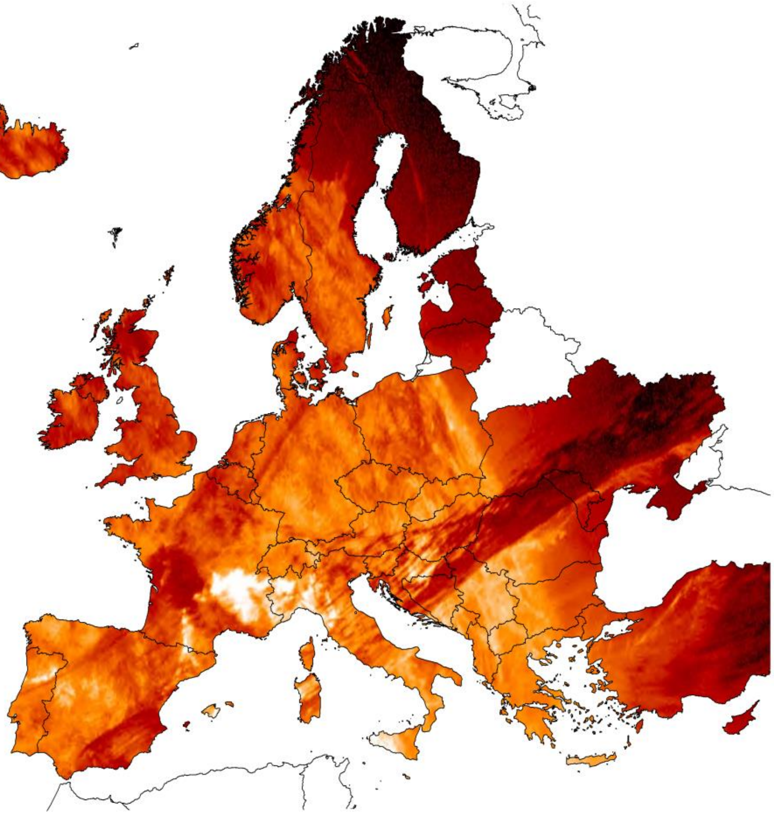

ESTMAP
Energy Storage Data Collection Report

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

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1. Executive Summary

The ESTMAP project has resulted in the development of a spatial GIS database with existing energy storage sites and potential sites and capacities for future large-scale centralized energy storage. The database is deployed in pan-European and regional energy systems analyses. This document describes the results of the data collection process (project work packages 3 and 4), and the set-up and contents of the spatial energy storage database including the preparation of these data for analysis (WP5).

The collection process is preceded by the definition of common database specification that covers all essential elements including critical analysis parameters (e.g. cost, performance, etc.). By this specification, a storage location is subdivided into a surface facility element (i.e. the storage plant) and the associated subsurface or above-ground reservoir in which the energy carrier is contained. The data collection itself has focused on energy storage technologies that typically deliver services to national energy grids and regional to local distribution networks. Storage technologies and reservoirs for all energy (carrier) types, such as gas, heat, electricity, compressed air, etc. are included. For reservoirs, a distinction is made between above-ground lakes (pumped hydro storage) and subsurface formations (hydrocarbon reservoirs, aquifers, salt formations/caverns, rock formations/caverns and abandoned mines). Besides the intrinsic properties, each reservoir has been characterized in terms of suitability for storage and maturity of technical evaluation.

The resulting database incorporates information on ~700 existing and planned storage facilities and ~4250 reservoirs which have been evaluated for underground gas storage (UGS), hydrogen storage (HES), compressed air energy storage (CAES), thermal energy storage (UTES) and above-ground pumped hydro storage[1] (PHS). The main contributing storage type is above-ground pumped hydro storage, with underground gas as second most developed option.

In general, the distribution and completeness of information and the types of storage reservoirs and identified technologies vary significantly across Europe. Besides the variable presence of natural conditions, this is due to the still pre-mature status of assessment and confidentiality of information.

Significant improvement and levelling of information may be achieved by geological mapping of potential subsurface reservoirs, establishing harmonized methods to assess energy storage capacities and identification and confirmation of location-specific sites that are considered primary potential targets for future energy storage development.

ESTMAP strongly recommends to set up appropriate procedures and means to maintain and regularly update the database with new contributions from third parties (industry) and national research results. Such updates will strengthen the position of the database as a one-stop location for obtaining actual information on energy storage. A better evaluation of various EU energy modelling results can be realized by stimulating the database to become a common agreed standard for such studies. Involvement from a broad user base will help in prioritizing and realizing the essential improvements required.

[1] One planned subsurface PHS is identified in Estonia

2. Introduction

This chapter gives a short overview of the project background and introduces the contents of the report and its relation to the other work packages in ESTMAP.

2.1. Project Background

The ESTMAP project (EC Service Contract no.: ENER/C2/2014-640/S12.698827) started in January 2015 and will finish end 2016.
The aim of the ESTMAP project is to collect public and available data on above-ground and subsurface energy storage and to prepare this data for the purpose of performing analyses on the European energy system. Figure 2-1 shows a schematic representation of the work packages in the project plan and the main project relationships. Below, a short description of each work package is given:

Work package 1: Project management

Coordination, communication

Work package 2: Specifications

Specification of the data collection and database definitions. Definition of the analyses modelling scope and input requirements

Work package 3: Subsurface Data Collection

Collection and processing of the data for subsurface storage potential and alternative subsurface uses. Control on quality, completeness, formatting and confidentiality.

Work package 4: Above-ground Data Collection

Collection and processing of the data for above-ground storage potential and alternative subsurface uses. Control on quality, completeness, formatting and confidentiality.

Work package 5: Database

Design, development and testing of the database framework. Integration, evaluation and mapping of the collected storage data. Performing checks on database integrity and consistency. Conversion of energy storage parameter data to analysis input decks.

Work package 6: Analysis

Testing the deployment of the database contents in pan-European and regional energy systems analyses. GIS-mapping and calculation of grid connection costs.

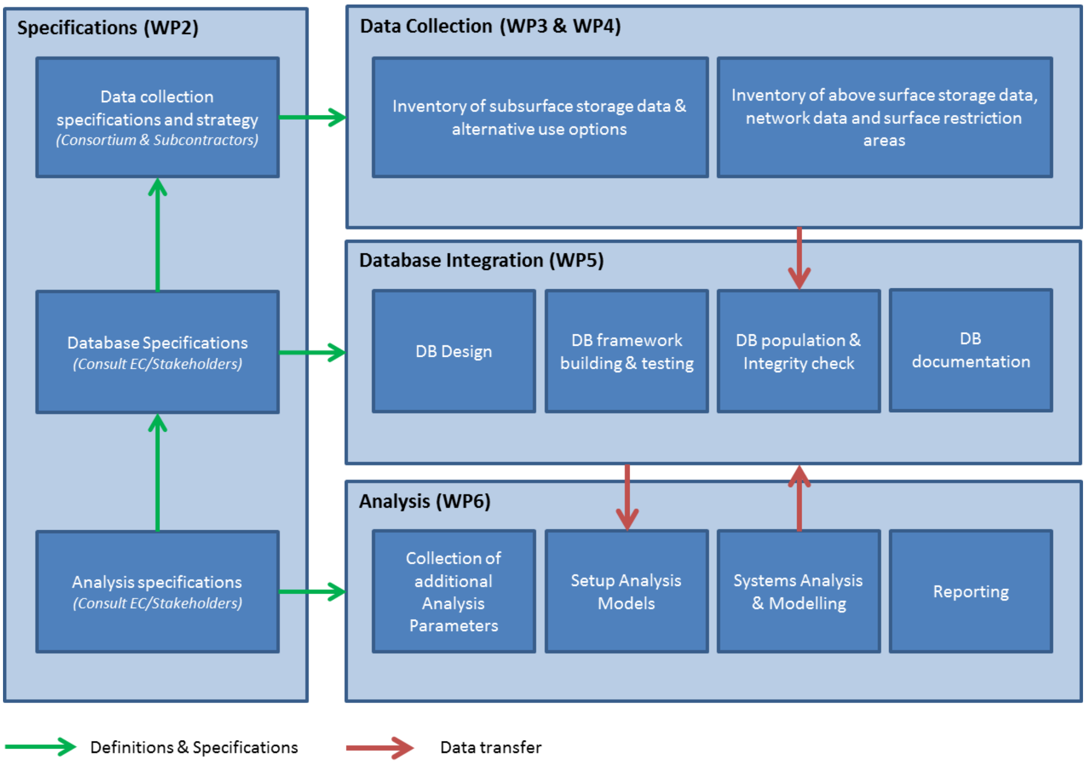

Figure 2-1: Project logic and defined work packages

A consortium consisting of the following parties has conducted the project:

- TNO (Netherlands): Overall project coordination and database development (WP1 & WP5)
- BRGM (France): Coordination of subsurface energy data collection (WP3)
- CGS (Czech Republic): Support of subsurface data collection (WP5)
- ECOFYS (Netherlands): Coordination of above surface data collection and energy systems analyses (WP4 and WP6)
- VITO (Belgium): Support of subsurface data collection and energy systems analyses (WP6)

The consortium contracted 24 national partners for subsurface data collection (Annex 3). IER Stuttgart was subcontracted for the TIMES pan-European energy systems modelling.

