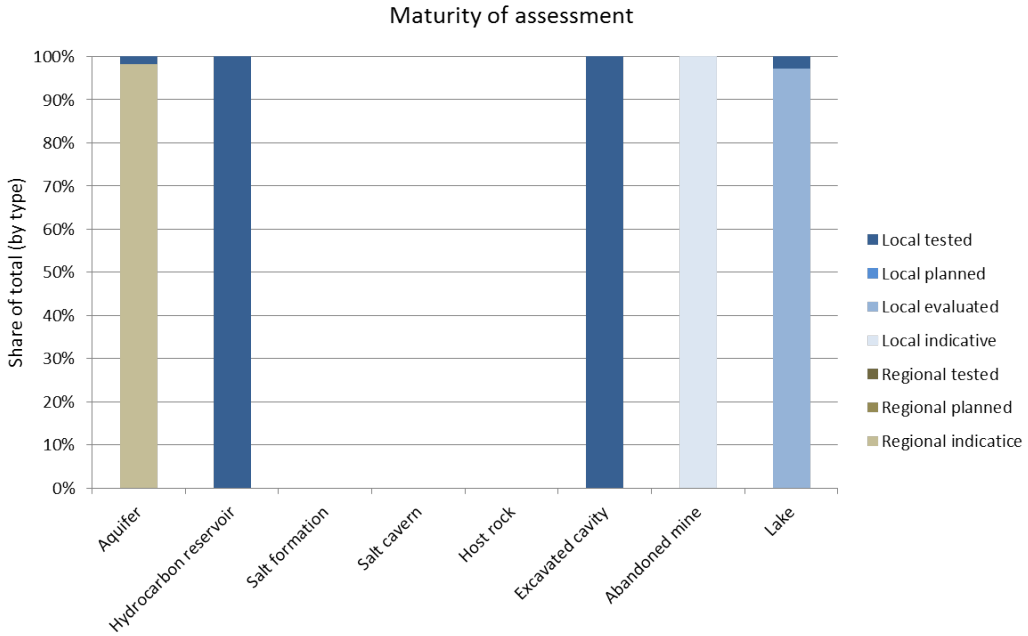

Figure 3.8-4: Czech Republic - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

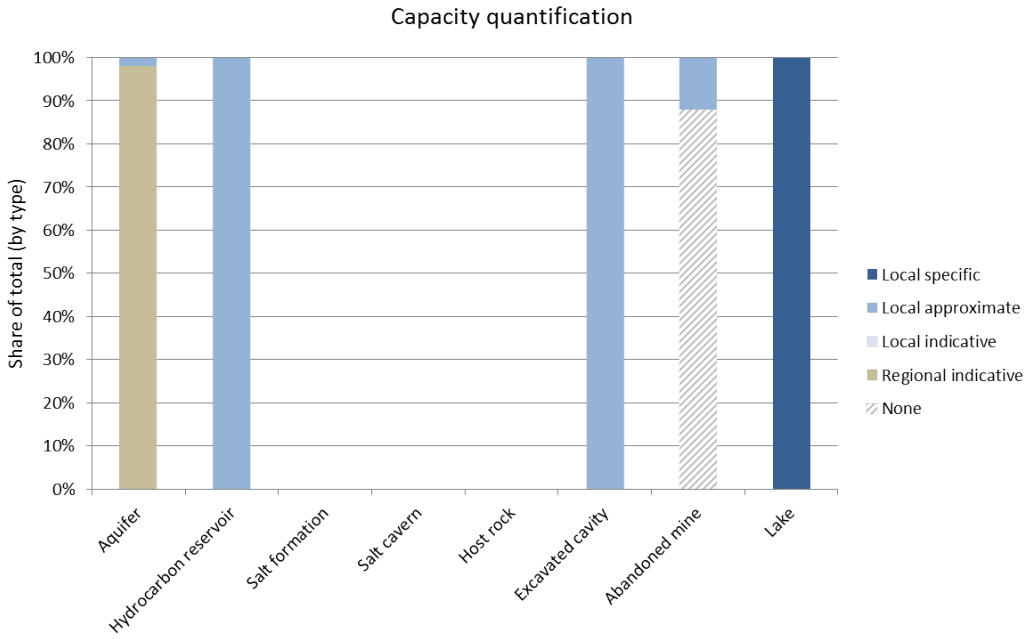

Figure 3.8-5: Czech Republic - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.9. Denmark

3.9.1. Provider administration

Main providing organisations subsurface storage information:

GEUS – Geological Survey of Denmark and Greenland
Subcontractor
Contact Person: Karen Lyng Anthonsen

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.9.2. Main data sources

Table 3.9-1: List of common sources used

Source name / URL	Description	Version / Date
Danish Energy Agency: Oil and Gas Production in Denmark and Subsoil Use 2013. http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/danmarks_olie-_og_gasproduktion_2013_uk.pdf	Reporting of oil and gas reserves Denmark	2013
The Nordic CO_2 Storage Atlas: https://data.geus.dk/nordiccs/	Assessment of CO_2 storage potential	2015
Danish Energy Agency: http://www.ens.dk/en/oil-gas/other-use-subsoil/gas-storage	Reporting of subsurface storage uses	2013
Geological Survey of Denmark: Vejbæk, O.V. & Britze, P. 1984: Top præ-Zechstein. Danmarks Geologiske Undersøgelse Map series 45.	National Geological Mapping publications	1984
EU GeoCapacity: http://www.geology.cz/geocapacity/events/copenhagen-presentations/Denmark_country%20review_Karen%20Lyng%20Anthonsen.pdf	Publication on geological storage capacities	2009
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.9.3. Storage Data Review Denmark

Denmark's main energy storage potential (UGS) exists in aquifers (traps) and salt caverns. Aquifers are also a primary targets for CO_2 storage. The identified potential is still quite immature and requires further location-specific evaluations. Pumped hydro storage has very low potential due to the absence of natural favourable conditions (sufficient elevation differences).

Table 3.9-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Denmark is almost completely covered by regional aquifers with some indicative theoretical potential for UGS. It is unknown whether these aquifers also represent potential for HES and UTES as well, but this could be assumed on generic geological grounds. Also note that a large part of the aquifers is located in offshore areas, further limiting potential for certain functions. Some 15 local-defined sites are considered suitable for CO_2 storage, but could possibly also support UGS. Overall the feasibilities and capacities are still premature and unconfirmed.	Identification of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Hydrocarbon reservoirs	For Denmark no onshore energy storage potential has been defined in hydrocarbon reservoirs. Virtually all known fields are located far offshore and are potential targets for EOR/CO_2 storage.	Probably very limited scope for future investigation
Salt formations and caverns	Thirteen onshore sites with salt caverns are included in ESTMAP. One has been developed for UGS (including specified operational working gas volumes). The suitability of the other sites (theoretically UGS, HES and CAES) is still premature and requires further assessment	Identification of location-specific potential, determination of expected capacities.
Host rock, caverns, mines	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential in this reservoir type
Lakes	No entries available in ESTMAP. Denmark was not included in the JRC-2013 assessment. Natural conditions are considered absent	Investigate if there is scope alternative PHS solutions

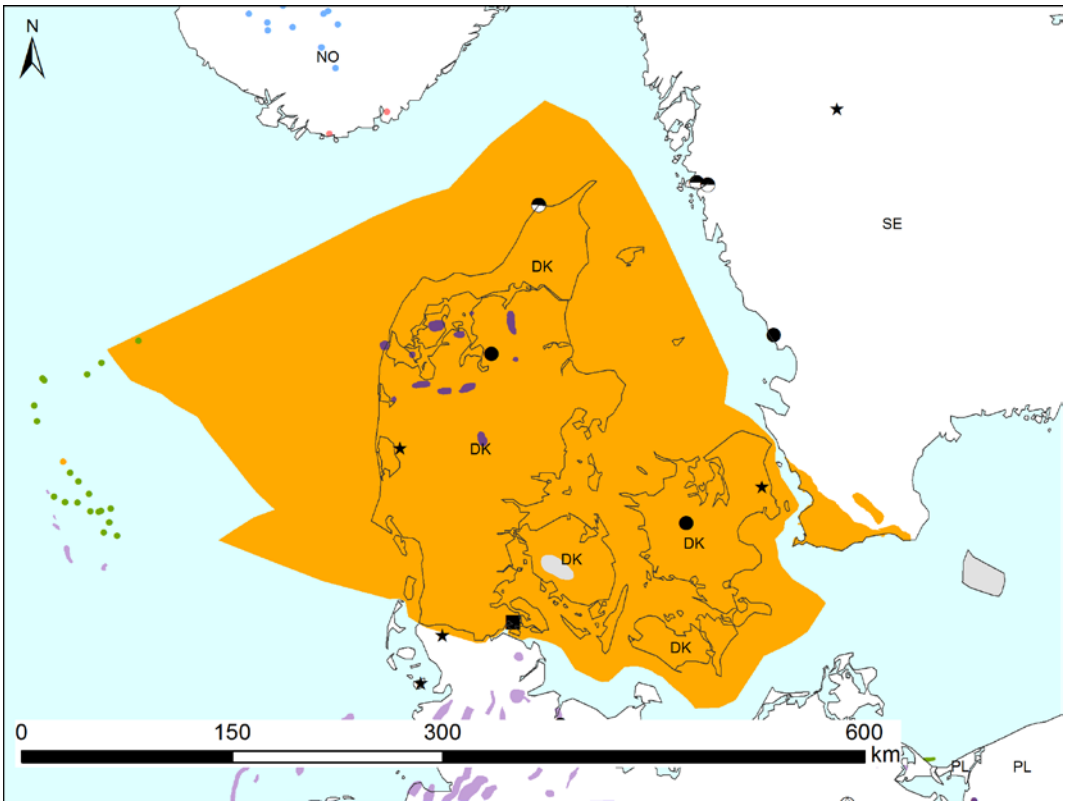

Figure 3.9-1: Denmark - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-53.

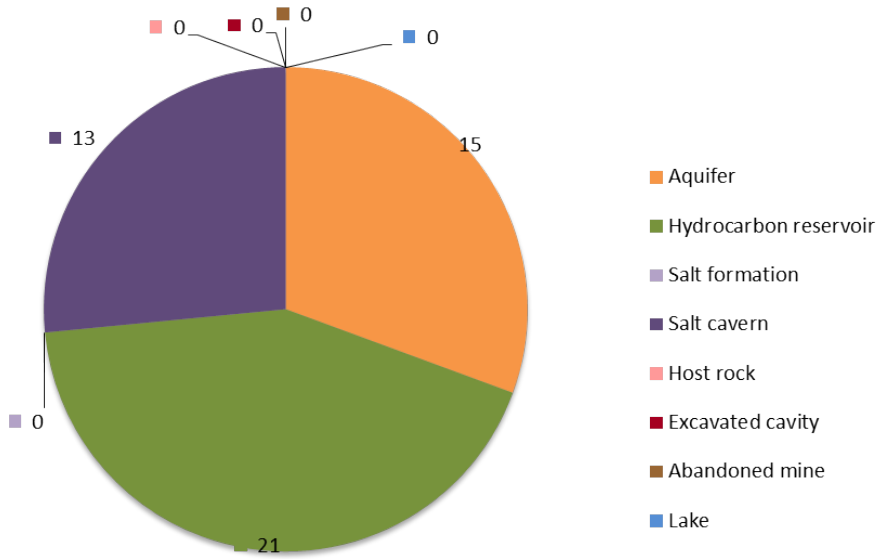

Figure 3.9-2: Denmark - Summary of energy storage reservoir types contained in the database

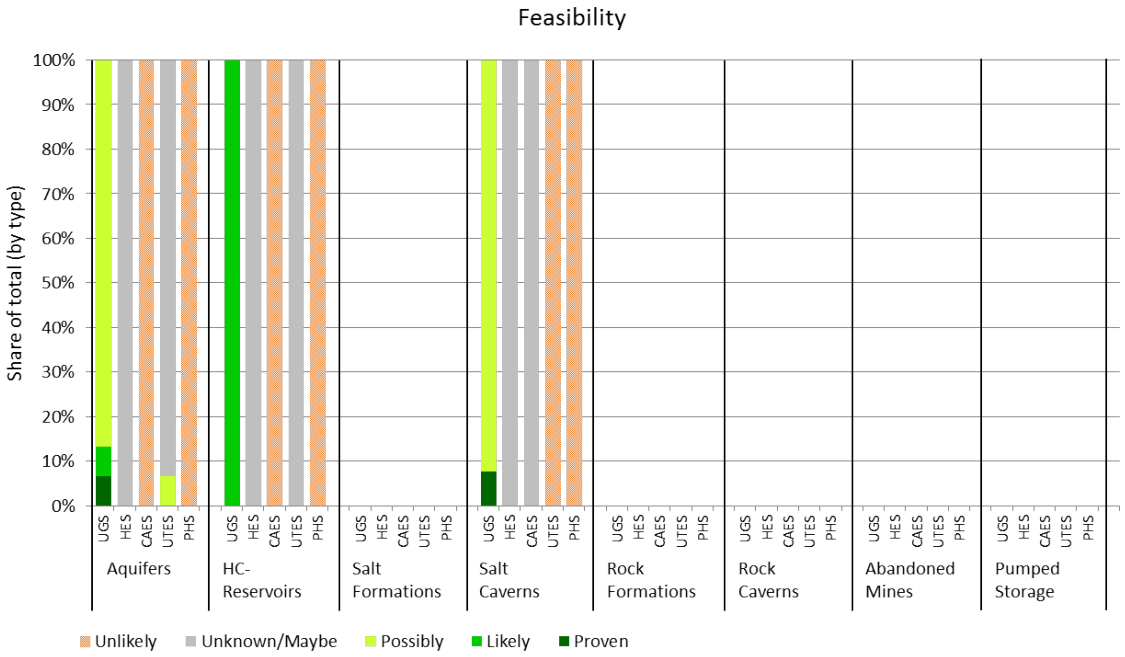

Figure 3.9-3: Denmark - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

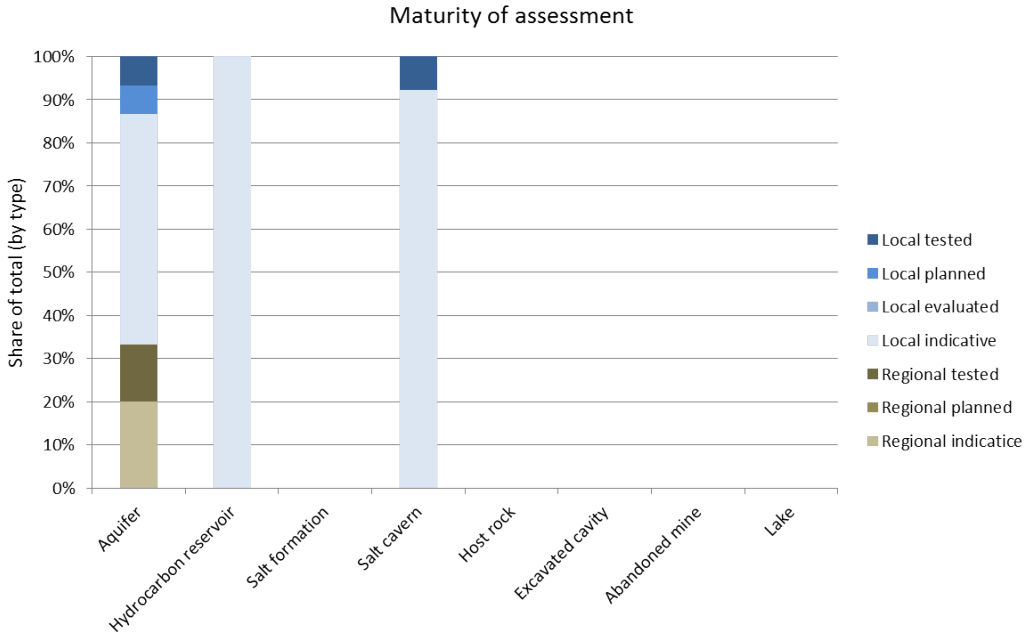

Figure 3.9-4: Denmark - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

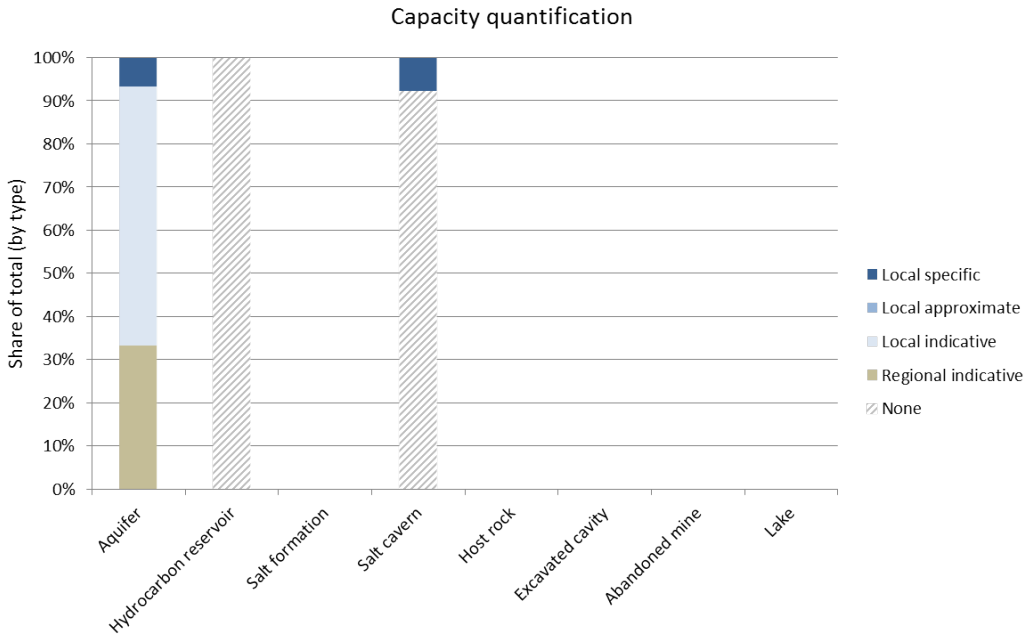

Figure 3.9-5: Denmark - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.10. Estonia

3.10.1. Provider administration

Main providing organisations subsurface storage information:

Tallinn University of Technology
Subcontractor
Contact Person: Alla Shogenova

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.10.2. Main data sources

Table 3.10-1: List of common sources used

Source name / URL	Description	Version / Date
Muuga Seawater-Pumped Hydro Storage Power Plant Project: http://energiasalv.ee/en/hydro-accumulation-power-plant	Operator, storage site technical information	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015

3.10.3. Storage Data Review Estonia

Estonia has very limited potential for energy storage development, mainly due to absence of natural favourable conditions. A seawater pumped storage system is being developed along the shoreline, which makes use of a subsurface rock cavern.

Table 3.10-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential is considered absent or very limited	No or very limited scope for future investigation
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered absent or very limited	No or very limited scope for future investigation
Salt formations and caverns	No entries available in ESTMAP. Potential is considered absent or very limited	No or very limited scope for future investigation
Host rock, caverns, mines	One local-defined host rock site is included in ESTMAP, which is planned for underground PHS development (only site known in Europe). Very little information is included regarding the expected capacity but according to the operator brochure this should be ~6 GWh of electrical energy (500MW x 12h).	Check whether there is future scope to investigate additional potential for this reservoir type
Lakes	No entries available in ESTMAP. Estonia was not included in the JRC-2013 assessment report as reservoir data were unavailable. Local conditions may be present but limited.	Investigate if there is scope for future PHS assessment once data are available.

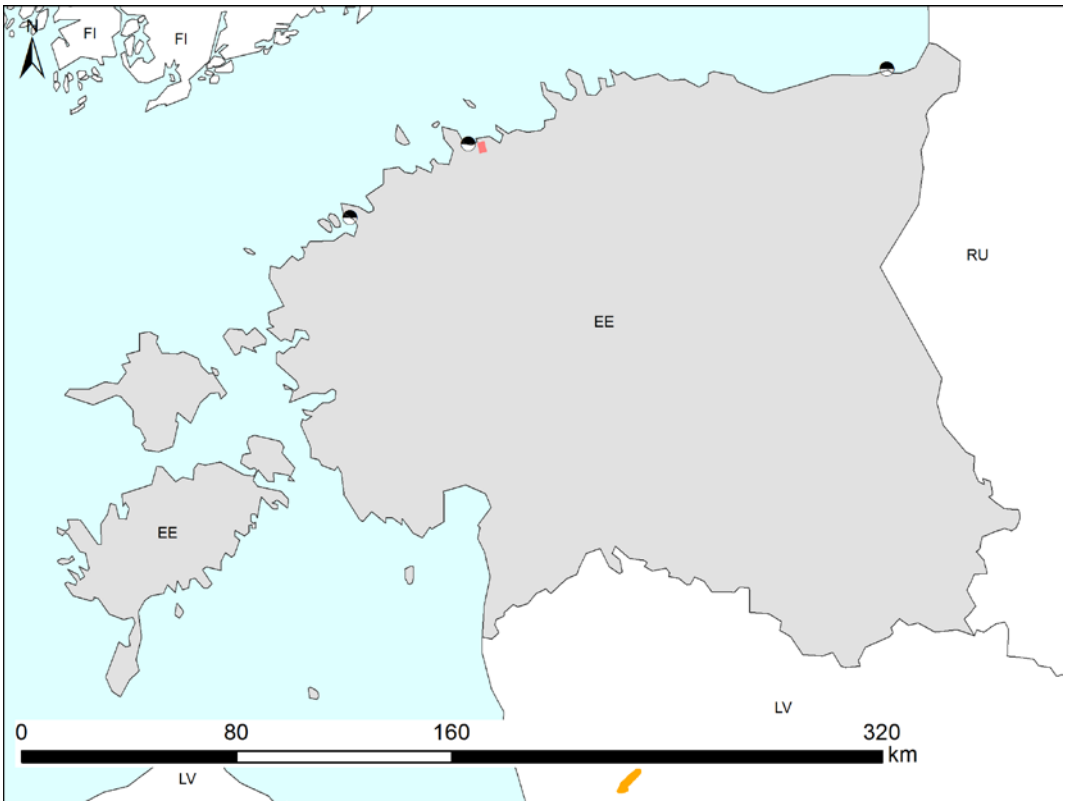

Figure 3.10-1: Estonia - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

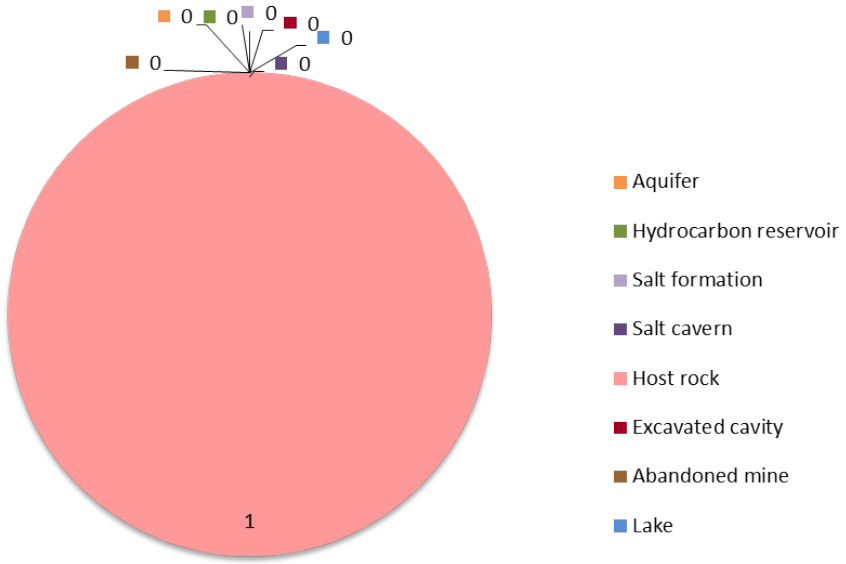

Figure 3.10-2: Estonia - Summary of energy storage reservoir types contained in the database

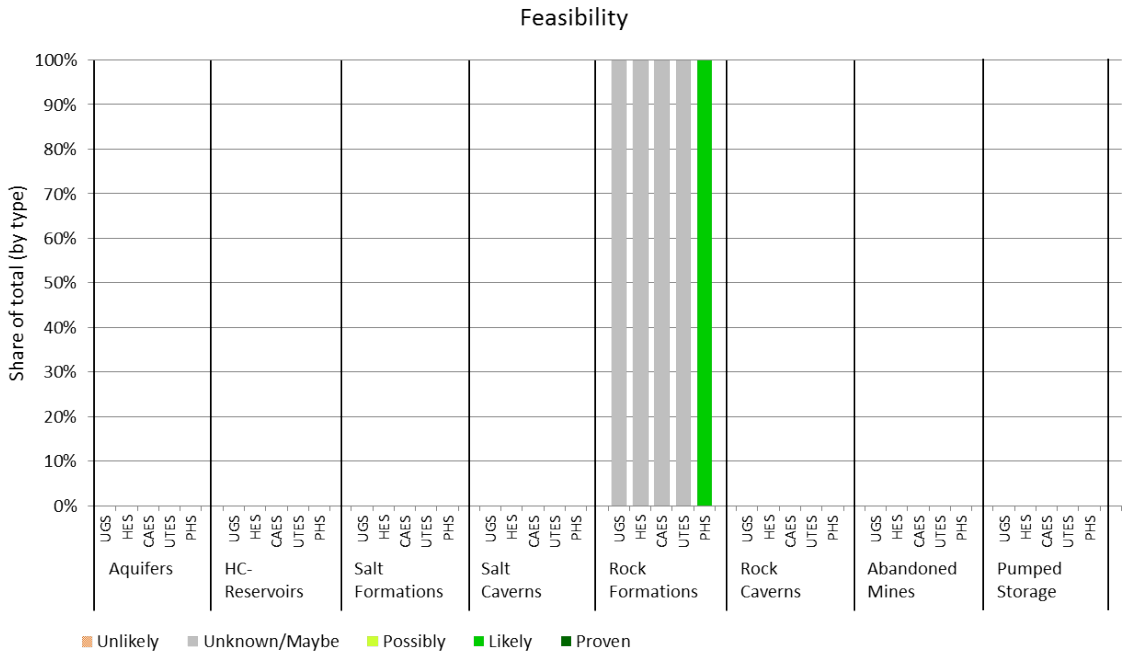

Figure 3.10-3: Estonia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

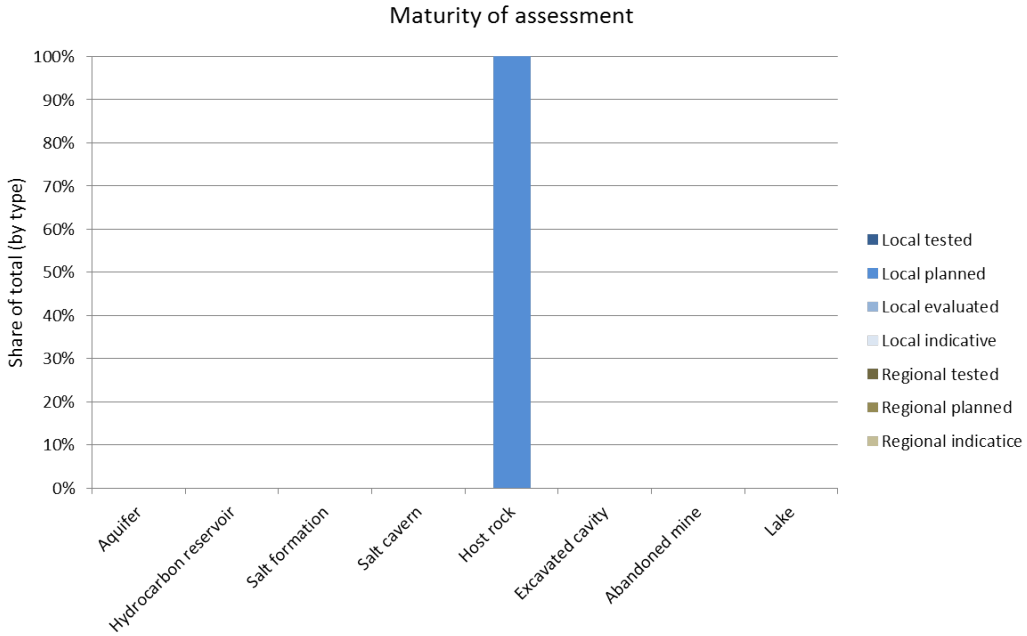

Figure 3.10-4: Estonia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

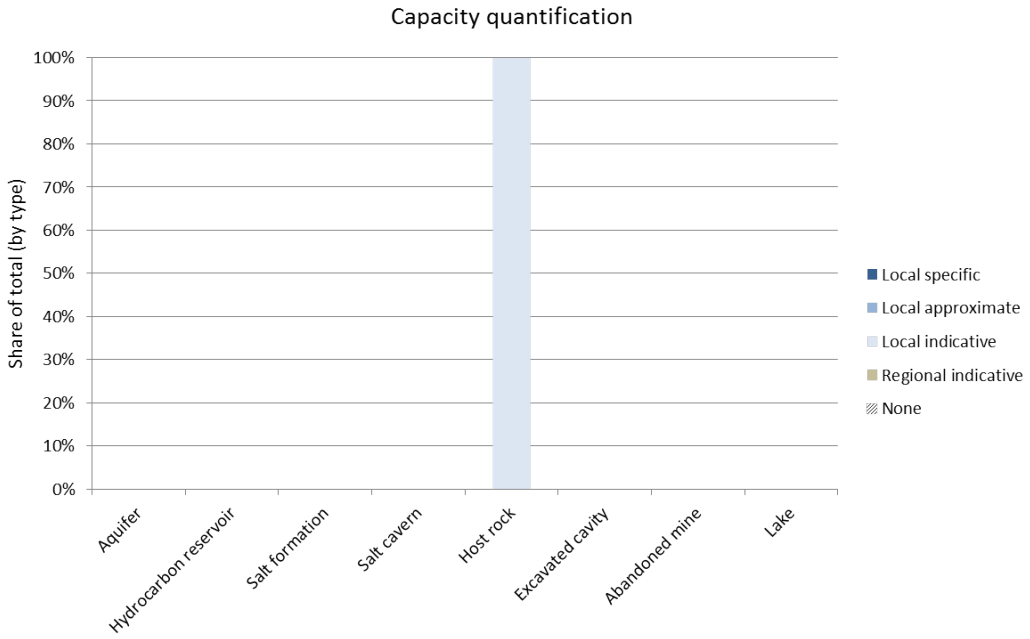

Figure 3.10-5: Estonia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.11. Finland

3.11.1. Provider administration

Main providing organisations subsurface storage information:

GTK – Geological Survey of Finland
Subcontractor
Contact Person: Tuija Vähäkuopus

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.11.2. Main data sources

Table 3.11-1: List of common sources used

Source name / URL	Description	Version / Date
Arola et al., 2014.Mapping the low enthalpy geothermal potential of shallow Quaternary aquifers in Finland	Publication on aquifer assessment	2014
VTT Research report VTT-R-04082-13:	Report on mines	2013
The Fennoscandian Ore Deposit Database: http://en.gtk.fi/informationservices/databases/fodd/disclaimer.html		
Salmi et al., 1985	Publication on rock cavern assessment	1985
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.11.3. Storage Data Review Finland

The primary energy storage potential in Finland is mainly limited to UTES and PHS. Potential for other technologies requires further geological mapping and assessment. Aquifers, mines, host rock and pumped storage lakes are the main reservoir types available.

Table 3.11-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Finland includes 20 local-defined aquifers with UTES as main target technology (mainly in the southern part of the country. Potential for UGS and HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. None of the sites included in ESTMAP has been develop as storage yet. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities. Sites are defined by mid-points as the exact extent (GIS shape) is not provided to ESTMAP.	Identification of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered absent	No scope for future investigation
Salt formations and caverns	No entries available in ESTMAP. Finland is not known to have salt formations that allow for development of suitable caverns.	No scope for future investigation
Host rock, caverns, mines	The dataset for Finland includes 16 local-defined mines and 6 regional-defined host rock formations with UTES as main target technology. Potential for UGS, HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. One of the host rock sites included in ESTMAP has been develop as UTES. The sites are parameterized to a limited extent only and there is no basis for estimating capacities. Sites are defined by mid-points as the exact extent (GIS shape) is not provided to ESTMAP	Identification of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Lakes	Finland has low realisable potential for PHS development. The few options (mostly in the north of the country) are either based on long distance (20 km) separated lakes or limited (50 m) vertical separation. None of these appears to be developed yet. All identified sites include specific determinations of energy storage capacities and lake volumes.	Confirm suitability and capacity from location-specific assessments.

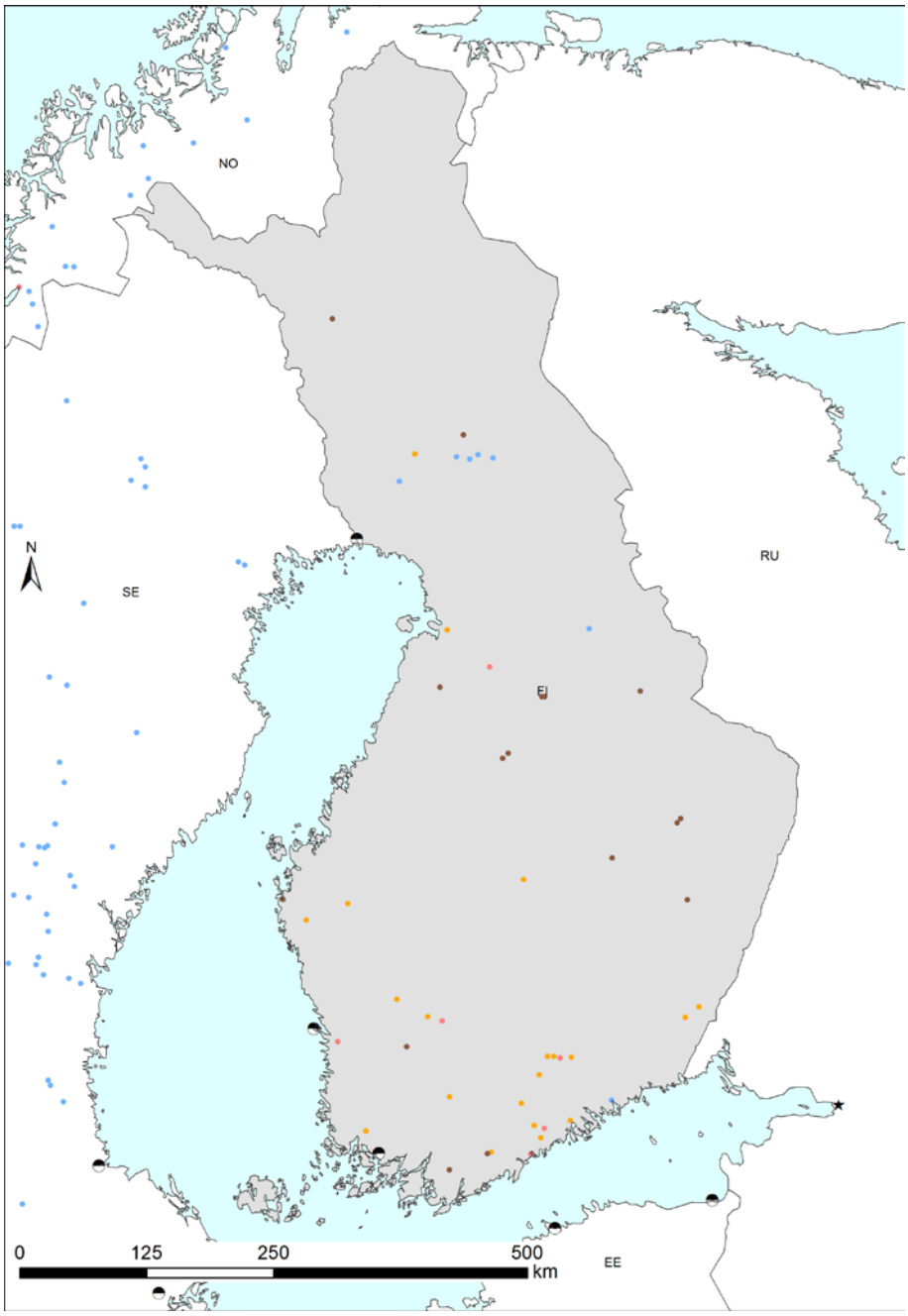

Figure 3.11-1: Finland- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

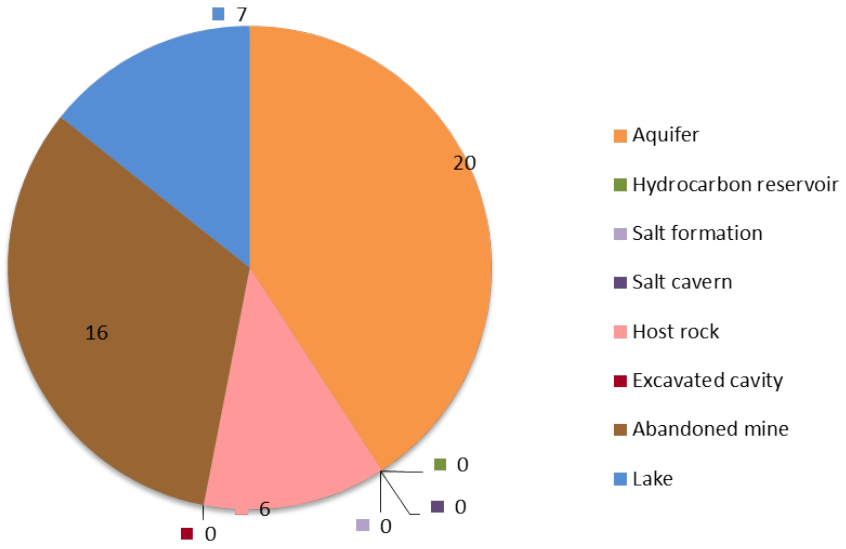

Figure 3.11-2: Finland - Summary of energy storage reservoir types contained in the database

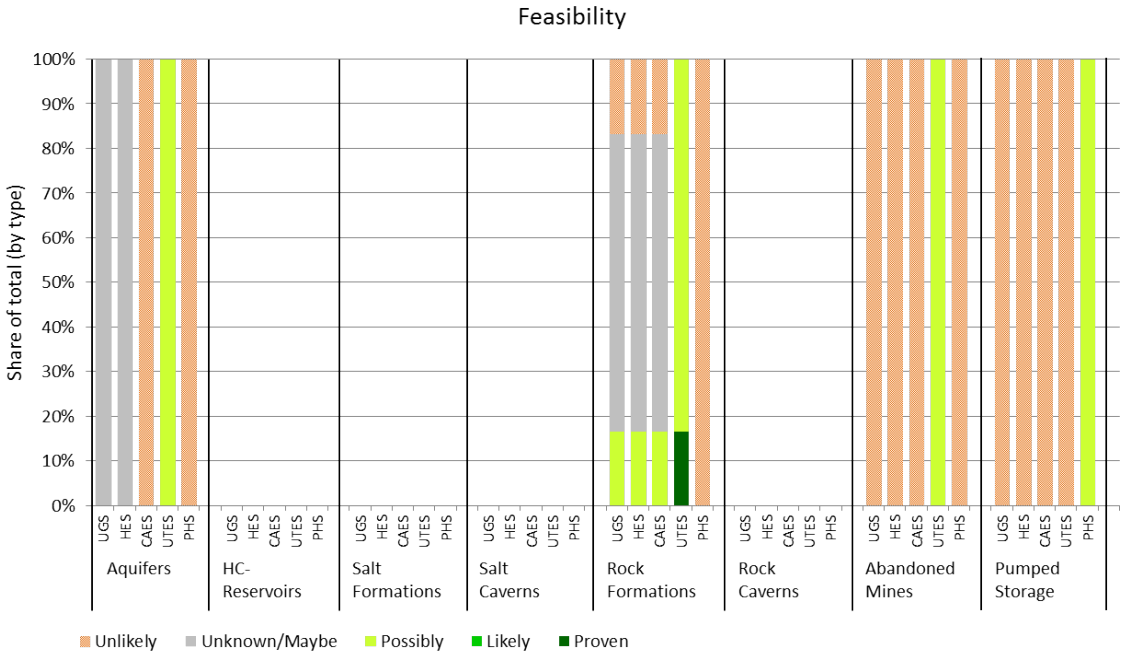

Figure 3.11-3: Finland - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

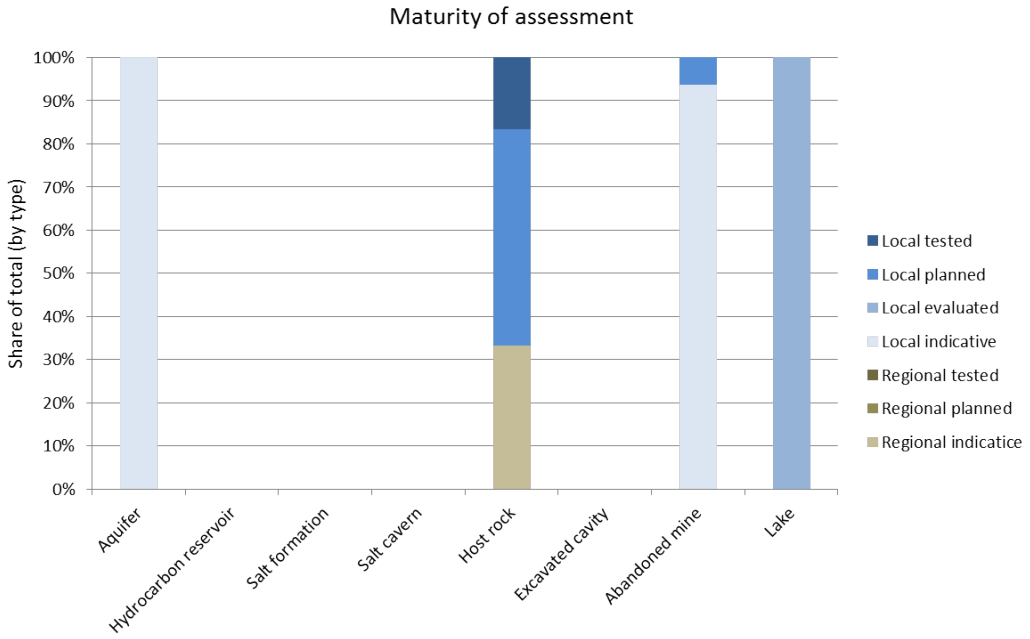

Figure 3.11-4: Finland - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

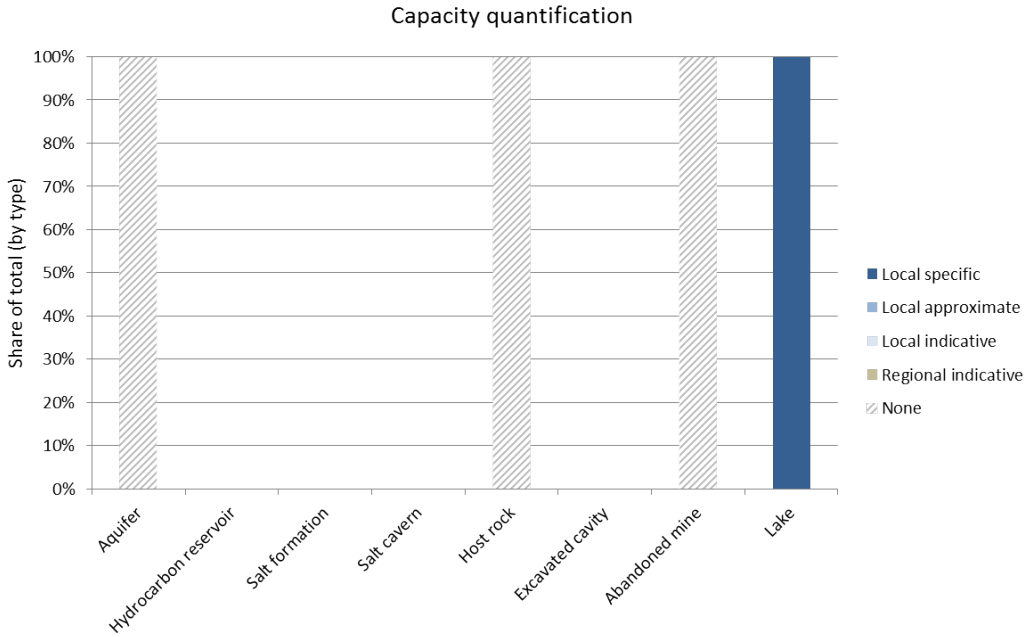

Figure 3.11-5: Finland - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.12. France