2.2. Data collection and database objectives

There are many existing and potential future capacities for energy storage. These capacities are present in the subsurface as well as above-ground and comprise a range of technologies for electricity, heat and gas services. While part of this information is accessible in fragmented form through separate databases, there is also a large share of information that is not yet disclosed. The aim of the database and data collection work packages in the ESTMAP project is to gather and integrate all known and publicly available information on energy storage capacities and to store this information into one harmonized and comprehensive spatial database that is designed to support analysis and planning of the future European energy system.

2.3. Report contents

Below a short overview of the scope and content of each chapter in this report is given:

Chapter 4: Provides a technical background to energy storage technologies and potential reservoirs for energy storage in the subsurface and above-ground .

Chapter 5: Gives a brief summary of the data specifications for natural reservoirs, storage facilities and storage technologies (Details are provided in Report).

Chapter 6: Reports the approach and results of the subsurface and above-ground data collection work.

Chapter 7: Provides an evaluation and review of the data collected, including EU overview maps, statistics and key findings and conclusions. In-depth country-by-country data reviews and discussions are provided in Report .

Chapter 8: Gives an overview of literature and data references.

2.4. Abbreviations

Table 2-1 lists the abbreviations used throughout the document.

Abbreviation	Description
AACAES	Advanced Adiabatic Compressed Air Energy Storage
CAES	Compressed Air Energy Storage
HES	Hydrogen Storage
LNG	Liquified Natural Gas
PHS	Pumped Hydro Systems
UPHS	Underground Pumped Hydro Systems
TES	Thermal Energy Storage
UGS	Underground Gas Storage
ATES	Aquifer Thermal Energy Storage
UTES	Underground Thermal Energy Storage
CTES	Cavern Thermal Energy Storage
SMES	Superconducting Magnetic Energy Storage
SC	Super Capacitators

Table 2-1: Abbreviations

3. Energy Storage Technical Background

This chapter provides an overview and description of the above-ground and subsurface energy storage technologies and types of storage reservoirs covered by the ESTMAP database. A brief summary of the essential energy storage data specifications is given in Chapter 4 with further details in Annex 1 and 2. .

3.1. Introduction

The concept of energy storage exists for a long time. Volta already invented the first true battery in 1800 [2] while for larger scale storage of electrical power pumped came in existence by 1929 [13] (the first hydroelectric power plant was already developed in 1890 in Switzerland). Nowadays ~48 GW of hydroelectric storage capacity exists in Europe vs ~173 GW being generated by hydroelectric power plants [1]. Compressed Air Energy Storage systems (CAES) are known to drive engines and other mechanisms since 1870 [3] but it was in 1978 in Huntorf – Germany that a first large-scale CAES plant was developed to provide storage services to the electricity grid [4]. Although only two of such plants exist nowadays (the other one being located in Alabama [5]), several pilot projects aim to improve the cost-performance efficiency of this technology with new innovative concepts. Besides the storage services for the electricity grid, there have been large-scale underground natural gas storage since [6] and aquifer thermal energy storages since the 1960’s [7].

Energy storage is a broadly defined technology providing services and flexibility for electricity, gas and heat at time intervals from seconds to months and scales ranging from individual households to supra-national supply. Over the last decade energy storage gained more and more attention as it is regarded one of the key solutions to mitigate the impacts of increasing renewable energy generation in our energy system and to ensure the quality and continuity of energy supply. Innovative technologies are investigated to deliver new storage services to our future energy needs or to improve the efficiency, capacity and implementation of existing technologies.

The ESTMAP project considers energy and energy storage in its broadest definition. The following paragraphs provide a brief introduction and generic technical background to various the types of energy storage technologies and storage reservoirs included in the ESTMAP database[2].

3.2. Definitions

This paragraph introduces some of the essential definitions and concepts that form the basis of the ESTMAP database.

Storage function and purpose

Energy storage may serve various purposes and can be implemented at various scales, ranging from European and national grid level down to household level. The purpose and demand will predominantly define the operational parameters, most of which are related to energy output (e.g. response time, delivery rate, load duration, etc.). The main roles of energy storage are:

Balancing of demand and supply: Energy demand and production is variable. Energy storage can be used to ensure supply of energy (gas, electricity or heat) during periods of high demand (e.g. peak consumption at hourly/daily basis or seasonal variation). Energy will be stored during periods of low demand and high (over)production.

[2] Although some technologies are not yet included in ESTMAP, the database is capable of storing the related information and parameters.

Grid management: Regulation of voltage and frequency. This type of function requires almost instant electricity discharge from storage over periods up to 30 minutes in order to stabilize the electricity grid output.

Energy efficiency: This purpose mostly concerns the integration of intermittent energy sources into the electricity grids. Examples are time-shifting (charging of cheap electrical energy during low demand periods and discharge during high demand periods) and integration with district heating and cooling. This takes mostly place on an hourly to daily basis but may also involve longer (weekly) periods when sun and wind have different production patterns (e.g. summer, winter).

Strategic reserves: For certain energy resources such as gasoil, strategic reserves may be required or desirable from a political standpoint. These reserves are stored over long (> year) periods and are only accessed in times of great shortage (e.g. during international conflicts).

Back-up power: For uninterrupted power supply the energy storage option may be used. This often requires short response times.

There are often alternatives to energy storage, especially in the case of balancing (e.g. increasing cross-border transmission capacity, demand side management, shifting between resource suppliers). The choice for energy storage thus competes with these other solutions in terms of technical efficiency, effectiveness and economic benefits/cost reductions. As a consequence, energy storages are specifically tailored and optimized for the service they should provide.

Energy storage concept

In general, energy storage involves the following steps:

1. Intake of energy from a fossil, electrical or thermal source
2. Optional conversion into an energy form suitable for storage
3. Containment (storage) of the (converted) energy resource (charging)
4. Release of the energy resource (discharge)
5. Optional conversion into a form of energy that is suitable for transport or application
6. Output to grid or end-user

Energy storage technologies may take input from either fossil fuel energy sources (e.g. gas grid), electrical energy sources (e.g. power grid or windmills) or thermal energy sources (e.g. industrial waste heat). Depending on the type of energy source, the storage technology and the storage output function, conversion steps may be required at the input and/or output side. In the case of fossil fuel energy storage no conversion steps are required. Natural gas can be stored directly from, and re-injected into the gas grid when needed. The same counts for thermal energy and a heat distribution grid. Energy storage from electrical sources however, often requires conversion steps to transform the electrical energy into other forms of energy that are suitable for storage (except for batteries and super conductors). These conversion steps involve electrolysis (hydrogen / power to gas, chemical energy), transport of water to higher altitudes (pumped hydro systems, gravitational energy), pressurization (CAES, mechanical energy), cooling (liquid air energy storage, thermal energy) and movement (flywheels, mechanical energy). Except for power to gas (e.g. generation of hydrogen from electricity for direct use in the gas grid, synthetic gas), reverse conversion steps are also required with discharge. Each conversion step will be performed at the cost of decreased round trip efficiency and increased response times at discharge.

Energy storage database components

For the purposes of creating a functional database within this study, an energy storage making use of a natural reservoir is considered to consist of two main elements:

1. The *energy storage facilities* define the above-ground facilities needed to regulate the intake, output and conversion of energy from and to the sources, distribution grids and end-users. In the ESTMAP database these facilities describe the actual operational cost and performance parameters. They are either linked to the above-ground or subsurface reservoirs required to store the energy carriers or defined as stand-alone technology without a location-specific reservoir (e.g. batteries, flywheels, etc.).

2. The *storage reservoirs* comprise the physical (natural) spaces into which the energy carriers are contained. These reservoirs can either be located in the subsurface (e.g. depleted hydrocarbon reservoir, salt cavern, etc.) or above-ground (in the case of a pumped hydro lake). The database parameters for storage reservoirs among others describe the spatial dimensions, maximum capacities and properties that are relevant to determining the feasibility and performance.

Figure 3-1 summarizes the various categories considered in ESTMAP. A storage reservoir may either be developed (i.e. linked to an existing and operational facility) or undeveloped (potential candidate for a future facility). Next there is a subdivision between above-ground and subsurface technologies (i.e. based on the location of the reservoir).

Undeveloped (subsurface) natural reservoirs are often suitable for more than one storage technology. Hence these reservoirs may be linked to different types of potential future facilities. Furthermore the defined capacity of the facility does not necessarily have to be the same as the maximum potential storage capacity of a reservoir. In practice the operational capacities are tailored to the local balancing needs on the basis of a specific cost and performance optimization.

For other (above-ground) storage technologies such as batteries, fly wheels, liquid air energy storage, and some types of compressed air energy storage and hydrogen storage, the physical storage is integrated in the energy facility. In these cases the facility is not linked to a storage reservoir, but exists as a stand-alone man made device or vessel. Such storages can in principle be developed anywhere (de-central, modular) and therefore there are no discriminating arguments or criteria for assessing geographic distributions of future potential.