3.12.1. Provider administration

Main providing organisations subsurface storage information:

BRGM – Bureau de Recherches Géologiques et Minières
ESTMAP Consortium Partner
Contact Person: Anne-Gaëlle Bader

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.12.2. Main data sources

Table 3.12-1: List of common sources used

Source name / URL	Description	Version / Date
Various scientific reports by BRGM	Geological investigations on subsurface characterization and storage potential	-
Geological Million map of France, Chantraine et al., 2003	Published assessment of natural gas storage potential and performance	2003
Storengy website: https://www.storengy.com/countries/france/fr/nos-sites/	Operational and site-specific data on existing and planned gas storages	2015
METSTOR Project	CO_2 storage project	-
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.12.3. Storage Data Review France

Above ground pumped storage lakes are by far the most frequently occurring reservoir type in the database for France. The lakes are local-defined and reasonably well assessed (volumes, feasibility) .Subsurface energy storage potential covers large areas, but is predominantly defined as regional aquifers, salt formations and host rock lacking good definitions of distinct feasibilities and capacities. Maturation of future potential strongly relies on identification of local prospective targets and assessment of expected capacities. Several local-specific sites for existing or planned UGS development are included (aquifers, hydrocarbon reservoirs, salt caverns)

Table 3.12-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Aquifers are mainly regional-defined, covering large areas. Distinct capacity determinations and identification of location specific suitability are lacking. Few local-defined sites have been developed as UGS and include information on operational working gas volumes..	Identification of location-specific potential, determination of expected capacities. Potential targets for further investigating UGS, HES and UTES potential
Hydrocarbon reservoirs	Only one site (developed as UGS) is included in ESTMAP. Approximate total gas volumes are reported. France has little domestic oil and gas production, therefore additional potential is considered very limited.	Limited scope for investigating future potential
Salt formations and caverns	Salt formations are regional-defined, covering large areas but lacking distinct capacity determinations and indications of location specific potential. Caverns all represent local-defined sites that have been developed as UGS and include working volumes.	Identification of location-specific potential in salt formations including determination of expected capacities. Potential target for further investigating UGS, HES and CAES potential
Host rock, caverns, mines	All host rock and mines are regional-defined, covering large areas but lacking distinct capacity determinations and identification of location specific potential. This is still very immature potential without existing or planned storage development	Identification of location-specific potential, determination of expected capacities. Potential targets for further investigating CAES, UTES and HES (abandoned mines only) potential
Lakes	Abundant realisable potential for pumped hydro storage is present in France (mainly S and SE parts of the country), including options based on two existing nearby (<10 km) lakes. Eleven out of 354 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

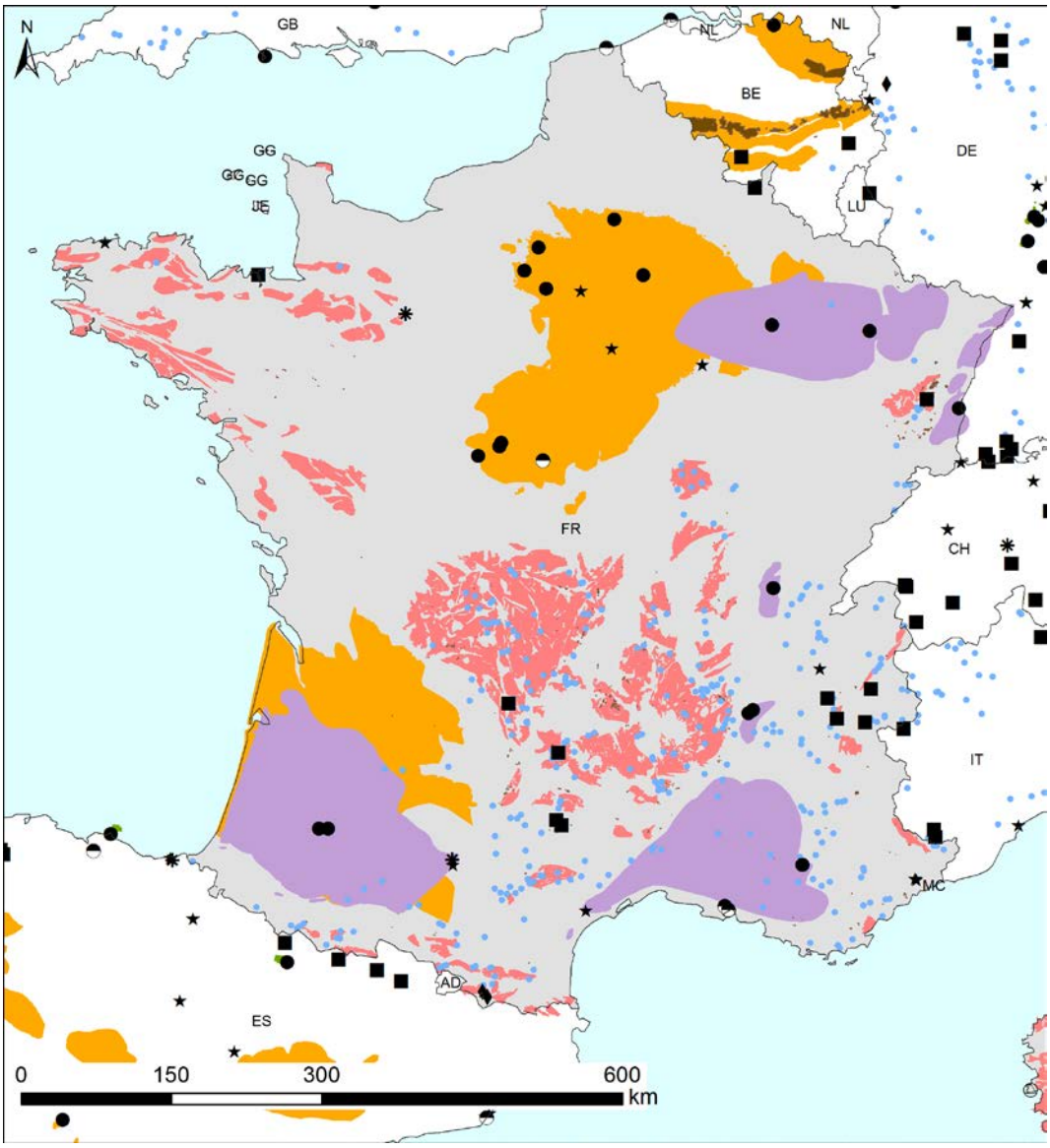

Figure 3.12-1: France - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

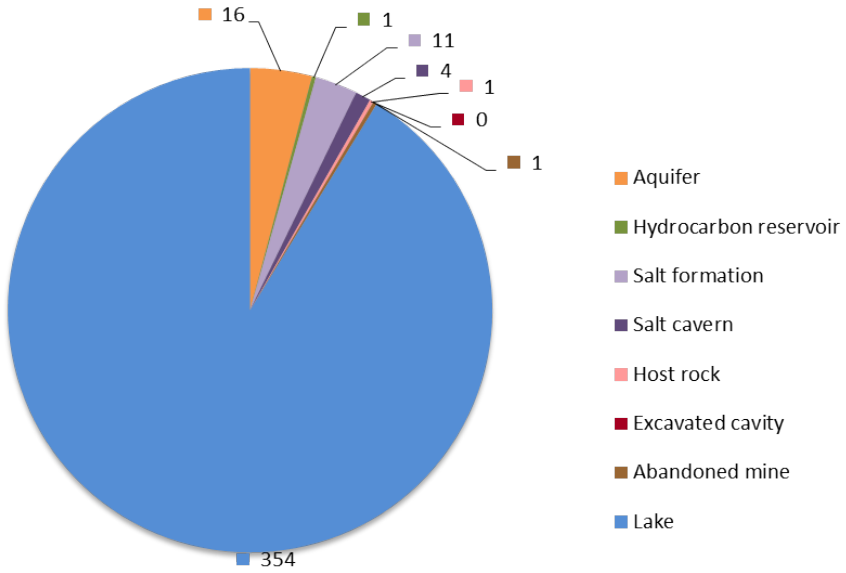

Figure 3.12-2: France - Summary of energy storage reservoir types contained in the database

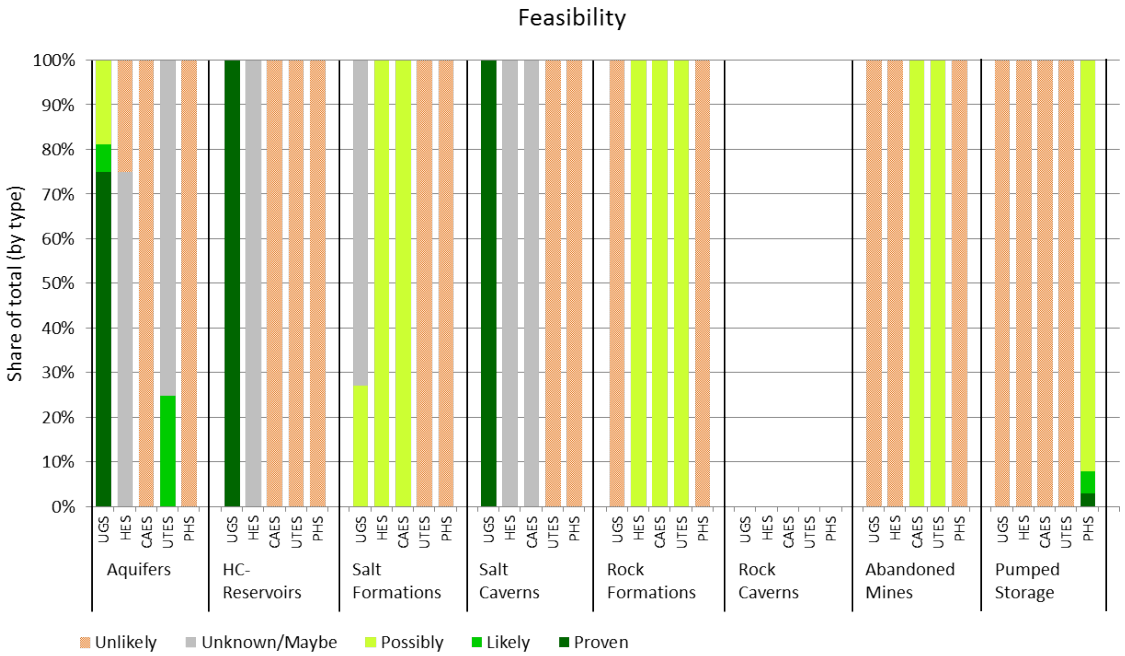

Figure 3.12-3: France - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

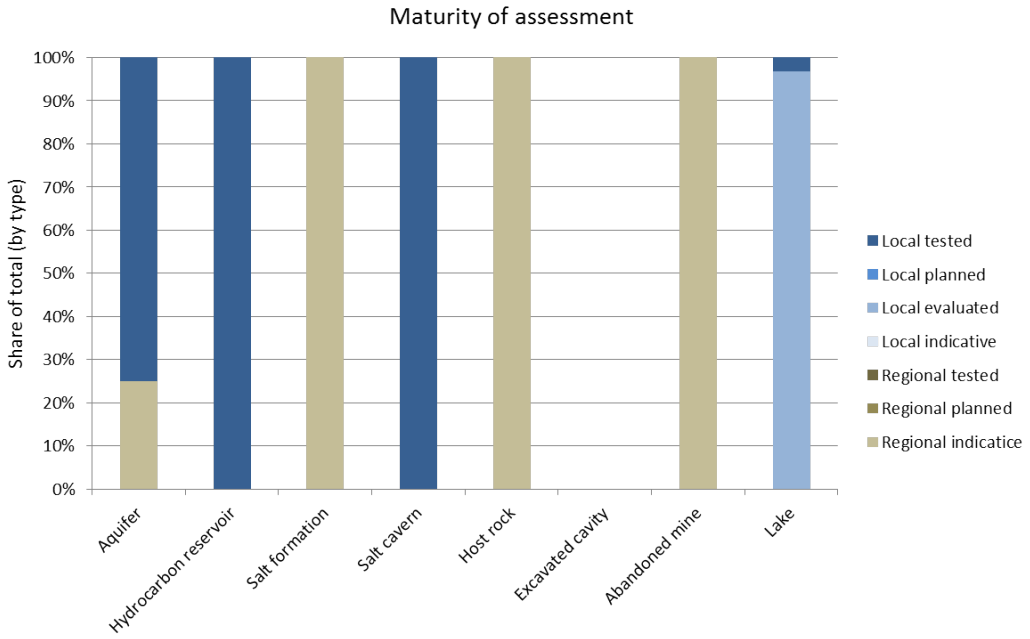

Figure 3.12-4: France - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

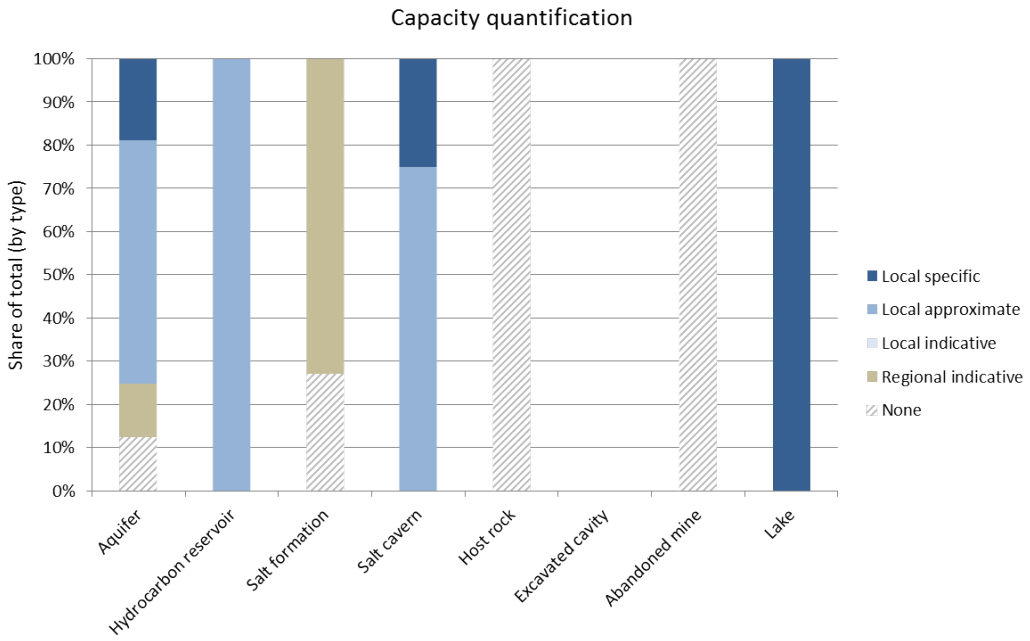

Figure 3.12-5: France - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.13. Germany

3.13.1. Provider administration

Main providing organisations subsurface storage information:

BRGM – Bureau de Recherches Géologiques et Minières
ESTMAP Consortium Partner
Contact Person: Anne-Gaëlle Bader

TNO – Geological Survey of the Netherlands
ESTMAP Consortium Partner
Contact Person: Serge van Gessel

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.13.2. Main data sources

Table 3.13-1: List of common sources used

Source name / URL	Description	Version / Date
LBEG - Erdöl und Erdgas in der Bundesrepublik Deutschland 2014	Reporting of oil and gas reserves Germany	2015
NIBIS Kartenserver: http://nibis.lbeg.de/	NIBIS Erdöl- und Erdgaslagerstätten WMS	2015
Project “InSpEE” – Speicherpotenzial für erneuerbare Energien (CAES & H2). Einblicke in das Inventar norddeutscher Salzstrukturen	Technical assessment report	2015
Salzstrukturen in Norddeutchland: https://services.bgr.de/wms/tieferuntergrund/inspee_salzstrukturen/?		2015
Various Operator websites and archives	VNG Gasspeicher GmbH GHG-Gasspeicher Hannover GmbH E.ON Gas Storage GmbH KGE - Kommunale Gasspeichergesellschaft Epe mbH & Co. KG Zechstein Energy Storage GmbH IVG Caverns GmbH EWE GASSPEICHER GmbH astora GmbH & Co. KG VNG Gasspeicher GmbH / WINGAS GmbH, VNG Gasspeicher GmbH Erdgasspeicher Peissen GmbH Storengy Deutschland GmbH	

	TEP Thüringer Energie Speichergesellschaft mbH / Thüringer Energie AG Berliner Erdgasspeicher GmbH & Co. KG / GASAG Berliner Gaswerke AG Enovos Storage GmbH RWE Dea Speicher GmbH / RWE Dea AG Bayernugs GmbH/ RWE Dea AG E.ON Kraftwerke GmbH http://www.neuralenergy.info/2009/06/caes.html; DOE DB; literature	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.13.3. Storage Data Review Germany

Germany covers a huge potential for energy storage, including various technologies for UGS, HES, CAES and PHS. On the one hand this huge potential can be explained by the existence of favourable conditions in the subsurface (salt structures and hydrocarbon fields) as well as above ground (elevation differences for pumped storage lakes). On the other hand the mapping and evaluation of potential sites has progressed to relatively mature levels. Potential for UTES is expected to be present as well, but this information was not available to ESTMAP at this stage. It should be noted that the information for Germany was not coordinated by a national subcontractor and retrieved from public sources. As details are not available, the identified future potential is still largely considered theoretical (generic assumptions) and unconfirmed.

Table 3.13-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Aquifers are known to exist over large regions of Germany. No concrete future storage potential is included in ESTMAP yet, except for seven local-defined sites that have been developed for UGS.	Check whether there is future scope to investigate and include potential for this reservoir type
Hydrocarbon reservoirs	A large (187) amount of hydrocarbon reservoirs (gas fields) have been included in ESTMAP, of which 15 gas fields are already operational UGS sites. The location of fields and storage uses are based on the LBEG 2015 publication “Erdöl und Erdgas in der Bundesrepublik Deutschland 2014”. Further information on UGS is derived from the GIE gas storage database Europe. For the non-storage operated fields no direct screening information was available regarding assessment of energy storage feasibility. The potential (UGS, HES) is purely based on generic geological assumptions which either need to be confirmed or discarded by site-specific research.	Confirm suitability and capacity from location-specific assessments (or check whether these assessments can be made public if available).
Salt formations and caverns	Recent mapping and assessment studies have resulted in an updated geological evaluation of salt formations in Germany. A large amount of these structures (salt diapirs and salt pillows) have been included in ESTMAP, based on the INSPEE 2015 publication and the information contained in the BGR geological web map services. Structures that are labeled as being explored to a poor degree in the INSPEE study, have been excluded. As no details are available to ESTMAP, the potential is just labeled as “theoretical” on the basis of the generic geological assumption that salt caverns may carry gas, hydrogen or compressed air. Further suitability must be determined by site-specific research. Twenty-eight sites are developed or planned for energy storage (mainly UGS, 1 existing CAES and 1 planned CAES). This information has been derived from the LBEG 2015 publication “Erdöl und Erdgas in der Bundesrepublik Deutschland 2014”, the GIE gas storage database Europe and the DOE energy storage database	Confirm suitability and capacity from location-specific assessments (or check whether these assessments can be made public if available).

Host rock, caverns, mines	No entries available in ESTMAP (has not been assessed for ESTMAP). Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Germany has abundant realisable potential for pumped hydro storage, though predominantly based on one existing and one (to be developed) potential lake. Nine out of 123 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

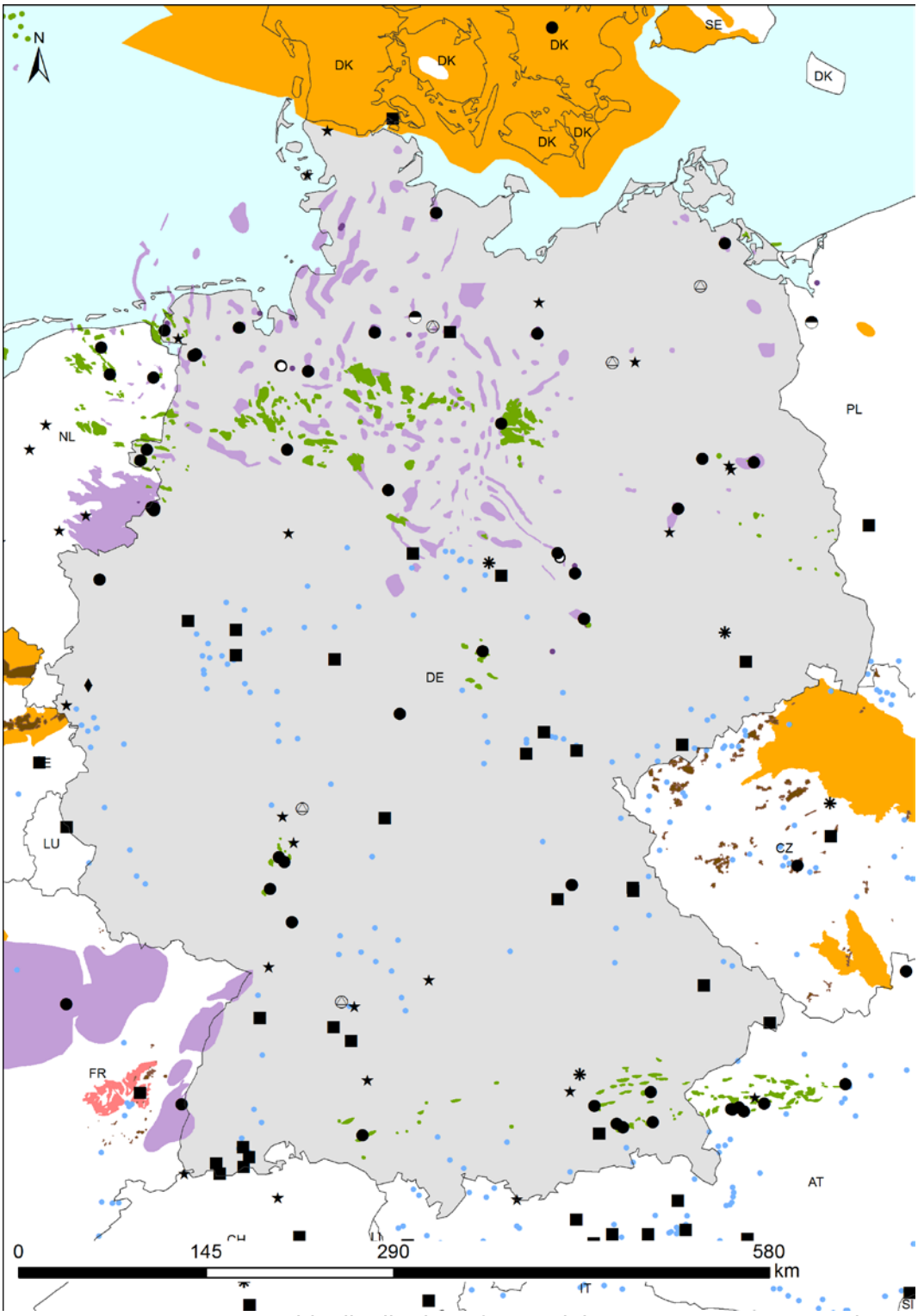

Figure 3.13-1: Germany - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5. After: LBEG-2015, Project InSpEE-2015 (service.bgr.de/wms), GIE-2015, DOE-2015, JRC-2013 (sources mentioned in Table 3.13-1)

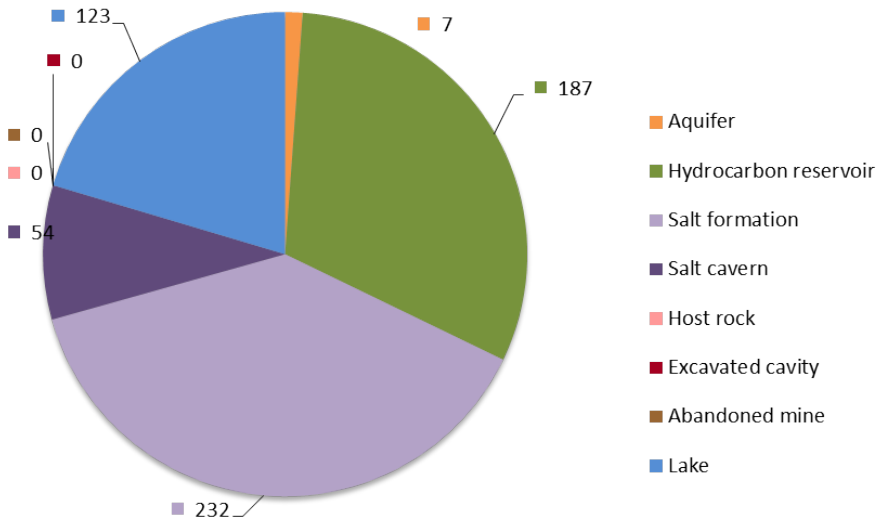

Figure 3.13-2: Germany - Summary of energy storage reservoir types contained in the database
Note: “Salt Caverns” indicates the number of sites where one or more caverns exist, not the number of individual caverns.

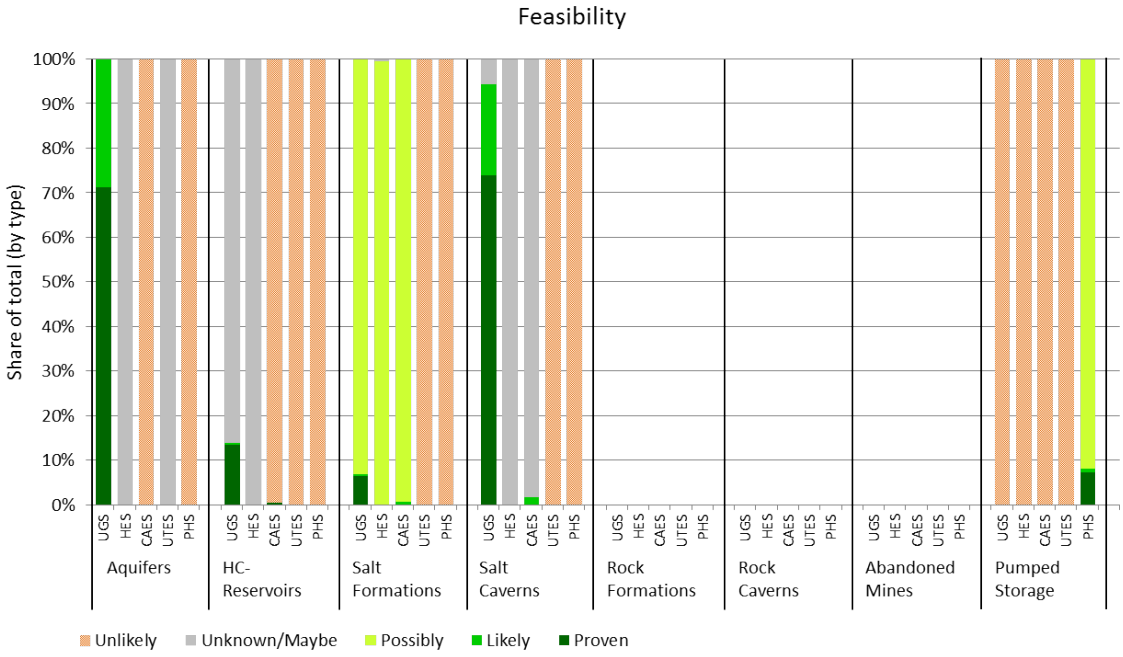

Figure 3.13-3: Germany - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

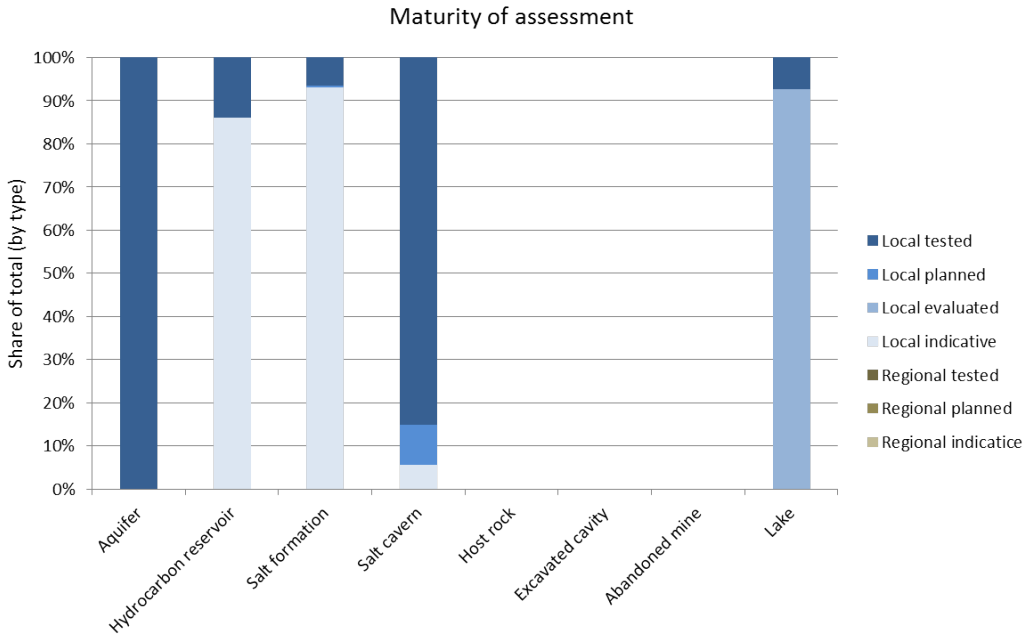

Figure 3.13-4: Germany - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

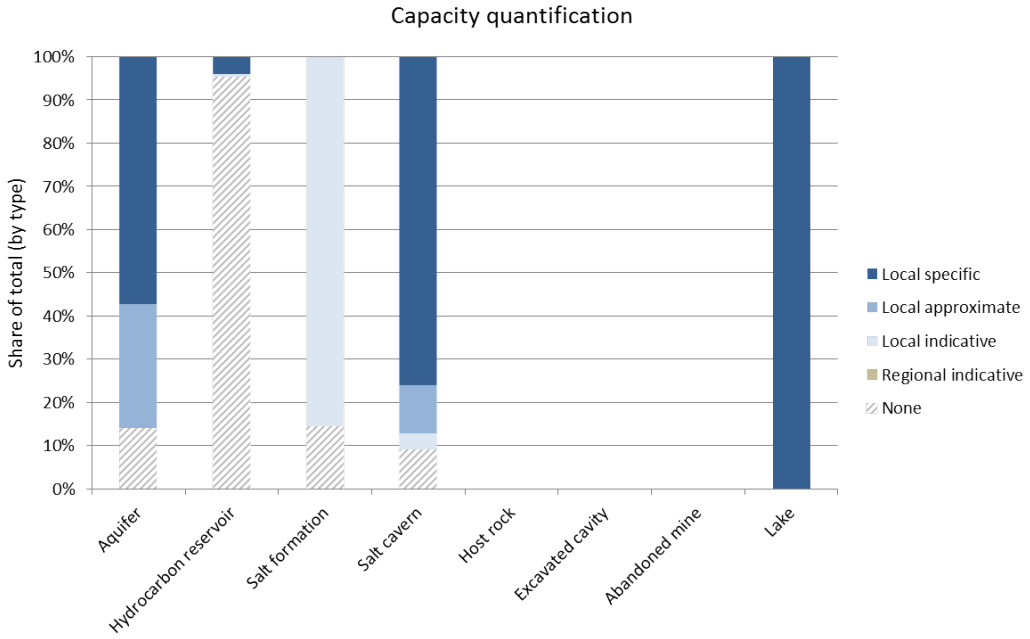

Figure 3.13-5: Germany - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.14. Greece

3.14.1. Provider administration

Main providing organisations subsurface storage information:

IGME – Institute of Geology and Mineral Exploration
Subcontractor
Contact Person: Apostolos Arvanitis

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.14.2. Main data sources

Table 3.14-1: List of common sources used

Source name / URL	Description	Version / Date
Allwood A.C, Burch I.W., Rouchy J.M. & Coleman M (2013), Morphological Biosignatures in Gypsum:Diverse Formation Processes of Messinian (*6.0 Ma) Gypsum Stromatolites	Scientific publications and reports	2013
Dandolos El. & Zorapas B. (2010), Hydrogeological Study of Eastern Central Greece, Assessment and evaluation of the hydrogeological parameters of groundwater and aquifers in Greece:	Scientific publications and reports	2010
Giannoulopoulos P. & Lappas I. (2010), Hydrogeological Study of Aegean Sea, Assessment and evaluation of the hydrogeological parameters of groundwater and aquifers in Greece	Scientific publications and reports	2010
Hatzigiannis G. & Xenakis M. (2003) GESTCO2: Study Area D Greek Onshore and offshore tertiary sedimentary rocks	Scientific publications and reports	2003
Institute of Geology and Mineral Exploration - IGME (1971), Geological Map of Greece 1:50.000- sheet Erithrai	Scientific publications and reports	1971
Kolios N. & Karydakis G. (2000), Geothermal Study of East Xanthi-Komotini Basin (Sappes region)	Scientific publications and reports	2000
Kolios N. (2000), Geothermal Study of East Xanthi-Komotini Basin (Mitrikou Lake region)	Scientific publications and reports	2000
Kolios N. , Koutsinos S., Kougoulis Ch.,	Scientific publications and reports	2005

Arvanitis A. & Karydakis G. (2005), Geothermal Study of Thessaloniki Basin		
Lazaridou M. (2010),Hydrogeological Study of East and Central Macedonia, Assessment and evaluation of the hydrogeological parameters of groundwater and aquifers in Greece	Scientific publications and reports	2010
Ministry of Environment, Energy and Climate Change (2010), Conversion of the South Kavala Gas Field into Underground Gas storage	Scientific publications and reports	2010
Nikolaou K. (2012), Hydrocarbon Exploration and Production in Greece / Petroleum Systems-Analogues-Discoveries & Perspectives	Scientific publications and reports	2012
Rigakis, N. (1999). Contribution to stratigraphic research on wells and outcrops of the Alpine formations in Western Greece, in relation to the petroleum generation efficiency of their organic matter	Scientific publications and reports	1999
Siemos N., Michalakis I. & Anastasopoulou S. (2010) ,Hydrogeological Study of Attica, Assessment and evaluation of the hydrogeological parameters of groundwater and aquifers in Greece	Scientific publications and reports	2010
Vakalopoulos P., Xenakis M. & Metaxas A., (1997), Study and evaluation of Evia's lignite basins	Scientific publications and reports	1997
Vasilatos C., Koukouzas N.. & Alexopoulos D. (2015), Geochemical Control of Acid Mine Drainage in Abandoned Mines: The Case of Ermioni Mine, Greece. Procedia Earth and Planetary Science	Scientific publications and reports	2015
Vassilis Karakitsios (2003), Evolution and Petroleum potential of the Ionian Basin (North-West Greece)	Scientific publications and reports	2003
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.14.3. Storage Data Review Greece

Greece has a varied potential for different storage technologies in aquifers, hydrocarbon reservoirs, salt formations and abandoned mines. There is also good potential for PHS in above ground lakes. Existing development is still very limited (one UGS, two PHS). The information provided has a reasonably good coverage of various parameters included in ESTMAP.

Table 3.14-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Greece includes 22 local to regional-defined aquifers. Thirteen sites have UTES as main target development. The other sites are intended for UGS. Potential for alternative storage purposes (e.g. HES) has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Direct capacity determinations are only provided for the UGS planned sites (working gas volumes).	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Hydrocarbon reservoirs	Four local-defined hydrocarbon reservoirs are included, one of which has been developed as UGS. The other three sites have assumed feasibility for UGS. Direct working gas volume determinations are provided. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is currently unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Salt formations and caverns	Seven local-defined salt formations are included, none of which has been developed for storage purposes yet. Target development is either UGS or HES. Direct working gas volume determinations are provided. Each site may represent potential for alternative storage purposes (either one of UGS, HES, CAES), but this has not been assessed yet. It is currently unknown whether there is scope for investigating additional potential in other salt formations.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Host rock, caverns, mines	There are four abandoned mines included in ESTMAP, three of which are intended for UTES. The mines are parameterized to a limited extent only and there is no basis for estimating capacities. It is unknown whether potential exists in host rock formations. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Lakes	Greece has moderate to abundant realisable potential for pumped hydro storage, though predominantly based on one existing and one (to be developed) potential lake. Two out of 38 sites	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

	included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	

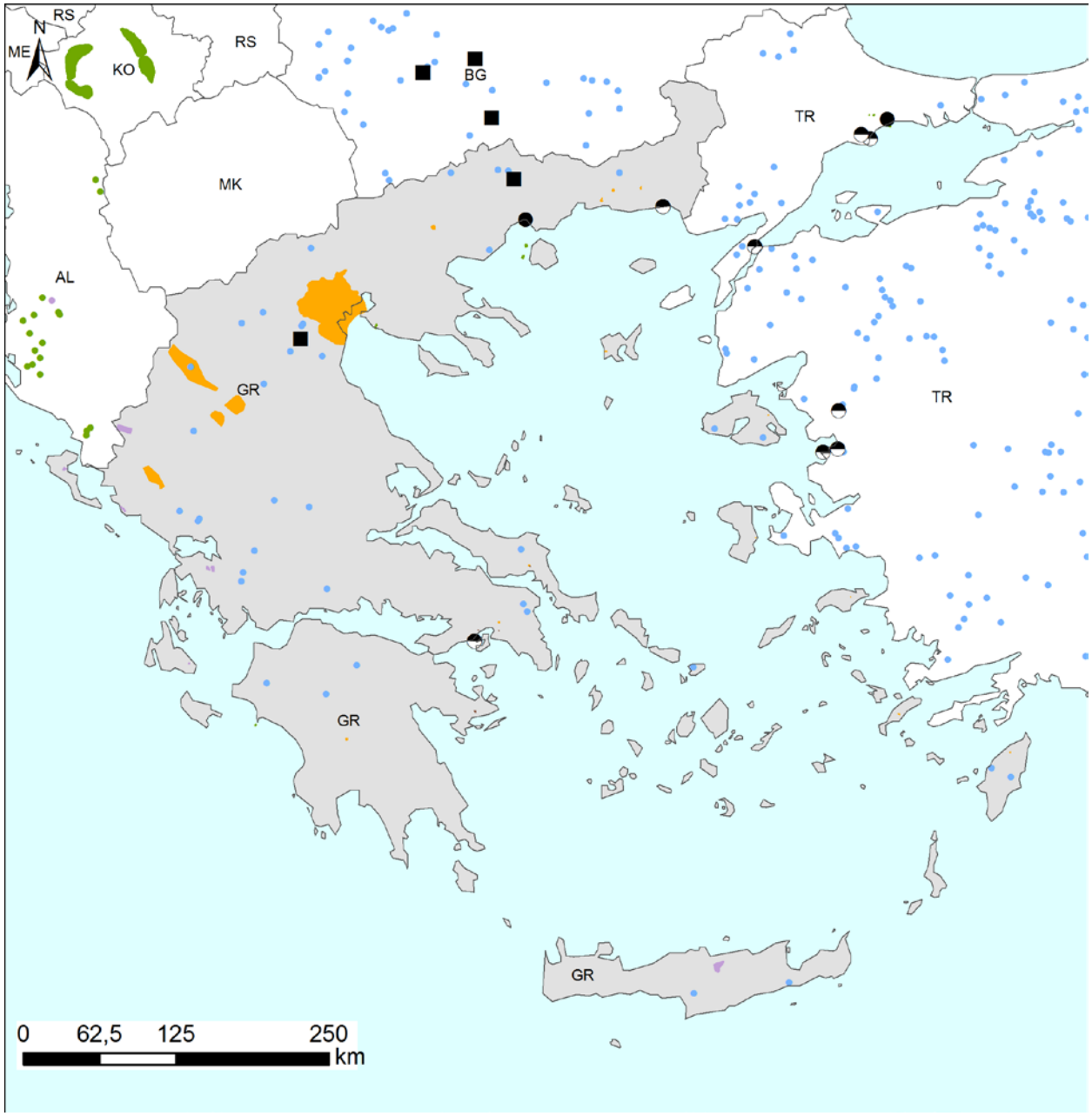

Figure 3.14-1: Greece - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

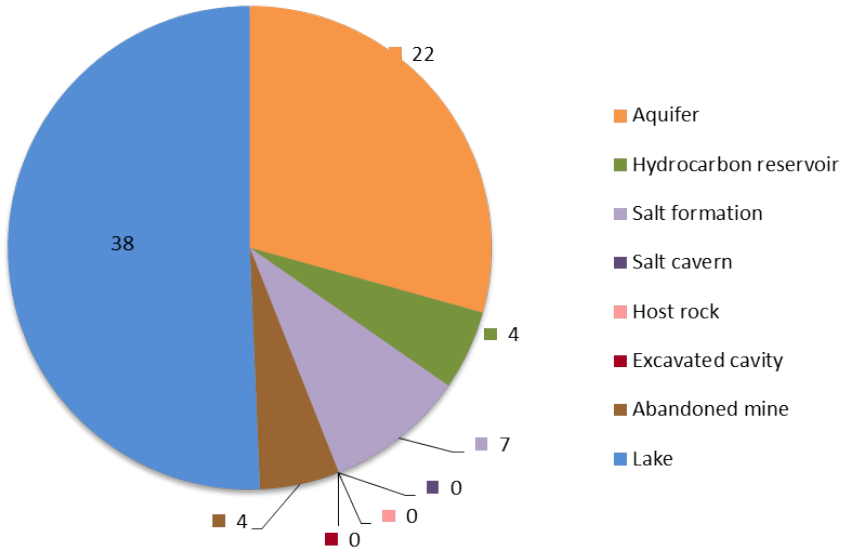

Figure 3.14-2: Greece - Summary of energy storage reservoir types contained in the database

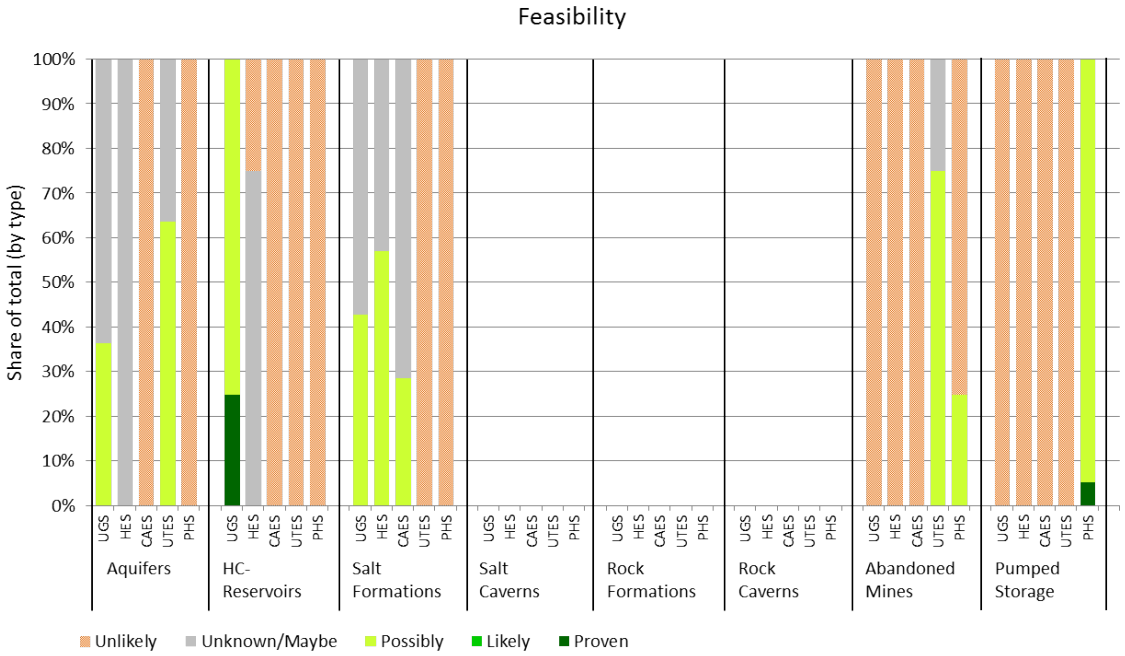

Figure 3.14-3: Greece - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

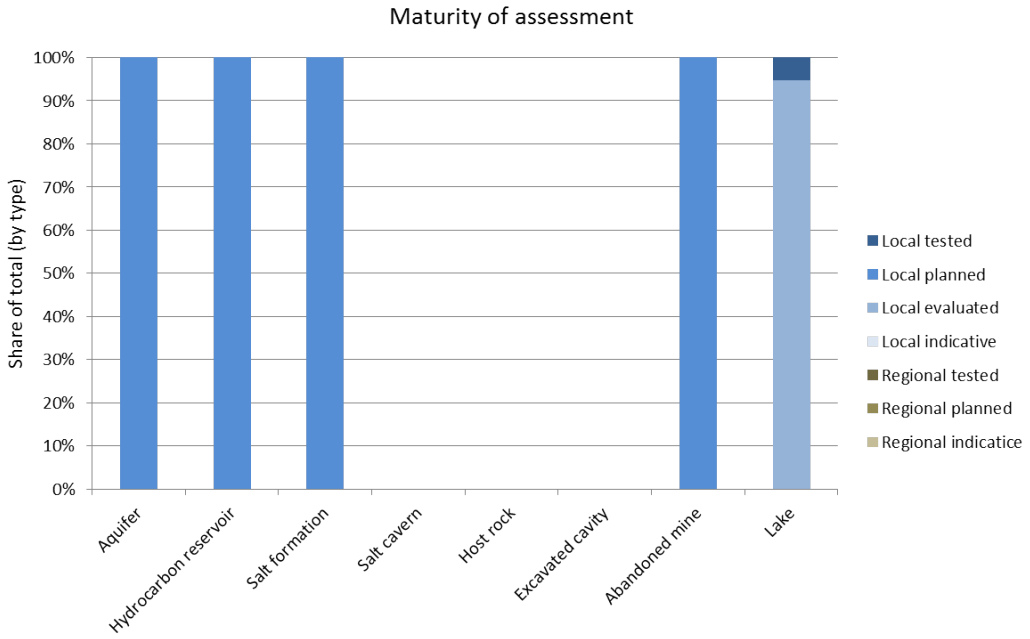

Figure 3.14-4: Greece - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

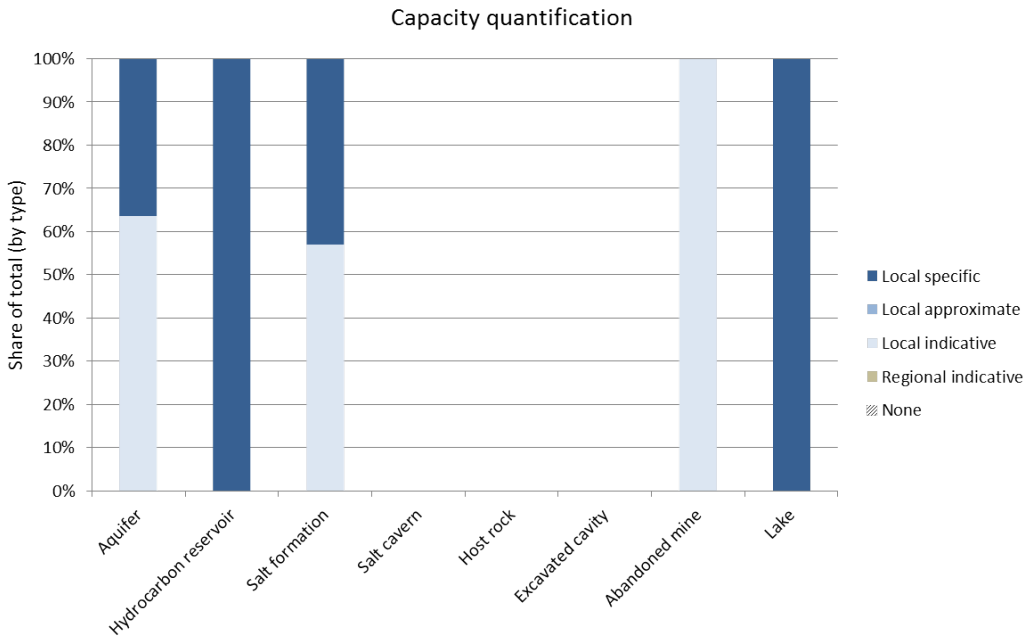

Figure 3.14-5: Greece - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.15. Hungary

3.15.1. Provider administration

Main providing organisations subsurface storage information:

MFGI – Geological and Geophysical Institute of Hungary
Subcontractor
Contact Person: György Falus

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.15.2. Main data sources

Table 3.15-1: List of common sources used

Source name / URL	Description	Version / Date
MFGI Geological data archives and map servers	Geological assessment data, Literature publications and reports on aquifers	2015
Operator reports, webpage of competent authority	Hydrocarbon reservoirs	2015
Bódi, T. (2004) Földalatti gáztárolás, gáztermelés. Egyetemi jegyzet, Miskolc p. 117.; Coats, K.H., (1966) Some technical and economic aspects of underground gas storage	Scientific study on underground gas storage in Hungary	2004
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.15.3. Storage Data Review Hungary

Hungary has good potential for UGS in hydrocarbon reservoirs including existing and planned developments. Potential for UTES may be present in aquifers but local suitability and capacities still need to be investigated. There is limited potential for PHS in above ground lakes.