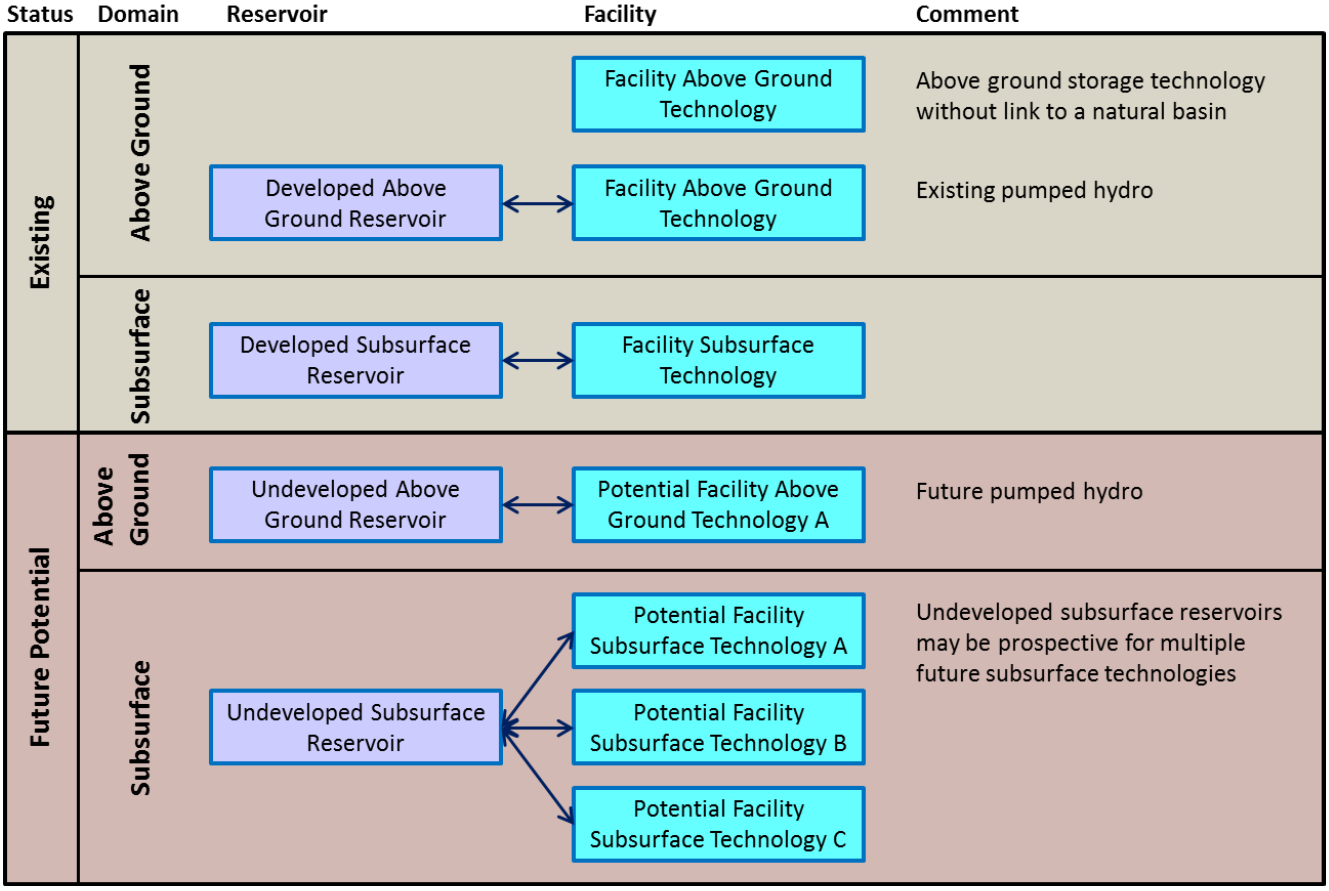

Figure 3-1: Overview of the different energy storage configurations considered in ESTMAP

Fundamental descriptive parameters

There are many descriptive parameters that determine the operation of an energy storage facility and its contribution to the energy system. Which ones are relevant, depends on the type of reservoir and technology used to deploy it. The most common parameters are:

Total storage volume or energy capacity: The maximum volume of gas or other energy carriers (e.g. water, hydrogen, compressed air) that can be stored. This capacity can be expressed as a more generic energy capacity (in MWh).

Working capacity or operational capacity: This is the effective gas volume (gas, hydrogen, compressed air), water volume (pumped hydro) or energy capacity (e.g thermal) that contributes to the output of the storage. In the case of certain technologies, a part of the total storage capacity is used for base or cushion volume (e.g. to operate the high pressures needed in a gas storage or the minimum water level in a lake). This volume is not a part of the operated working volume or energy capacity.

Production rate or delivery rate: The rate at which energy (or an energy carrier) can be delivered to the grid or the end-user. This rate depends on many factors such as the flow rate properties of the subsurface reservoir, the flow rate band width of the storage infrastructure, compression, etc. For a gas-related storage (natural gas, hydrogen, compressed air) the delivery rate may vary as the pressure in the storage reservoir declines during withdrawal.

Intake rate: The complement of delivery rate (i.e. the rate at which the storage reservoir is being refilled).

Response time: The time needed by the energy storage to reach the required output to the grid, counted from the moment that this output is requested. Some storage technologies are able to respond almost instantly. Other technologies may require start-up times up to an hour.

Load duration: The maximum time during which the storage is able to provide a non-intermittent minimum required delivery rate. This parameter mainly distinguishes a storage between a peak function (short-lived delivery up to some hours or days) and base load or seasonal delivery (long-lived delivery over several weeks or months).

Costs: The capital and operational cost of energy storage systems, as potential revenues, vary considerably between storage concepts and technologies. Governed by the use function of the storage technology economics ultimately determine the role of storage concepts in the current and future energy system.

ESTMAP database scope

The ESTMAP project covers energy storages that comply with the following definitions:

1. Future energy storages are relevant to delivering centralized services to the transmission grid or are capable of delivering services at a town, regional or national level. Existing small-scale, decentralized household and enterprise level storages can be incorporated in the database, but ESTMAP has not actively pursued information on all existing locations (e.g. heat exchange systems, batteries at homes or industries, individual local gas storage tanks).

2. Future storage potential will only be determined on the basis of clear definition criteria. These criteria include specific requirements existing in distinct geographic areas (e.g. distribution of geological formations and subsurface characteristics) or definitions that exclude certain areas for development. No future potential will be defined for non-geographically bound storage technologies.

3. The storage options are expected to be technically and economically viable (now or in the near future). The technology is either commercially implemented or being developed in demonstration and pilot projects. Purely conceptual technologies or options that are far from economic development are not included. The same counts for optional storage reservoirs that are located far offshore.

In the following sections each storage technology included in ESTMAP is briefly described.

3.3. Subsurface Energy Storage Technologies

Natural Gas storage (UGS)

Storage of natural gas is a mature technology that has been implemented on many locations worldwide [20]. This technology takes direct input of gas from the gas grid and injects it in an underground reservoir such as a depleted gas field, salt or rock cavern, or aquifer. At periods of high demand the gas is produced from the storage and directly injected into the gas grid again. Gas storages can be developed at various scales serving different demand profiles such as peak storage (small storage reservoirs – often salt caverns or small depleted gas fields needed for balancing high demand periods of hours up to several days) and seasonal storage (large aquifer or depleted hydrocarbon reservoirs – oil and gas – developed to balance high demand periods of several weeks to months). Some gas storages are integrated into the national gas distribution grid.

Other storages work on open access basis where third parties can lease a part of the working capacity.

Above-ground natural gas storage is typically stored as LNG. Non-LNG storage options include gasholders and bullets, which are outside the scope of this study.

Underground Pumped Hydro Storage (UPHS)

This technology is based on the same concept as traditional (above-ground) pumped hydro systems where electric energy is used to transport a large volume of water to a higher elevation level. As the water runs down, it drives a turbine to generate electricity again. In UPHS one or both water reservoirs are developed in the subsurface (excavated cavities or mines). The gravitational energy is either established by elevation differences between the two reservoirs/basins or by using large pistons [9]. Due to the high cost of developing such a system this technology is still in experimental stage. A 650 kW pilot facility is in operation in the Czech Republic (Jeremenko mine near Ostrava) and a pilot location is planned for a 500 MW development in Estonia [11]

Hydrogen Storage (HS)

Besides being a common resource for the chemical industry, hydrogen is emerging as a fuel for transport and a means to store energy (power to gas). Hydrogen storage can be implemented as one of the solutions to efficiently integrate renewable energy sources into the energy system.

Hydrogen can be generated through the process of electrolysis, using excess power from intermittent sources such as solar and wind energy. Hydrogen has some potential to be injected into the regular gas grid (directly or after conversion to syngas). It can also be used as a fuel for electricity generation or transport.

Due to its small molecular size, hydrogen diffuses easily and therefore requires storage reservoirs with adequate seals. As for natural gas or CAES, the underground storage options for hydrogen are predominantly depleted gas fields and aquifer formations with salt seals, or artificially constructed salt caverns. Minor potential may exist in depleted oil fields, abandoned mines or excavated rock caverns. Smaller volumes of hydrogen can be stored above-ground in pressured storage vessels.

To date, only few hydrogen storage sites have been listed, among others one in the UK near Teeside [12]. Teeside was commissioned in 1972 and contains three caverns in bedded salt with a storage volume for each cavern about 70 000 m^3 at 350 meter depth.

Compressed air energy storage (CAES)

There are two large scale Compressed-Air Energy (CAES) facilities that use salt caverns for storage: Huntorf-Germany with 290MW and 2-3 hour duration [4] and McIntosh-US with 110MW and ~26 hour duration [5]. CAES is widely developed as a small-scale above-ground technology.

A CAES facility converts electrical energy into mechanical energy by using electrical pumps to compress the air. The compressors are driven by excess electrical energy from windmills or base load electricity production (e.g. nuclear and coal fired power plants) during off peak load periods. The compressed air is temporarily stored in above-ground pressure vessels (small scale CAES) or subsurface storage space (large scale CAES). During peak load periods, compressed air is released (expansion) in order to drive turbines for generating electricity to the grid. A CAES facility acts as a minute reserve[3] for levelling peak electrical energy consumption during time intervals of several hours up to a day. Conventional adiabatic CAES has limited efficiency and works on the basis of a gas turbine which uses the stored compressed air. Higher efficiencies are possible with

[3] power output that can be made available within a few minutes

Advanced Adiabatic (AACAES) systems where the compression heat is stored in a medium and reused to heat the expanding air stream. Here no gas turbines are needed.

CAES has a long history as an above-ground technology using pressure vessels for air storage. The scale and capacity of these technologies is limited and feasible for local demand only. Large scale CAES needed for grid balancing requires bigger storage volumes that are present in the subsurface. All large-scale CAES facilities existing to date are developed in salt caverns. These caverns provide required high flow rates for optimal performance and efficiency Alternative options for CAES development exist in excavated cavities (hard rock, salt or limestone formations), depleted natural gas reservoirs and structural traps in porous aquifer units. Although these options may present more flexibility in terms of geographic placement of CAES, they also pose economic hurdles on development and operations. Excavation of cavities is very expensive and high flow rates in aquifers and reservoirs are harder to attain due to porosity and permeability restrictions.

Thermal Energy Storage (TES)

Thermal energy storage (TES) in fact covers a large storage family with different technologies both above-ground and subsurface. On a main level these are:

- *Sensible heat storage (SHS)*: Thermal energy storage by raising the temperature of a solid or liquid (e.g. water). Underground storage of sensible heat in both liquid and solid media is being used for typically large-scale applications.
- *Latent heat storage (LHS)*: Based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. The storage capacity of the LHS system with a phase changing material (PCM) can offer a higher storage capacity compared to SHS systems. It also enables target-oriented discharging temperature that is set by the constant temperature of the phase change.
- *Thermo-chemical storage (TCS):* Can offer even higher storage capacities. Thermo-chemical reactions can be used to accumulate and discharge heat and cold on demand (also regulating humidity) in a variety of applications using different chemical reactants.

At present, TES systems based on sensible heat are commercially available while TCS and PCM-based storage systems are mostly under development and demonstration. SHS can be developed as a small scale (<10 MW) above surface technology, or large scale systems can be developed in the subsurface, e.g.:

- *Aquifer thermal energy storage (ATES)*: An open-loop energy storage system that uses a natural underground water-permeable layer as a storage medium for thermal energy and groundwater as the thermal energy carrier. In such configurations, the energy can be either injected into or extracted from aquifers using one or more injection wells and extraction wells, coupled through hydraulic pumps and heat exchangers. ATES is the geothermal technology with the highest energy efficiency but strongly relies on the right aquifer properties and conditions. ATES is favourable for large-scale energy storage, for example on a seasonal basis.
- *Borehole thermal energy storage (BTES)*: Has the same working principle as ATES, however it is a closed-loop system that stores thermal energy in the bedrock using borehole heat exchangers (sometimes > 100 wells). BTES is not limited to specific reservoir locations such as aquifers. It is suitable for both small- and large-scale energy applications, depending on the number of installed heat exchangers. This technology for example enables storage of heat extracted from a building during the summer, or for example harvested via solar panels, and then reuse it during the winter season.
- *Cavern thermal energy storage (CTES)*: Uses large underground water reservoirs such as rock caverns. Some of the caverns are created in the subsoil especially to serve as thermal energy storage systems to store hot/cold water underground, however CTES also includes abandoned mines and oil reserves. CTES has the advantage, in most cases, of providing a

high loading/unloading power simply by pumping water into and out of caverns faster. Due to high investment costs there are only a handful number of applications today.

High temperature thermal energy storage has been used to store heat from concentrating solar facilities for use after the sun sets. Abengoa's Solana 280 MW solar power station in Arizona began operating in October 2013 with six hours of thermal energy storage. Close on its heels is Solar Reserve's 110 MW Crescent Dunes power tower solar thermal plant in Nevada that has 10 hours of storage and has been completed in 2014. Heat from the concentrating solar mirrors is transferred to a molten salt solution and stored in insulated tanks. When the sun goes down, heat from the stored molten salt solution is transferred to produce steam that powers a conventional steam boiler [13].

3.3.1. Above-ground technologies

Liquid Natural Gas storage (LNG)

The transport of liquefied natural gas (LNG) requires the liquefaction, intermediate storage and re-gasification of the gas. When LNG is received at most terminals, it is transferred to insulated storage tanks that are built to specifically hold LNG. When natural gas is needed, the LNG is warmed to a point where it converts back to its gaseous state. This is accomplished using a regasification process involving heat exchangers [15]

Battery Storage

Electrochemical energy storage technologies convert electricity to chemical potential for storage and then back again. Batteries can be broken down into three main categories: conventional, high temperature, and flow. Basic battery technology has a history longer even than that of pumped storage, though cost effective means of storing bulk energy in batteries has been a challenge. Unlike some other storage technologies, batteries have exhibited limited cycling times owing mainly to electrode fouling and electrolyte degradation. Advanced batteries are also the major focus of research into improving storage technology, with advances in materials and designs taking place at a rapid rate [13].

Pumped Hydro Storage (PHS)

Pumped hydro stores energy by using electricity to pump water from a lower reservoir to an upper reservoir and recovering the energy by allowing the water to flow back through turbines to produce power. Pumped storage technology is very similar to traditional hydro power plants, and the first pumped storage plant was constructed in 1929 [13]. Pumped hydro storage (pumped storage) has grown to be the most prevalent and mature energy storage technology, with 129 GW of installed capacity worldwide. European PHS capacity is reported by JRC (following Eurostat) to be around 42.6 GW [16]. Pumped storage is a very versatile technology capable of providing valuable benefits from intra-hour through multiple-day time periods. Janssen et al. [17] confirms the estimate of up to 50 GW of installed capacity and adds that PHS is by far the largest energy storage facility. They also emphasize the relative low specific capital requirements, high capacity and long discharge time. Costs of PHS are highly situational, depending on size, siting and construction [14].

Fly wheels (FW)

Flywheels store electrical energy by speeding up inertial masses (rotors). Typically rotating masses rest on very low friction bearings (e.g., magnetic) in evacuated chambers designed to reduce friction as much as possible. Energy is transferred in and out using a motor-generator that spins a shaft connected to the rotor [13].

Super Capacitators (SC)

Capacitors consist of two electrical conductors separated by a non-conducting material (the dialectric). When a charge is applied across the plates electrical charge builds up on either side. Energy is stored in the electrical field between the two plates [13].

Superconducting Magnetic Energy Storage (SMES)

Superconducting Magnetic Energy Storage (SMES) uses the flow of direct current through a cryogenically cooled superconducting coil to generate a magnetic field that stores energy. Once the superconducting coil is charged, the current will not deteriorate and the magnetic energy can be stored indefinitely. The stored energy is released by discharging the coil. Cryogenic refrigeration is required to keep the device cold enough to maintain superconducting properties [13].

Liquid Air Energy Storage (LAES)

Liquid Air Energy Storage is sometimes referred to as Cryogenic Energy Storage. The word “cryogenic” refers to a gas in a liquid state at very low temperatures. The working fluid is Liquefied Air or Liquefied Nitrogen. The systems share similar performance characteristics to pumped hydro and can harness industrial low-grade waste heat/ waste cold from co-located processes, converting it to power. Size range extends from around 5MW/15MWh to >50MW/250MWh and with capacity and energy being de-coupled, the systems are very well suited to long duration applications [10].

3.4. Subsurface Energy Storage Reservoirs

As mentioned, for the purpose of constructing a coherent database, we make the distinction between (natural) *reservoirs* used for storage and the *facilities*. This section provides a short overview of energy storage reservoirs defined in the subsurface and above surface (pumped hydro lakes only).

Some global characteristics and criteria for storage activity are mentioned in the sections below. Please note however, that actual suitability of a specific rock unit or site for a certain type of energy storage has to be determined by detailed investigations and involves additional arguments to technical criteria.

Aquifers

Aquifers are porous, water bearing rock formations (Figure 3-2). At deep intervals this water is mostly saline. Aquifers often extend over large, regional areas (sometimes tens to hundreds of kilometres) within which the depth, thickness and rock properties may vary considerably. These variations mainly depend on the geological basin development (i.e. shape, size and subsidence rate of the sedimentary basin), depositional environment (e.g. fluvial, marine, aeolian) and post-depositional structural evolution (i.e. vertical offset of aquifers by fault movements, erosion due to uplift and sub-areal exposure, alteration of rock properties due to deep burial and diagenesis).