Table 3.15-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Hungary includes 17 regional-defined aquifers which cover a large part of the country. All aquifers are considered feasible for UTES only. Assessment is still premature and location-specific investigations are required to confirm suitability. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities yet.	Investigation and confirmation of location-specific potential and expected capacities for UTES.
Hydrocarbon reservoirs	28 local-defined hydrocarbon reservoirs are included, 6 of which have been developed as UGS and 8 of which are planned for UGS development. For the other 14 sites UGS feasibility is assumed yet unconfirmed. Direct working gas volume determinations are provided for the existing and planned UGS sites. For the other sites approximate total gas volumes are available. Potential for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	No entries available in ESTMAP. As far as known Hungary does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Hungary has only three known sites with realisable potential for pumped hydro storage, all of which are based on one existing and one (to be developed) potential lake. None of these appears to be developed yet. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

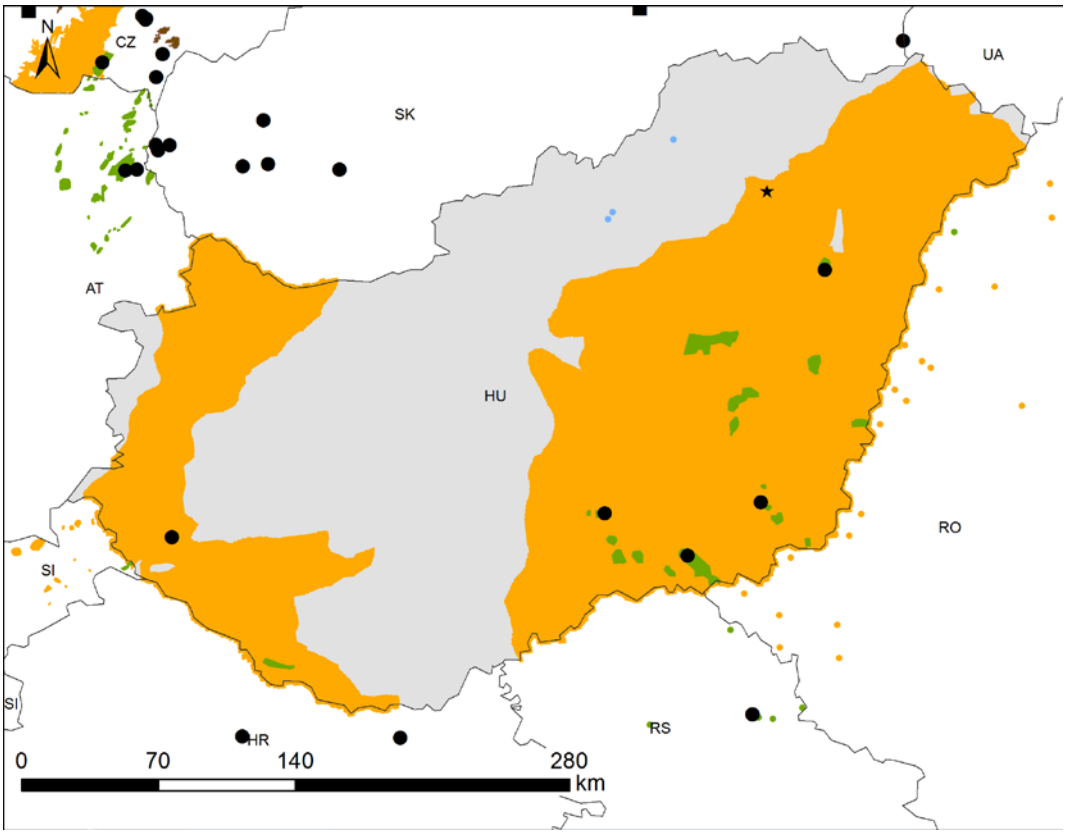

Figure 3.15-1: Hungary- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

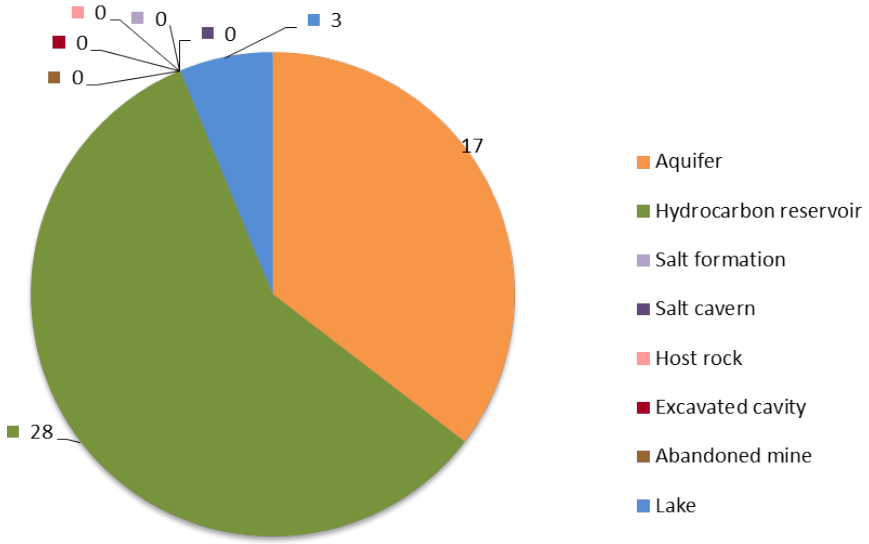

Figure 3.15-2: Hungary - Summary of energy storage reservoir types contained in the database

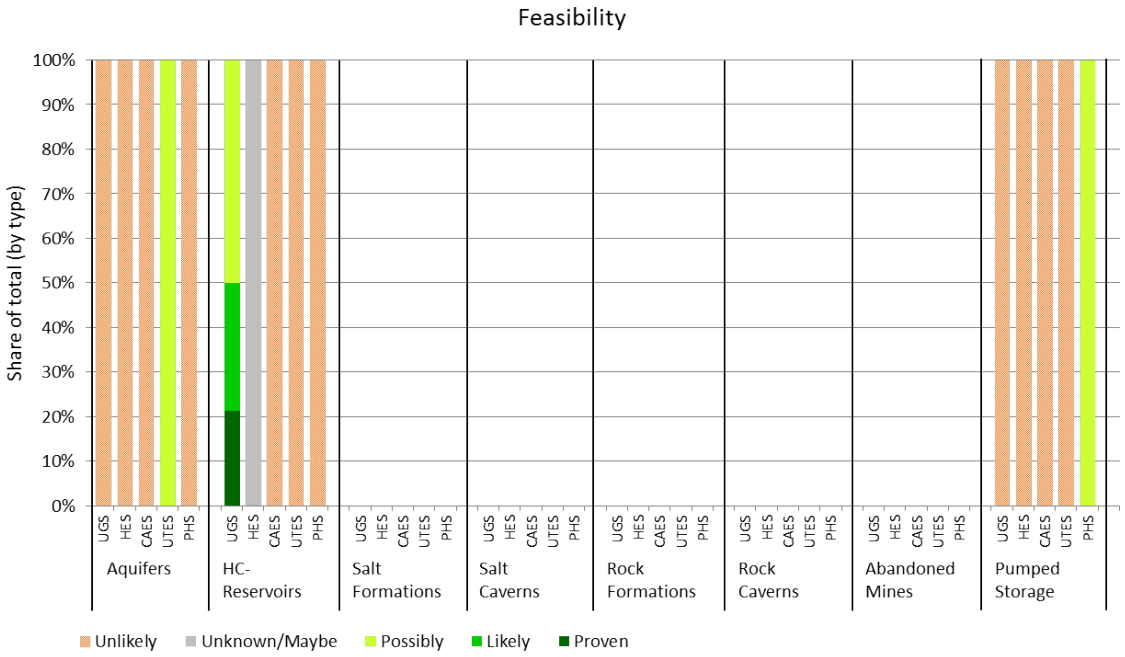

Figure 3.15-3: Hungary - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

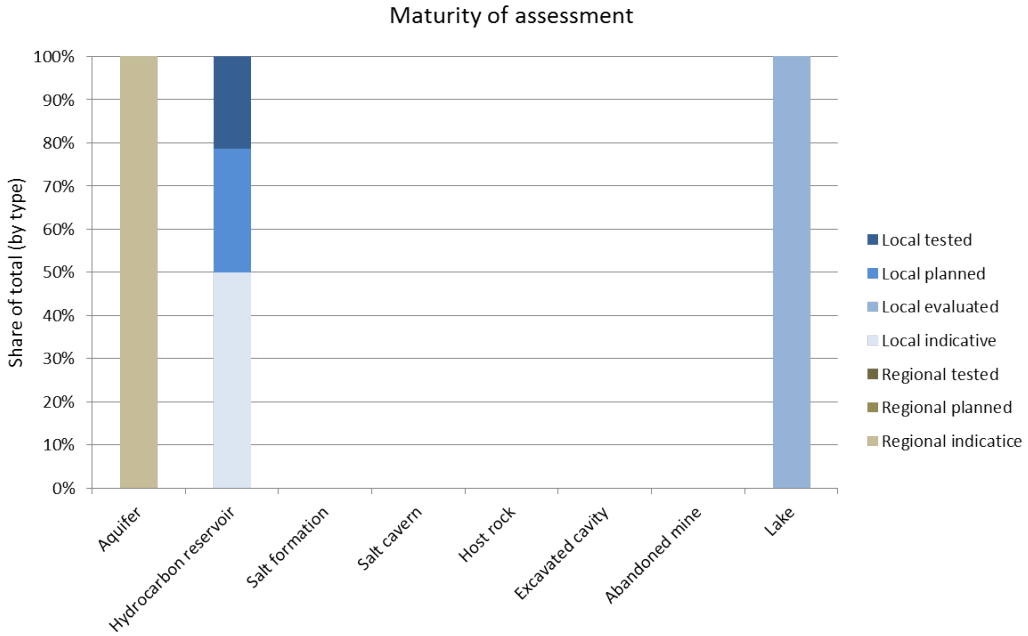

Figure 3.15-4: Hungary - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

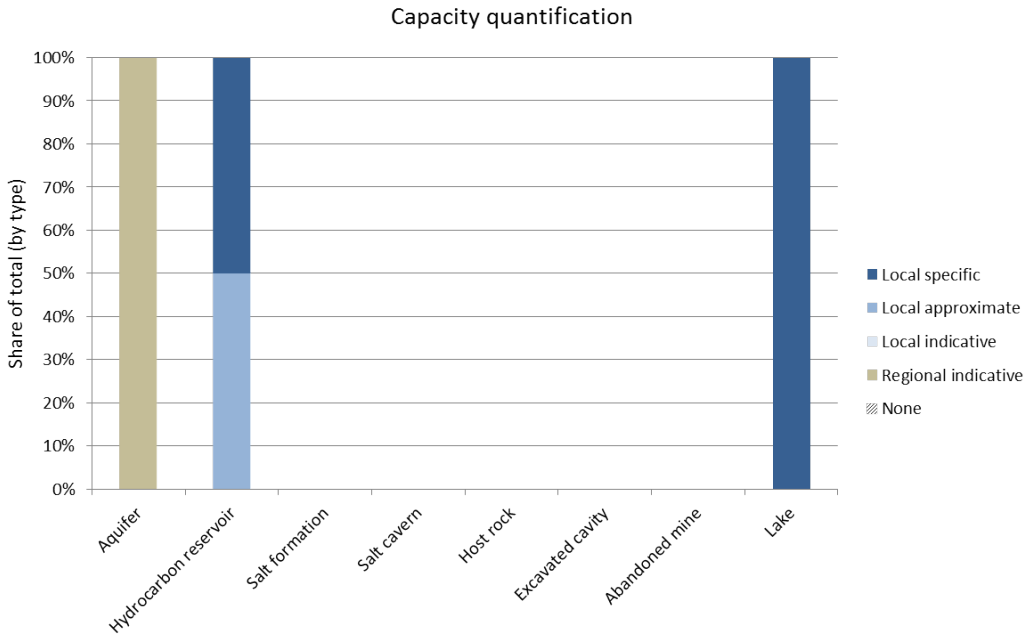

Figure 3.15-5: Hungary - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.16. Ireland

3.16.1. Provider administration

Main providing organisations subsurface storage information:

BRGM – Bureau de Recherches Géologiques et Minières
ESTMAP Consortium Partner
Contact Person: Anne-Gaëlle Bader

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.16.2. Main data sources

Table 3.16-1: List of common sources used

Source name / URL	Description	Version / Date
Operator website: http://www.kinsale-energy.ie/gas-storage.html	Site specific data	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.16.3. Storage Data Review Ireland

Only limited information on subsurface energy storage potential has been found for Ireland. Above ground potential for PHS is present in several lakes. Possibly there is additional potential in salt formations or rock formations.

Table 3.16-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential may be present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Only one site (developed as UGS) has been included in ESTMAP. Direct working gas volume determinations are provided. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is currently unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Check whether there is future scope to investigate potential for this reservoir type
Salt formations and caverns	No entries available in ESTMAP. Subsurface salt deposits are known to exist along the northern and offshore margins of Ireland. Information on energy storage potential is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Ireland has low to moderate realisable potential for pumped hydro storage, all of which is based on one existing and one (to be developed) potential lake. One out of 11 sites included in ESTMAP is developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

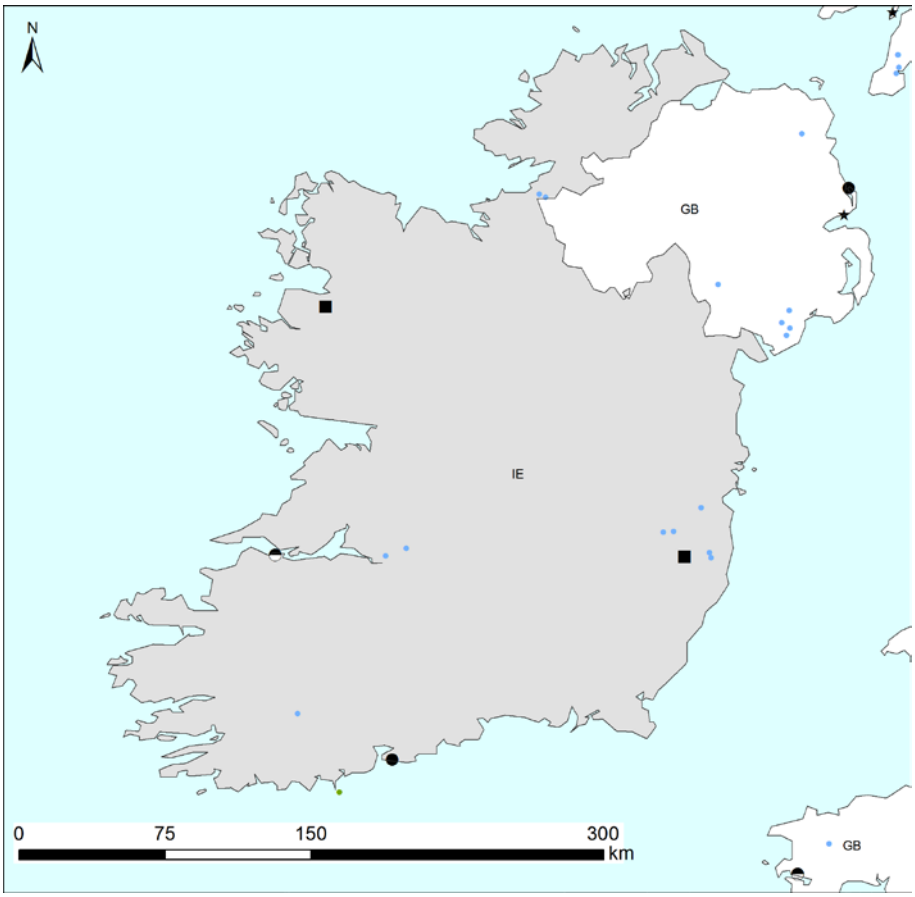

Figure 3.16-1: Ireland- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

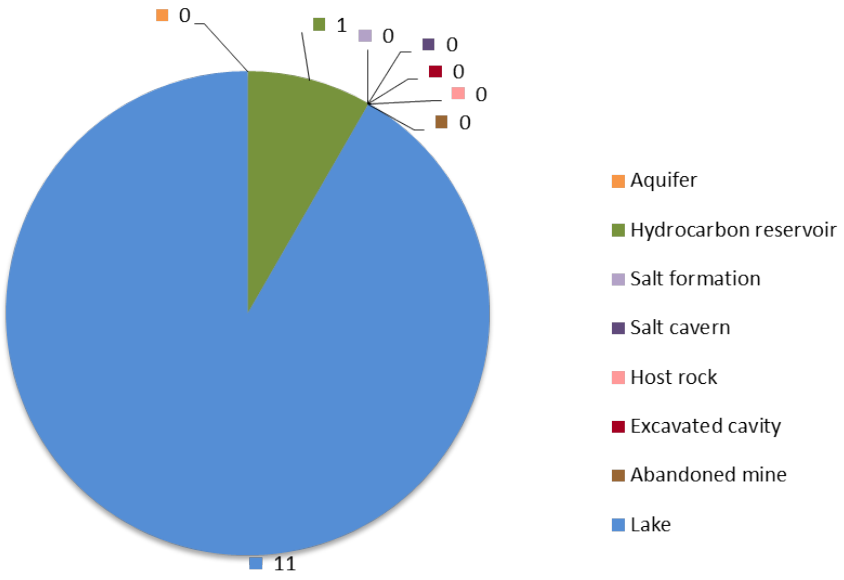

Figure 3.16-2: Ireland - Summary of energy storage reservoir types contained in the database

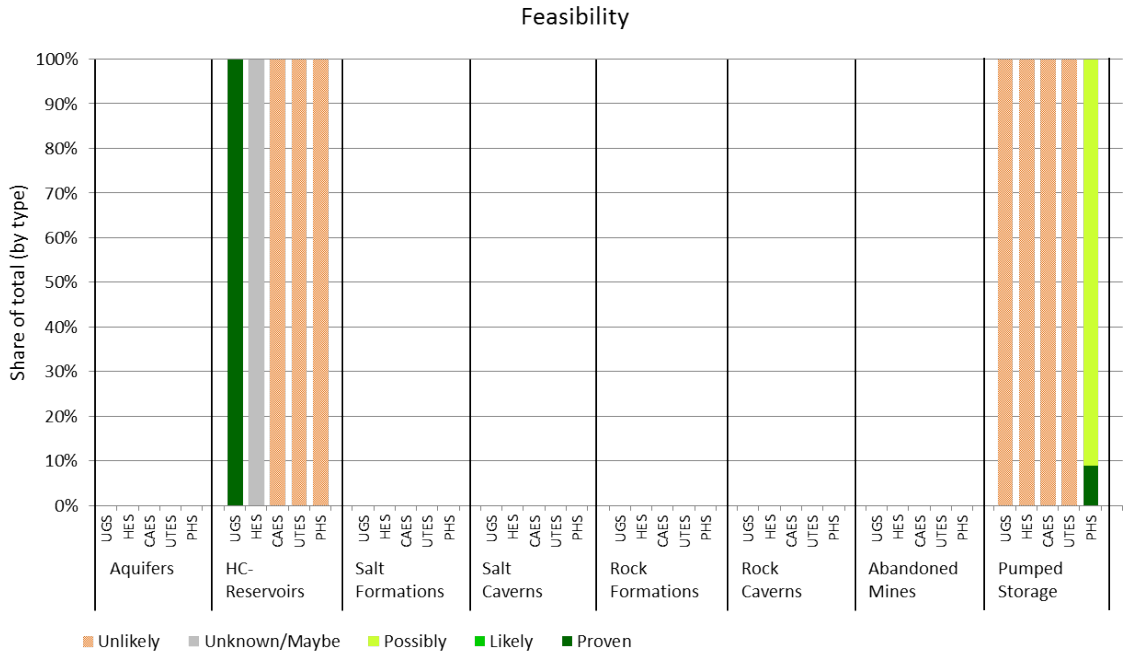

Figure 3.16-3: Ireland - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

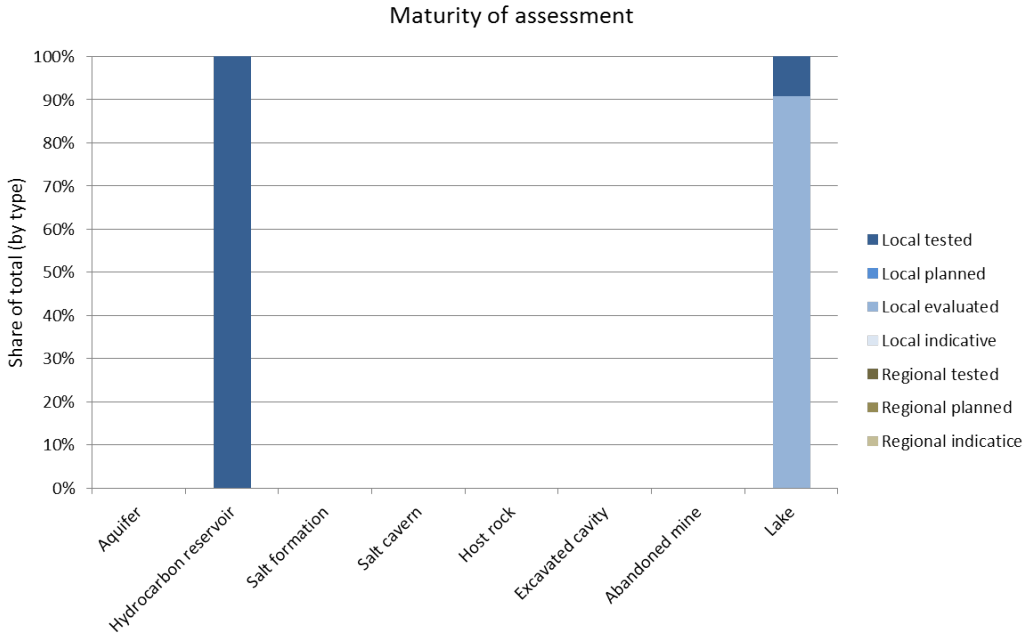

Figure 3.16-4: Ireland - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

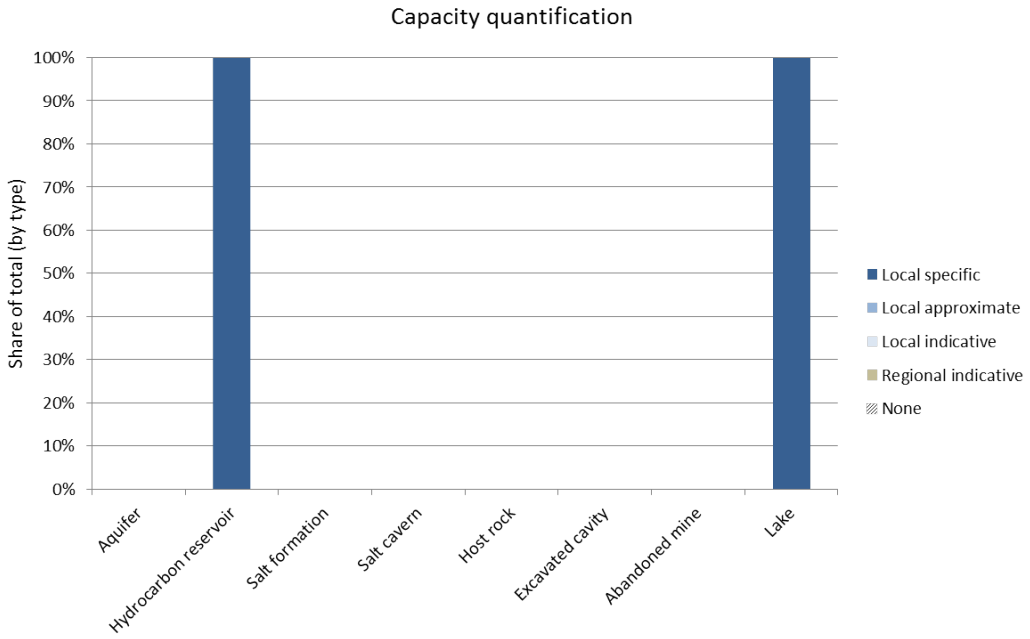

Figure 3.16-5: Ireland - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.17. Italy

3.17.1. Provider administration

Main providing organisations subsurface storage information:

ISPRA – Institute for Environmental Protection and Research
Subcontractor
Contact Person: Dr. Fernando Ferri

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.17.2. Main data sources

Table 3.17-1: List of common sources used

Source name / URL	Description	Version / Date
Ministry of Economic Development - Min. Environment: http://unmig.mise.gov.it	Site specific information on gas storages. Operator and literature	2015
Osservatorio Geofisico Sperimentale OGS: from a publication on CCS potential (IJGGC - 2011)	Geological storage information on aquifers	2011
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.17.3. Storage Data Review Italy

Italy has good potential for UGS in hydrocarbon reservoirs (existing and planned development). Additional potential is considered present in aquifers but this needs to be confirmed by further location-specific investigations. Salt formations and rock formations are not included in ESTMAP but may represent some further potential. There is abundant potential for PHS in many above ground lakes.

Table 3.17-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Italy includes 12 regional-defined aquifers which are spread across the country. All aquifers are considered suitable for UGS but assessment is still premature and location-specific investigations are required to confirm this potential (except for one tested site). Potential for HES and UTES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. None of the sites included in ESTMAP have been developed as storage yet. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment..
Hydrocarbon reservoirs	23 local-defined hydrocarbon reservoirs are included, 10 of which have been developed as UGS (with planned expansion for 6 sites) and 13 of which are intended or planned for future UGS development. Note that the expansion sites are included as separate capacities in ESTMAP. Direct working gas volume determinations are provided. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	No entries available in ESTMAP. Subsurface salt deposits are known to exist in local parts of Italy. Information on energy storage potential is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Italy has huge realisable potential for pumped hydro storage, including many options based on two existing nearby (<10 km) lakes. Thirteen out of 355 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

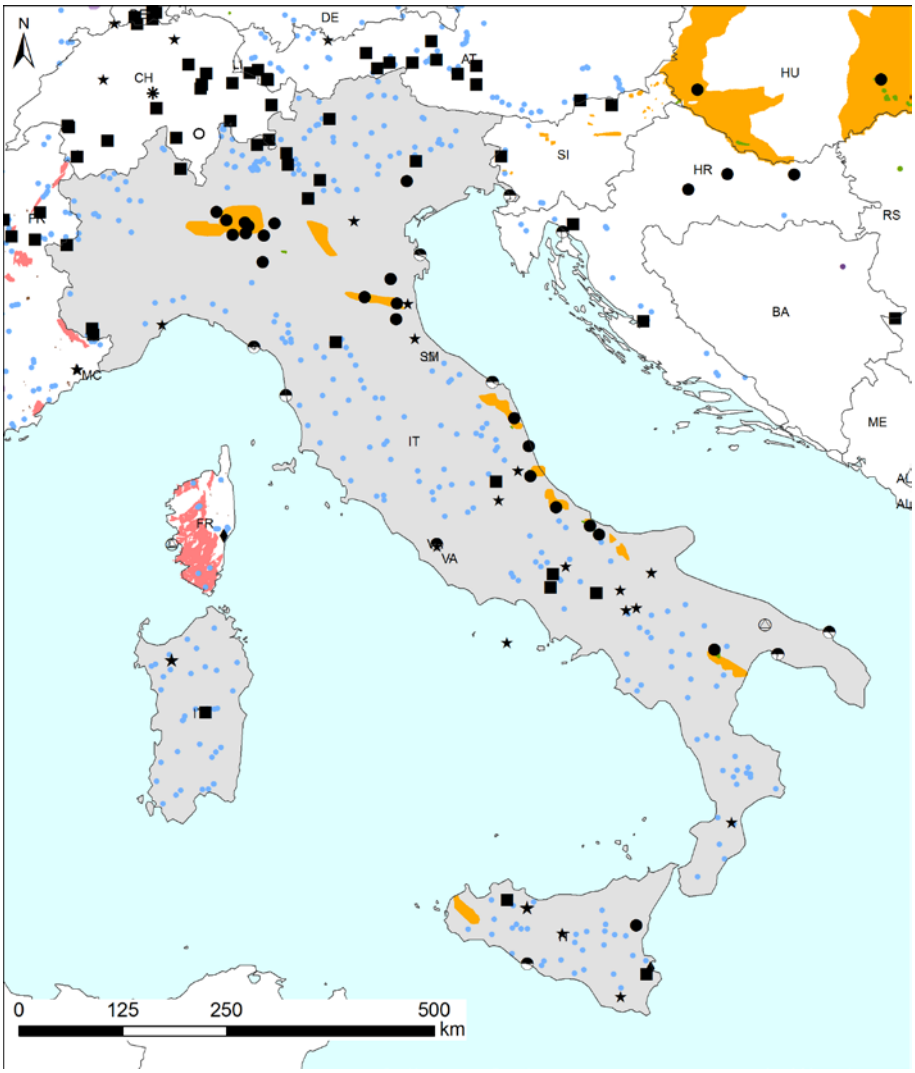

Figure 3.17-1: Italy - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

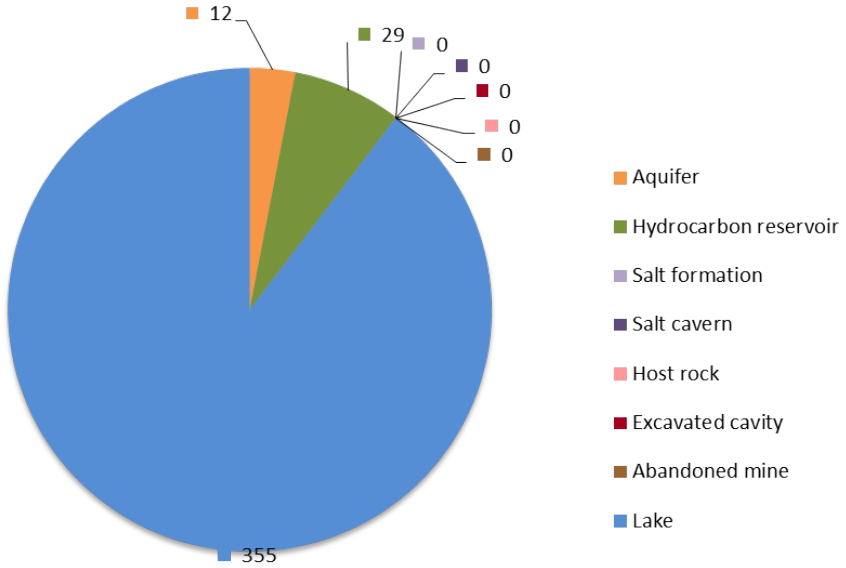

Figure 3.17-2: Italy - Summary of energy storage reservoir types contained in the database

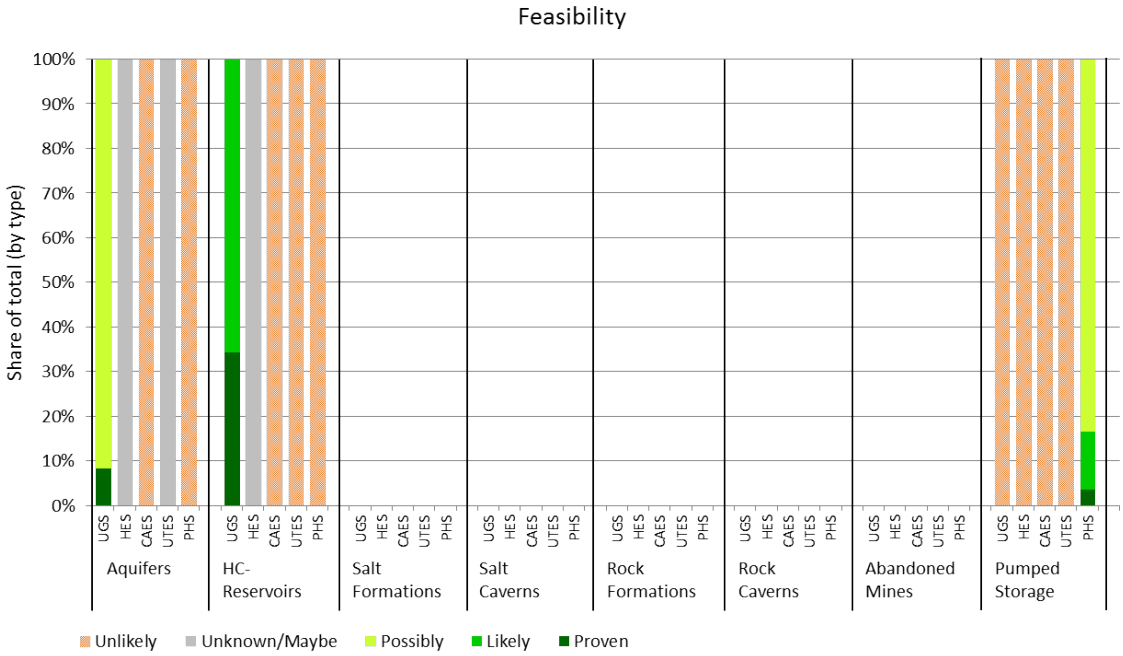

Figure 3.17-3: Italy - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

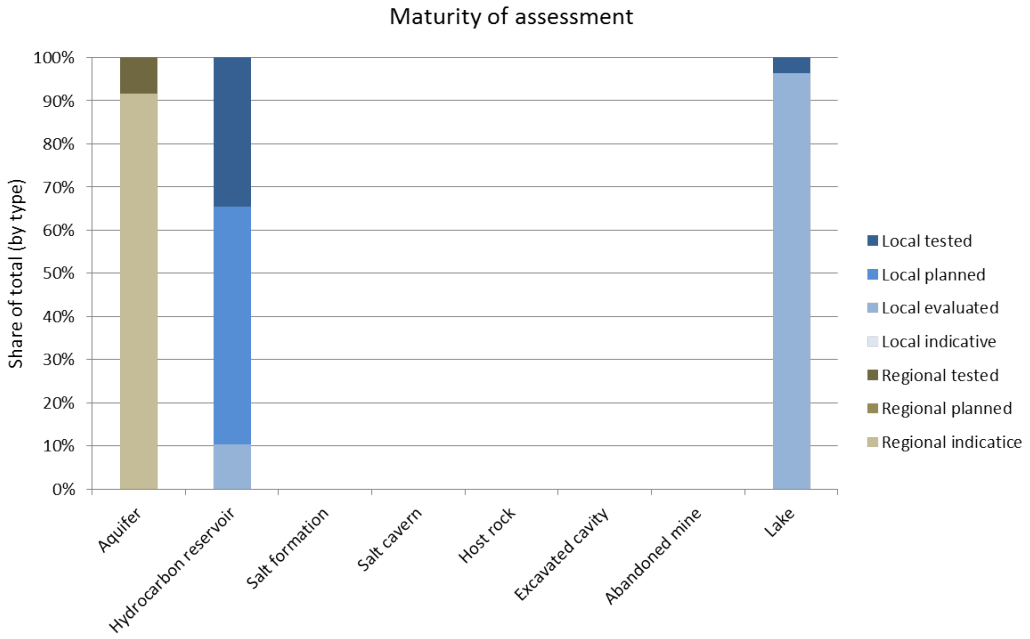

Figure 3.17-4: Italy - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

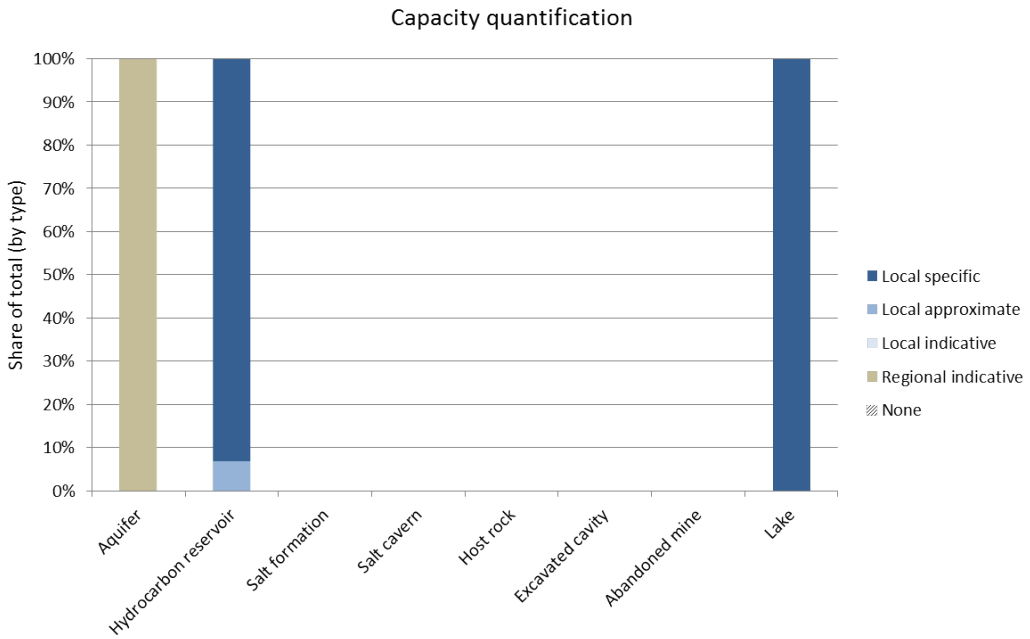

Figure 3.17-5: Italy - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.18. Kosovo

3.18.1. Provider administration

Main providing organisations subsurface storage information:

AGS – Albanian Geological Survey
Subcontractor
Contact Person: Dr. Arben Pambuku

Main providing organisations above ground storage information:

No provider

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.18.2. Main data sources

Table 3.18-1: List of common sources used

Source name / URL	Description	Version / Date
Kosovo Geological Survey data archives	Generic information on hydrocarbon reservoirs	

3.18.3. Storage Data Review Kosovo

Currently known energy storage potential for Kosovo is limited to a few hydrocarbon reservoirs considered feasible for UGS. Additional potential may be present in pumped storage lakes but these are not assessed yet. There is no existing energy storage development known for Kosovo.