The pore space of an aquifer may be suitable for storing gases at locations where this aquifer is sealed by an impermeable cap rock (e.g. rock salt, clay stone, anhydrite) and where tectonic movements or specific stratigraphic layouts have resulted in the formation of local geological traps. The geology of aquifers is similar to depleted hydrocarbon production fields (see next section), yet the suitability of a potential aquifer site has to be proven and tested through geological exploration and characterization whereas this is quite ensured in the case of depleted fields. Furthermore, gas storage in aquifers usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance than for depleted fields. On the other hand, deliverability rates may be enhanced by the presence of an active water drive. Aquifers have been successfully developed for gas storage in many places around the world.

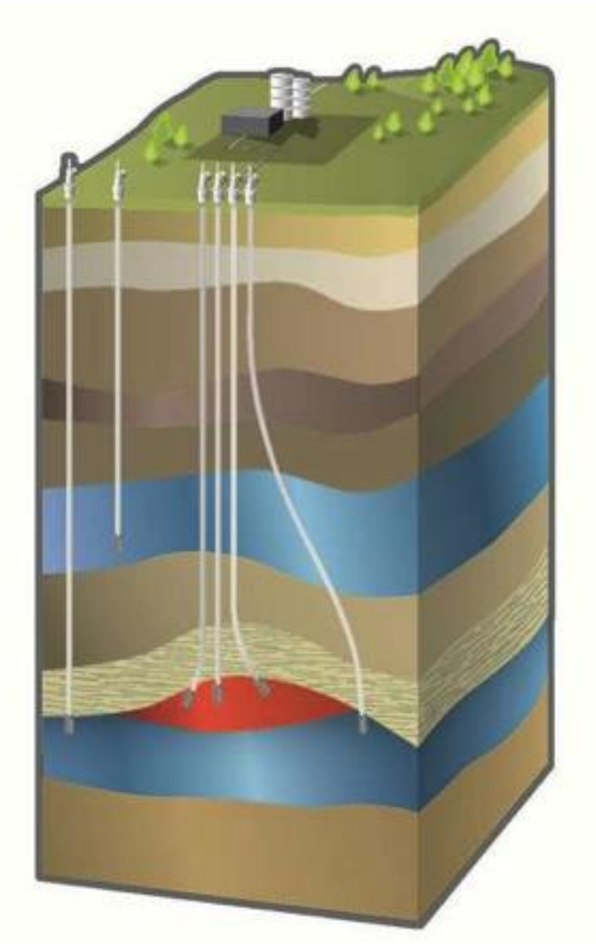

Figure 3-2: Schematic representation of storage into aquifers (blue) and (depleted) hydrocarbon reservoirs (red). The vertical scale is not consistent with reality. Source: http://www.geostockgroup.com/en/underground-storage/porous-media).

Depleted hydrocarbon reservoirs

Depleted hydrocarbon reservoirs represent specific parts of a porous aquifer (often sandstone, carbonate) into which oil or gas has been trapped and subsequently been produced (Figure 3-2). At geological time scales, the containment of these reservoirs has been proven for the specific fossil fuel types at pre-development (initial) pressure conditions. Reservoirs can be used to store gas or liquids.

Depending on the degree of aquifer support and type of development, the reservoir will have been subject to a certain amount of pressure depletion.

Salt formations and caverns

Salt formations correspond to rocks composed of mineral halite (NaCl) or rock salt. Rock salt has formed as a result of evaporation of saline waters, mostly within (semi) confined basins. The thickness of salt beds ranges from a few centimetres to hundreds of meters. Natural evaporite cycles often include deposition of other minerals such as anhydrite/gypsum and carbonate rocks which alternate with the salt beds. Salt is characterized by extremely low permeability and considered impermeable to most substances. This ensures a very high-quality containment for fluids, either as a cap-rock above a porous reservoir or as an artificially cavern reservoir within the rock salt unit itself.

Salt formations are characterized by low density compared to other underground sedimentary rocks. This density difference and the plasto-viscous behaviour of rock salt at high temperature and pressure, has locally resulted in salt flow and the formation of salt mounds and pillars which sometimes reach heights of several kilometres above the original base of the salt bed. When the flowing salt rises to depth intervals less than ca. 2000 to1500 metres, it becomes more stable and suitable for development of caverns.

Salt caverns are created by the process of solution mining (Figure 3-3). Fresh water is injected through a borehole into the salt formation order to dissolve the salt. The resulting brine is then extracted thereby gradually shaping a cylindrical cavern shape. Caverns are typically situated at depths ranging between 200 and 2000 metres. The caverns are usually elongated in shape - several hundred metres in height and several tens of metres in diameter - and may have a volume of several hundred thousand cubic metres. Their shape and volume are determined by sonar and their stability is periodically monitored.

Salt caverns provide very high withdrawal and injection rates relative to their working gas capacity.

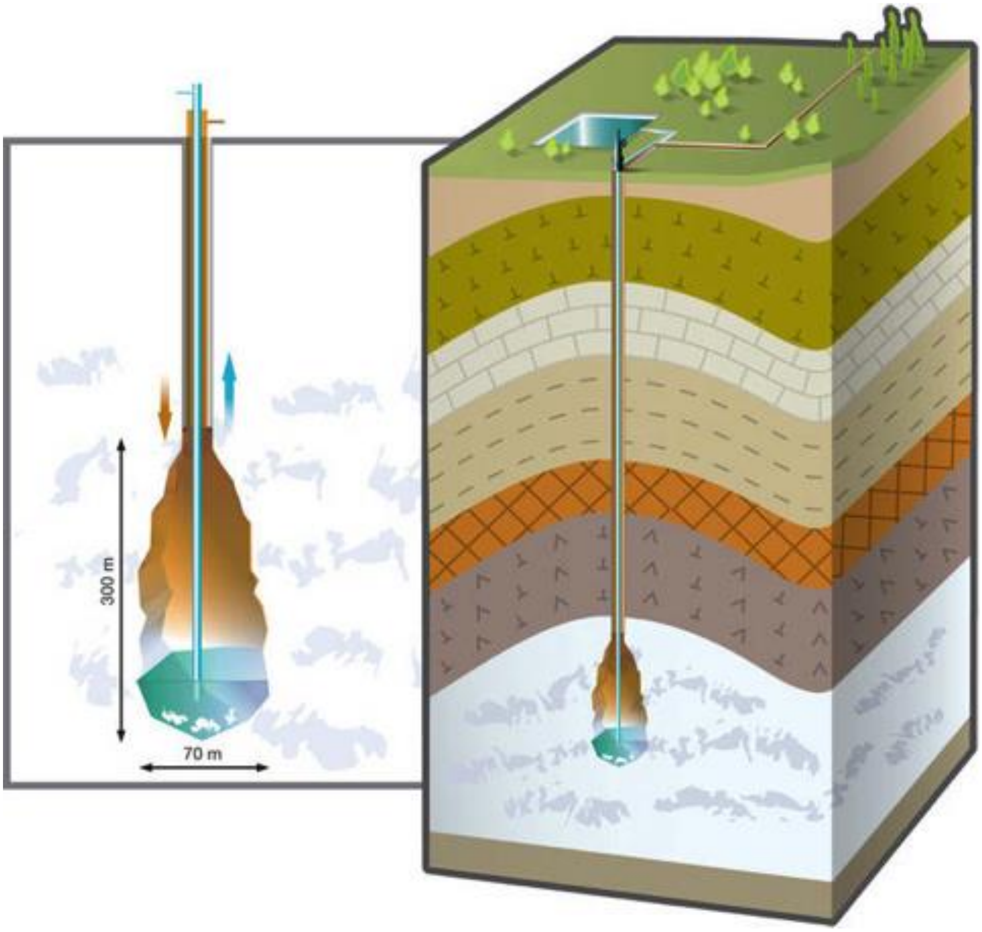

Figure 3-3: Schematic representation of salt cavern storage. The vertical scale is not consistent with reality. Source: http://www.geostockgroup.com/en/underground-storage/salt-leached-caverns).

Engineered and mined rock caverns

Mined cavern consists of one or more galleries excavated in rock from a vertical shaft or inclined drift (Figure 3-4). Typical cavern depths vary from 70 to 200 m.

Suitable rocks for storage should meet the following criteria [18]:

- The cavern host rock should be as impervious and free of fractures as possible to minimize leakage;
- The rock should be strong enough requiring little or no artificial support of the cavern roof for the given dimensions. Stronger the rock type, the larger the size of the cavern that can be constructed;
- The rock should be uniform and should have little or no jointing, faults and other discontinuities such as shear zone. This impacts the strength of the rock, leakage potential and the dimensions of the underground openings;
- For economic reasons, the rock should be easy to excavate for the shafts and underground caverns;
- The rocks through which the shaft will pass should not be incompetent or be heavy water bearing, since water control in shaft sinking would require stabilization techniques such as grouting or freezing, which are expensive;
- Shale and siltstone have been most favourable types of sedimentary rocks because they are impervious, and relatively easy to excavate. However, these rocks require extensive artificial supports, such as roof bolts;
- Igneous and metamorphic rocks are also impervious, could form tight caverns and are strong enough to have self-supporting roofs of the caverns. Large size caverns can be constructed in these types of rocks.