Table 3.18-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential may be present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Four local-defined hydrocarbon reservoirs are included, none of which have been developed as UGS yet. Assessment of feasibility is still premature and will require further location-specific investigations. Capacities are approximated from total gas volumes. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Salt formations and caverns	No entries available in ESTMAP. As far as known Kosovo does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Kosovo was included in the JRC-2013 assessment report, but these data were not publicly available. Kosovo has 5 known sites with realisable potential for PHS development. All are based on one existing lake and one (to be developed) potential lake.	Include PHS assessment data once publicly available

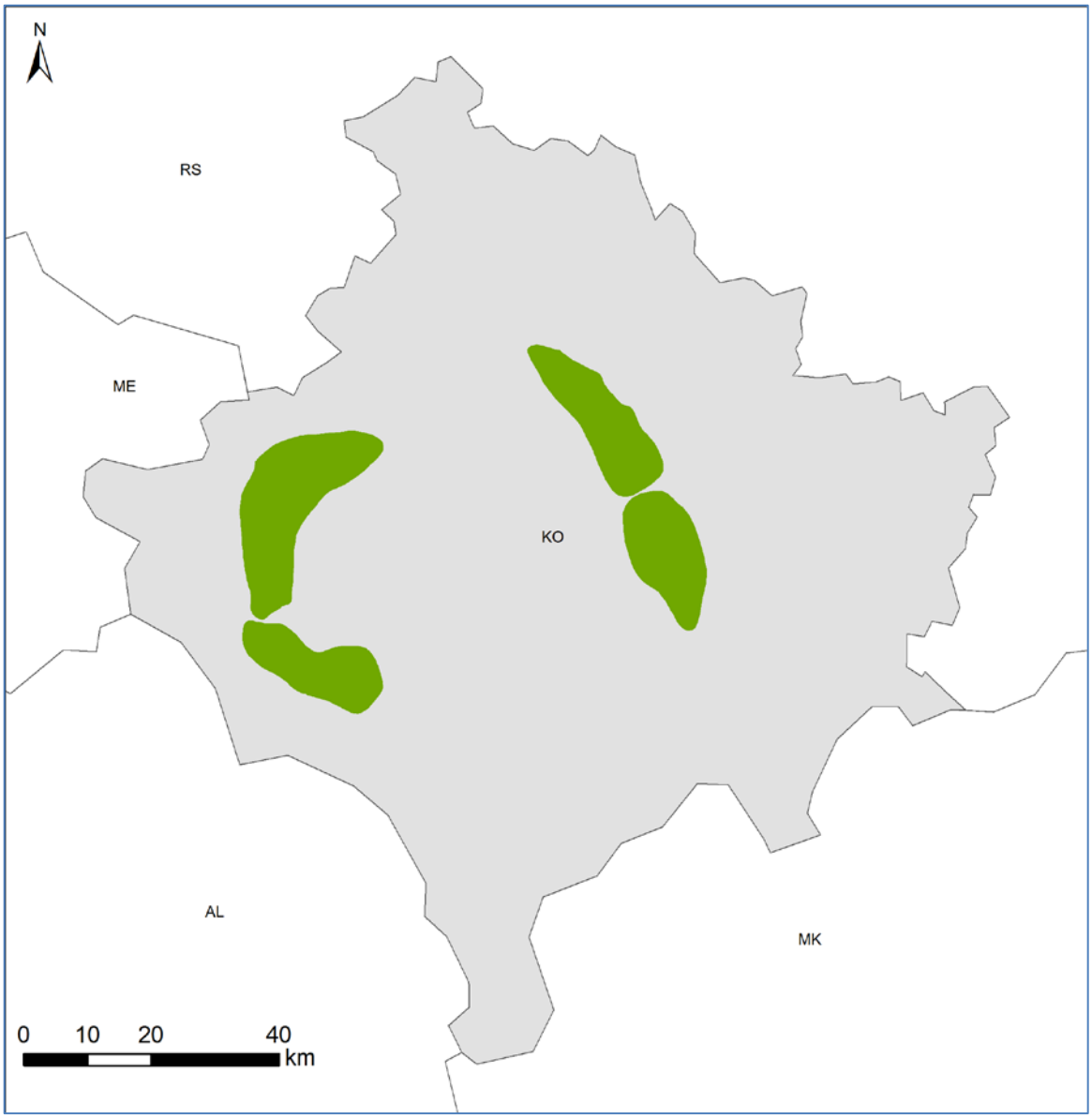

Figure 3.18-1: Kosovo - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

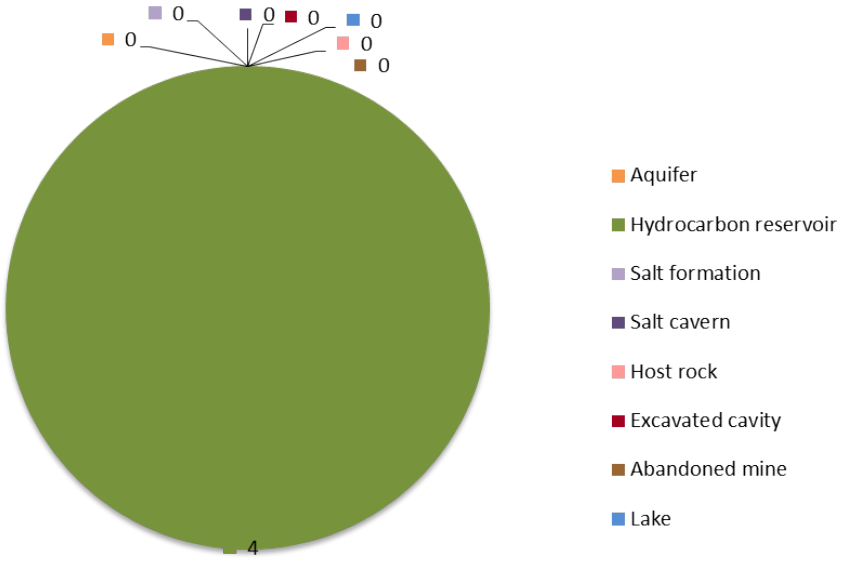

Figure 3.18-2: Kosovo - Summary of energy storage reservoir types contained in the database

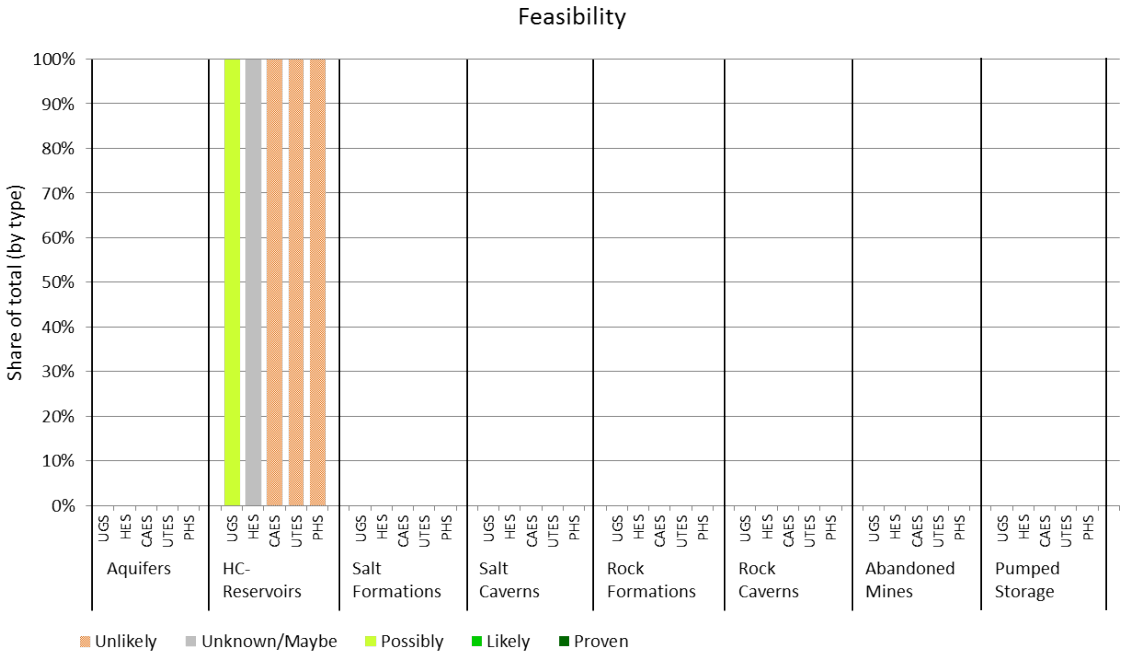

Figure 3.18-3: Kosovo - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

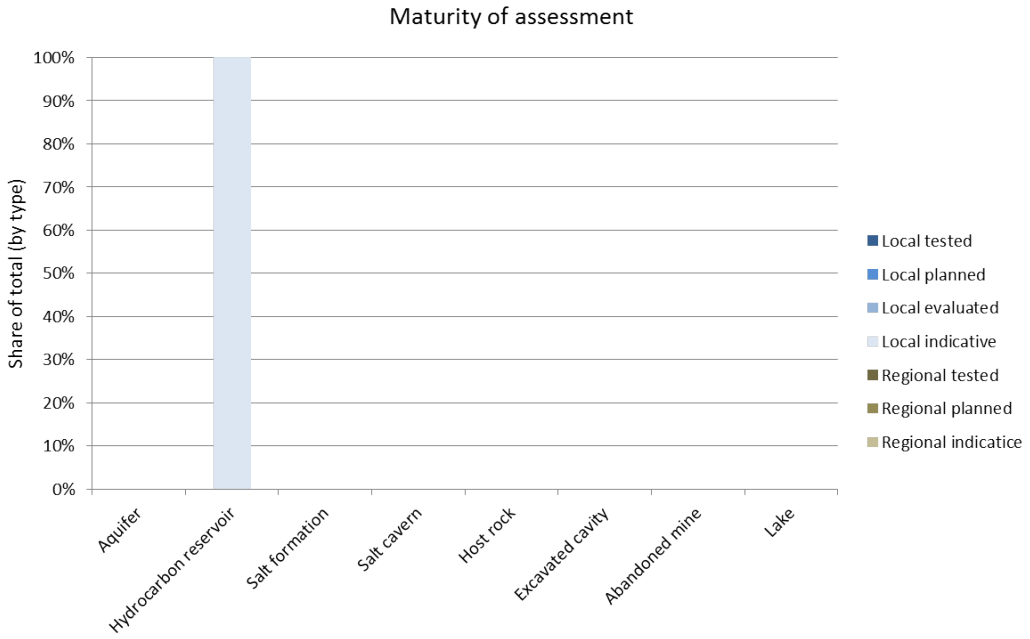

Figure 3.18-4: Kosovo - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

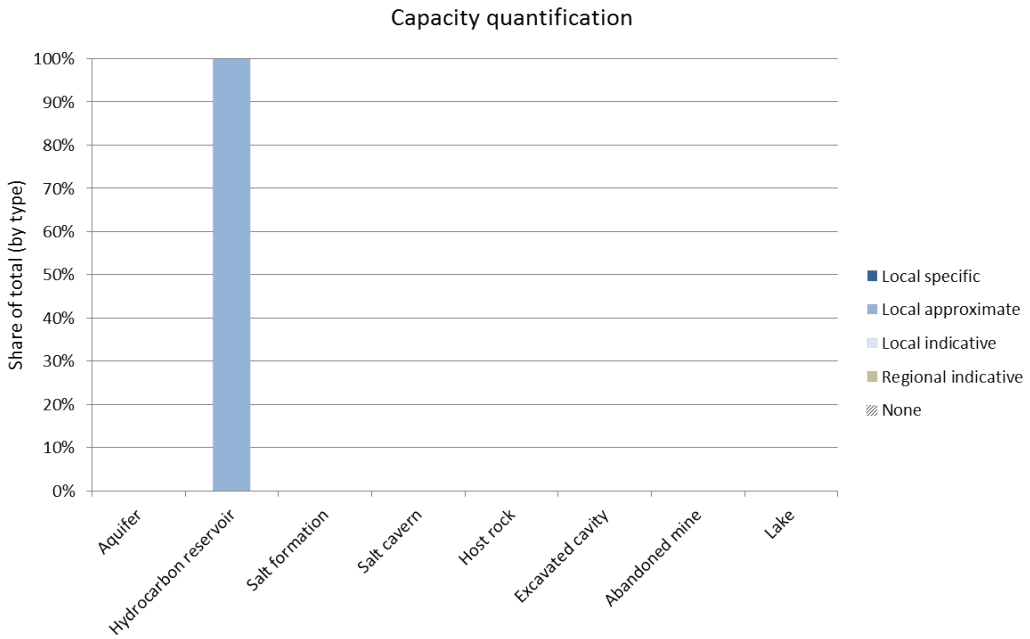

Figure 3.18-5: Kosovo - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.19. Latvia

3.19.1. Provider administration

Main providing organisations subsurface storage information:

Tallinn University of Technology (Estonia)
Subcontractor
Contact Person: Alla Shogenova

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.19.2. Main data sources

Table 3.19-1: List of common sources used

Source name / URL	Description	Version / Date
CO2Stop project (2014), based on EU GeoCapacity data	Assessed CO_2 storage capacities	2013
Semenov E. 2010. Osobennosti formirovanija i ocenka kollektorskih i ekranirujushih svoistv terrigennuh porod pri sozdanii podzemnyh xranilish gaza v vodonosnyh plastah	Geological storage information on aquifers	2010
Shogenov, K., Shogenova, A., Vizika-Kavvadias, O. 2013. Petrophysical properties and capacity of prospective for CO_2 geological storage Baltic offshore and onshore structures	Geological storage information on aquifers	2013
Kazbulat Shogenov. 2015."Petrophysical models of the CO_2 plume at prospective storage sites in the Baltic Basin"	Geological storage information on aquifers	2015
Reservoir data from industrial reports, survey	Geological storage information on aquifers	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015

3.19.3. Storage Data Review Latvia

Latvia has various aquifers that are suitable for UGS purposes. One is already developed as UGS, for another there are plans for development. The aquifers are also prospective targets for CO_2 storage. Other storage functions (HES, CAES, UTES) are nor investigated but may theoretically exist. There is limited or no potential for storage in hydrocarbon reservoirs and salt formations. Potential in host rock formations has not been investigated yet. The same is true for above ground potential in pumped hydro lakes.

Table 3.19-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	There are 18 local-defined aquifers, one of which is developed for UGS and another of which is planned for UGS. Six aquifers are positively evaluated for UGS but have no plans yet. For these aquifers specified operational capacities (working gas volumes) are available. The remaining aquifers are theoretically suitable for UGS but have not been assessed in further detail yet. All aquifers (except for one) are identified as potential target for CO_2 storage. Other storage functions (HES, CAES, UTES) are nor investigated but may theoretically exist on the basis of generic geological assumptions. Regional mapping and assessment may reveal additional prospective storage sites.	Further assessment of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in these reservoirs. Regional geological mapping and assessment in order to identify additional prospective aquifers.
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered absent or very limited	No or very limited scope for future investigation
Salt formations and caverns	No entries available in ESTMAP. As far as known Latvia does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Latvia was not included in the JRC-2013 assessment report as reservoir data were unavailable. Conditions may however be present.	Investigate if there is scope for future PHS assessment once data are available.

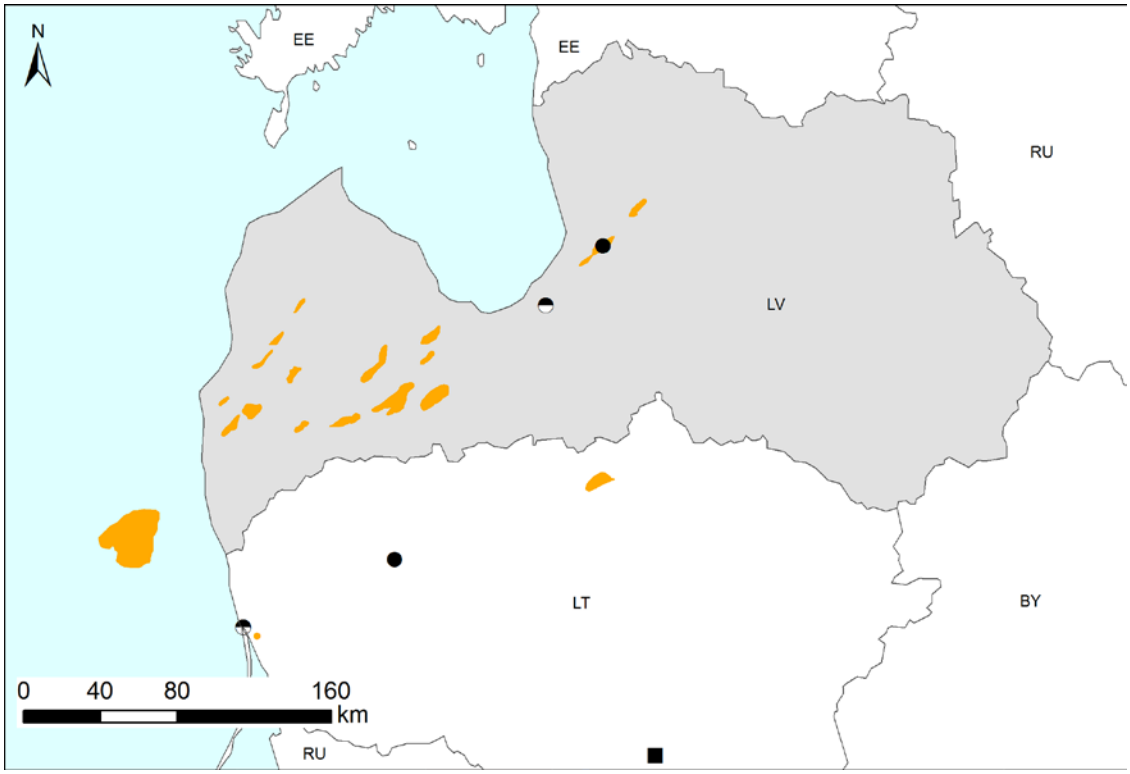

Figure 3.19-1: Latvia - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

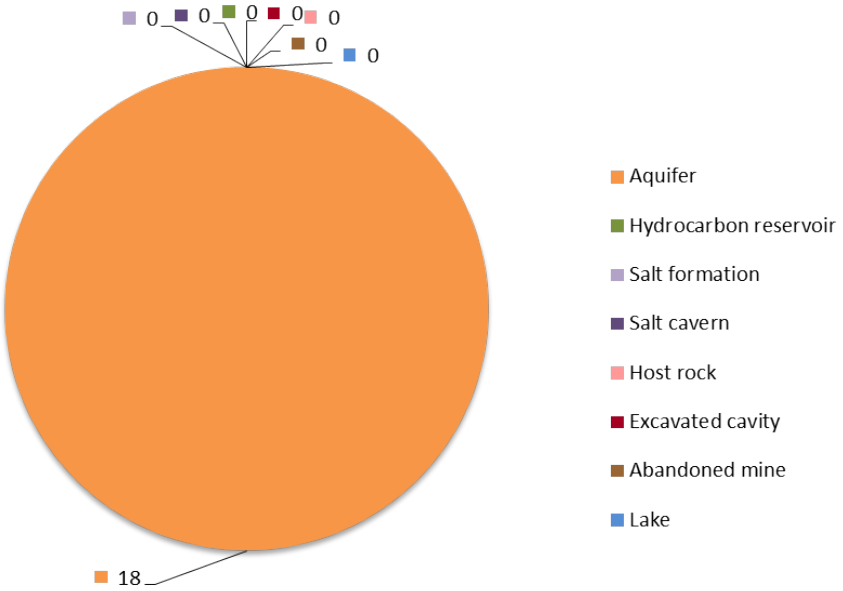

Figure 3.19-2: Latvia - Summary of energy storage reservoir types contained in the database

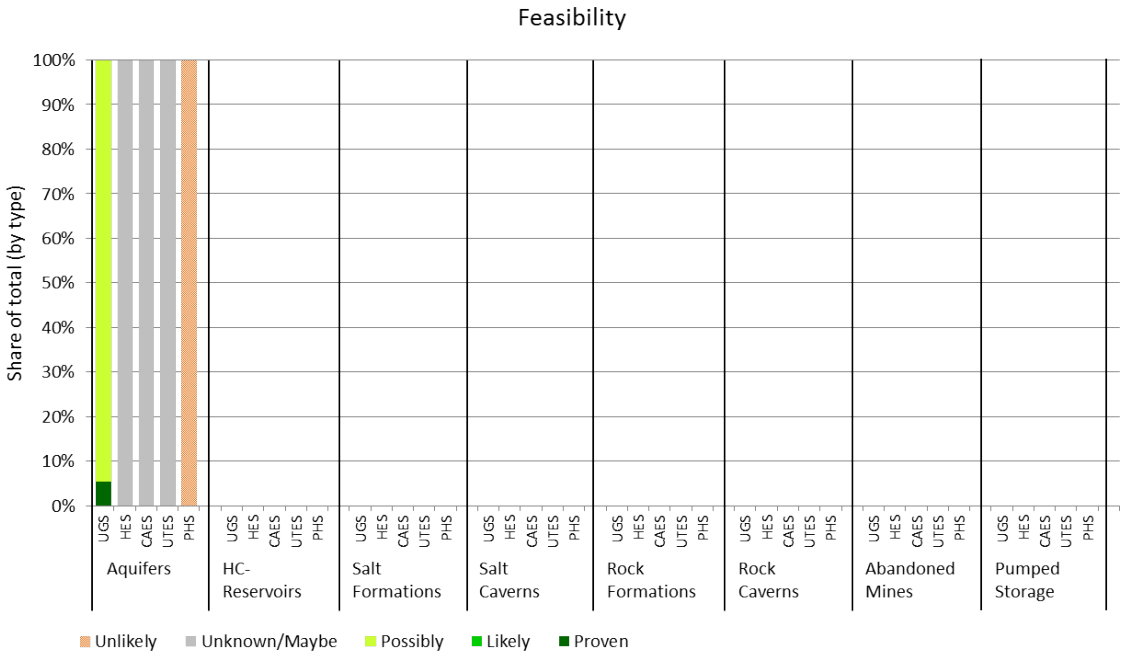

Figure 3.19-3: Latvia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

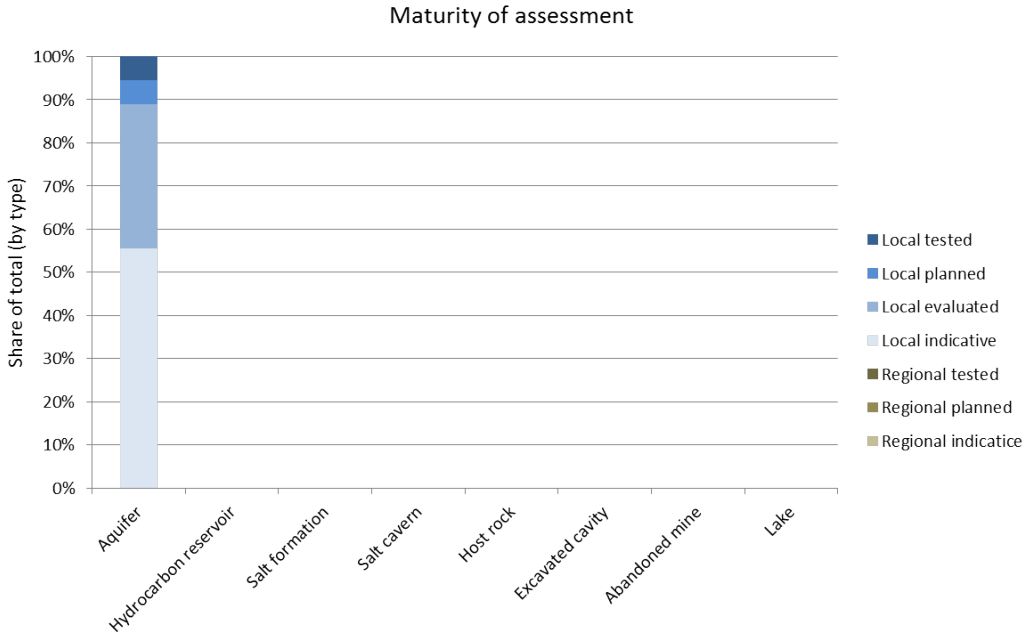

Figure 3.19-4: Latvia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

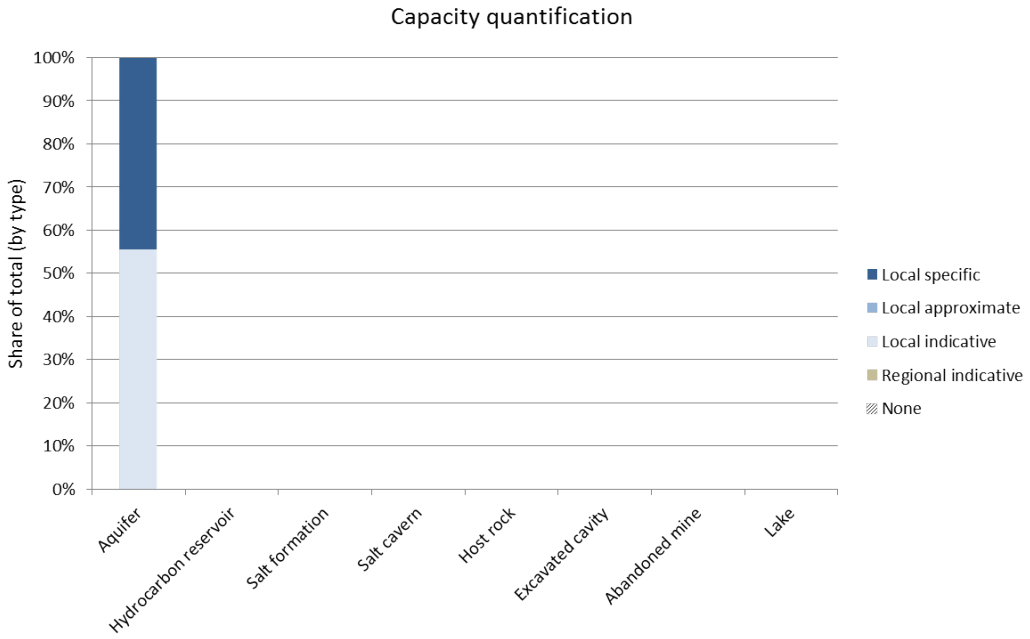

Figure 3.19-5: Latvia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.20. Lithuania

3.20.1. Provider administration

Main providing organisations subsurface storage information:

Nature Research Centre
Subcontractor
Contact Person: Saulius Sliaupa

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.20.2. Main data sources

Table 3.20-1: List of common sources used

Source name / URL	Description	Version / Date
Reservoir data from industrial reports, survey	Geological storage information on aquifers	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.20.3. Storage Data Review Lithuania

Lithuania has few aquifers that are suitable for UGS purposes. One is already developed as UGS, for another there are plans for development. One aquifer will be developed as UTES. Other storage functions (HES, CAES, UTES) are nor investigated but may theoretically exist. There is limited or no potential for storage in hydrocarbon reservoirs and salt formations. Potential in host rock formations has not been investigated yet. The same is true for above ground potential in pumped hydro lakes.

Table 3.20-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	There are only three local-defined aquifers, one of which is developed for UGS and another of which is planned for UGS. For the UGS developed aquifer specified operational capacities (working gas volumes) are available. The third aquifer is developed as a geothermal power plant and will be used for UTES in the future. Other storage functions (HES, CAES, UTES) are nor investigated but may theoretically exist on the basis of generic geological assumptions. Regional mapping and assessment may reveal additional prospective sites for UTES.	Further assessment of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in these reservoirs. Regional geological mapping and assessment in order to identify additional prospective aquifers.
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered absent or very limited	No or very limited scope for future investigation
Salt formations and caverns	No entries available in ESTMAP. As far as known Lithuania does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Lithuania was not included in the JRC-2013 assessment report as reservoir data were unavailable. Conditions may however be present.	Investigate if there is scope for future PHS assessment once data are available.

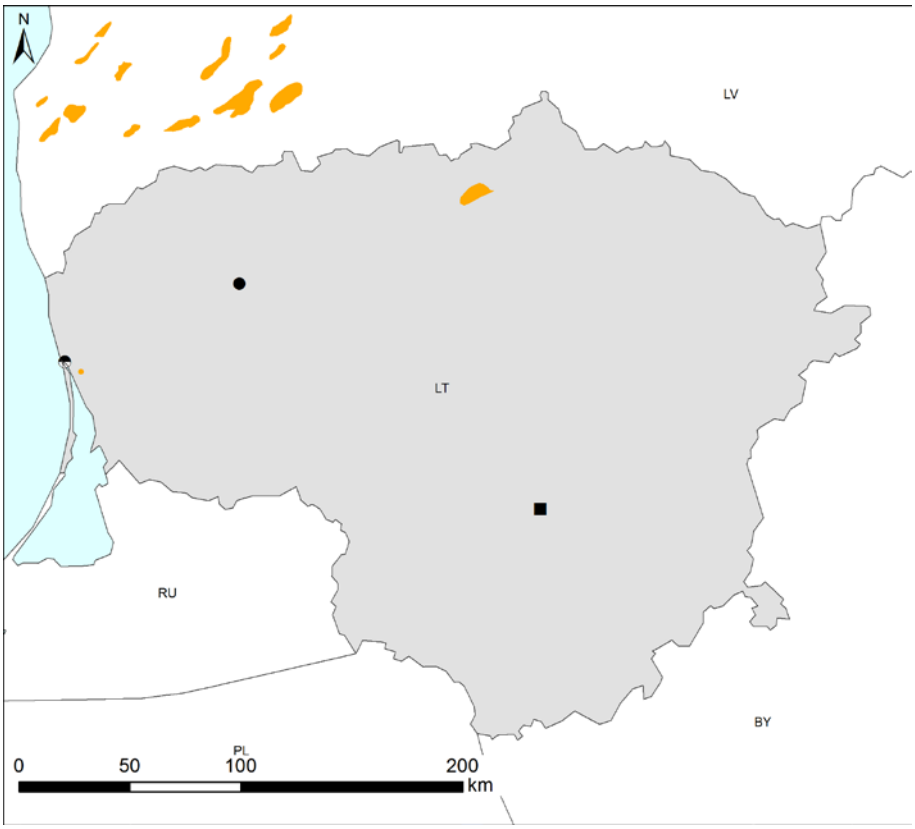

Figure 3.20-1: Lithuania - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

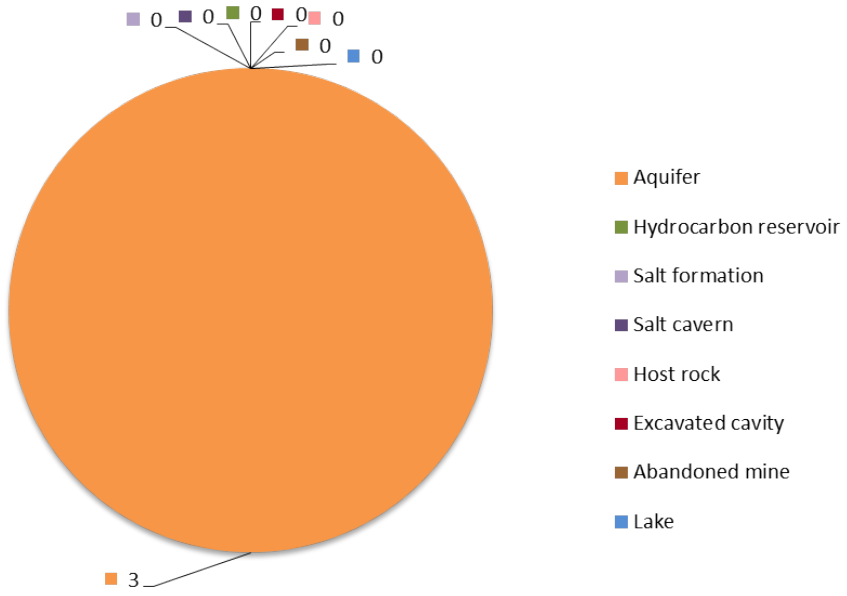

Figure 3.20-2: Lithuania - Summary of energy storage reservoir types contained in the database

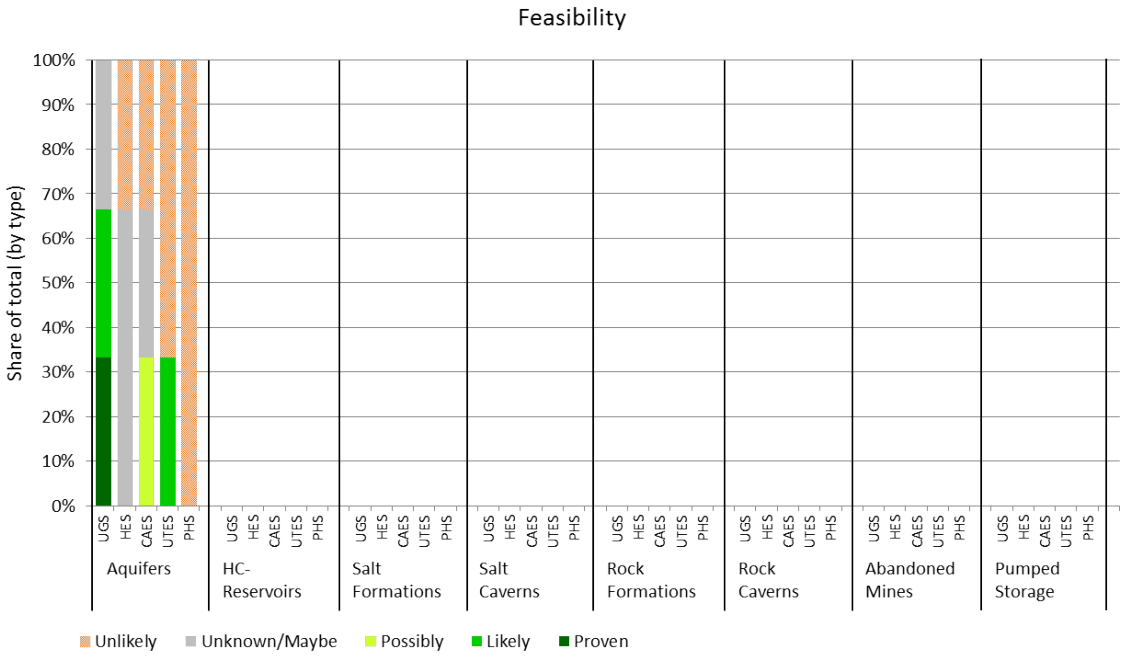

Figure 3.20-3: Lithuania - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

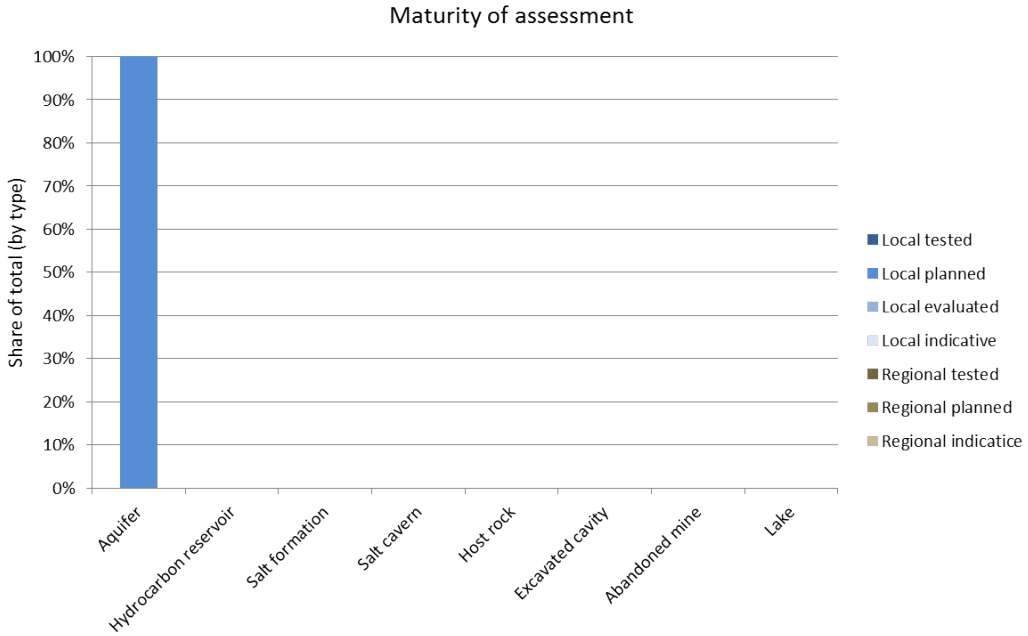

Figure 3.20-4: Lithuania - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

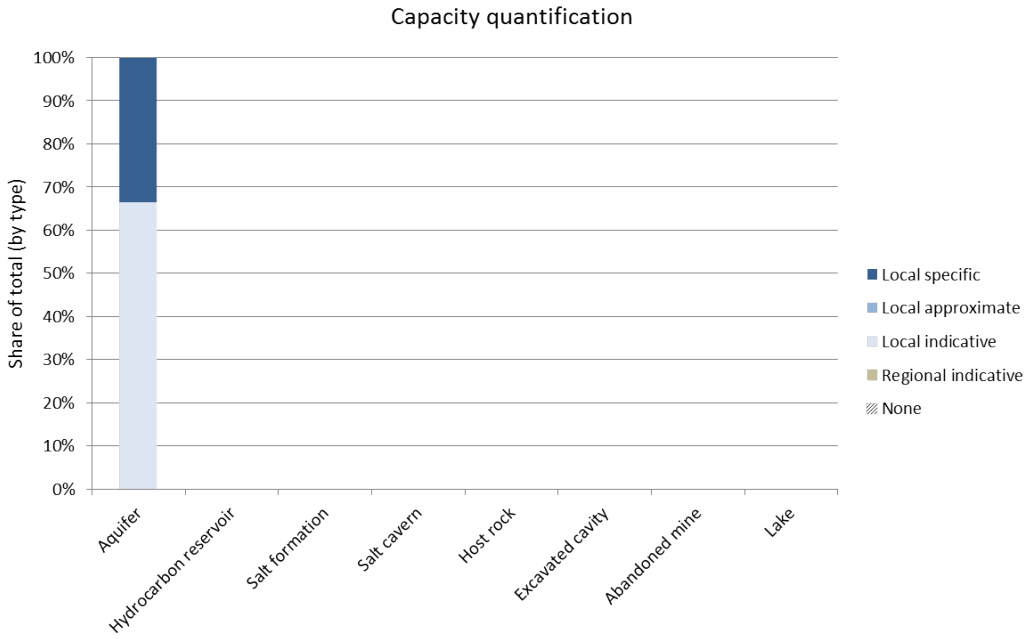

Figure 3.20-5: Lithuania - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.21. Netherlands

3.21.1. Provider administration

Main providing organisations subsurface storage information:

TNO – Geological Survey of the Netherlands
ESTMAP Consortium Partner
Contact Person: Serge van Gessel

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.21.2. Main data sources

Table 3.21-1: List of common sources used

Source name / URL	Description	Version / Date
TNO - Netherlands Oil and Gas portal (www.nlog.nl)	National repository with mining and E&P data	November 2015
Juez-Larré et al, 2016: Using underground gas storage to replace the swing capacity of the giant natural gas field of Groningen in the Netherlands. A reservoir performance feasibility study	Published assessment of natural gas storage potential and performance	2016
TNO, 2014. Information documents salt pillars	Geological assessment of salt structures in the Netherlands	2014.11.07
GIE, 2015: Gas Storage Map Europe (www.gie.eu)	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.21.3. Storage Data Review Netherlands

The main reservoir types for energy storage in the Netherlands are (partly) depleted gas reservoirs (primarily used for UGS) and salt caverns/formations (used for UGS and considered potentially suitable for HES and CAES). Shallow to intermediate deep aquifers may provide options for UTES but are still only regional-defined. One abandoned mine has also been deployed to this end. No storage potential included from pumped storage lakes and host rock formations.

Table 3.21-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Regional-defined, covering large area but lacking distinct capacity determinations and indications of local-specific potential. Partially outlined aquifer areas indicative for UTES. No storage development yet.	Identification of location-specific potential, determination of expected capacities. Potential targets for further investigating UTES development
Hydrocarbon reservoirs	Dominant storage potential for UGS in Netherlands, Local-defined with distinct capacity determination. Potential candidates for HES and CAES but still lacking appropriate assessment.	Confirming local suitability and maturing capacity and performance determinations. Targets for UGS development. And assessing suitability for HES, CAES.
Salt formations and caverns	Predominantly local-defined as salt pillars. Feasibility still largely based on generic geological criteria. Lacking distinct capacity determination (rough indications). Storage caverns developed at three sites, one developed for UGS.	Confirming local suitability and maturing capacity and performance determinations. Targets for assessing suitability for UGS, HES and CAES
Host rock, caverns, mines	No potential identified in host rock, except for an abandoned mine which is developed for UTES.	No or very limited scope for future investigation
Lakes	No entries available in ESTMAP. The Netherlands ware not included in the JRC-2013 assessment. Natural conditions are considered absent	Investigate if there is scope alternative PHS solutions

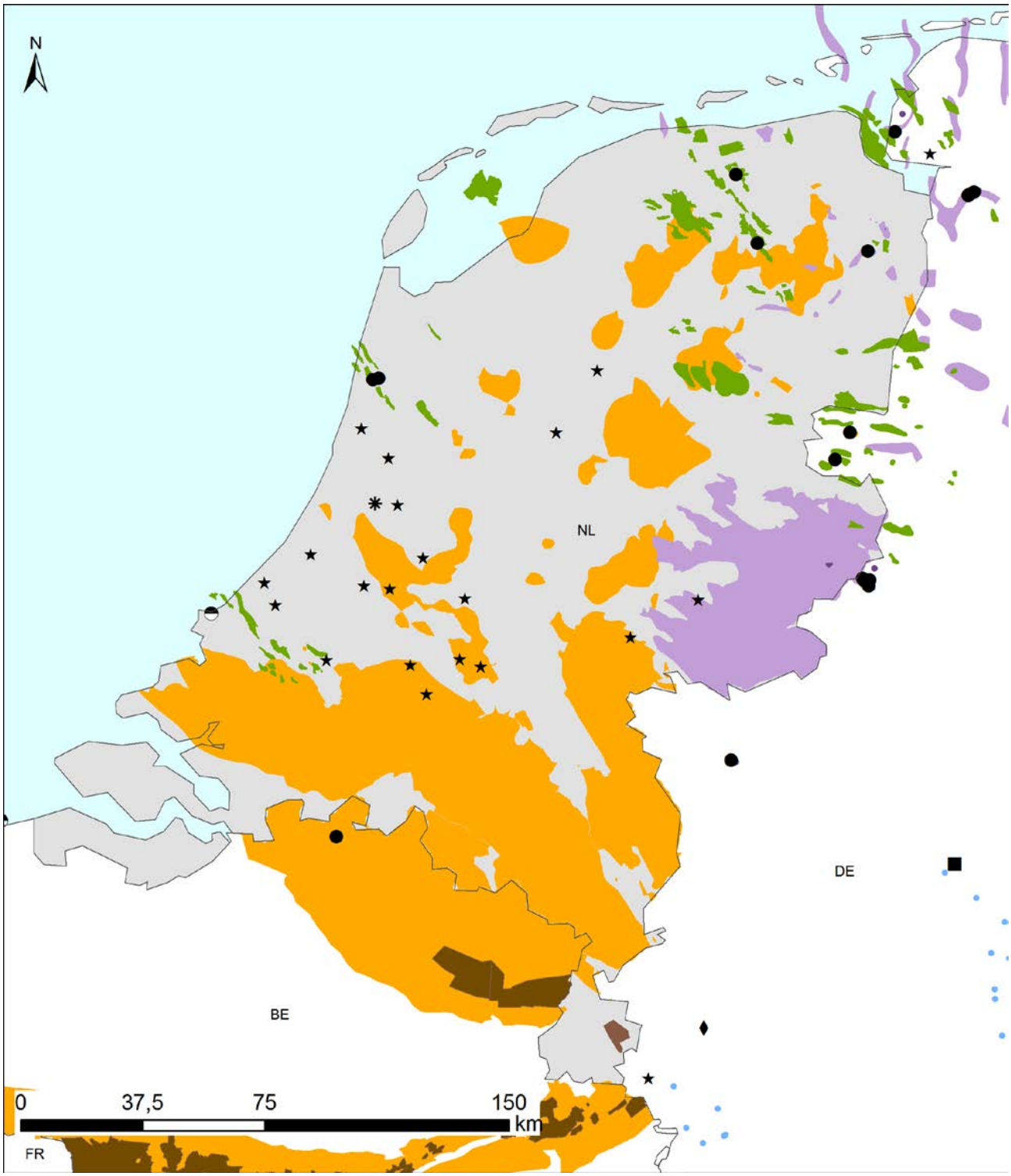

Figure 3.21-1: Netherlands - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

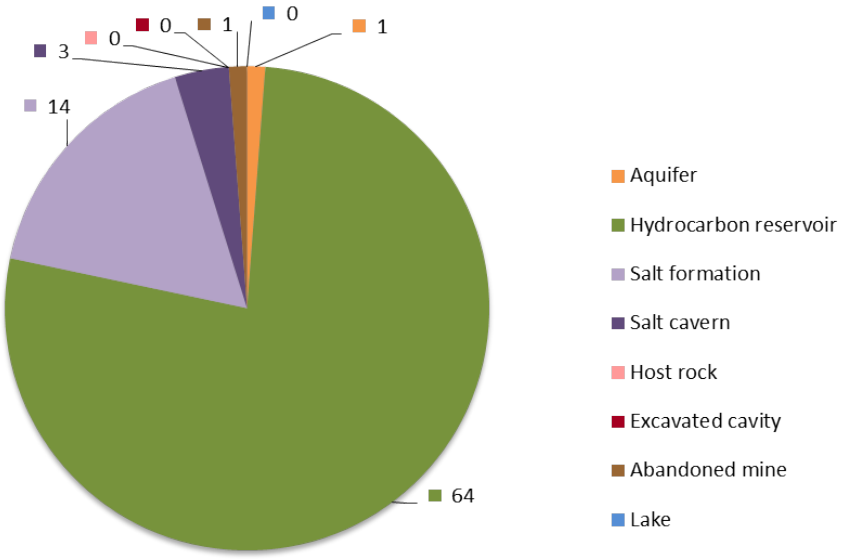

Figure 3.21-2: Netherlands - Summary of energy storage reservoir types contained in the database

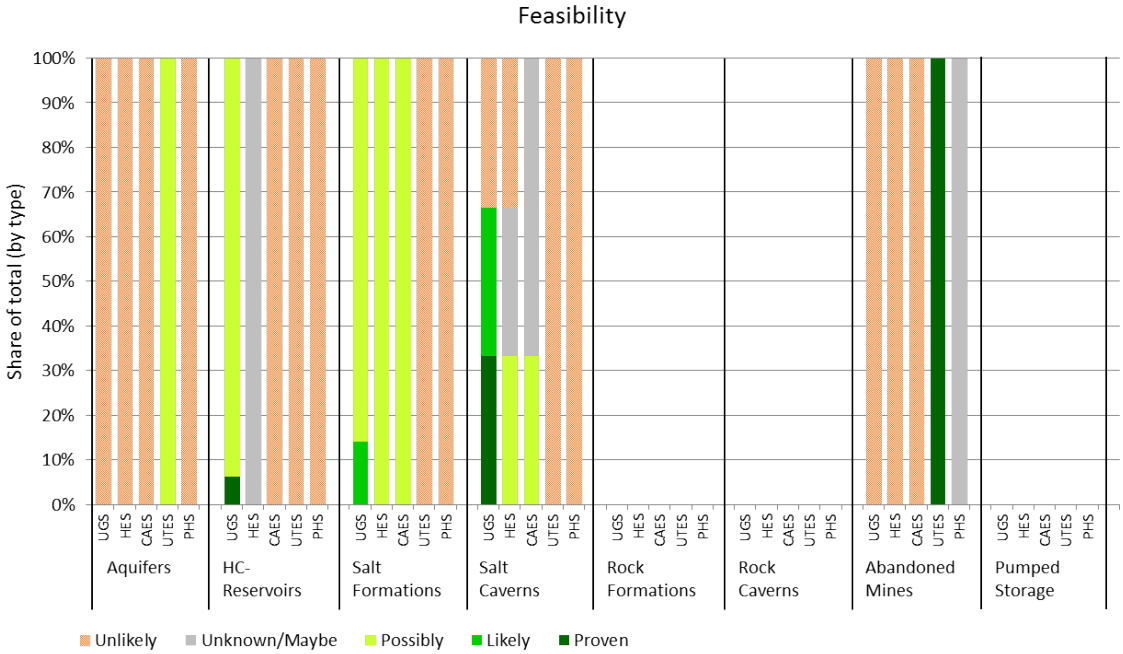

Figure 3.21-3: Netherlands - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

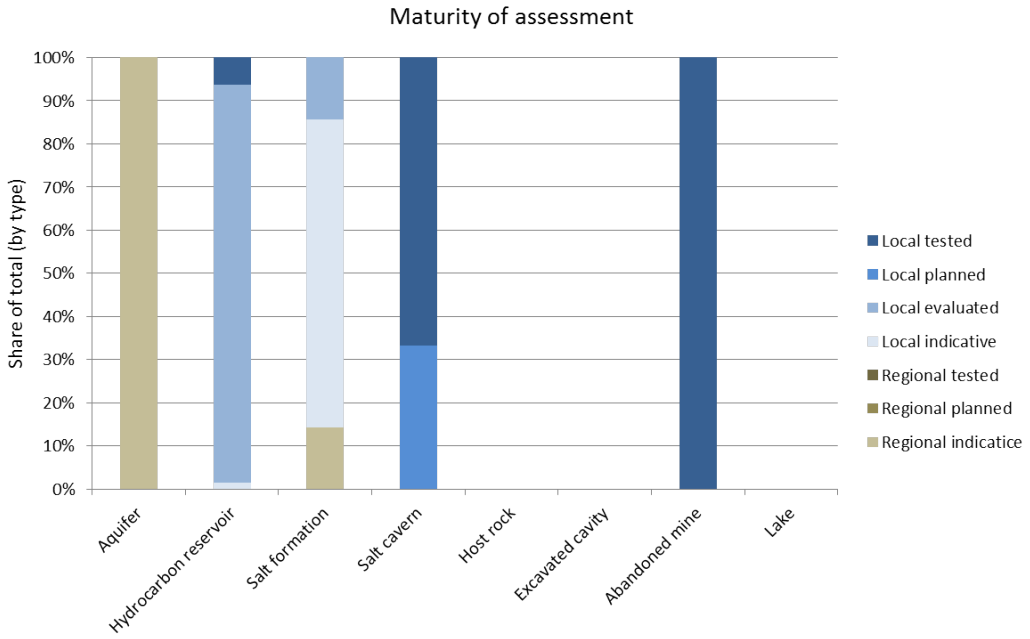

Figure 3.21-4: Netherlands - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

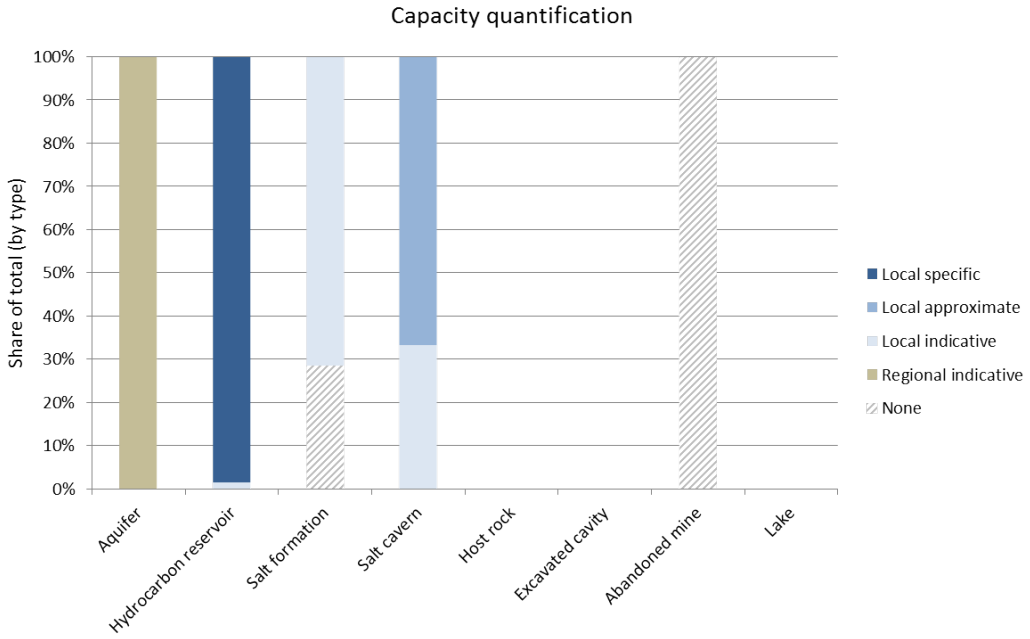

Figure 3.21-5: Netherlands - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.22. Norway

3.22.1. Provider administration

Main providing organisations subsurface storage information:

Asplan Viak AS
Subcontractor
Contact Person: Henrik Holmberg

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.22.2. Main data sources

Table 3.22-1: List of common sources used

Source name / URL	Description	Version / Date
Norwegian geological survey Data archives and reports	Geological information on host rock	2015
Midttømme. K., R.K.Ramstad., J. Müller (2015) Geothermal Energy- country update for Norway Proceedings, WGC2015- Melbourne, Australia	Geological information on host rock, geothermal assessment	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.22.3. Storage Data Review Norway

Norway's key potential for energy storage is defined in host rock formations (UTES) and above ground lakes (PHS). There may possibly be some offshore potential for UGS (hydrocarbon reservoirs) but no information is available to ESTMAP.

Table 3.22-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential is considered present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered present in offshore reservoirs. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate offshore potential for this reservoir type
Salt formations and caverns	No entries available in ESTMAP. As far as known Norway does not have onshore salt formations that allow for development of suitable caverns. Some near shore potential may be present in the southern offshore areas	Check whether there is future scope to investigate offshore potential for this reservoir type
Host rock, caverns, mines	Norway has 44 local-defined host rock sites which are developed for BTES (Borehole Thermal Energy Storage). Direct operational thermal storage capacities are provided. No other storage purposes are considered possible here. Additional potential may be present at other locations but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and local evaluation of host rock formations may reveal further potential for (thermal) energy storage
Lakes	The Norway has abundant (144) realisable potential for pumped hydro storage, including many options based on two existing nearby (<10 km) lakes. All identified sites include specific determinations of energy storage capacities and lake volumes. Norway has 4 pumped hydro power plants but no pumped storage development. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

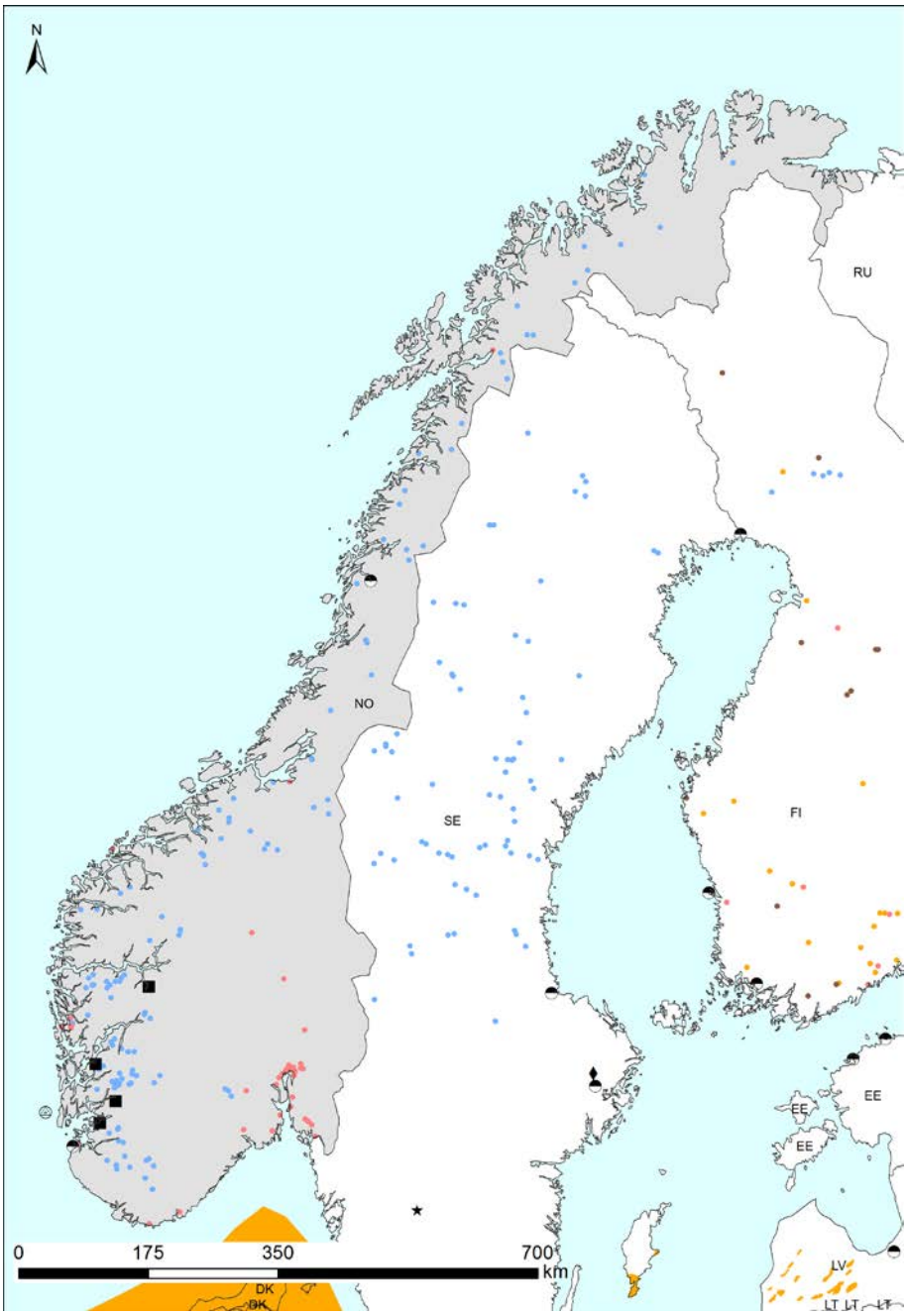

Figure 3.22-1: Norway - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

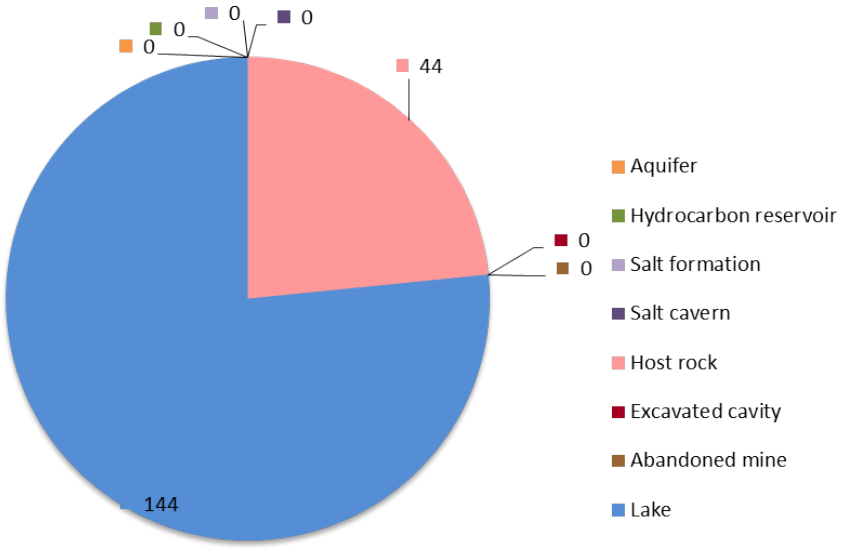

Figure 3.22-2: Norway - Summary of energy storage reservoir types contained in the database

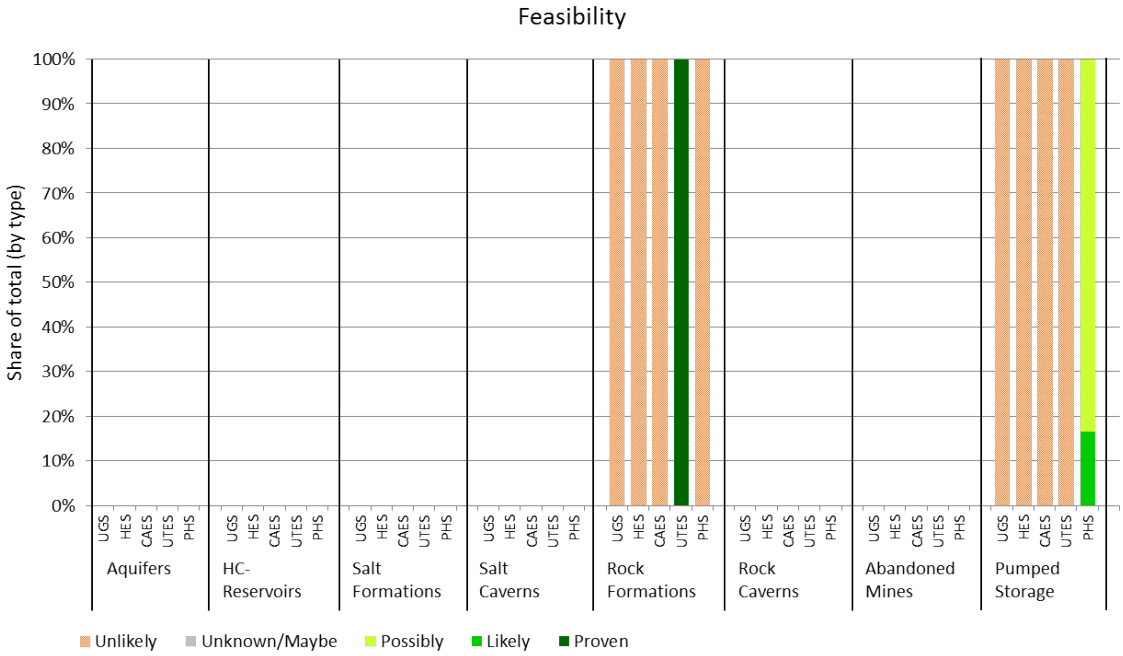

Figure 3.22-3: Norway - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

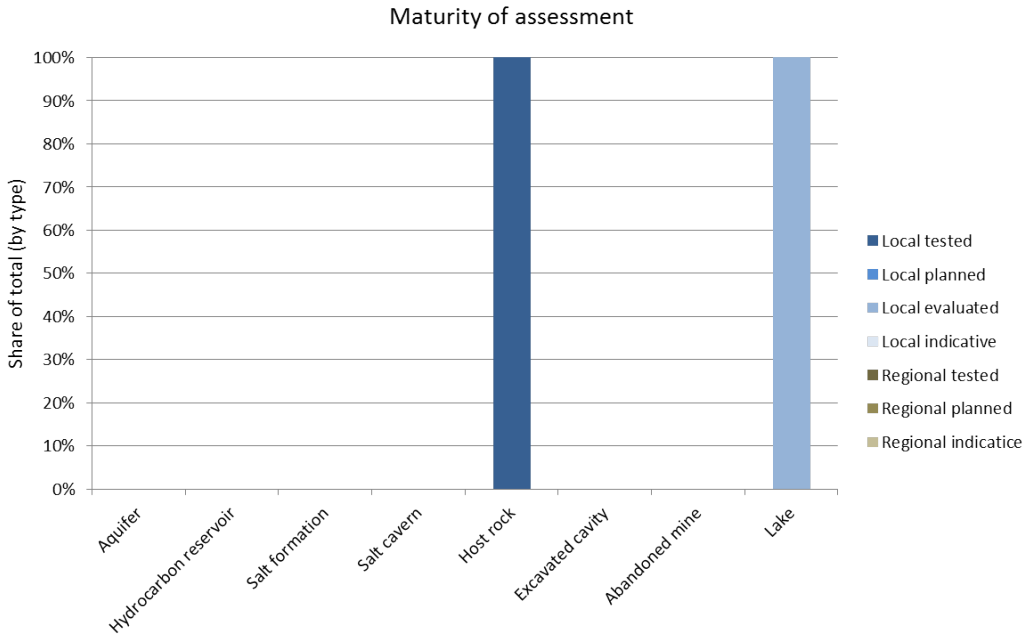

Figure 3.22-4: Norway - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

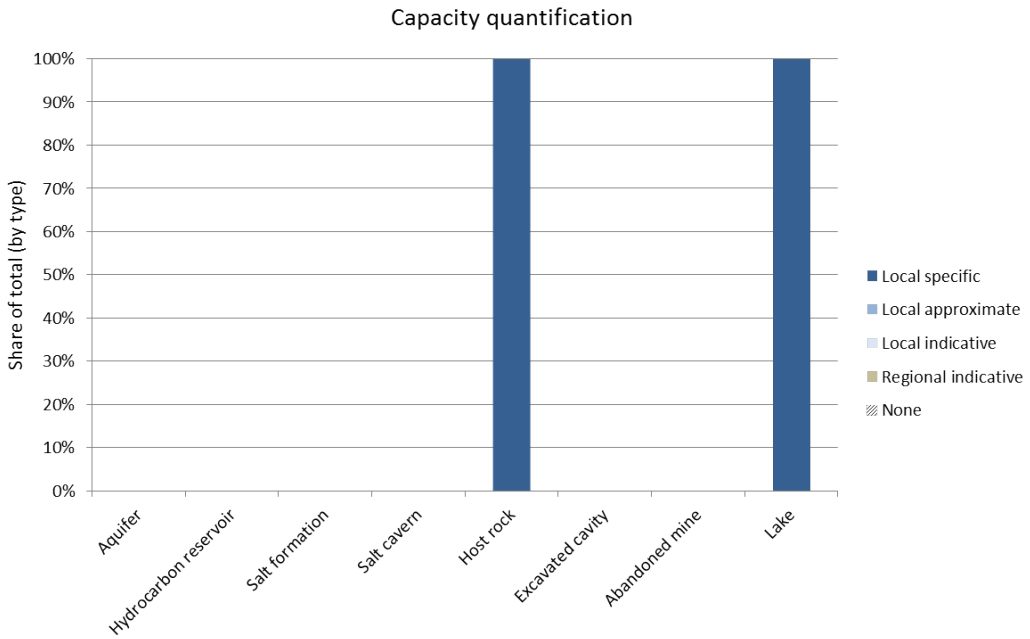

Figure 3.22-5: Norway - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.23. Poland

3.23.1. Provider administration

Main providing organisations subsurface storage information:

PGI – Polish Geological Institute
Subcontractor
Contact Person: Adam Wójcicki

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.23.2. Main data sources

Table 3.23-1: List of common sources used

Source name / URL	Description	Version / Date
National register of mineral and hydrocarbon resources (PGI-NRI): https://www.osm.pgnig.pl/en	Operational data on gas storage	2015
Operator website zielonagora: http://zielonagora.pgnig.pl/	Operational data on gas storage	2015
Various studies and surveys	Scientific publications and reports on storage potential	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.23.3. Storage Data Review Poland

Poland has good potential for UGS in hydrocarbon reservoirs and salt caverns, many of which already been developed to this end. Aquifers and one abandoned mine are target for UTES. There is scope for revealing additional potential through geological mapping and location-specific assessment of aquifers, salt formations and rock formations. Poland has several above ground lakes that are considered suitable for PHS. One has already been developed; another site is planned.

Table 3.23-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Poland includes 3 local-defined aquifers, none of which are developed for energy storage yet. Two aquifers are positively tested for UTES development and one aquifer is planned for UGS. Suitability for alternative storage purposes (e.g. HES) has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Direct capacity determinations are provided (working gas volumes and thermal energy storage capacities). Large regional-defined aquifers are known to be present in Poland but here no local-defined potential has been defined yet or this information was not available to ESTMAP.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Identification of location-specific potential within other regional-defined aquifers
Hydrocarbon reservoirs	In total 64 local-defined hydrocarbon reservoirs are included in ESTMAP, 8 of which are positively tested for UGS (including definitions of operational working gas volumes) and one of which is actually developed as UGS. The rest is considered a potential future target for further investigations, (UGS, HES potential) on the basis of generic geological assumptions. For these site no data was available for determining capacities. All reservoirs are located in the southern and western part of the country	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Salt formations and caverns	The database includes 8 salt caverns of which 3 have been developed for UGS and 2 are planned for UGS development. Capacities are either defined by gas working volumes or approximated by total cavern volumes. Suitability for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Additional potential is considered present in other salt formations but this is still under investigation. No information was available to ESTMAP.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Identification of location-specific potential within other regional-defined salt formations
Host rock, caverns, mines	Poland has one abandoned mine which is planned for UTES. No data regarding energy storage capacities are available. Poland has more mines and rock formations for which there may be scope to investigate future potential for energy storage. No information was available to ESTMAP.	Confirmation of location-specific suitability and expected capacities. Regional mapping and identification of location-specific potential within rock formations. Identification of storage potential

		in other mines.
Lakes	Poland has low to moderate realisable potential for pumped hydro storage, all of which is based on one existing and one (to be developed) potential lake. The potential is located in the SW margin of the country. One out of 14 sites included in ESTMAP is developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

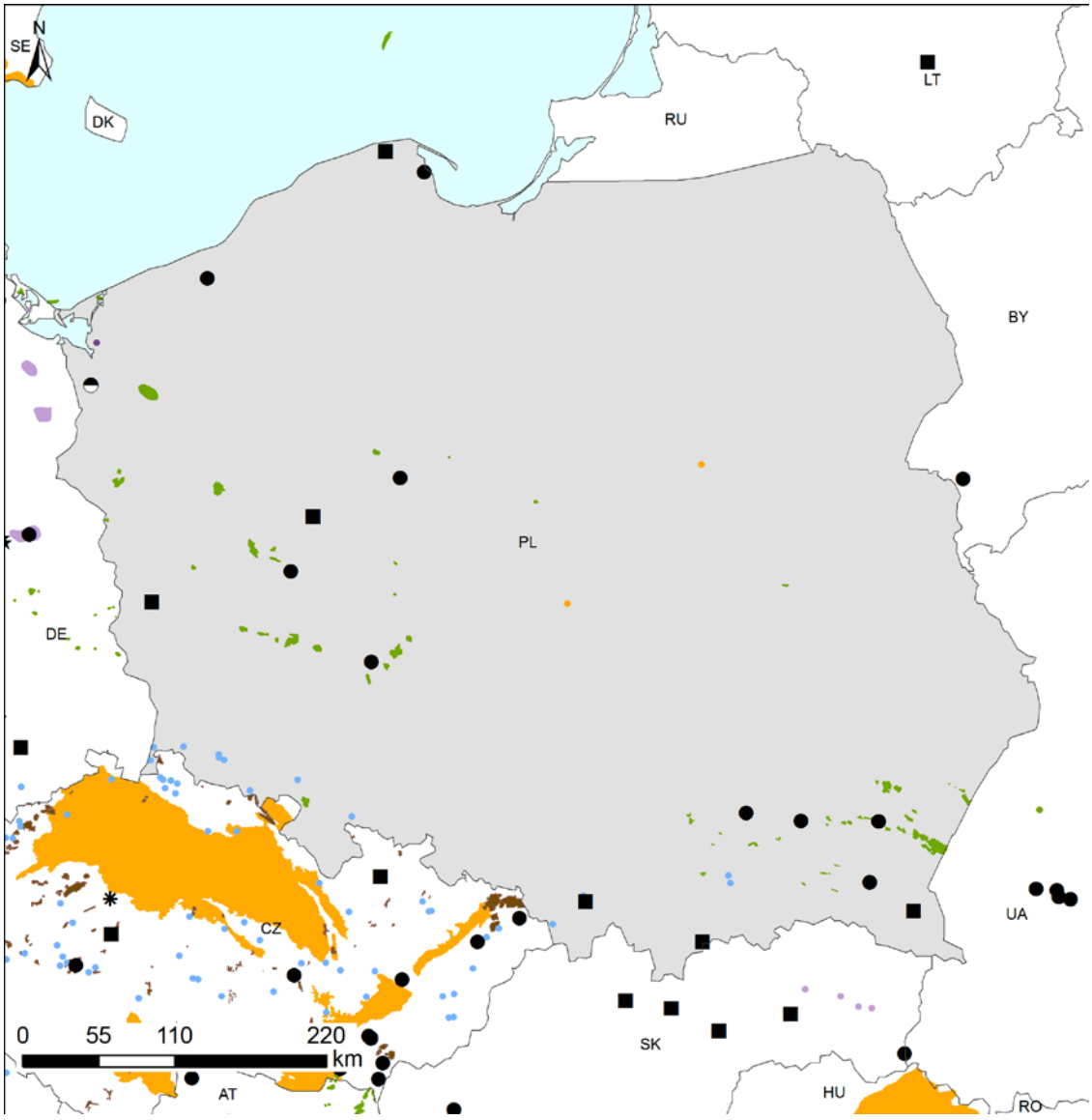

Figure 3.23-1: Poland - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

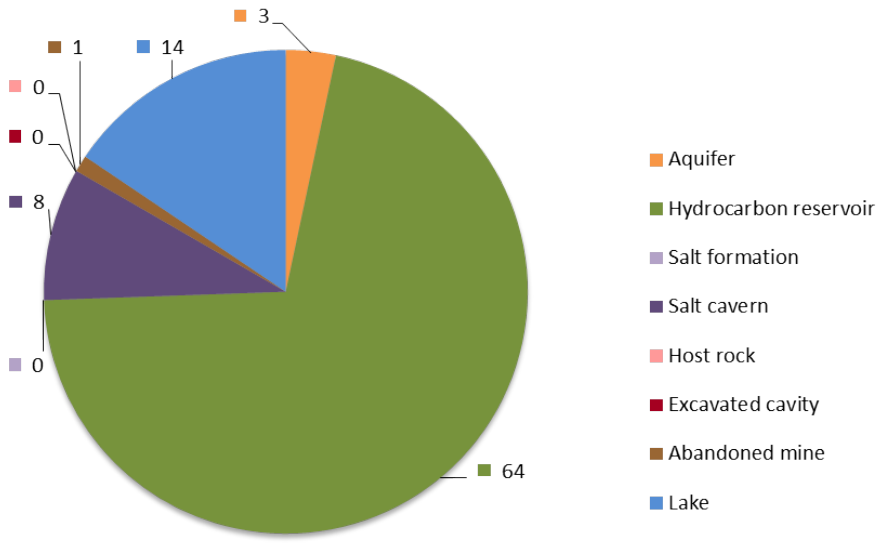

Figure 3.23-2: Poland - Summary of energy storage reservoir types contained in the database

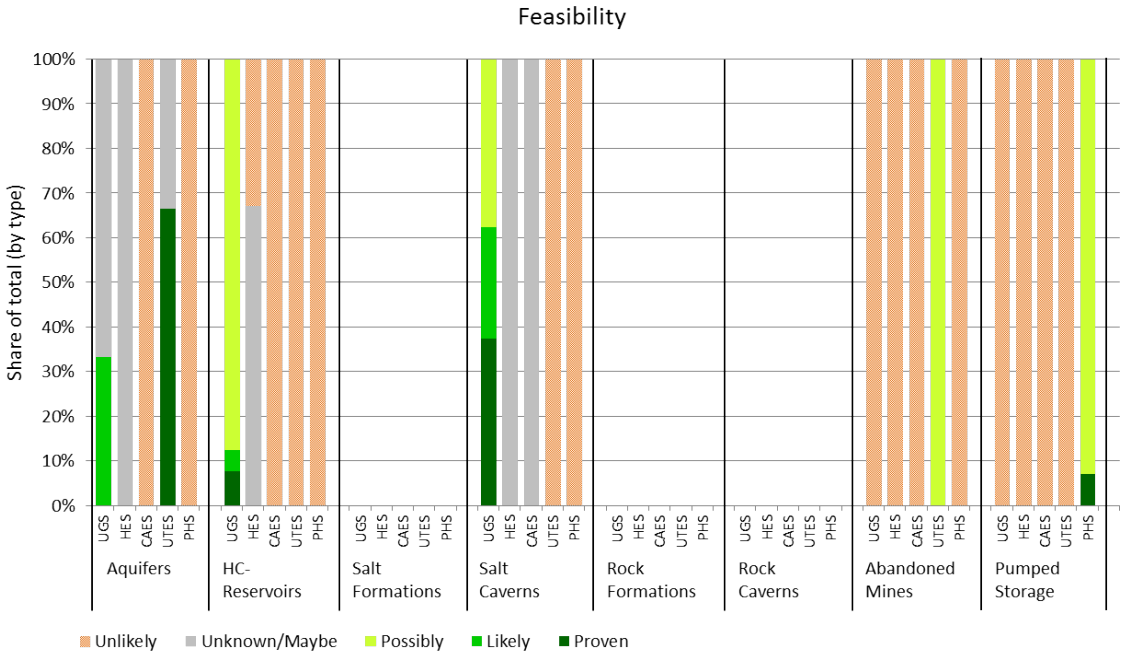

Figure 3.23-3: Poland - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

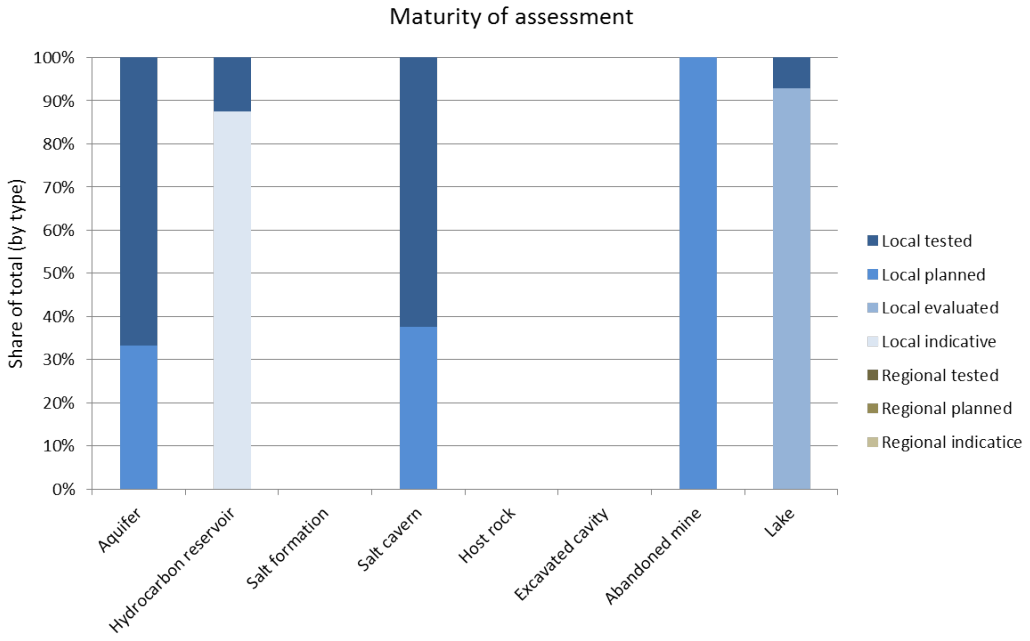

Figure 3.23-4: Poland - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

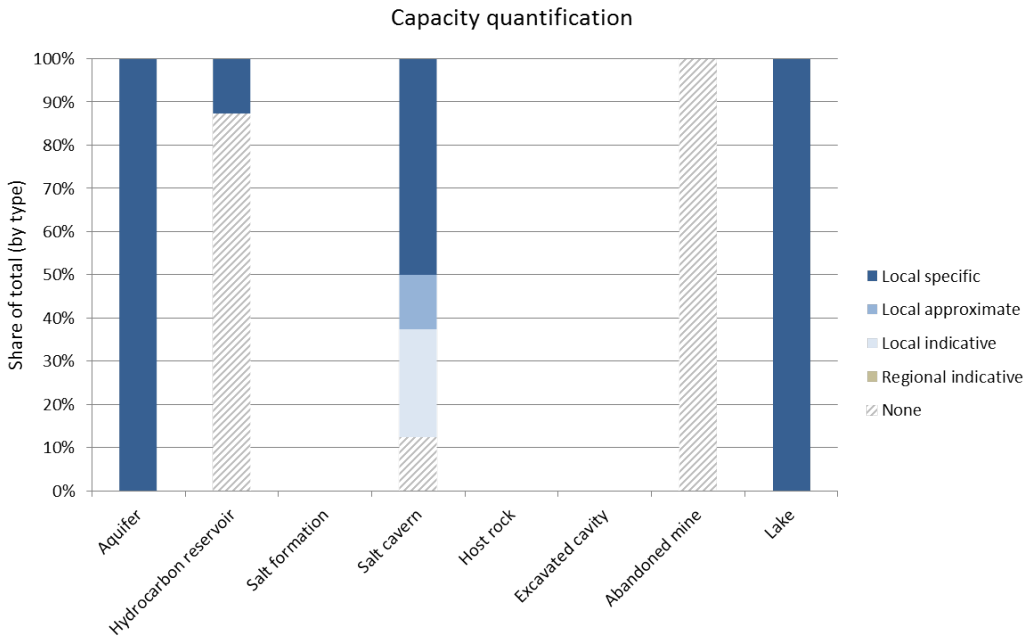

Figure 3.23-5: Poland - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.24. Portugal

3.24.1. Provider administration

Main providing organisations subsurface storage information:

Universidade de Évora
Subcontractor
Contact Person: Júlio Ferreira Carneiro

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.24.2. Main data sources

Table 3.24-1: List of common sources used

Source name / URL	Description	Version / Date
Associação Portuguesa de Empresas Petrolíferas (2001)	Scientific publications and reports	2015
Canilho, M.H. (1989), Elementos de Geoquímica das rochas do maciço Ígneo de Sines	Scientific publications and reports	1989
Cavaco, L. (2013), Definição de reservatórios geológicos para armazenamento de energia em ar comprimido e sinergias com produção de energia	Scientific publications and reports	2013
Costa, L. (2009). Potencial de Armazenamento Subterrâneo de Gás Natural do Território Nacional	Scientific publications and reports	2009
COMET Project - Boavida, D. et al (2011). An integrated infrastructure for CO_2 transport and storage in the West Mediterranean	Scientific publications and reports	2011
CUF - QI S.A.	Operator technical data	
Dias, G. et al (1998), U–Pb zircon and monazite geochronology of post-collisional Hercynian granitoids from the Central Iberian Zone (Northern Portugal)	Scientific publications and reports	1998
González-Clavijo & Valadares, A estrutura do complexo de Monchique	Scientific publications and reports	
KTEJO Project - Pereira, N., Carneiro, J.F., Araújo, A., Bezzeghoud, M., Borges, J. (2014), Seismic and structural geology constraints to the selection of CO_2 storage sites—The	Scientific publications and reports	2014

case of the onshore Lusitanian basin		
Nunes, P. (2010), Armazenamento Subterraneo de Gas Natural	Scientific publications and reports	2010
REN Armazenagem	Operator technical data	
Solvay Portugal	Operator technical data	
Zbyszewski, G. & Faria, J. B. (1971). O Sal-Gema em Portugal Metropolitano: suas jazidas, características e aproveitamento	Scientific publications and reports	1971
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.24.3. Storage Data Review Portugal

Table 3.24-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Portugal includes 6 regional-defined aquifers in the west of the country which are considered a target for CAES. There might be scope to investigate potential for UGS, HES and UTES as well. Overall assessment is still premature and location-specific investigations are required to confirm suitability. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities yet. Further potential may be present in other aquifers.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Hydrocarbon reservoirs	No entries available in ESTMAP. Potential is considered absent	No scope for future investigation
Salt formations and caverns	Seventeen local-defined salt formations and 9 salt dissolution caverns are included in ESTMAP. Two salt mines are included as well but reported under mines (salt excavation). The majority of the caverns are either developed or to be developed for UGS and are also likely to be appropriate for CAES or HES if the present or projected role is abandoned For the salt dissolution caverns concrete operational capacities are provided (working volumes). For the salt formations there is no or limited data available for estimating capacities.	Confirmation of location-specific suitability and expected capacities for the salt formations. Check whether there is future scope to investigate alternative potential in the salt formations and the possibility of applying storage technologies other than UGS in the salt caverns.
Host rock, caverns, mines	Eleven regional-defined rock formations and 3 mined (excavated) caverns are included in ESTMAP (two of which are actively producing and situated in salt formations). For the two cavities in salt mines, which are likely candidates for CAES, an estimation of capacity is available on the basis of total volumes. For the other rock cavern, total available storage volume is known. The identified rock formations are only theoretically suitable for energy storage options. There may be additional potential for storage in abandoned mines, but that information is not publicly available.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Lakes	Portugal has moderate to abundant realisable potential for pumped hydro storage, including many options based on two existing nearby (<10 km) lakes. Seven out of 62 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

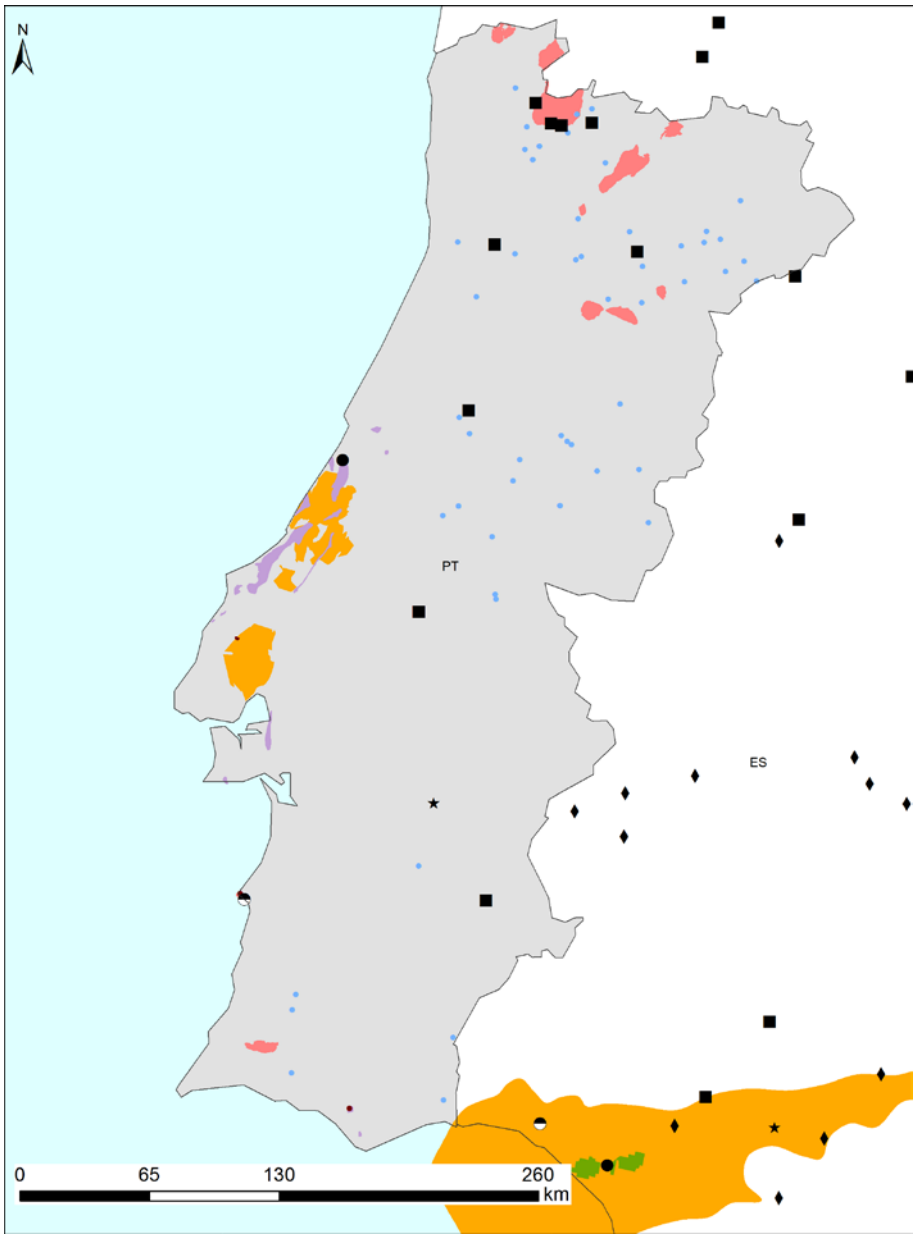

Figure 3.24-1: Portugal - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

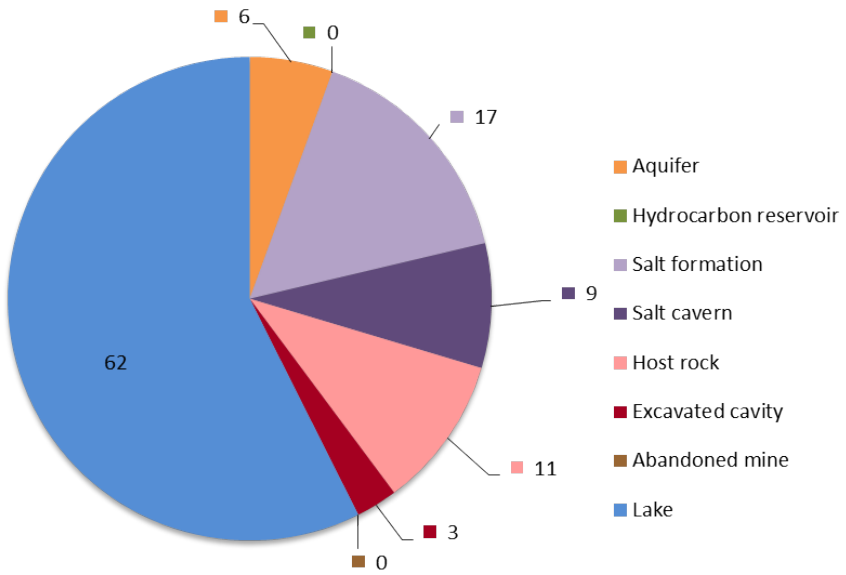

Figure 3.24-2: Portugal - Summary of energy storage reservoir types contained in the database