The stored product is prevented from escaping on the principle of hydraulic containment: the caverns are located at such a depth that the static head of the water table is greater than the pressure of the stored product. There is therefore a pressure gradient towards the inside of the cavern, preventing the stored product from migrating. The water pressure in the rock can be enhanced artificially by special water supply systems “the water curtains”

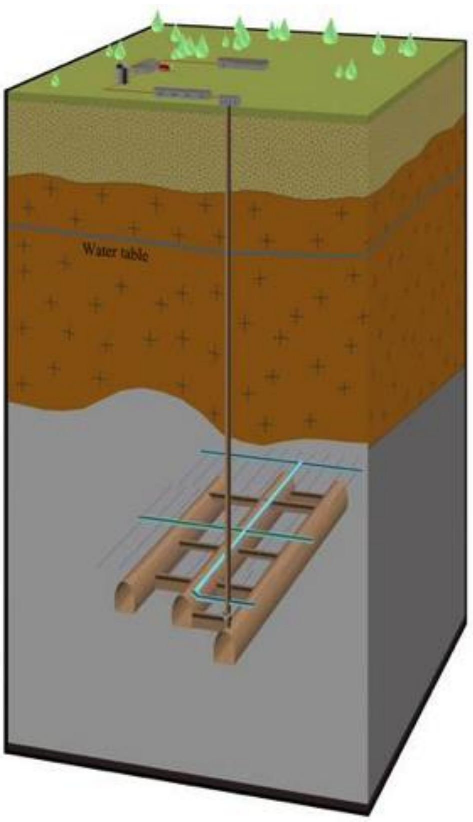

Figure 3-4: Schematic representation of mined rock cavern storage. The vertical scale is not consistent with reality. (Source: http://www.geostockgroup.com/en/underground-storage/mined-caverns).

A subtype of mined caverns is the lined mined caverns (Figure 3-5). This concept is a combination of the two following technologies:

- the underground storage in mined rock caverns,
- the membrane containment used for conventional LNG tanks and ocean carriers.

This type of storage cavern is particularly adapted for regions without geological potential for other types of underground storages. As there are no clear distinctive and location specific feasibility criteria, this reservoir type is not included for future potential assessment.

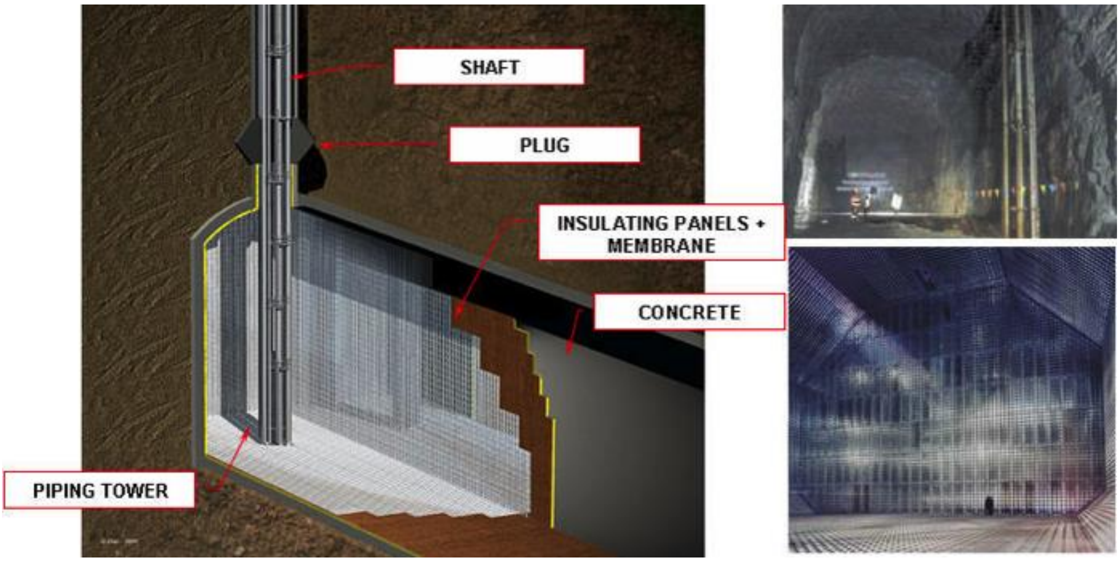

Figure 3-5: Schematic representation of lined mined rock cavern storage. The vertical scale is not consistent with reality. (Source: http://www.geostockgroup.com/en/underground-storage/lined-mined-cavern).

Classical mines are created with the intent to excavate valuable raw minerals and coal. Generally the design of these mines is not tuned with the specific criteria for underground storage. Still some of the abandoned mine shafts and galleries may be suitable for storage functions such as the Mine Water Thermal Storage in the southern part of the Netherlands.

3.5. Above-ground water reservoirs

The most common large-scale energy storage is provided by Pumped Hydroelectric Systems. These systems rely on the presence of two water (lake) reservoirs at different elevation levels. The volume of water and height difference of the lakes determines the capacity and load-duration. Lakes can either have formed by nature or may be created by damming valleys. Alternative options for pumped hydro in flat and low land areas are developed by creating diked areas in large lakes or near shore parts of the sea.

3.6. Suitability of reservoirs for energy storage technologies

Table 3-1 provides an overview of the currently known techno-economic feasibility and maturity of each storage technology within the different types of reservoirs. Empty cells indicate that no storage of the given type is foreseen to take place within the associated reservoir.

Storages	Natural Gas	Hydrogen	Thermal	CAES	UPHS	PHS	CO_2
Depleted hydrocarbon reservoirs	++	?		?			+
Aquifers and traps	++	?	++	?			+
Salt caverns	++	+		+			
Abandoned mines	?		+		?		
Engineered cavities, Host rock	+	?	+	?	?		
Lakes						+	

Table 3-1: Overview of technical suitability for storage in each reservoir type, as considered in ESTMAP.

++: Mature technology, widely implemented
+: Proven technology, sparsely implemented
?: Prospective technology: pre-commercial pilots and conceptual designs

4. Storage data and technology specifications

This chapter describes the main aspects of the data contained in the database. Detailed specifications are given in Annex 2 (storage reservoirs) and 3 (storage facilities). This is an update to the specifications described in ESTMAP-D3.01 & D4.01.

4.1. Data specification structure

Figure 4-1 represents the main data specification elements contained in the database and their link to the analysis input. Each of the data specification elements is briefly described below.

A) Energy storage facility specification

This part contains all descriptive parameters (technical, economical, location, etc.) of the above-ground and grid-connected infrastructure belonging to an energy storage development. These data provide direct operational input (performance, cost) to the energy systems analysis and cover technologies that are linked to subsurface and above-ground reservoirs or have no link to reservoirs (e.g. batteries).

B) Reservoir specification (Chapter 4.3)

This part contains the descriptive parameters of the above-ground and subsurface natural storage reservoirs including, identification, geometry, development, characteristics, properties and technology-specific assessment data. The data in these reservoir tables are in principle not suited for direct input into the energy systems analysis process. For existing energy storages, the facilities are linked to the reservoir entries if relevant. For future energy storage potential, hypothetical (notional) storage facilities are defined on the basis of the attributes of (undeveloped) reservoirs and specifications of the technology that can be attached to the reservoir.

In addition to the reservoir and facility specifications, the ESTMAP project also includes a definition of typical economical and operational technical parameters specific to each energy storage technology (Storage technology specifications). These values are among others derived from existing analogues and published literature sources and used to convert the ESTMAP data into datasets that are input to the Energy Systems Analysis (Report **Error! Reference source not found.**). The definition of the storage technology specifications and the process used to convert the reservoir data into analysis input parameters is described in Report **Error! Reference source not found.**.

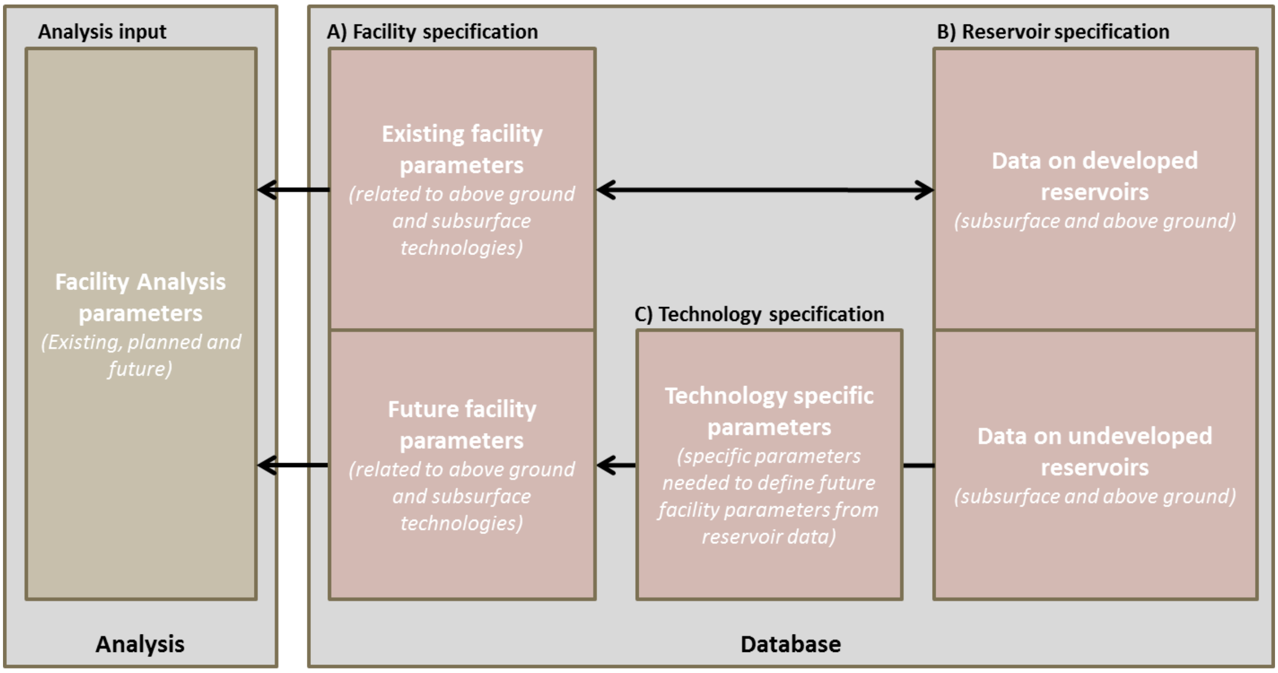

Figure 4-1: Structure of the data specification elements in the database and the relation to the analysis input data.