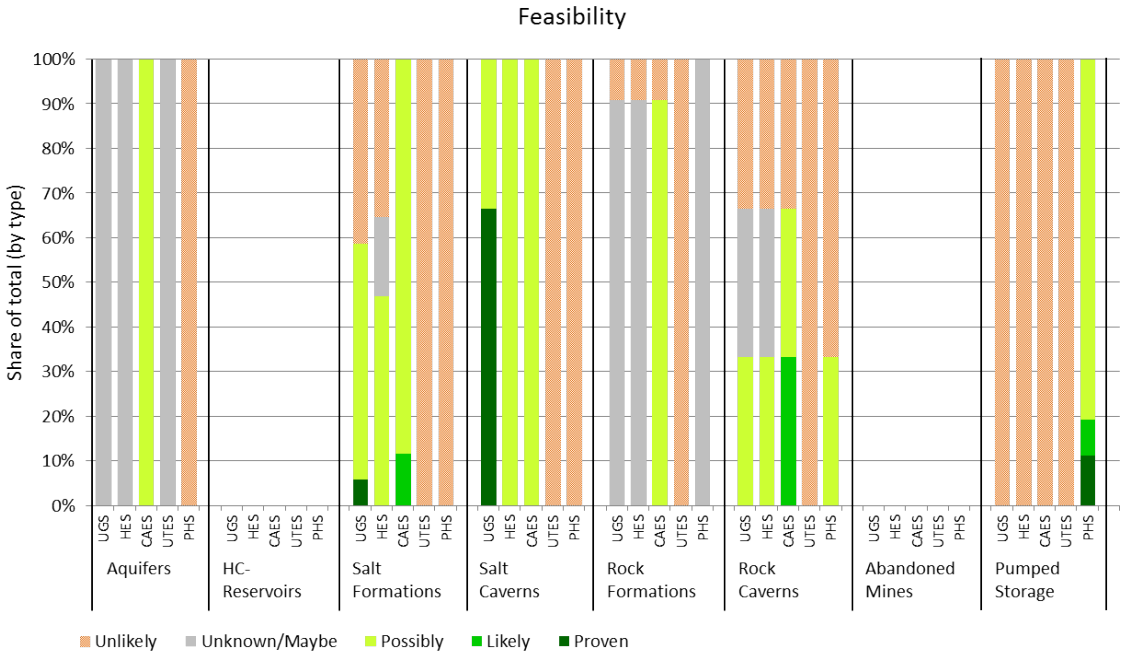

Figure 3.24-3: Portugal - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

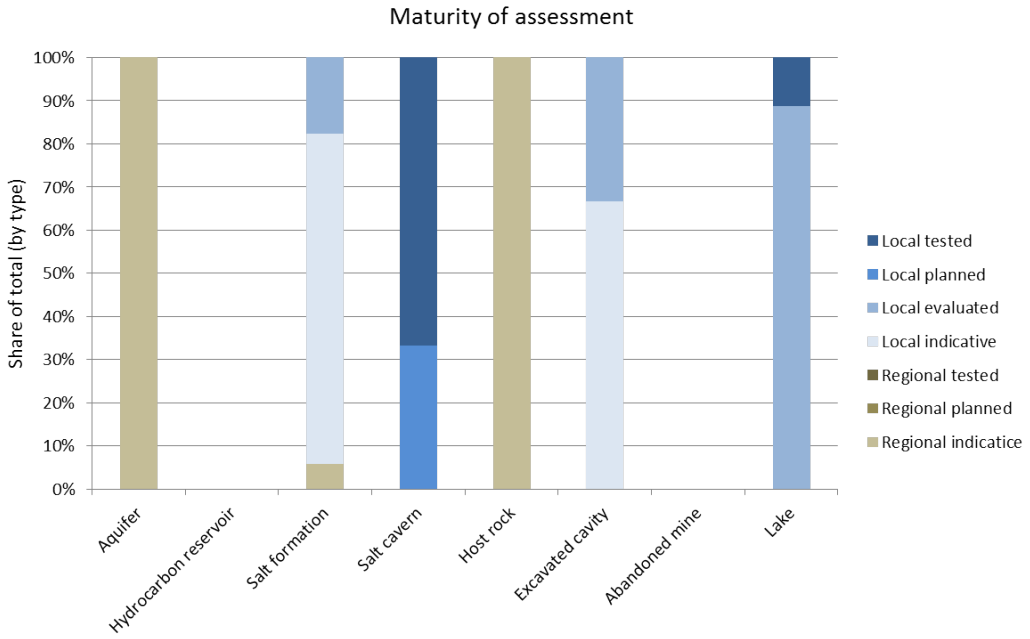

Figure 3.24-4: Portugal - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

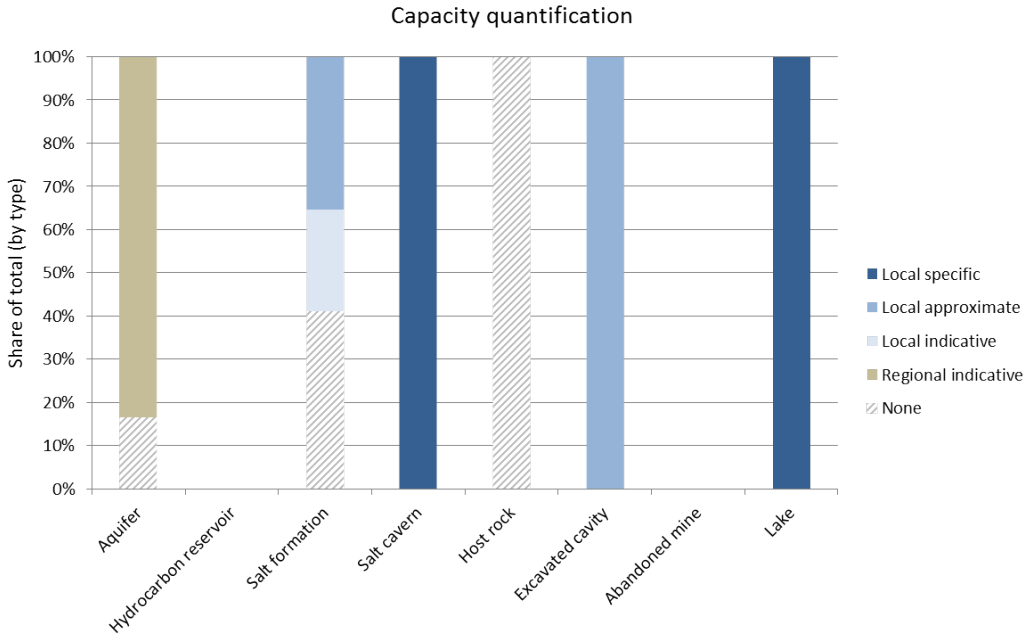

Figure 3.24-5: Portugal - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.25. Romania

3.25.1. Provider administration

Main providing organisations subsurface storage information:

National Institute for Marine Geology and Geoecology - GeoEcoMar
Subcontractor
Contact Person: Dr. Sorin Anghel

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.25.2. Main data sources

Table 3.25-1: List of common sources used

Source name / URL	Description	Version / Date
ROMAGAZ: http://www.romgaz.ro/en/activities/storage.html	Site specific data operator	
SALROM: http://www.salrom.ro/	Site specific data operator	
SALINAPRAID: http://www.salinapraid.ro/	Site specific data operator	
DEPOMURES: http://www.depomures.ro/index.php	Site specific data operator	
AMGAZ: http://www.amgaz.ro/aboutus.htm	Site specific data operator	
M. Rosca, M. Antics, M. Sferle, 2005. Geothermal Energy in Romania: Country Update 2000-2004	Scientific publications and reports: regional aquifer assessment	2005
Amos News Database: http://www.amosnews.ro/arhiva/capacitatea-stocare-gazelor-naturale-se-va-dubla-pana-2007-06-01-20	Databases / archives	2007
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.25.3. Storage Data Review Romania

Romania has considerable potential for UGS in hydrocarbon reservoirs, most of which is either existing or planned for development. Some are also considered suitable for CAES. Other potential subsurface reservoirs include aquifers (UTES) and salt caverns (UGS, HES, CAES). Assessment of feasibility for these reservoirs is still pre-mature. Romania has good potential for PHS in above ground lakes, but this information was not available to ESTMAP.

Table 3.25-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Romania includes 24 local-defined aquifers which are part of larger regional aquifers. All sites are considered potential candidates for UTES. Potential other potential includes UGS and HES. The potential has not yet been thoroughly assessed and is still based on generic geological assumptions. None of the sites included in ESTMAP have been developed as storage. The aquifers are parameterized to a limited extent only and there is no or very little basis for estimating capacities. So far there is very limited scope for revealing additional potential in other aquifers. The exact extent is unknown as more detailed geographical data were unavailable to ESTMAP.	Confirmation and assessment of location-specific potential and expected capacities.
Hydrocarbon reservoirs	Eleven local-defined hydrocarbon reservoirs are included, 8 of which has been developed as UGS and 3 of which are planned for UGS development. For most sites direct operational capacities are available (working gas volumes). Some have only limited information is available with regards to estimating capacities. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Three sites have been found proven or likely feasible for CAES development. There is very limited scope for investigating additional potential from other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Salt formations and caverns	Eight local-defined salt caverns are included, all of which are still undeveloped. Potential for UGS, HES and CAES has not been assessed yet (or information is not available), though there may be scope for further investigation of this potential on the basis of generic geological assumptions. There is very limited or no information available for estimating storage capacities. It is currently unknown whether there is scope for investigating additional potential in other salt formations.	Confirmation of location-specific suitability and expected capacities. Check whether there is scope to extend information on existing potential on the basis of regional mapping and assessments.
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Romania was	Include PHS assessment data

	included in the JRC-2013 assessment report, but these data were not publicly available. Romania has 56 known sites with realisable potential for PHS development. Except for two sites these are all based on one existing lake and one (to be developed) potential lake. There is one existing reversible hydro power plant.	once publicly available

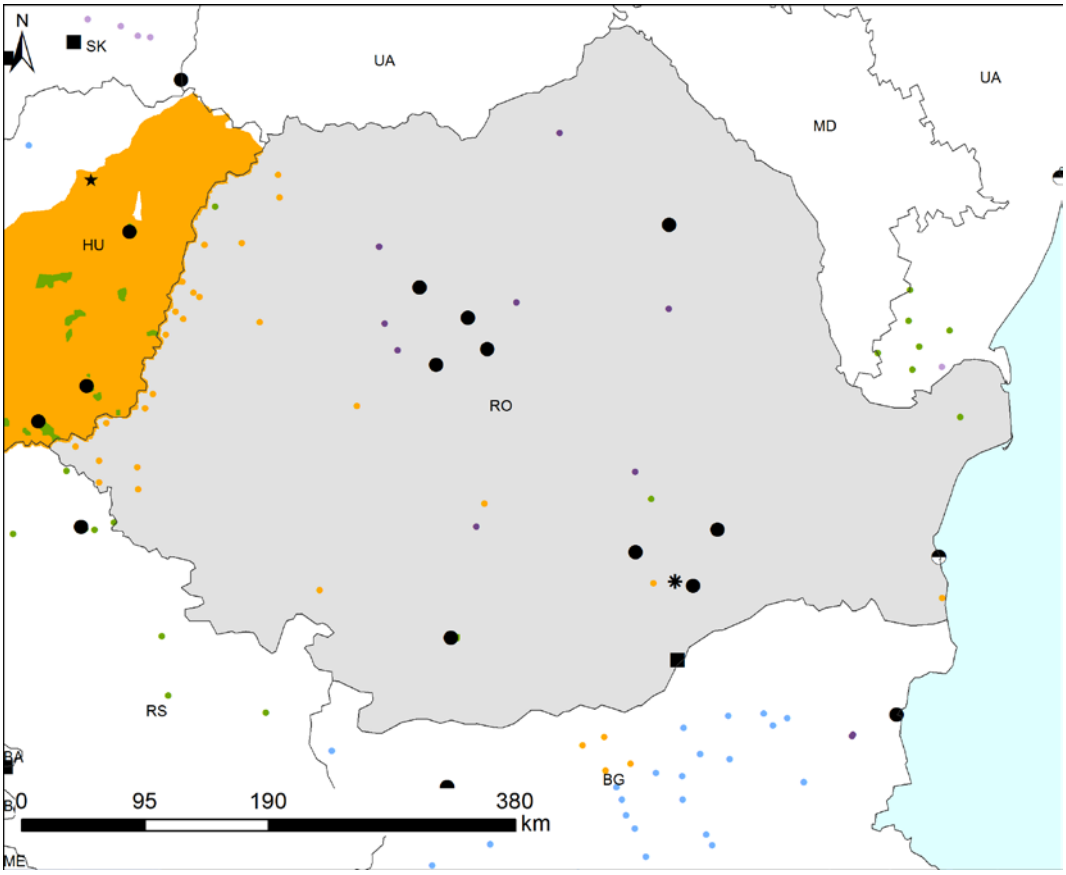

Figure 3.25-1: Romania - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

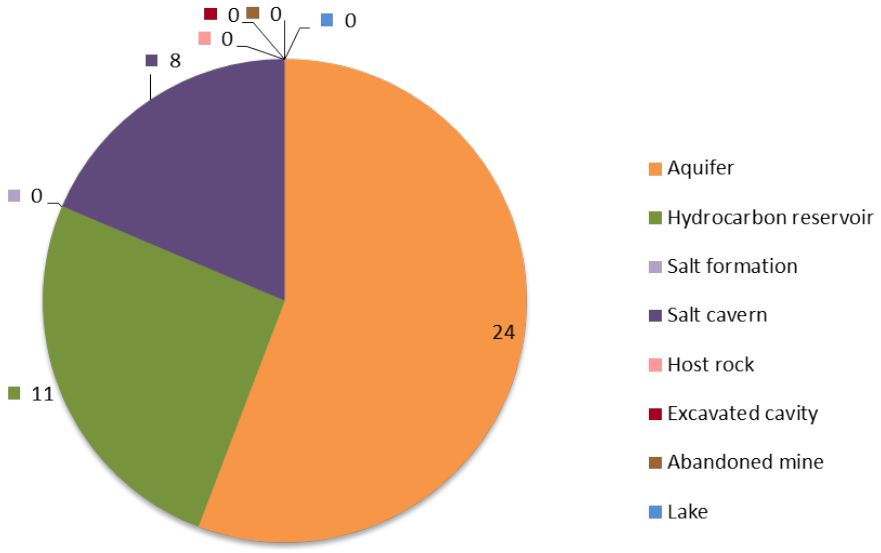

Figure 3.25-2: Romania - Summary of energy storage reservoir types contained in the database

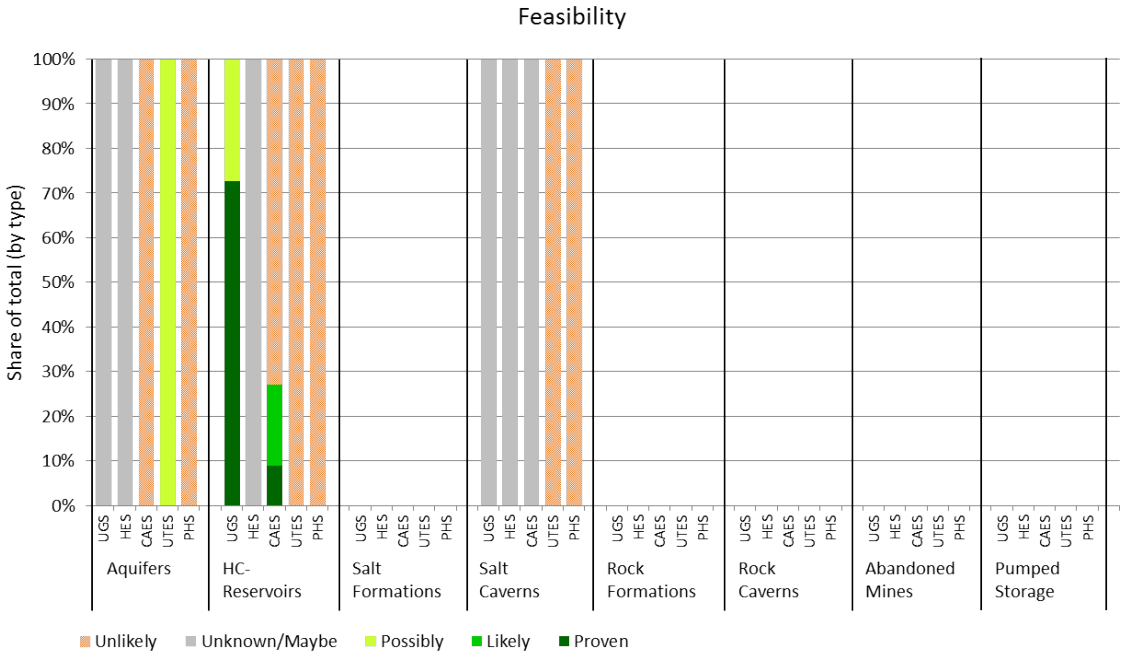

Figure 3.25-3: Romania - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

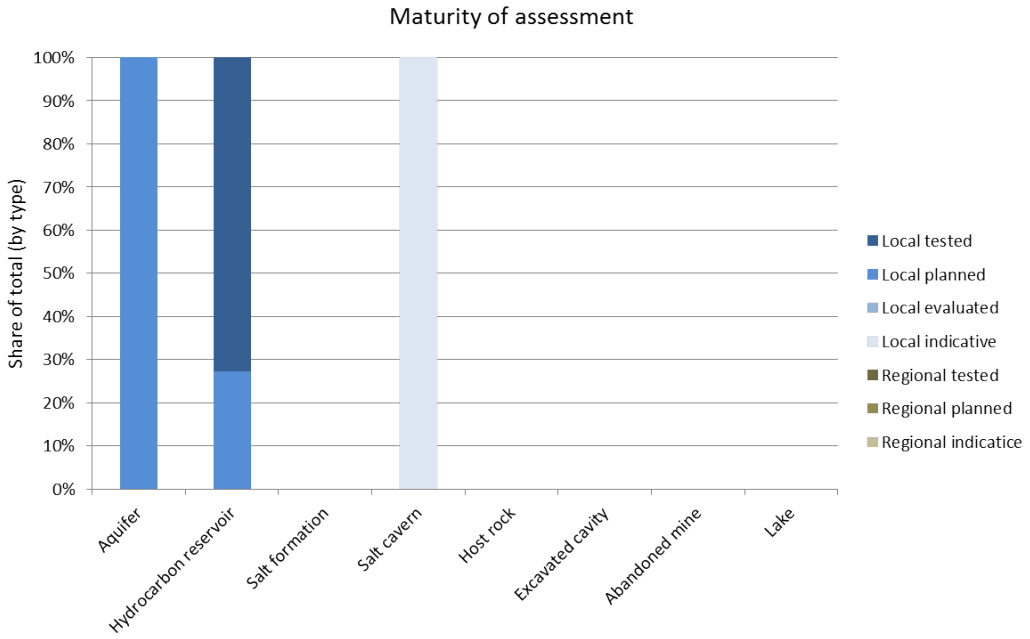

Figure 3.25-4: Romania - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

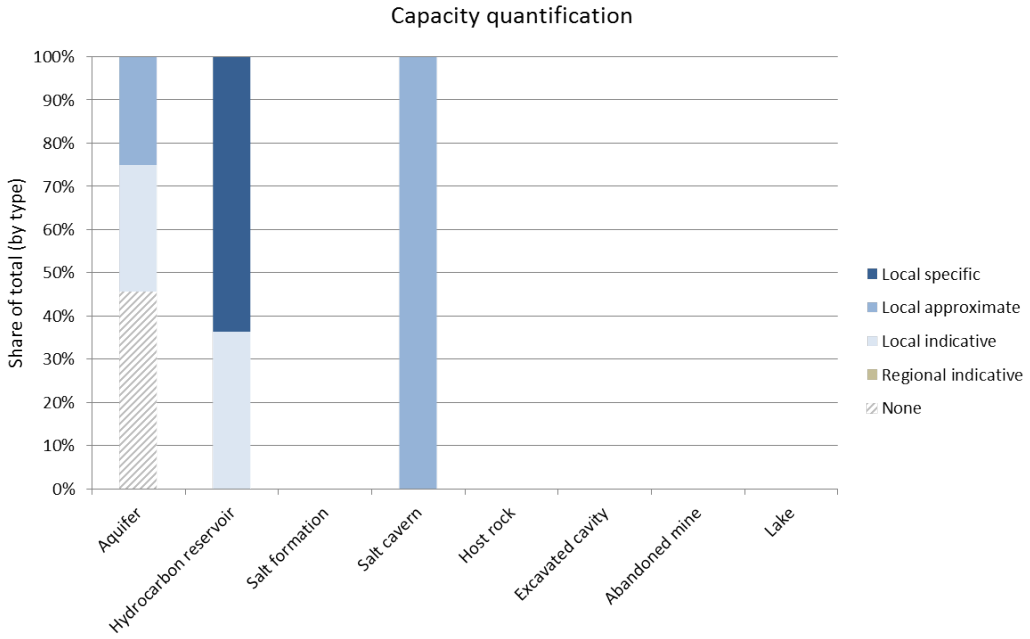

Figure 3.25-5: Romania - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.26. Serbia

3.26.1. Provider administration

Main providing organisations subsurface storage information:

BRGM – Bureau de Recherches Géologiques et Minières
ESTMAP Consortium Partner
Contact Person: Anne-Gaëlle Bader

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.26.2. Main data sources

Table 3.26-1: List of common sources used

Source name / URL	Description	Version / Date
Ministry of Mining and Energy of the Republic of Serbia - Powerpoint from O. A. Miocinovic , Advisor for Gas	Scientific publications and reports	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.26.3. Storage Data Review Serbia

Information on energy storage potential in Serbia is still relatively limited. Some potential for UGS (one developed site and 4 planned sites) is present in hydrocarbon reservoirs. PHS potential has been found in above ground lakes, but this information was not available to ESTMAP. Further subsurface regional mapping and assessment may reveal additional potential (e.g. aquifers).

Table 3.26-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential is considered present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Eight local-defined hydrocarbon reservoirs are included, one of which has been developed as UGS and 4 of which are planned for UGS development. Limited information is available concerning feasibility assessment. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Further location-specific investigations may be required. Except for the developed UGS site, There is no information available for estimating capacities.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	No entries available in ESTMAP. As far as known Serbia does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Serbia was included in the JRC-2013 assessment report, but these data were not publicly available. Serbia has 43 known sites with realisable potential for PHS development. Except for one site these are all based on one existing lake and one (to be developed) potential lake. There is one existing reversible hydro power plant along the western boundary.	Include PHS assessment data once publicly available

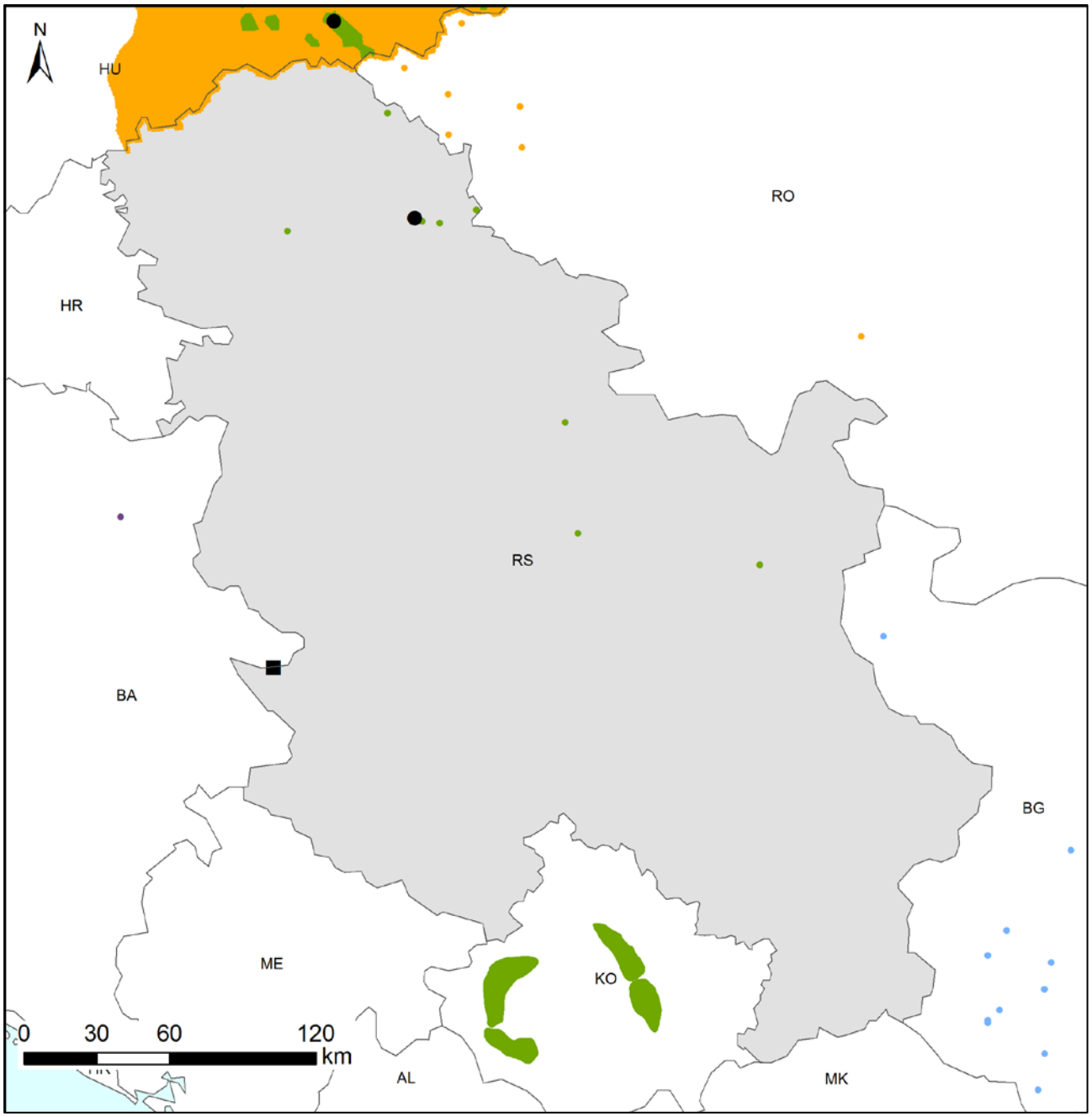

Figure 3.26-1: Serbia - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

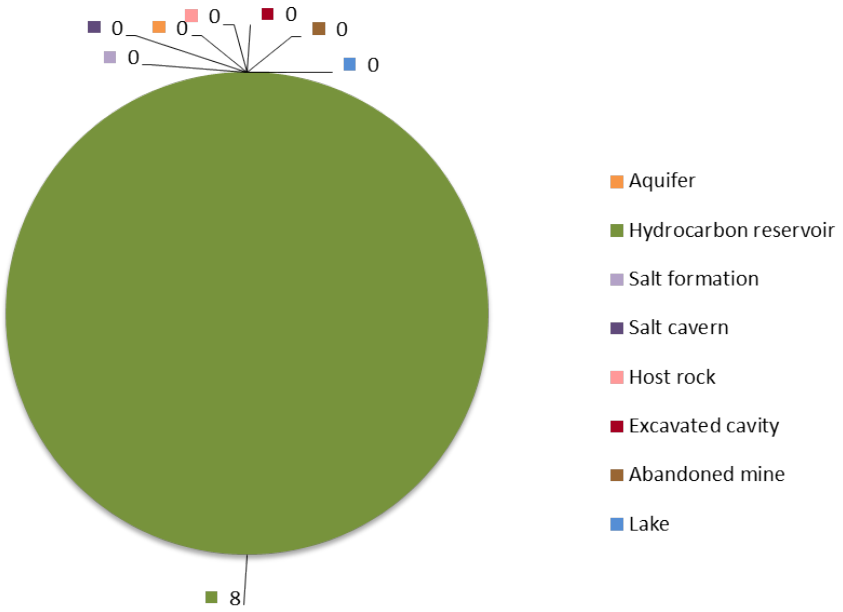

Figure 3.26-2: Serbia - Summary of energy storage reservoir types contained in the database

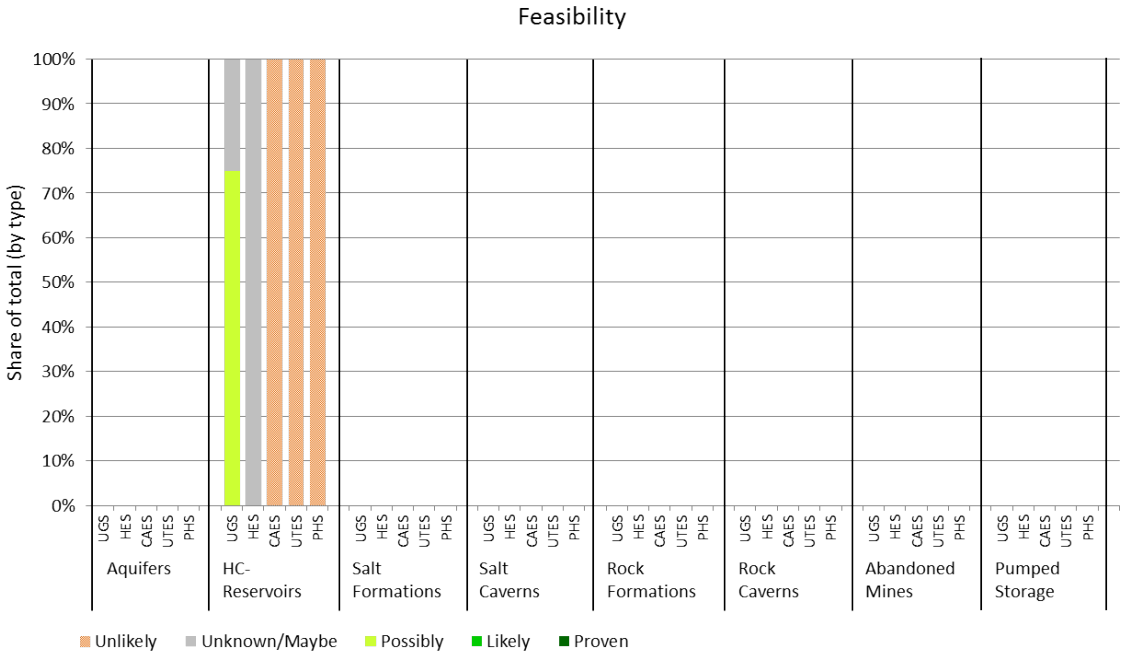

Figure 3.26-3: Serbia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

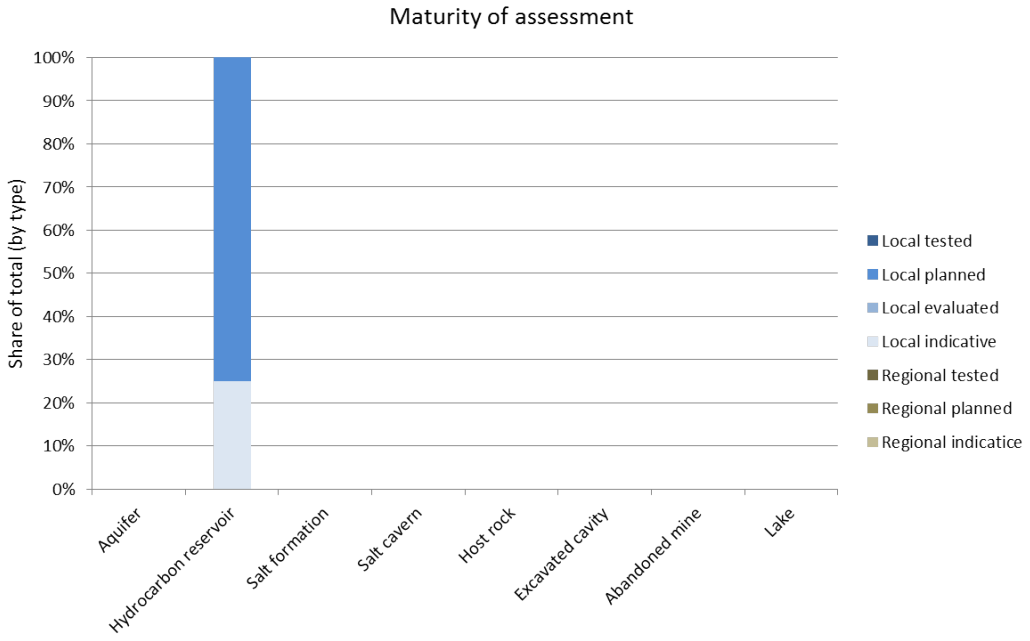

Figure 3.26-4: Serbia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

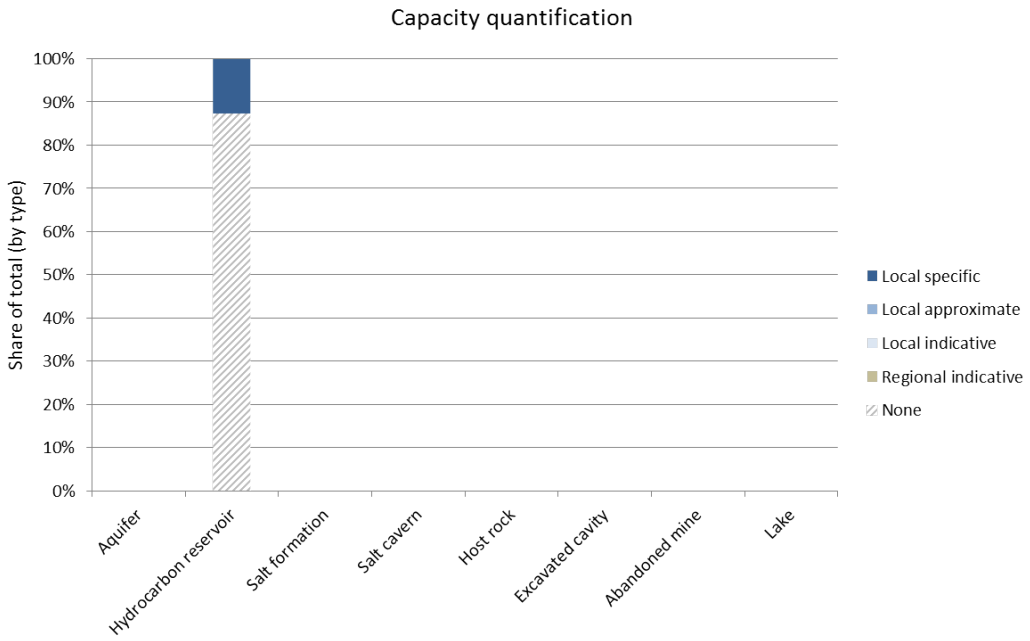

Figure 3.26-5: Serbia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.27. Slovakia

3.27.1. Provider administration

Main providing organisations subsurface storage information:

CGS – Czech Geological Survey
ESTMAP Consortium Partner
Contact Person: Jan Holecek

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.27.2. Main data sources

Table 3.27-1: List of common sources used

Source name / URL	Description	Version / Date
Various internet and literature resources	Not specified	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.27.3. Storage Data Review Slovakia

Information on energy storage potential in Slovakia is still relatively limited. Data are all derived from public sources (no national data provider). Hydrocarbon reservoirs are a primary target for UGS. Some PHS potential is already being utilized in above ground lakes and some more storage potential of this type is available across the country. This information was however not available to ESTMAP. Further subsurface regional mapping and assessment may reveal additional potential.

Table 3.27-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Potential is considered present. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Nine local-defined hydrocarbon reservoirs are included, 3 of which have been developed as UGS and 6 of which are planned for UGS development. Operational capacities are approximated by total gas volumes. Potential for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. It is currently unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	Four regional-defined salt formations are included, three of which are still undeveloped. Potential for UGS, HES and CAES has not been assessed yet (or information is not available) though there may be scope for further investigation of this potential on the basis of generic geological assumptions. There is very limited or no information available for estimating storage capacities. It is currently unknown whether there is scope for investigating additional potential in other salt formations.	Confirmation of location-specific suitability and expected capacities. Check whether there is scope to extend information on existing potential on the basis of regional mapping and assessments.
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries for assessed potential available in ESTMAP. Slovakia was included in the JRC-2013 assessment report, but these data were not publicly available. Slovakia has 8 known sites with realisable potential for PHS development. All are based on one existing lake and one (to be developed) potential lake. The storage facility data include information on 4 developed PHS sites.	Include PHS assessment data once publicly available

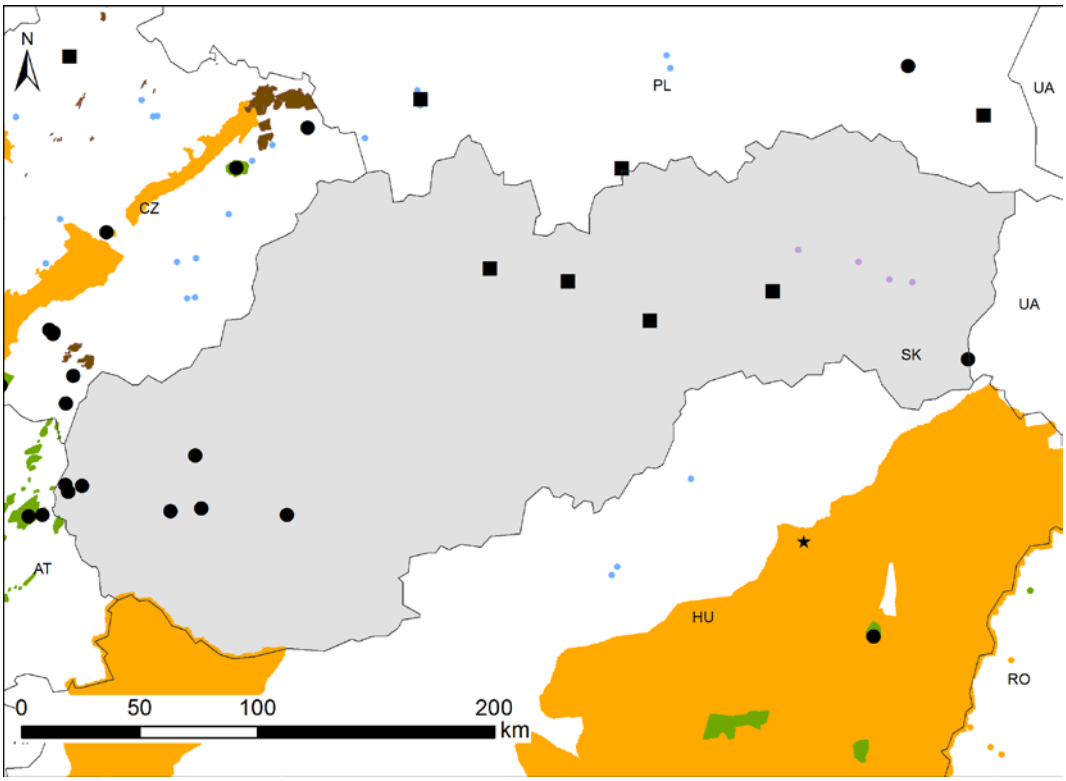

Figure 3.27-1: Slovakia - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

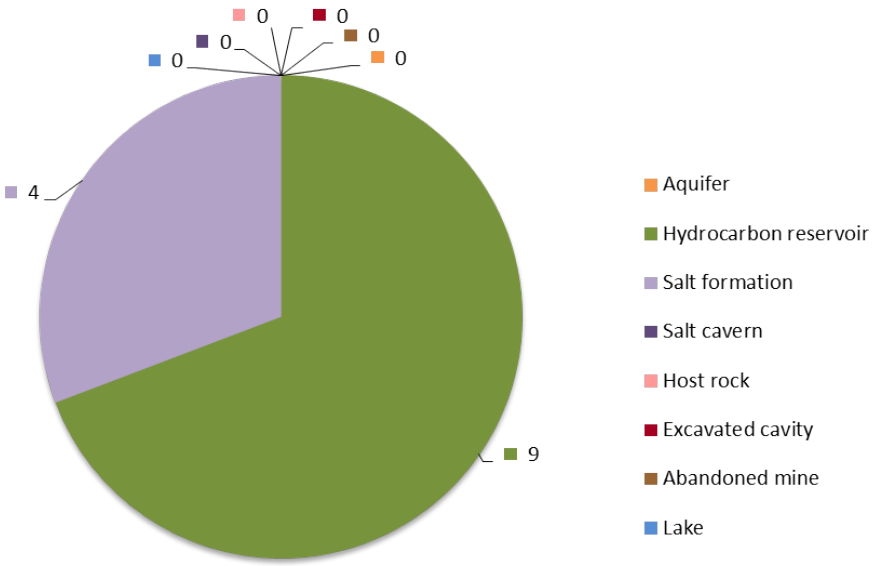

Figure 3.27-2: Slovakia - Summary of energy storage reservoir types contained in the database

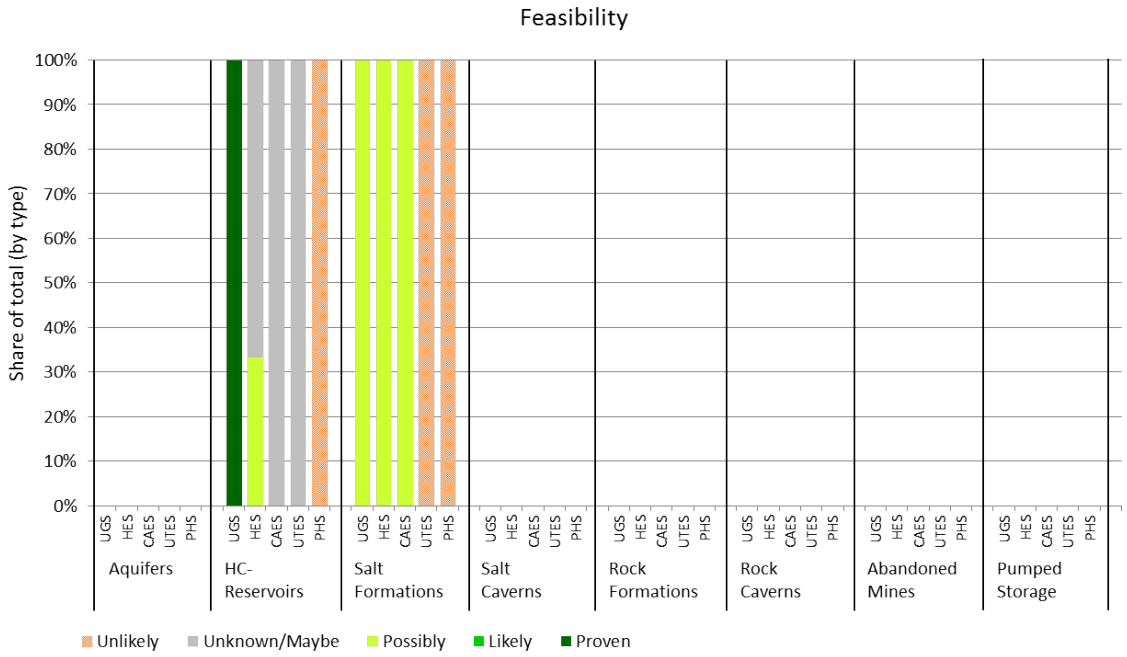

Figure 3.27-3: Slovakia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

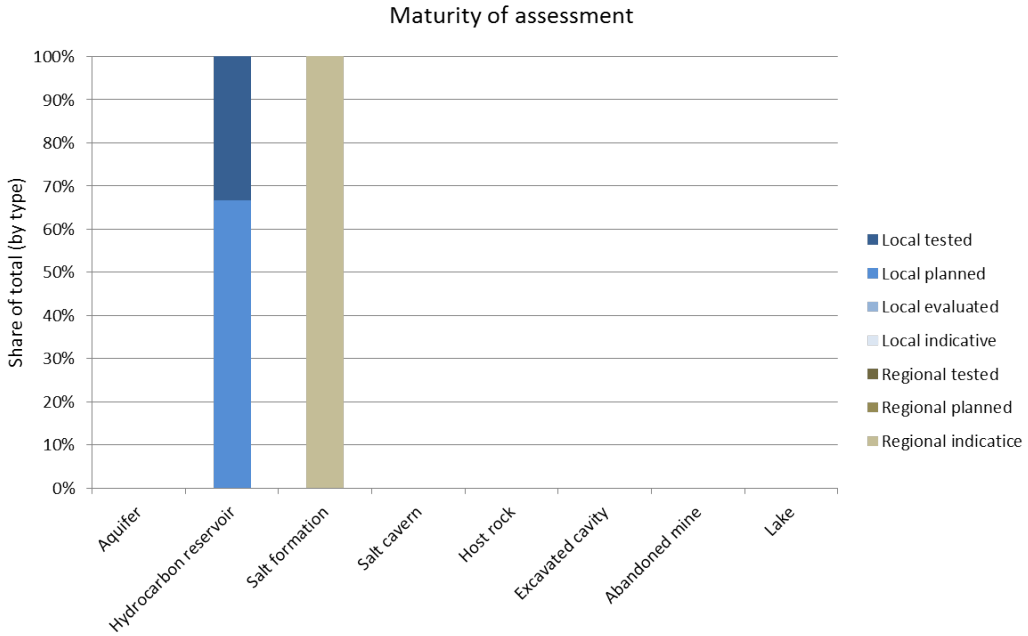

Figure 3.27-4: Slovakia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

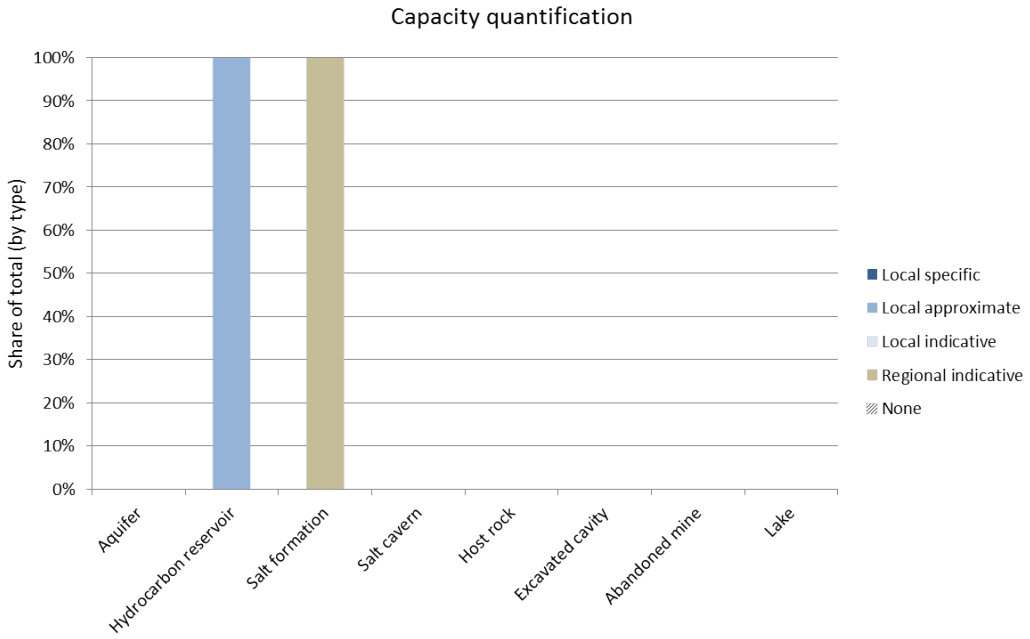

Figure 3.27-5: Slovakia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.28. Slovenia

3.28.1. Provider administration

Main providing organisations subsurface storage information:

Geoinzeniring
Subcontractor
Contact Person: Marjeta Car

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.28.2. Main data sources

Table 3.28-1: List of common sources used

Source name / URL	Description	Version / Date
Geological Research data, maps and reports	Aquifer mapping and research	December 2008
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.28.3. Storage Data Review Slovenia

Energy potential in Slovenia has been investigated to a limited extent only. Options for UGS and UTES (and possibly also HES and CAES) may be present in various aquifers. Hydrocarbon reservoirs may provide additional potential for UGS. All subsurface sites are considered possible targets for CO_2 storage. Slovenia has a little potential for PHS in several above ground lakes.

Table 3.28-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Slovenia includes 27 local and one regional-defined aquifer which are spread across the country. All aquifers are considered suitable for UGS and CO_2 storage but assessment is still premature and location-specific investigations are required to confirm this. Potential for HES and UTES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. None of the sites included in ESTMAP have been developed as storage yet. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities. Further potential may be revealed by geological mapping.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type. Check whether there is scope to extend existing potential on the basis of regional mapping and assessment.
Hydrocarbon reservoirs	Four local-defined hydrocarbon reservoirs are included, none which have been developed for storage purposes. Capacities are approximated by total gas volumes. Potential for UGS, HES and CAES has not been assessed (or information is not accessible), though there may be scope for further investigation of this potential on the basis of generic geological assumptions. The sites are also possible targets for CO_2 storage. It is currently unknown whether there is scope for investigating additional potential in other hydrocarbon reservoirs.	Confirmation of location-specific suitability and expected capacities. Check whether there is scope to extend existing potential on the basis of exploration data.
Salt formations and caverns	No entries available in ESTMAP. As far as known Slovenia does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Slovenia has low realisable potential for PHS development. All identified sites are based on a combination of one existing and one potential (to be developed) lake. One out of five sites identified by JRC-2013 are operational as PHS. On site is under investigation Few additional theoretical options with two lakes or >10km lake separation exist but these are not publicly available to ESTMAP. Past investigations considered 4 locations in Vuhred, Brezno, Lehen and Lobnica. These sites have been discarded in the 1980's.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

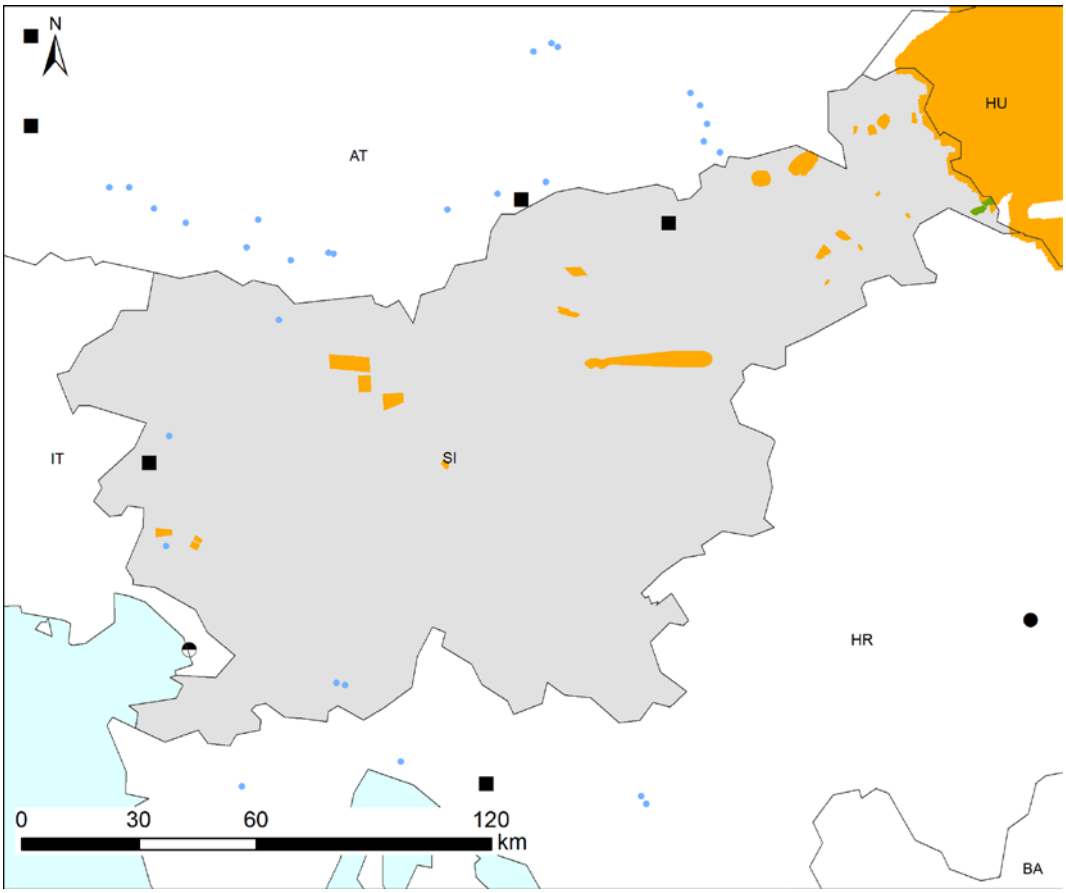

Figure 3.28-1: Slovenia - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

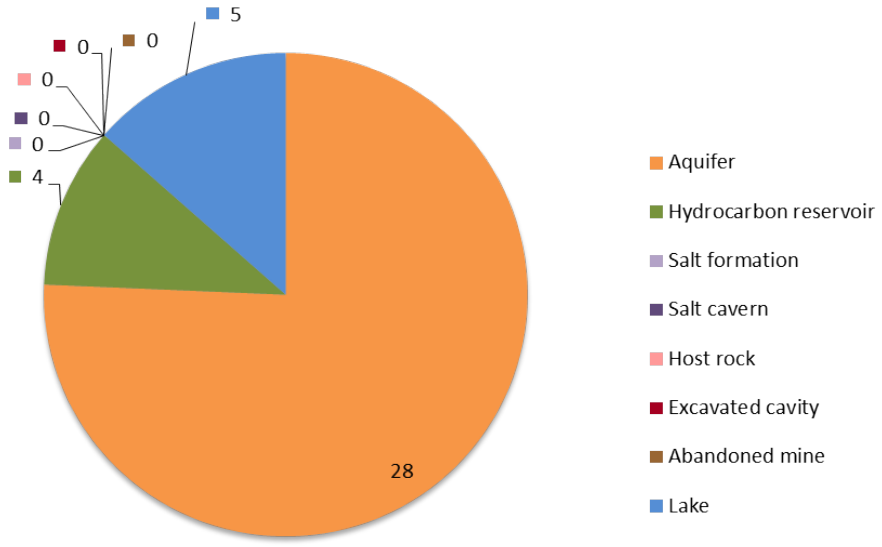

Figure 3.28-2: Slovenia - Summary of energy storage reservoir types contained in the database

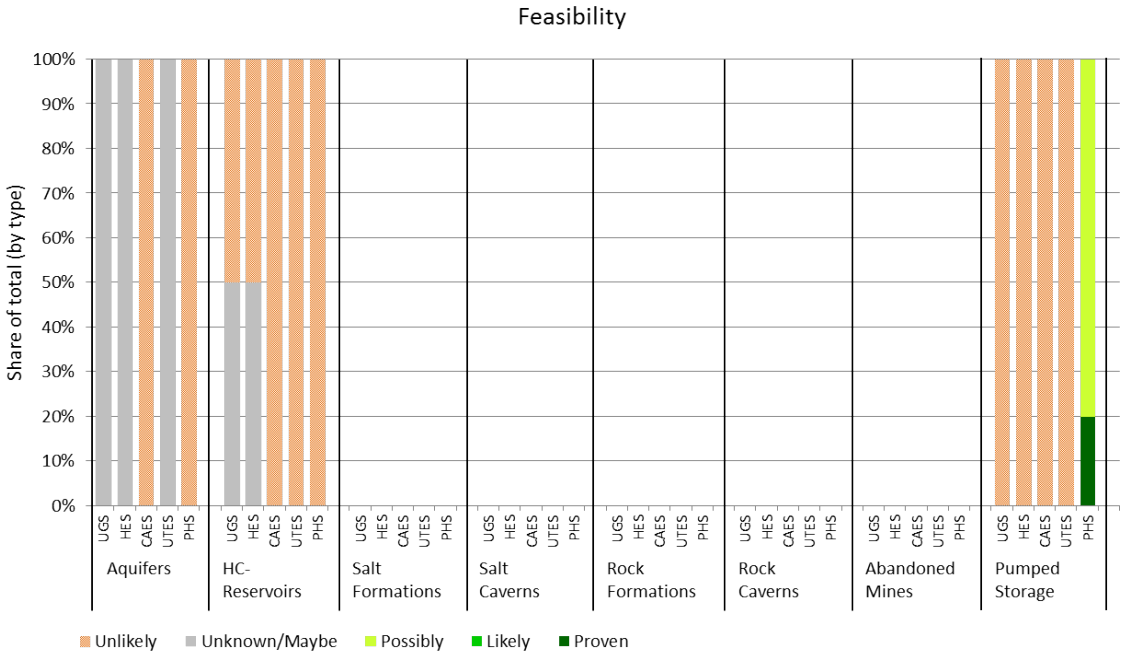

Figure 3.28-3: Slovenia - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

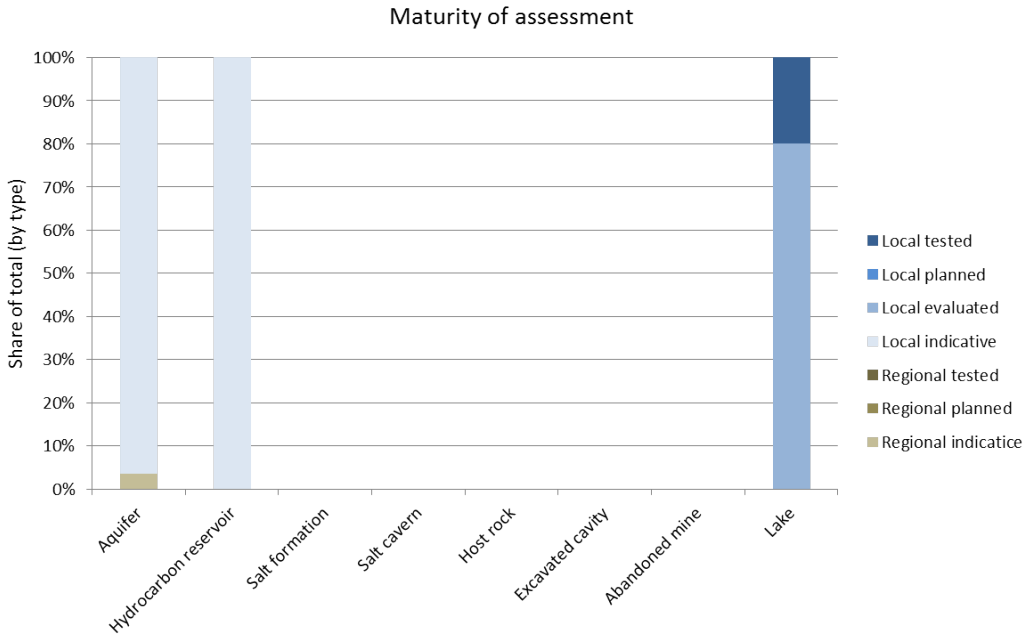

Figure 3.28-4: Slovenia - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

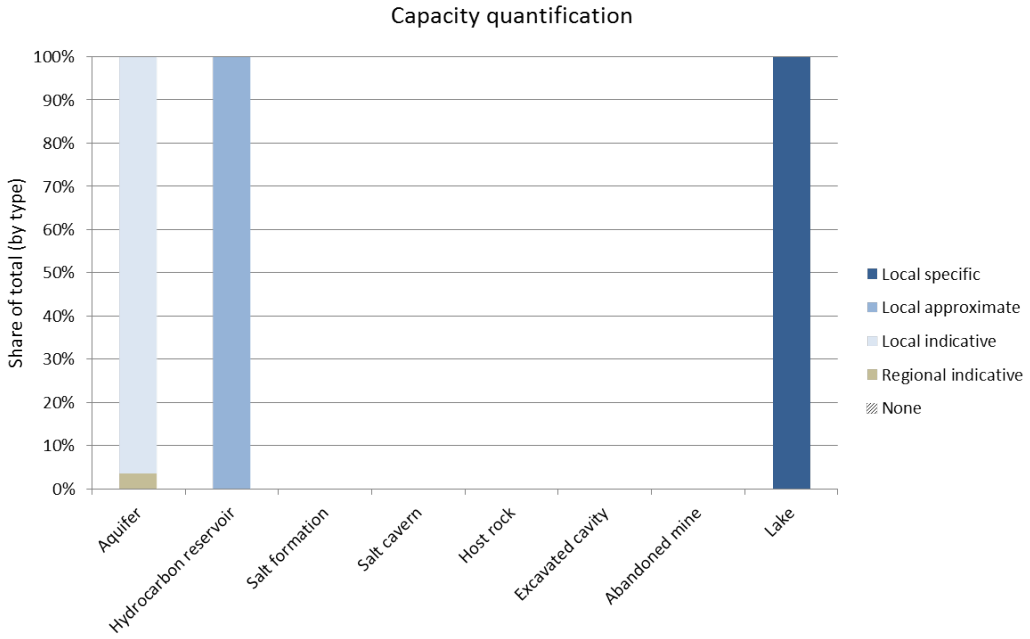

Figure 3.28-5: Slovenia - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.29. Spain

3.29.1. Provider administration

Main providing organisations subsurface storage information:

IGME – Instituto Geológico y Minero de España
Subcontractor
Contact Person: Celestino García de la Noceda Márquez

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.29.2. Main data sources

Table 3.29-1: List of common sources used

Source name / URL	Description	Version / Date
EU GeoCapacity: http://www.geology.cz/geocapacity	Assessment of CO_2 Storage potential	2009
operator website, Ministry of Industry, Energy and Tourism: geoportal.minetur.gob.es	Reporting of oil and gas reserves	2015
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.29.3. Storage Data Review Spain

Spain's key energy storage potential is present in pumped storage lakes. This information is however unavailable to ESTMAP. In the subsurface various regional-defined aquifers are regarded a primary target for CO_2 storage but these may also be suitable for UGS. Four hydrocarbon reservoirs and one aquifer are already developed for UGS. Further energy storage potential may be revealed by future research on salt formations and host rock formations.

Table 3.29-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	Spain has several regional-defined aquifers spread across the country, which are considered a primary target for CO_2 storage (planned activity). The aquifers may potentially also host UGS but this should be confirmed by location-specific assessment. One local-defined site has been developed for UGS. In theory the aquifers may also define scope for HES or UTS (based on generic geological assumptions). Availability of information for estimating potential capacities is very limited.	Identification of location-specific potential, determination of expected capacities. Check whether there is future scope to investigate alternative potential in this reservoir type.
Hydrocarbon reservoirs	Four local-defined hydrocarbon reservoirs have existing UGS development. For these sites operational capacities are provided. Prospectivity from additional sites is considered to be limited. Future assessments are needed to confirm alternative uses for HES.	Limited scope for assessing new sites. Check whether there is future scope to investigate additional potential for the existing sites.
Salt formations and caverns	No entries available in ESTMAP. Subsurface salt deposits are known to exist along the eastern margins of Spain. Information on energy storage potential is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate/include additional potential for this reservoir type
Host rock, caverns, mines	One abandoned mine has been developed for UTES. Only limited information is available to estimate the capacity. Additional future potential is considered presence. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate/include additional potential for this reservoir type
Lakes	No entries available in ESTMAP. Spain was included in the JRC-2013 assessment report, but the data is not publicly available to ESTMAP. Spain has a huge realisable potential for PHS including 165 existing sites based on two nearby (<10km) lakes and 639 sites based on one existing lake and nearby (<10km) potential to develop a new lake. ESTMAP contains information on 19 existing and 1 planned PHS storage facility.	Include PHS assessment data once publicly available

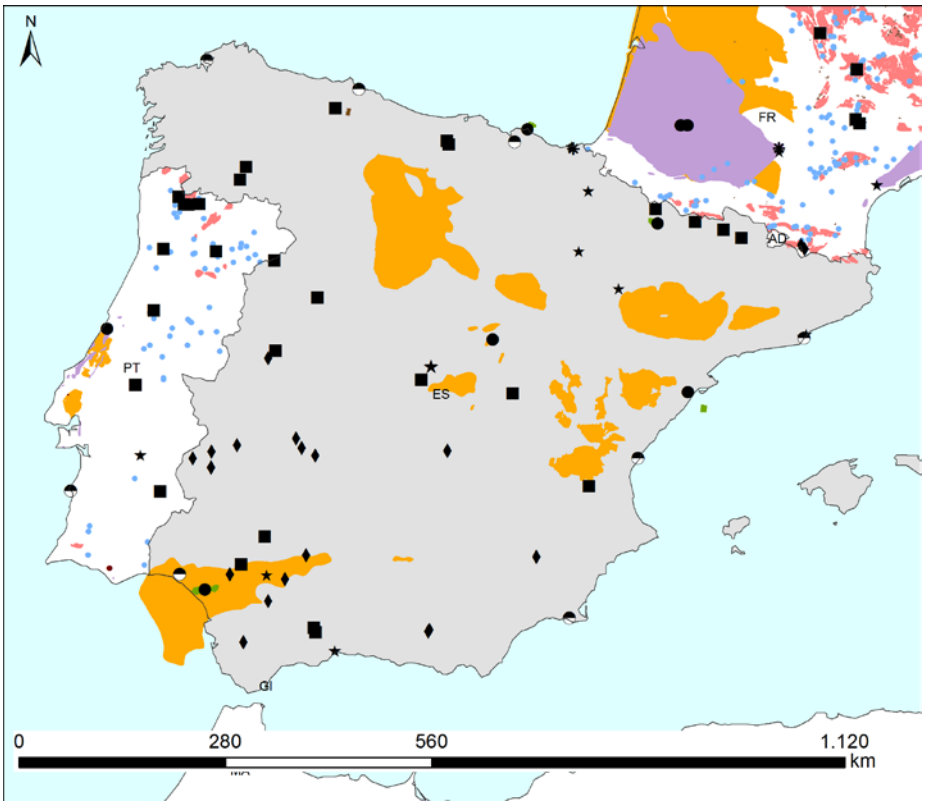

Figure 3.29-1: Spain- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

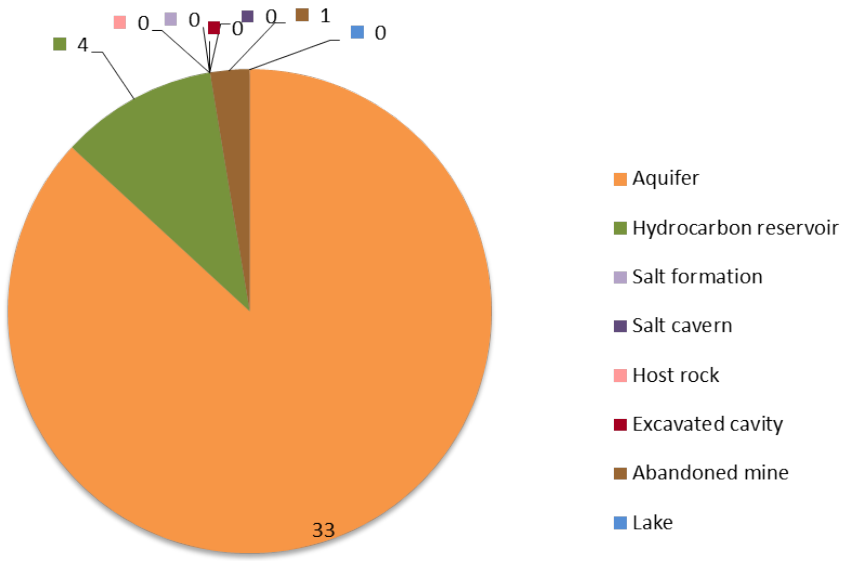

Figure 3.29-2: Spain - Summary of energy storage reservoir types contained in the database

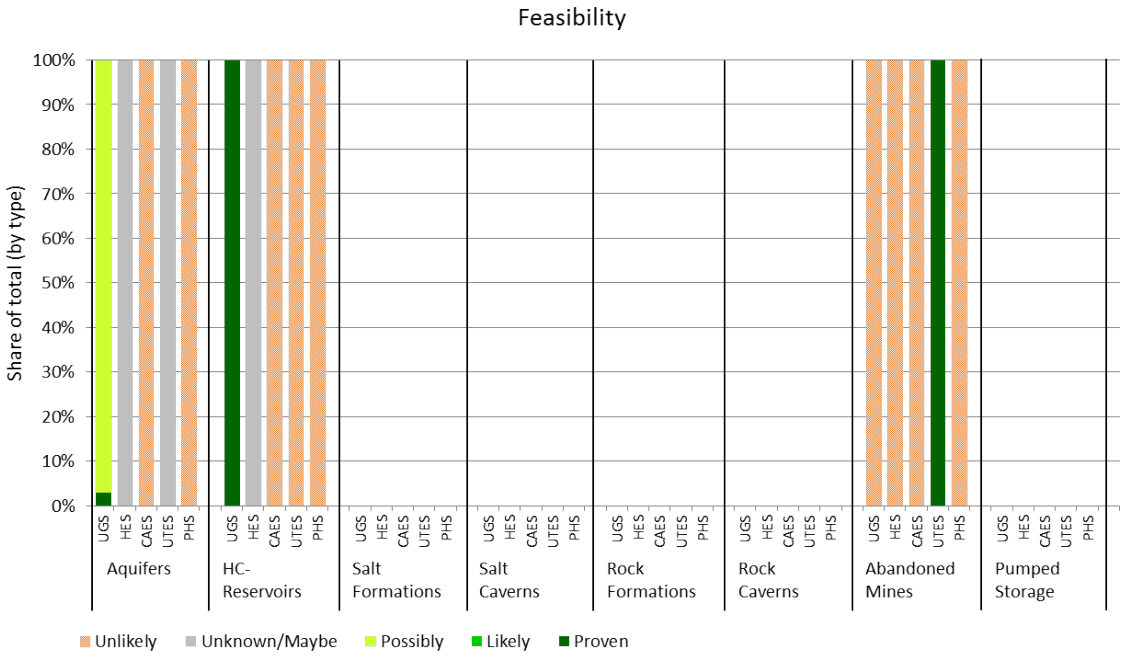

Figure 3.29-3: Spain - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

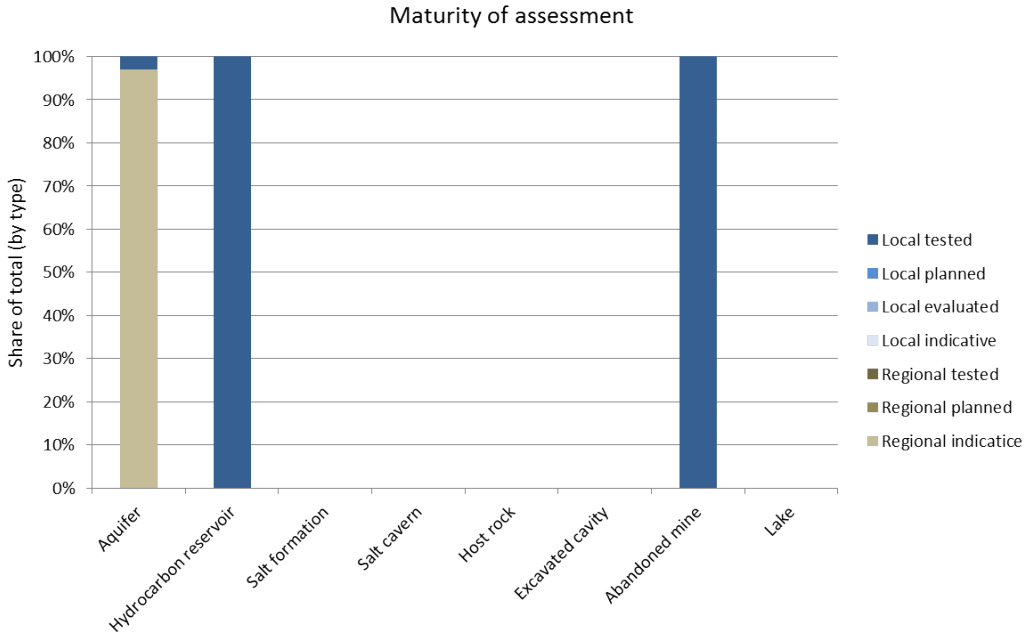

Figure 3.29-4: Spain - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

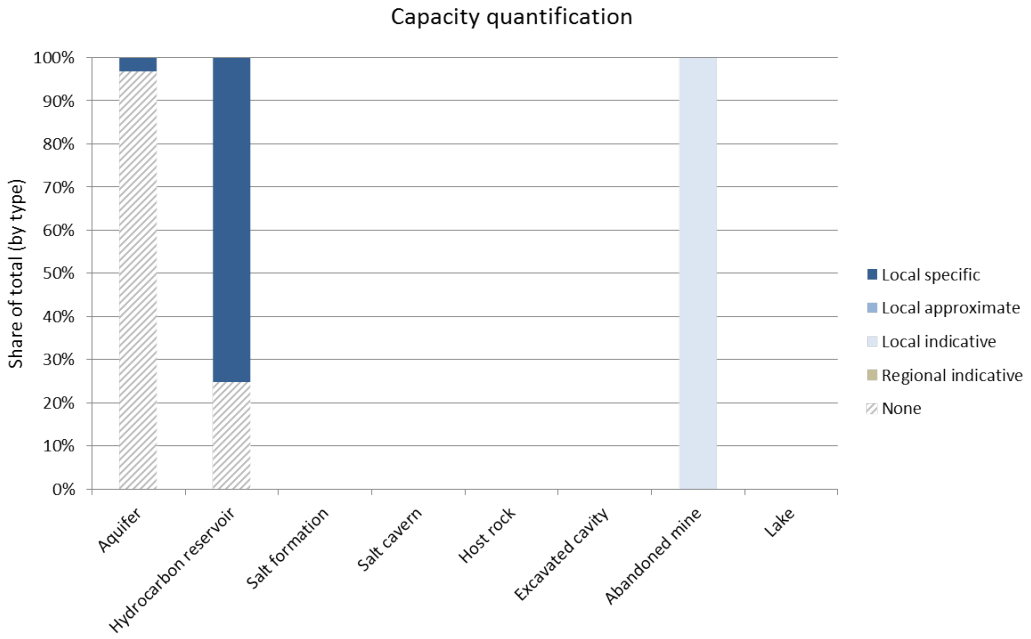

Figure 3.29-5: Spain - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.30. Sweden

3.30.1. Provider administration

Main providing organisations subsurface storage information:

SGU – Geological Survey of Sweden
Subcontractor
Contact Person: Prof. Mikael Erlström

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.30.2. Main data sources

Table 3.30-1: List of common sources used

Source name / URL	Description	Version / Date
Geological Research data: Seismic and Well data	Aquifer mapping and research	
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.30.3. Storage Data Review Sweden

The main energy storage potential in Sweden is defined in above ground pumped storage lakes (PHS). Limited potential is present in subsurface aquifers, all of which still depends on further location-specific assessment and confirmation of suitability.

Table 3.30-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Sweden includes 10 regional-defined aquifers located at the southern margin of the country. All sites are considered potential candidates for UGS and possibly also HES and UTES. This potential has not been thoroughly assessed though and is still based on generic geological assumptions. None of the sites included in ESTMAP have been developed as storage yet. The aquifers are parameterized to a limited extent only and there is no basis for estimating capacities. There is very limited scope for revealing additional potential in other aquifers.	Confirmation and assessment of location-specific potential and expected capacities.
Hydrocarbon reservoirs	No entries available in ESTMAP. Unknown whether potential exists. Information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential in this reservoir type
Salt formations and caverns	No entries available in ESTMAP. As far as known Sweden does not have salt formations that allow for development of suitable caverns.	No or very limited scope for future investigation
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Sweden has moderate to abundant realisable potential for PHS development. Except for one site all potential is based on one existing lake and one (to be developed) potential lake. None of the sites included in ESTMAP appears to be developed yet. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments.

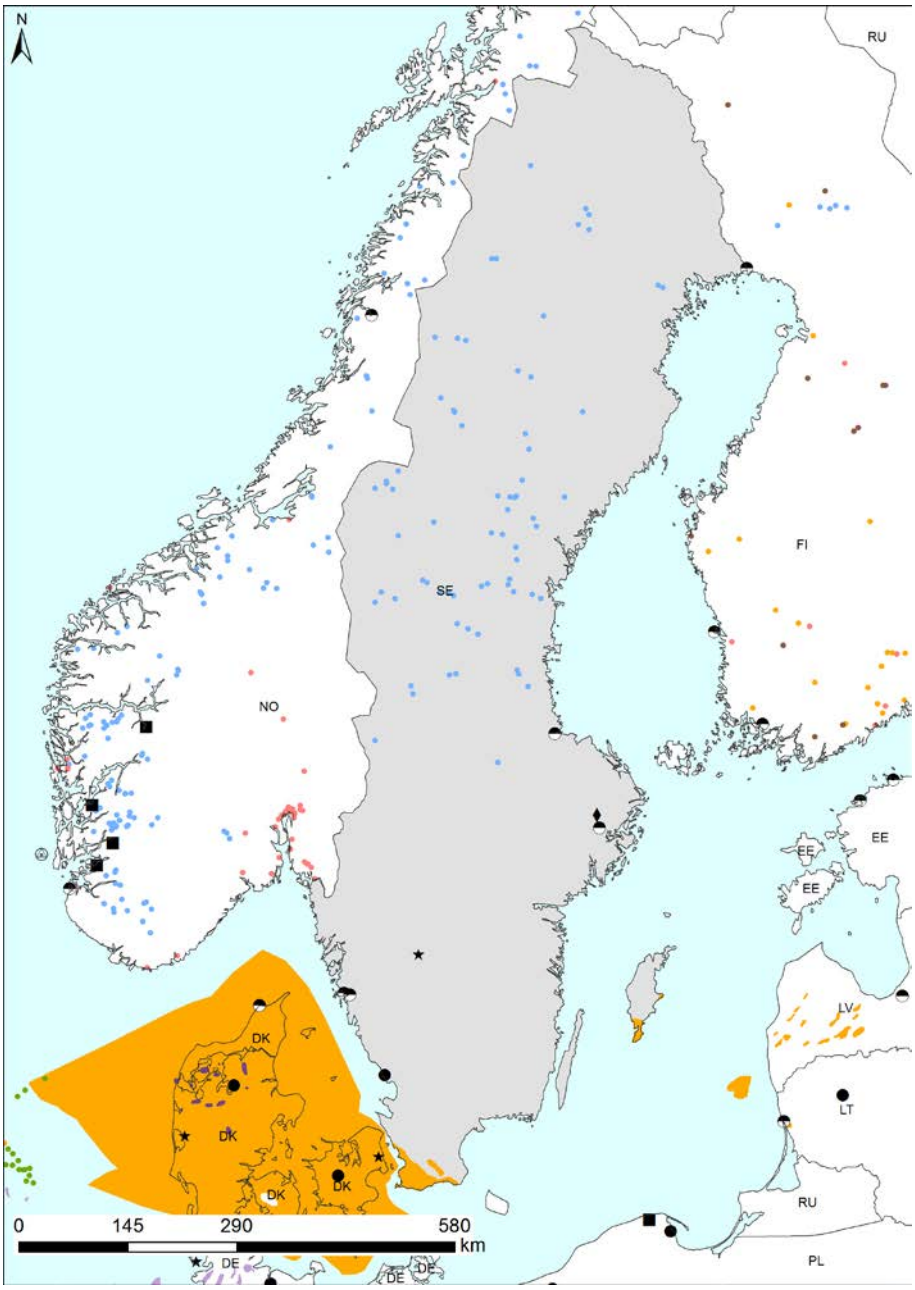

Figure 3.30-1: Sweden - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

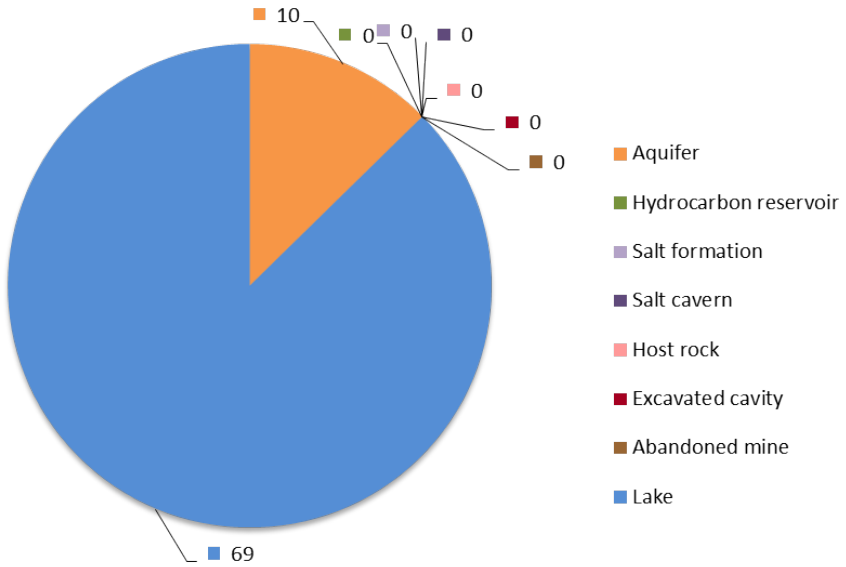

Figure 3.30-2: Sweden - Summary of energy storage reservoir types contained in the database

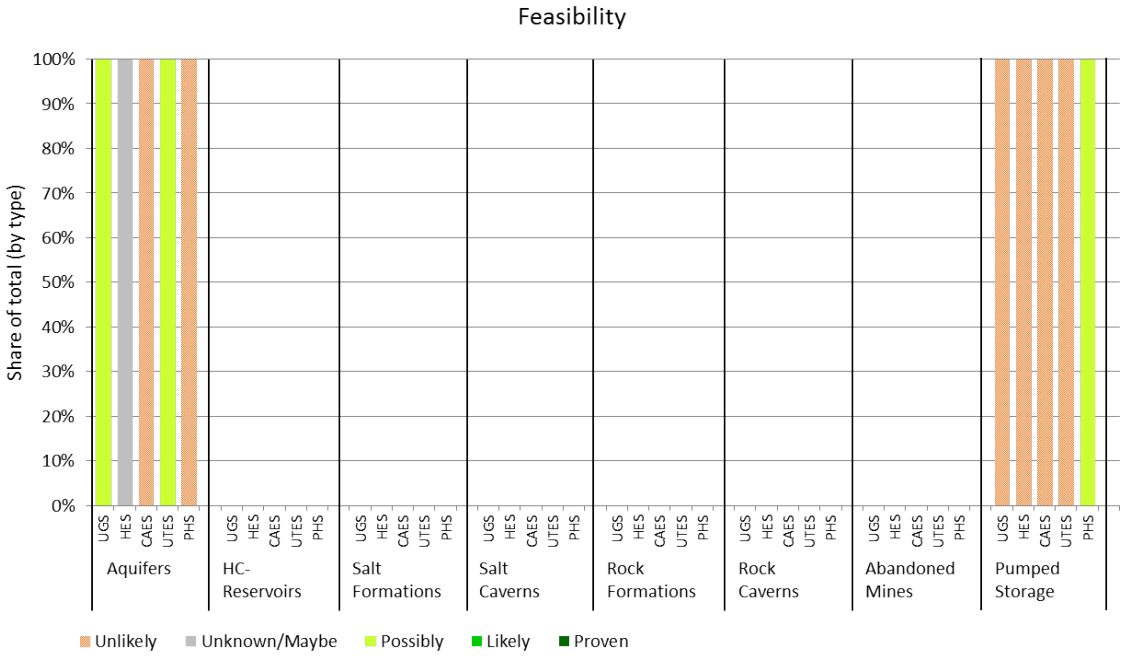

Figure 3.30-3: Sweden - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

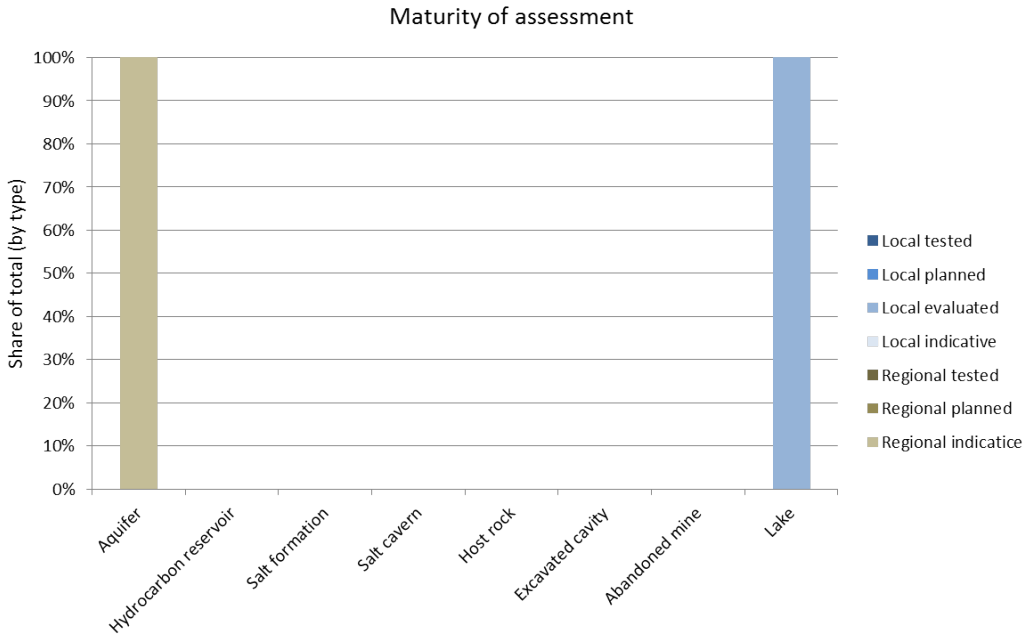

Figure 3.30-4: Sweden - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

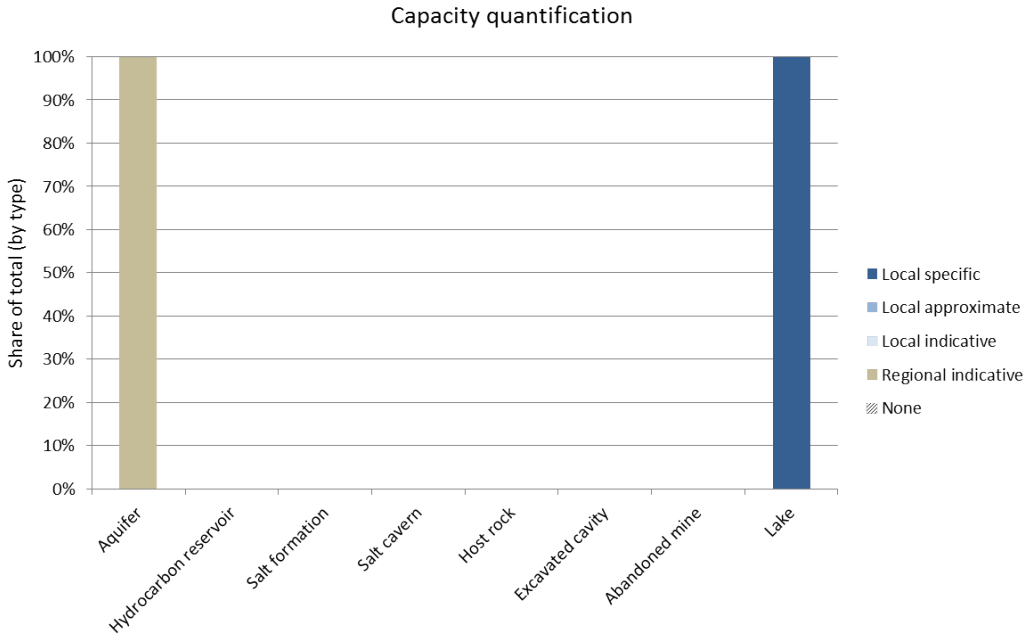

Figure 3.30-5: Sweden - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.31. Turkey

3.31.1. Provider administration

Main providing organisations subsurface storage information:

Middle East Technical University, Petroleum Research Centre, Ankara-Turkey
Subcontractor
Contact Person: Caglar Sinayuc

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.31.2. Main data sources

Table 3.31-1: List of common sources used

Source name / URL	Description	Version / Date
Sahin, S. et al., 2012. Design and status of the only underground gas storage project in Turkey after three years of operation	Scientific publications and reports	2012
Dulger, M. G., 2014. Tuz Gölü Natural Gas Underground Storage Project (in Turkish)	Scientific publications and reports	2014
Jordan, F., 2014. Tarsus Underground Gas Storage Project	Scientific publications and reports	2014
Abravcı, S., 2014. Silivri Natural Gas Storage Facility and Current State (in Turkish)	Scientific publications and reports	2014
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.31.3. Storage Data Review Turkey

The main energy storage potential in Turkey is defined by pumped hydro lakes. None of these appear to have developed yet. Limited potential for UGS (developed and planned) is present in hydrocarbon reservoirs and salt formations. Future regional mapping and assessment could reveal additional potential for UGS, HES and CAES in salt formations and possibly also host rock formations.

Table 3.31-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Further potential is considered present. Information is currently either not publicly available or the potential has not been assessed to a sufficient degree yet.	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Four local-defined hydrocarbon reservoirs are included, two of which have been developed as UGS. The other two sites are planned for UGS development. Direct operational capacities (gas working volumes) are provided. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions.	Confirmation of location-specific suitability and expected capacities. There is very limited scope to investigate additional capacities in this reservoir type.
Salt formations and caverns	Two local-defined salt caverns are included, all of which are planned for UGS development. Direct operational capacities (gas working volumes) are provided. Potential for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Additional potential may be present at other locations but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate additional potential in this reservoir type (regional geological mapping and local assessment).
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	Turkey has huge realisable potential for pumped hydro storage, including many options based on two existing nearby (<10 km) lakes. The ESTMAP database does not include any information on existing development. All identified sites include specific determinations of energy storage capacities and lake volumes. Further theoretical sites are identified but not publicly available to ESTMAP.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential.