4.2. Energy storage facility specifications

Figure 4-2 provides a simplified schematization of the different tables contained in the storage facility specification and the internal database relationships. A detailed description of all facility data fields is given in Report **Error! Reference source not found.**. Each of the main specification categories is briefly described below.

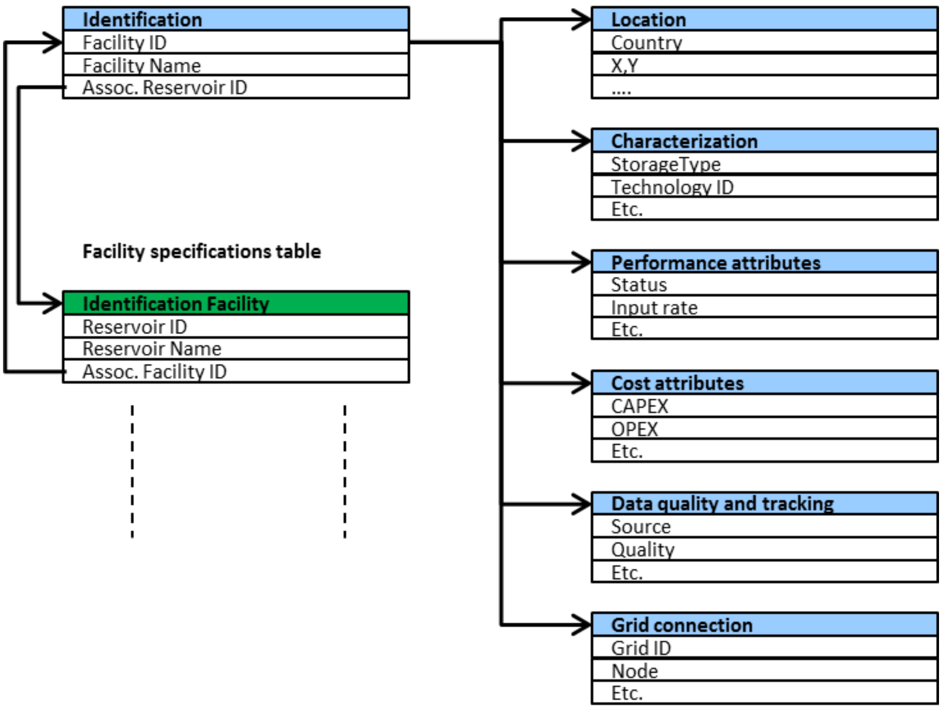

Figure 4-2: Schematic overview of the storage facility specification data tables and their relationships.

Object identification
This category provides the main identifiers that can be used to discriminate and select the individual storage facilities and make links to the other database components. Obligatory data fields include the unique database id and the full name of the facility. Optionally a link to the connected storage reservoirs deployed by this facility can be defined (i.e. developed energy storages in natural subsurface and above-ground lake reservoirs).

Storage facility characterisation
This category provides the general technical description that characterizes the storage facility. The obligatory fields are a definition of the type of energy carrier (inbound and outbound) as well as the storage type. The latter is divided into a component describing the generic form of storage (Natural gas, Compressed air, Pumped Hydro, etc.) and a component describing in more detail the storage concept (Advanced adiabatic CAES, Lithium-Ion Battery, Open-loop pumped hydro, etc.). Optionally the type of service can be provided (frequency control, load balancing, seasonal storage, etc.)

Storage facility location
This category determines the location of the facility. Longitude and Latitude (ERTS-89) as well as country codes are obligatory. Optionally the name of cities and provinces can be provided to facilitate spatial selections. A free descriptive field is available for further site specification.

Development and Grid connection
These are all optional fields including the development status (prospective, operational, planned, etc.), the name of the operator (if known), the service start and end dates, and a description/categorization of the grid connection.

Storage facility performance attributes
This category includes all numerical parameters determining the technical performance of the facility. These parameters include:

- intake and production capacities (MW or m^3/day)
- working volumes (MWh or m^3)
- cycle efficiencies
- exogenous charging and loss rates
- maximum annual production cycles
- ramp-up and ramp down rates
- annual availability
- required on/offline times
- construction times
- technical life times
- availability (fraction of nominal capacity)

Many of these parameters are separately defined for the intake equipment, production equipment and the overall storage equipment. All values can be provided in mean, minimum and maximum ranges.

Storage facility cost attributes
This category includes all numerical parameters determining the costs of the facility. These parameters include:

- capital costs
- fixed operation and maintenance costs
- variable operation and maintenance costs
- start-up and shutdown costs
- total intake and production costs

- connection costs
- subsidies

Like the performance parameters, most of these parameters are separately defined for the intake process, production process and the overall storage process. Costs related to intake and production are given in €/MW (€/m^3/day for gas) or €/MW/year (€/m^3/day/year for gas). Storage costs are in €/MWh (€/m^3 for gas) or €/MW/year (€/m^3/year for gas). All values can be provided in mean, minimum and maximum ranges.

Data quality and tracking

This is a database administrative category describing the source, quality and date of the information included for a certain storage facility.

4.3. Energy storage reservoir specifications

As explained, a conceptual distinction is made between the energy storage facilities and the natural reservoirs linked to these facilities. These reservoirs are naturally and geographically bounded and defined by specific *subsurface* as well as *above-ground* conditions. Reservoirs may either already be connected to existing energy storage facilities or represent future potential for connecting to new facilities.

The specifications distinguish between the storage reservoir categories listed in Table 4-1. Although many of the parameters and attributes in this specification will be generic, some will be applicable to a limited range of reservoir types only.

Reservoir type	Domain	Dependencies	Nature of storage space
Depleted reservoir	subsurface	Oil or gas production	Pores
Aquifers	subsurface		Pores
Rock salt formations	subsurface	Development of caverns (solution mined or excavated)	Option to create cavern
Salt caverns	subsurface		Cavern
Cavity host rock unit	subsurface	Excavation of cavity	Option to create cavern
Excavated cavities	subsurface		Cavern
Abandoned mines	subsurface	Mining activity	Cavern
Lakes	Above-ground / subsurface		Surface/subsurface basin

Table 4-1: List of all reservoir categories defined in the specifications

Figure 4-3 provides a simplified schematization of the different tables contained in the storage reservoir specification and the internal database relationships.