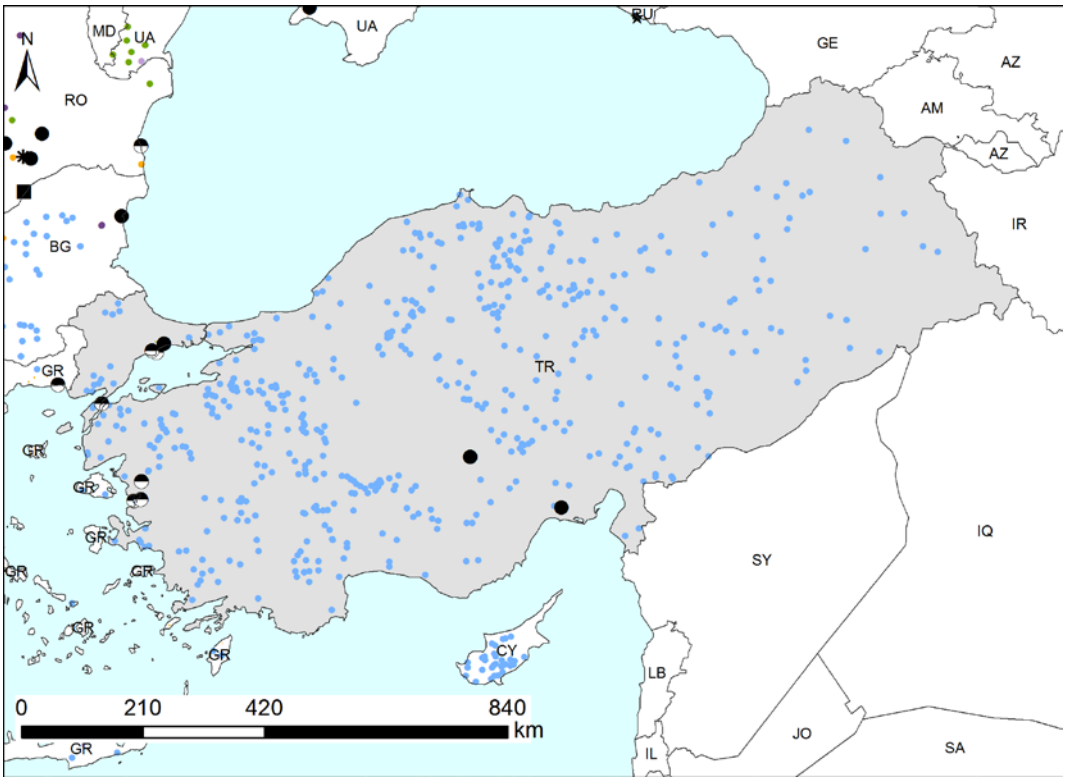

Figure 3.31-1: Turkey - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

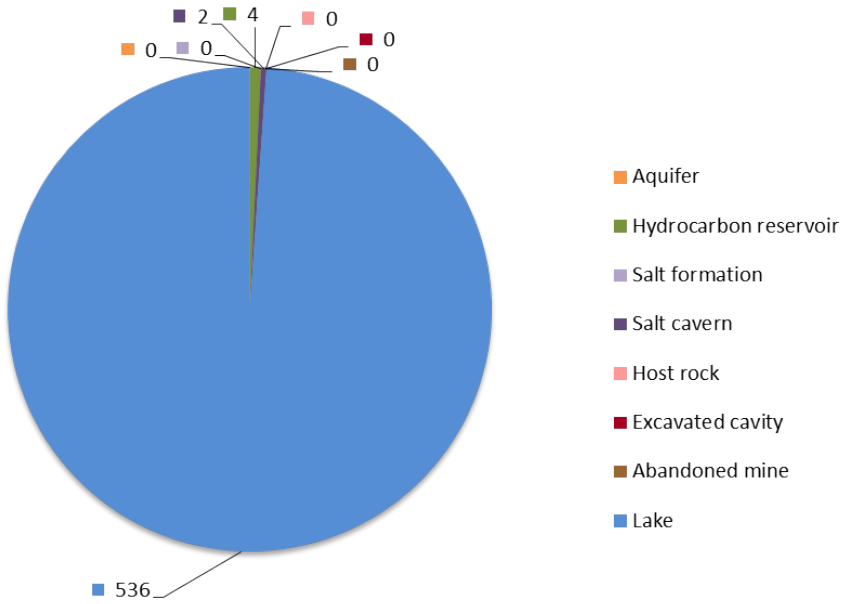

Figure 3.31-2: Turkey - Summary of energy storage reservoir types contained in the database

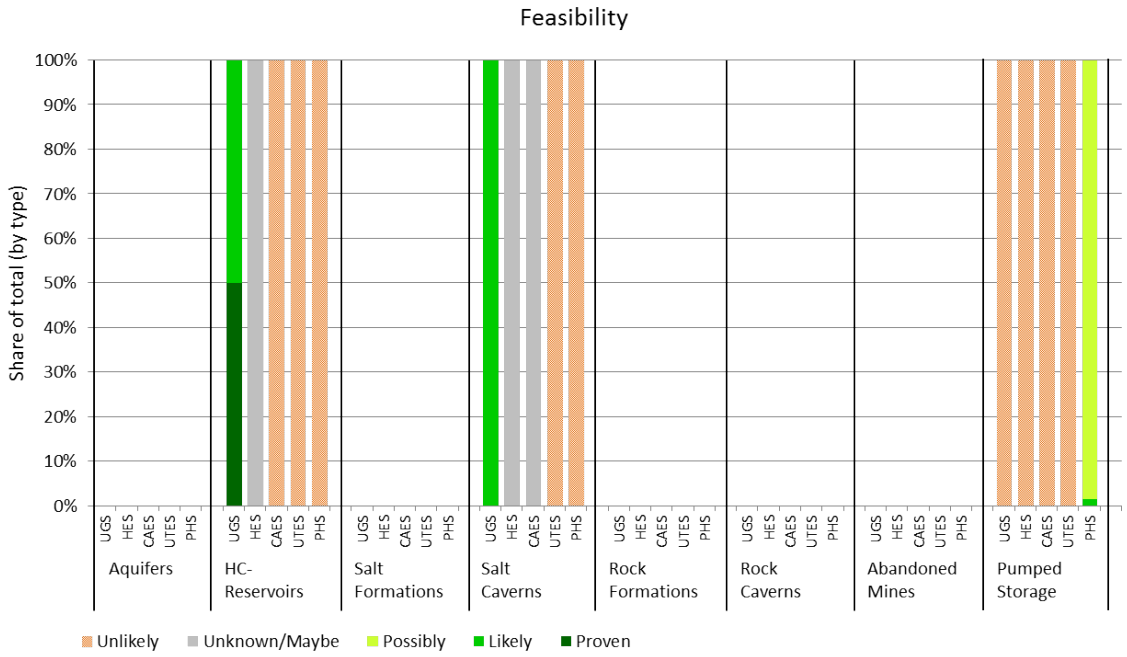

Figure 3.31-3: Turkey - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

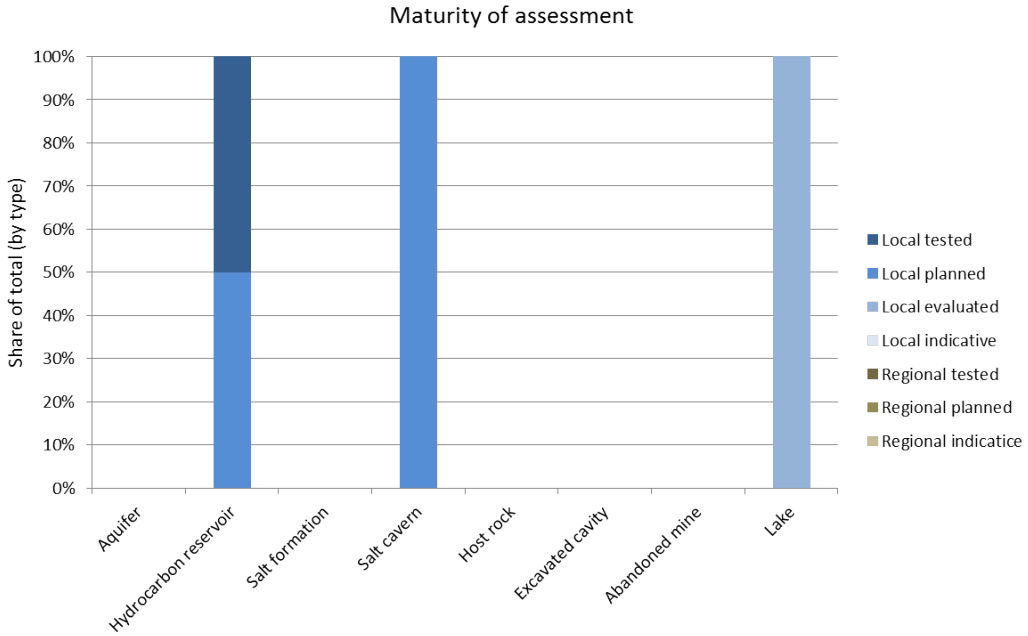

Figure 3.31-4: Turkey - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

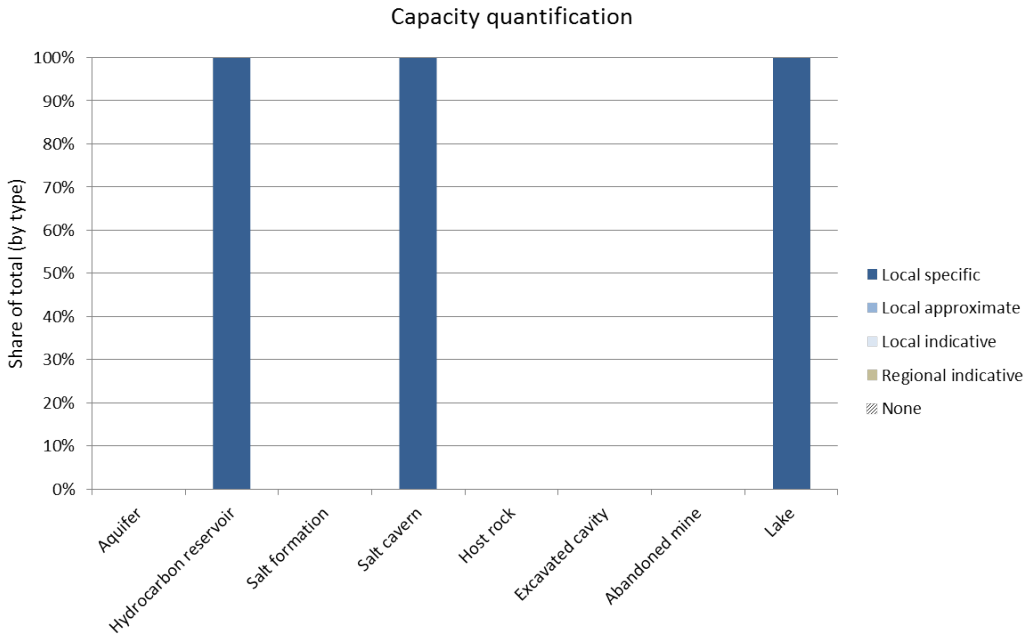

Figure 3.31-5: Turkey - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.32. Ukraine

3.32.1. Provider administration

Main providing organisations subsurface storage information:

SRDE: State Research and Development Enterprise “Geoinform of Ukraine”
Subcontractor
Contact Person: Boris Malyuk

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.32.2. Main data sources

Table 3.32-1: List of common sources used

Source name / URL	Description	Version / Date
Operator Licence Documents	Site specific technical data	
GeoInform, 1974. Geological structure and reserves estimation for West-Sosnovskoe gas-condensate deposit, 1974 (In Russian).		1974
GeoInform, 1975. Suvorovskaya and Kiliyskaya fields by Ukrainian thematic group on underground gas storages (In Russian)	Report on results of structure drilling, Scientific publications and reports	1975
GeoInform, 1978. Assessment of oil and gas potential and prognostic reserves of geological regions in the western borderland of USSR (In Russian).	Scientific publications and reports	1978
GeoInform 1978. Analysis and elaboration of data on prospecting-exploration works for underground gas storage in Ukraine and Moldavia with further recommendations.	Scientific publications and reports	1978
GeoInform, 1979. Analysis and compilation of data on exploration works for underground gas storage in Ukraine with further recommendations (In Russian)	Scientific publications and reports	1979
GeoInform, 1984. Results of exploration drilling in Staro-Troyanskaya field and complex data elaboration (with regard to underground gas storage) (In Russian).	Scientific publications and reports	1984
GeoInform, 1984.Geological structure and estimation of gas reserves in Lower Carboniferous sediments of Yurievskoe		1984

deposit in Dnepropetrovskaya Oblast of Ukrainian SSR in 1974-1984 (In Russian).		
GeoInform, 1984. Chervonoarmeyskaya, Orekhovskaya, Valya-Perzheyskaya, Suvorovskaya, Kiliyskaya, Bolgradskaya, Bannovskaya and Loshchinovskaya fields of Fore-Dobrujean trough (In Russian)	Report on prospecting and detailed seismic studies, Scientific publications and reports	1984
GeoInform, 1985. Results of detailed exploration in Staro-Troyanskaya field (with regard to underground gas storage) (In Russian).	Scientific publications and reports	1985
GeoInform, 1990. Proposals for new underground gas storages development within period of XIII Five-Year Plan and in perspective up to year 2015 (In Russian).		1990
GeoInform, 1993. Geological structure and estimation of gas reserves in Lower Permian and Upper Carboniferous sediments of West-Staroverovskoe deposit in Kharkovskaya Oblast (In Russian).		1993
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015

3.32.3. Storage Data Review Ukraine

The main energy storage technology identified for Ukraine is UGS (existing and planned sites in hydrocarbon reservoirs, salt caverns and aquifers. Assessment of technologies is still pre-mature or information was not available. PHS potential was not assessed but may be expected considering surface relief. There is still scope for further regional and local assessment of additional future potential.

Table 3.32-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	The dataset for Ukraine includes two local-defined aquifers which are developed for UGS. Working gas volumes are provided. There may be scope for investigating storage potential in other aquifers	Regional geological mapping and assessment of aquifers may reveal further potential for energy storage
Hydrocarbon reservoirs	Twenty-two local-defined hydrocarbon reservoirs are included, almost all of which are positively tested for UGS and half of which is already developed as UGS. The remaining sites are planned for UGS development. Direct operational capacities (gas working volumes) are provided. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions.	Confirmation of location-specific suitability and expected capacities. There is very limited scope to investigate additional capacities in this reservoir type.
Salt formations and caverns	One local-defined salt caverns is included, which are planned for UGS development. Direct operational capacities (gas working volumes) are provided. Potential for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Additional potential may be present at other locations but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Confirmation of location-specific suitability and expected capacities. Check whether there is future scope to investigate additional potential in this reservoir type (regional geological mapping and local assessment).
Host rock, caverns, mines	No entries available in ESTMAP. Some potential may be expected (mountain areas, basement rocks, mines) but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential for this reservoir type
Lakes	No entries available in ESTMAP. Ukraine was not included in the JRC-2013 assessment report (not a part of the research area). Conditions may however be present.	Investigate if there is scope for future PHS assessment once data are available.

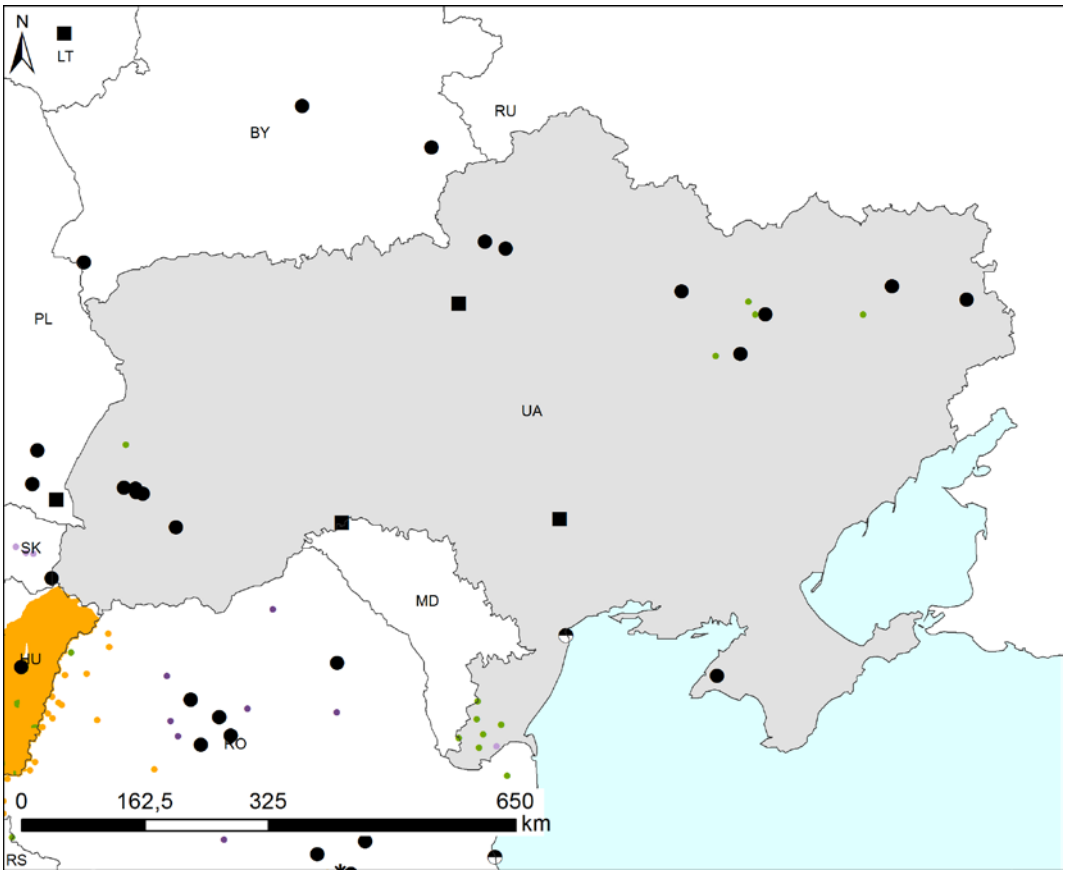

Figure 3.32-1: Ukraine - Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

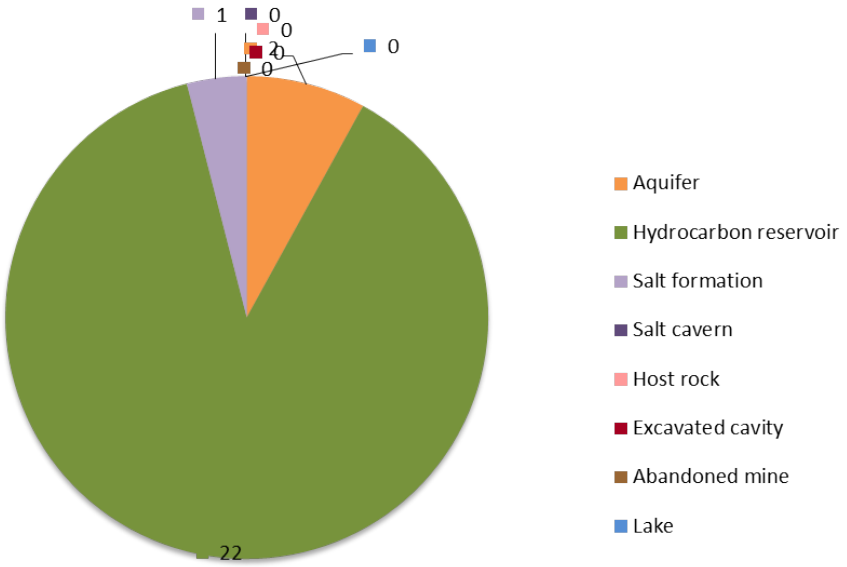

Figure 3.32-2: Ukraine - Summary of energy storage reservoir types contained in the database

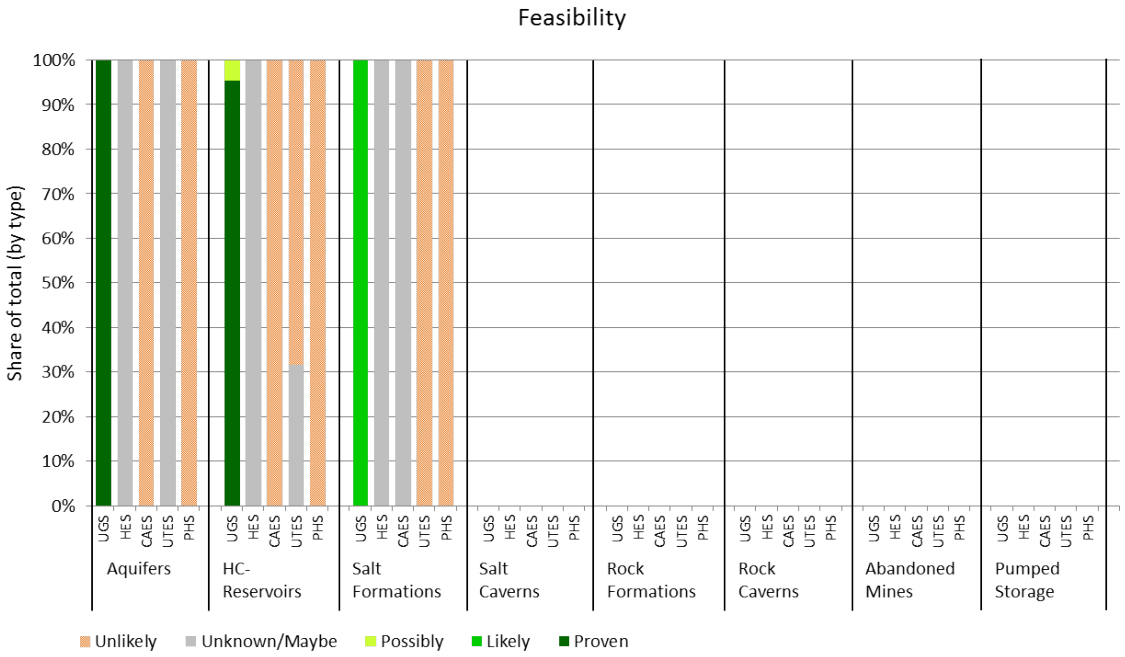

Figure 3.32-3: Ukraine - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

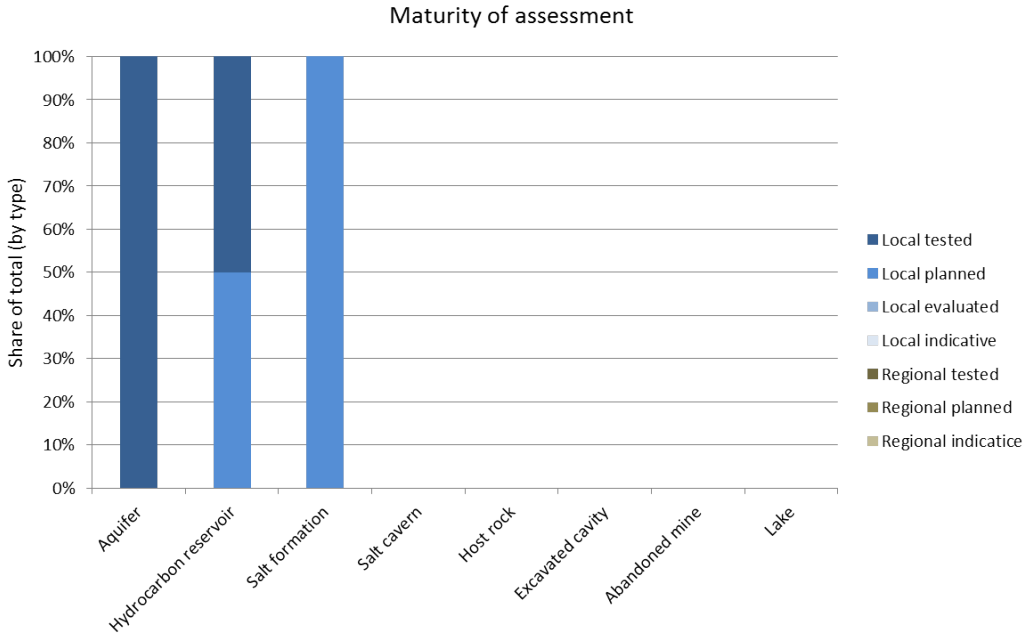

Figure 3.32-4: Ukraine - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

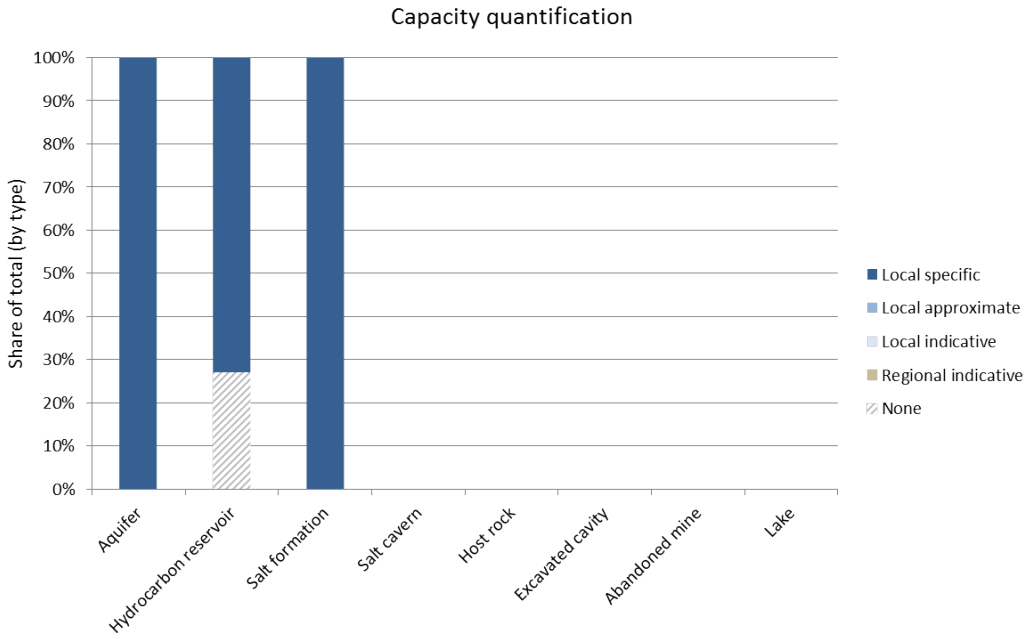

Figure 3.32-5: Ukraine - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

3.33. United Kingdom

3.33.1. Provider administration

Main providing organisations subsurface storage information:

BGS– British Geological Survey
Subcontractor
Contact Person: David Evans

Main providing organisations above ground storage information:

ECOFYS Netherlands
ESTMAP Consortium Partner
Contact Person: Eline Begemann

Last Version Delivery Dates:

2015.11.27 (subsurface data)
2015.11.26 (above ground data)

3.33.2. Main data sources

Table 3.33-1: List of common sources used

Source name / URL	Description	Version / Date
BGS, data archives and reports	Site specific and survey information	2014
GIE, 2015: Gas Storage Map Europe	Overview of planned and operated underground gas storage	April 2015
DOE, 2015: Global Energy Storage Database: https://www.energystorageexchange.org	Overview of planned and operational energy storage projects across the globe	April 2015
JRC, 2013. Assessment of the European potential for pumped hydropower energy storage	A GIS-based assessment of pumped hydropower storage potential	2013

3.33.3. Storage Data Review United Kingdom

For the subsurface storage potential in the UK only sites with existing or planned development have been provided, most of which concern UGS. There is probably still scope for assessing future potential in aquifers, salt formations and host rock formations. For the above ground the UK has abundant existing and future potential for PHS.

Table 3.33-2: Evaluation and summary of data and energy storage potential

Reservoir Type	Status description, remarks	Recommended actions maturing and extending future potential
Aquifers	No entries available in ESTMAP. Aquifers are known to be present in the UK. Information on future potential was either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate potential in this reservoir type (geological mapping and assessment).
Hydrocarbon reservoirs	Five local-defined hydrocarbon reservoirs are included, 2 of which have been developed as UGS and 3 of which are planned and have gained consents for UGS development. Direct working gas volume determinations or approximate total gas volumes are provided. At present, sites are defined by mid-points. More detailed outlines are available at www.gov.uk. Potential for HES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. Additional potential is present in offshore fields (one deployed for UGS and 6 planned but stalled. Offshore information was not included so far, but will be considered with future updates.	Check whether there is future scope to investigate additional potential in this reservoir type
Salt formations and caverns	Eighteen local-defined storage cavern facilities are included, 16 of which are developed or planned as UGS, one of which is developed as HES and one of which is planned as CAES. In most cases direct working gas volume determinations or approximate total gas volumes are provided. Sites are defined by mid-points as the exact extent (GIS shape) is not provided to ESTMAP. It is noted that there is a consented offshore Gateway Project using 20-24 salt caverns in the East Irish Sea. This information will be considered with future updates. Potential for HES and CAES has not been assessed as an alternative or additional option for the sites included in ESTMAP. It is assumed though that there may be scope for further investigation of this potential on the basis of generic geological assumptions. There may be additional future potential in other salt formations (including UK offshore waters), but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	Check whether there is future scope to investigate additional potential in this reservoir type (geological mapping and assessment).
Host rock, caverns, mines	One local-defined rock cavern has been developed for LPG storage. Direct working gas volume determinations are provided. The site is defined by a mid-point as the exact extent (GIS shape) is not	Check whether there is future scope to investigate additional potential in this reservoir type (geological mapping and

	provided to ESTMAP. Potential for HES and CAES has not been assessed though there may be scope for further investigation of this potential on the basis of generic geological assumptions. There may be additional future potential in other rock formations but this information is either not publicly available or the potential has not been assessed to a sufficient degree yet.	assessment).
Lakes	The United Kingdom has huge realisable potential for pumped hydro storage, including many options based on two existing nearby (<10 km) lakes. Five out of 756 sites included in ESTMAP are developed as PHS. All identified sites include specific determinations of energy storage capacities and lake volumes. Further information may be included from studies on top-cliff site potential (pumped sea water), which are among carried out for Scotland.	Confirm suitability and capacity from location-specific assessments. Consider future inclusion of theoretical potential and top cliff sites..

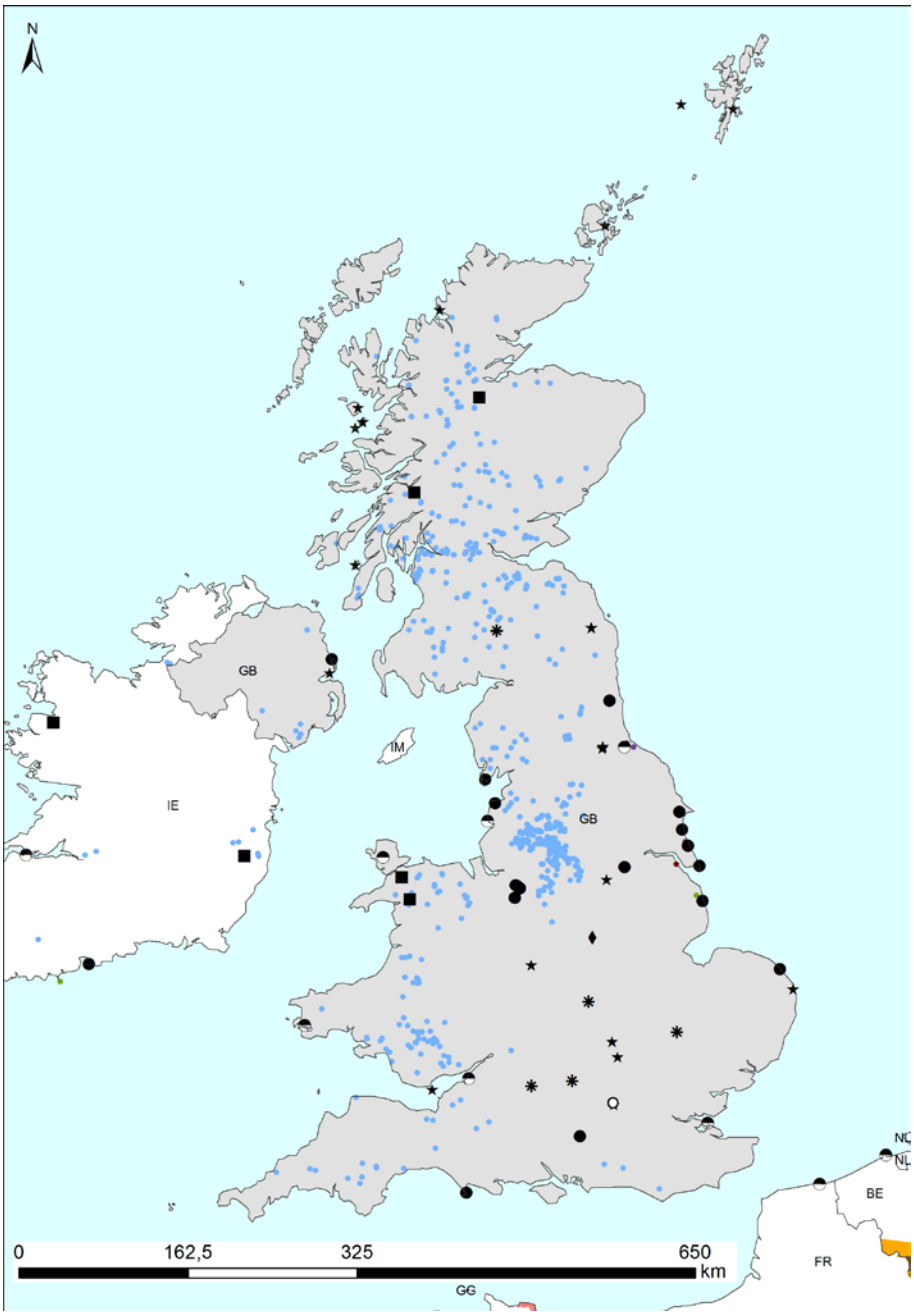

Figure 3.33-1: United Kingdom- Geographic distribution of potential energy storage reservoirs and locations of known energy storage facilities. The legend is explained in Paragraph 1.2, Page 4-5.

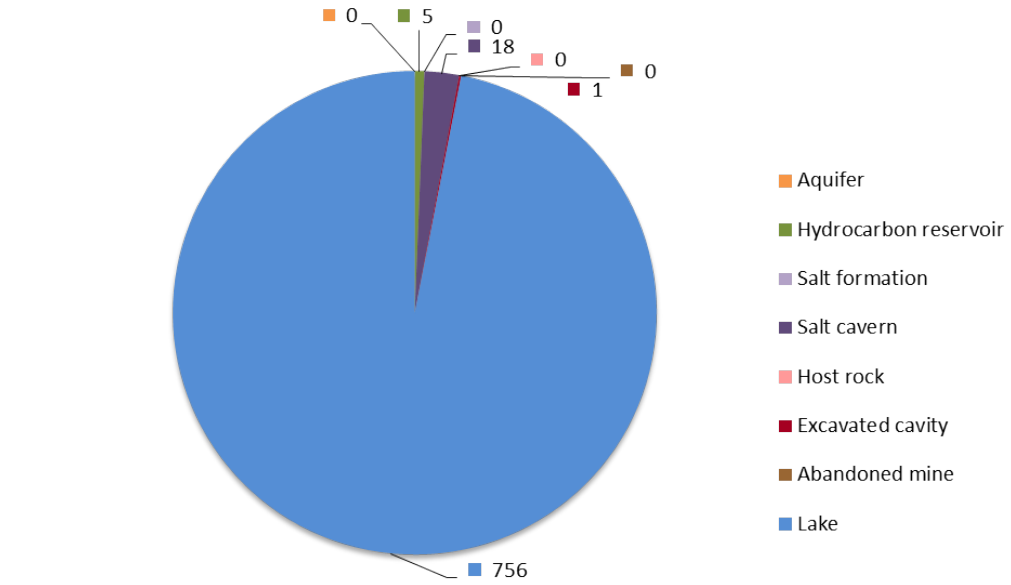

Figure 3.33-2: United Kingdom - Summary of energy storage reservoir types contained in the database

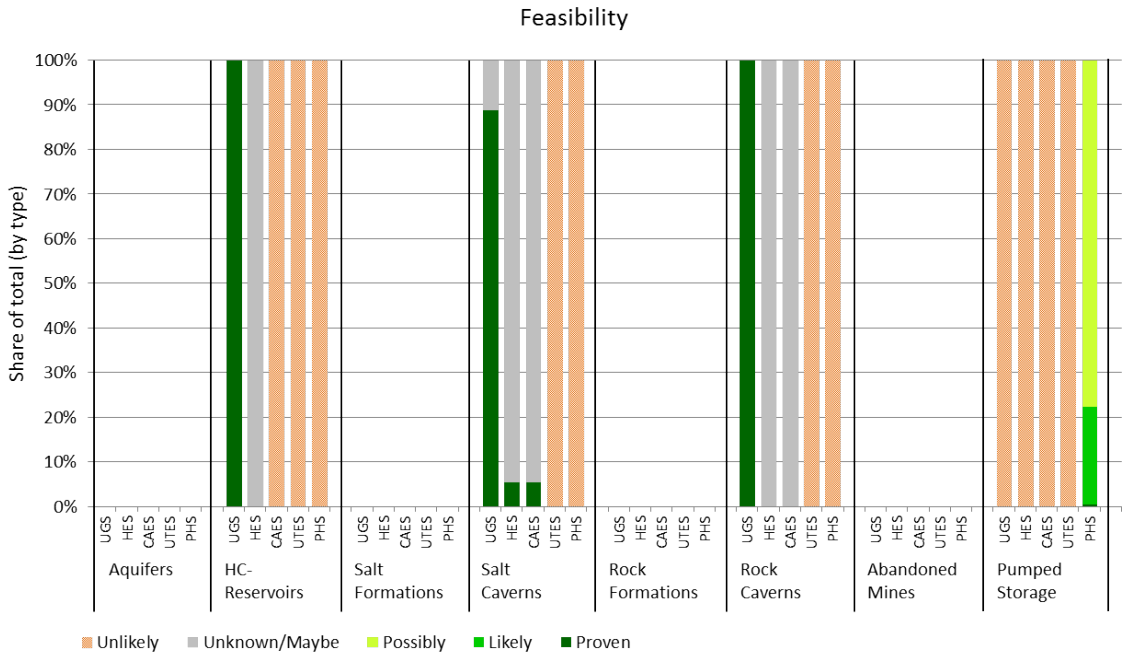

Figure 3.33-3: United Kingdom - Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type. Classes are explained in Paragraph 1.2

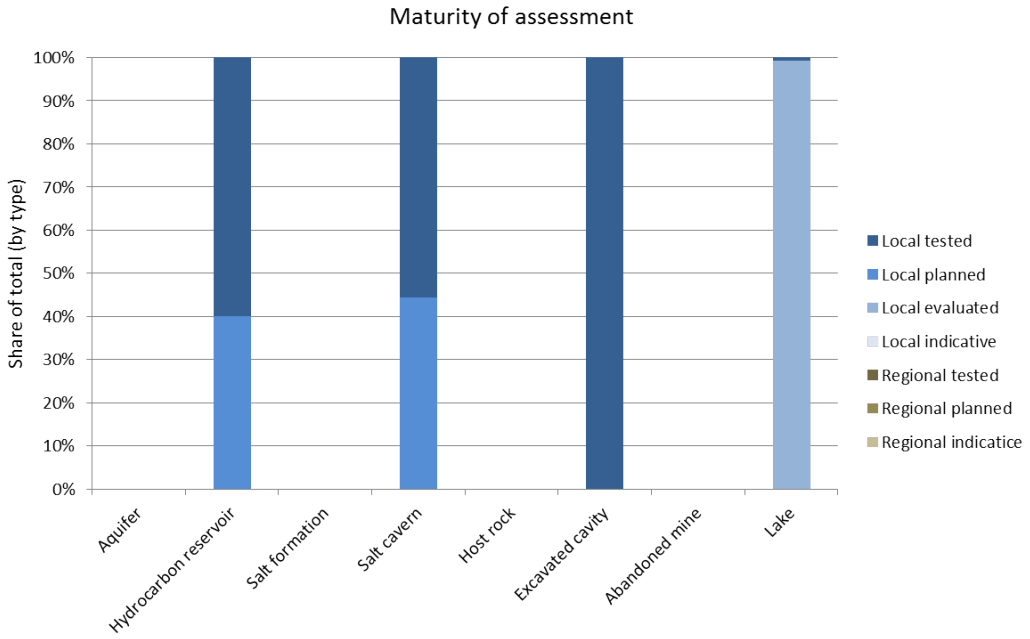

Figure 3.33-4: United Kingdom - Maturity of assessment for each reservoir category. Classes are explained in Paragraph 1.2

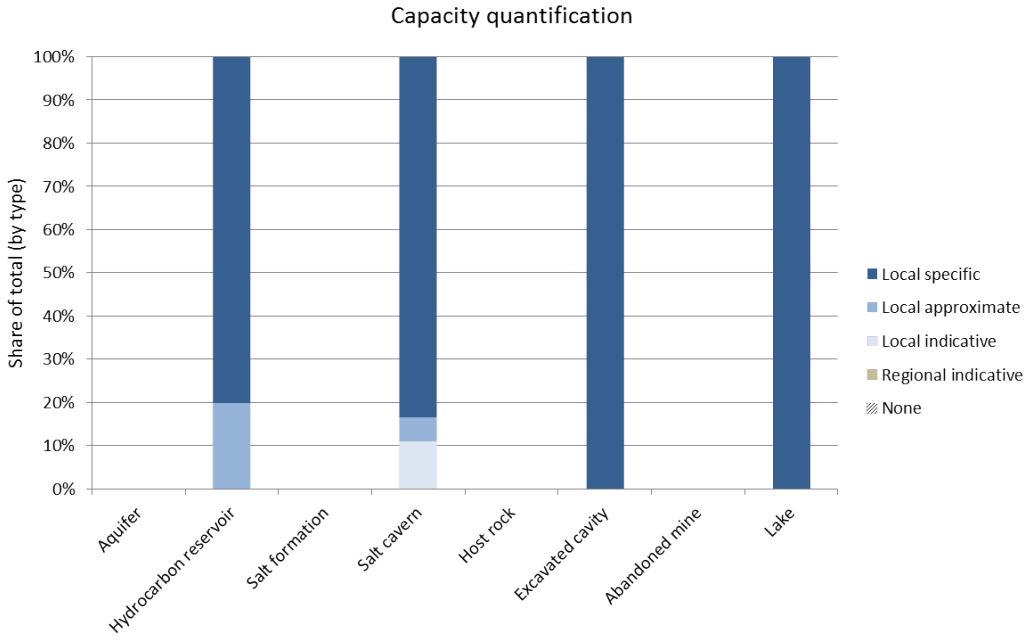

Figure 3.33-5: United Kingdom - Quality of capacity determination for each reservoir category. Classes are explained in Paragraph 1.2

4. Key Findings and conclusions related to data collection

- Approximately 4250 existing, planned and future potential sites for large-scale energy storage are identified in ESTMAP. Target technologies include Underground Gas Storage (UGS), Hydrogen Storage (HES), Compressed Air Energy Storage (CAES), Thermal Energy Storage (UTES) and above ground Pumped Hydro Storage[3] (PHS).

- Pumped Hydro Storage in lakes is the most numerous potential type in the ESTMAP database . Second most occurring potential type is UGS in hydrocarbon fields, aquifers and salt caverns.

- In general the nature and distribution of energy storage potential across Europe is very diverse. On the one hand this is due to the variable presence of natural conditions. On the other hand the still very pre-mature status of energy storage potential assessment plays an important role. Confidentiality is also influencing the extent to which capacities and technical parameters are defined in ESTMAP since the project only worked with publicly available data.

- Several key actions to fill in major knowledge and information gaps can be recommended
    - Harmonize and extend geological mapping of subsurface reservoirs that are considered suitable for energy storage
    - Establish harmonized methods to assess energy storage capacities and performance indicators. Include stochastic approaches to assess uncertainties and confidence levels.
    - Further identify and confirm location-specific potential for multiple storage options and uniformly rank these options on the basis of technical, economic and environmental criteria.
    - Select and prepare sites (full assessment and development design) that are primary targets for potential energy storage demonstration projects.

- ESTMAP strongly recommends to set up appropriate procedures and provide the means to maintain and regularly update the database with new contributions from third parties (industry) and outcomes of both European and national research and development activities.

[3] One planned subsurface PHS is identified in Estonia