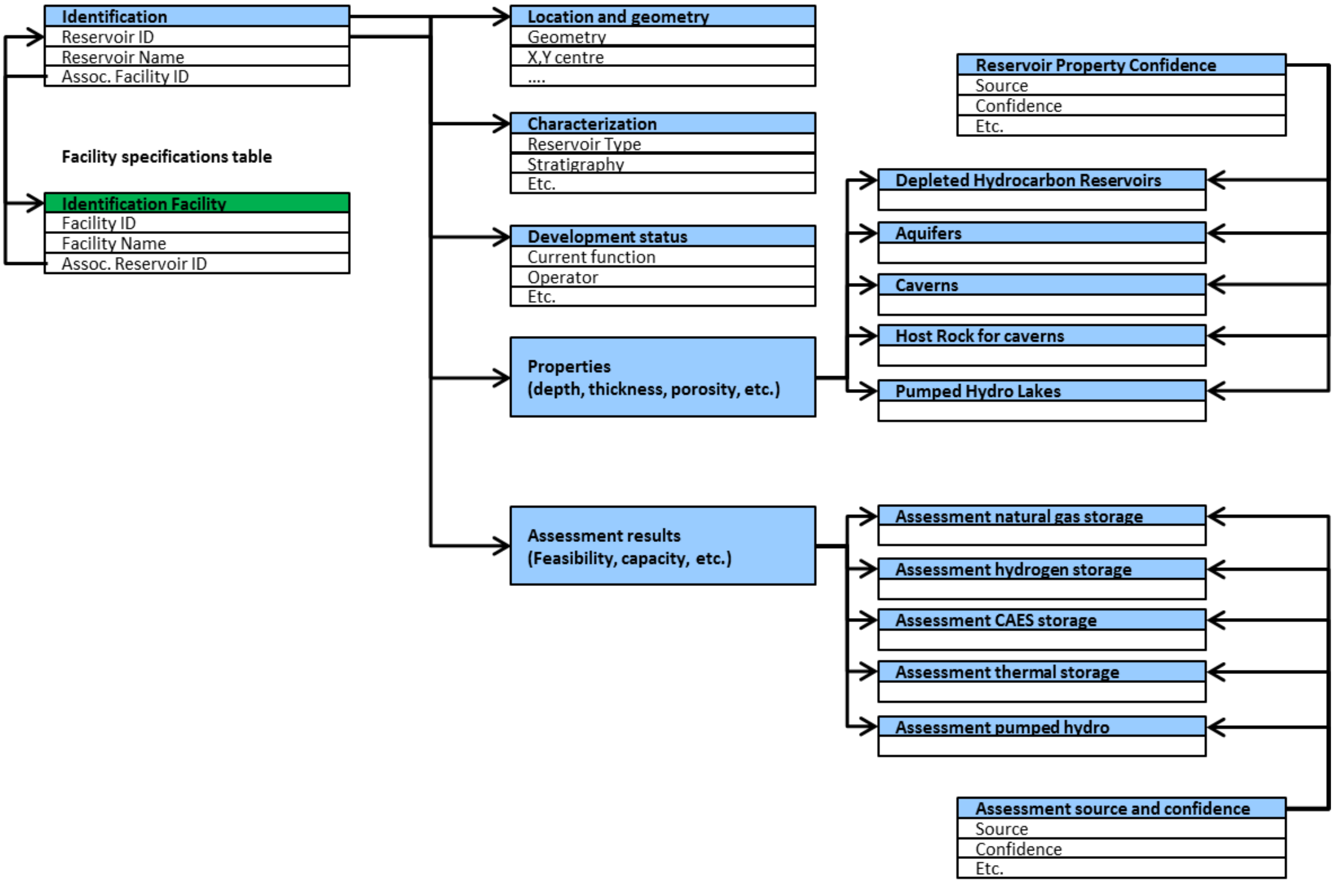

Figure 4-3: Schematic overview of the reservoir specification data tables and their relationships.

Reservoir identification

This category provides the main identifiers that can be used to discriminate and select the individual storage reservoir and establish links to the other database components. Obligatory data fields include the unique database id and the full name of the reservoir. For certain reservoir types it is possible to define sub basins or parent-child links (e.g. a reservoir trap that is part of a larger aquifer). Optionally a link to the storage facility (if exists) can be provided.

Reservoir location and geometry

This category determines the location of the reservoir in longitude and latitude (mid-point ERTS-89) as well as country codes (obligatory). For most reservoirs a GIS shape of the geographical outline are provided as well. Other obligatory fields are a definition of the domain (subsurface or above-ground) as well as the spatial hierarchy (e.g. determining whether the reservoir is regionally or locally defined; see Figure 4-4). Optionally the name of cities, states and provinces as well as geological regions and structural elements can be provided to facilitate spatial selections.

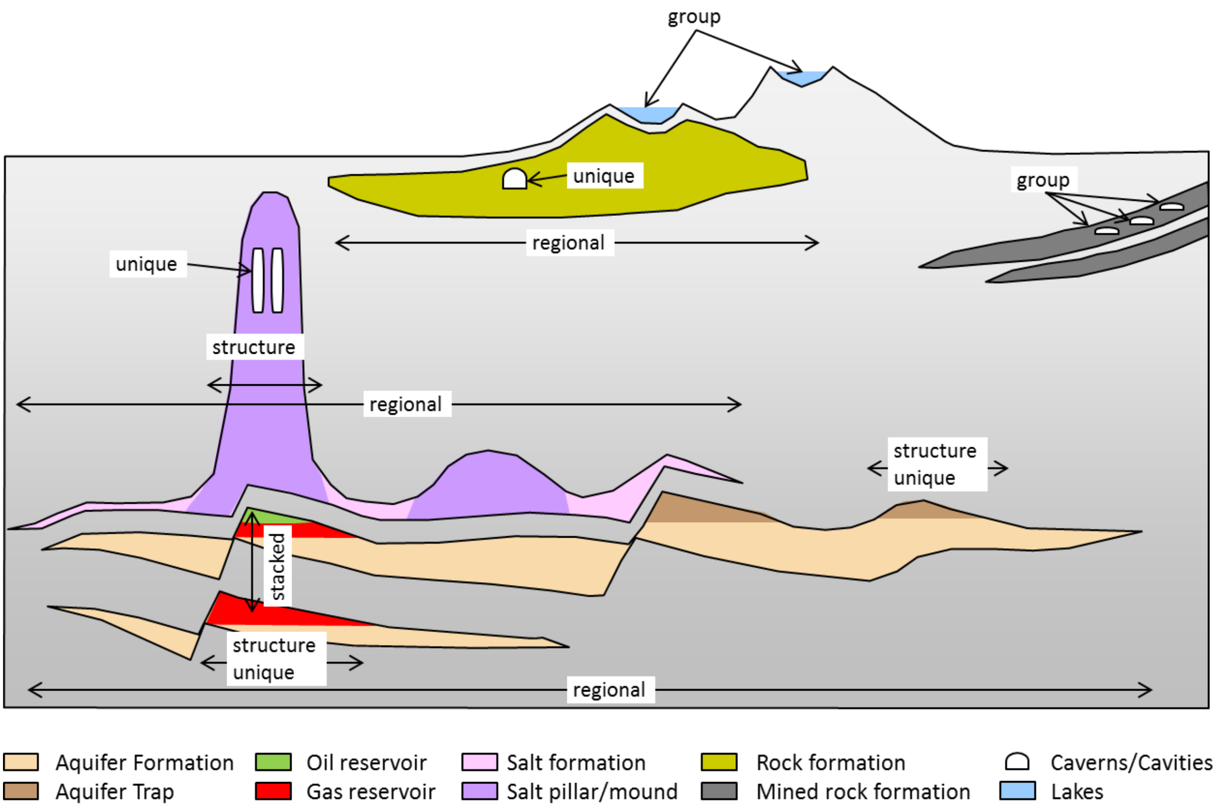

Figure 4-4: Schematized overview of different reservoir types and spatial definitions (hierarchies). Caverns can be linked to regional rock and salt formations. Hydrocarbon fields and traps can be part of larger regional aquifers.

Reservoir characterization

This category provides the general geographical and geological description that characterizes and categorizes the storage reservoir. The obligatory fields are main reservoir type (aquifer, salt formation, etc.) and reservoir subtype (trap, bedded salt, pillar, etc.). Other optional database fields are stratigraphy (among other for correlation purposes and determining potential overlaps with other subsurface functions), main and seal lithology (determining feasibility and performance aspects), and fluid fill (water, oil, gas, etc.).

Reservoir properties (per type)

This category includes all intrinsic and physical reservoir properties. These properties are mostly relevant for determining expected technical performances and include:

- Dimensions (depth, thickness, height, area)
- volumes (bulk rock, pore, cavern, mined, initial and recoverable oil/gas, lake, etc.)
- number of caverns
- porosity
- permeability, transmissivity, productivity
- temperature, heat in place
- pressure

Each value can be defined as mean, minimum and maximum ranges. Furthermore an indication of the confidence level can be provided (proven/tested, estimated, assumed, etc.)

Storage Assessments

For each reservoir an indication of feasibility for various storage functions is provided. The assessed functions are:

- natural gas storage
- hydrogen storage
- compressed air energy storage
- thermal storage
- pumped hydro storage

The assessment is indicated as proven, probable, possible, theoretically, etc. and includes a degree of confidence (measured/tested, assessed, assumed, etc.). Besides the feasibility indication, an estimation of expected performance parameters is given (total volume, working volume, cushion volume, energy capacity, etc.). Each value can again be provided in mean, minimum and maximum ranges.

Development status

This category first of all describes the current and planned developments (gas production, storage, mining, etc.) as well as availability for storage development. Where known, additional information concerning operator, licences, ownership, end dates, drilling activities, etc. can be provided. There is also room to indicate possible restrictions related to Natura-2000 areas, groundwater protection, urban development or alternative subsurface uses. With regards to the latter an additional category has been added in which a link to other databases can be provided that describe these alternative potentials (e.g. CO2SToP for ccs development). Finally a new set of fields has been added describing actions that would eventually be required in order to mature and develop a storage function for the given reservoir (regional prospecting, local evaluation, exploration, storage space engineering, etc.) as well as current and planned storage types.

Data quality and tracking

This is a database administrative category describing the source, quality and date of the information included for a certain storage reservoir.

5. Data collection approach

This chapter describes the data collection approach and results for both the subsurface and above-ground energy storage information in ESTMAP. It addresses the data sources that have been consulted and used, the data processing workflows for shaping the data into the database format and ensuring quality and consistency with the specifications (Annex 1 and 2) and the known limitations regarding the completeness and applicability of the data for further uses.

The main objective of the data collection work packages is to provide the essential information needed for mapping the European energy storage potential and defining the input to energy systems analyses. The subsurface data collection work (WP3) was coordinated by BRGM with assistance from CGS and TNO. The above-ground data was collected by ECOFYS (WP4). Figure 5-1 shows the relation to the other work packages in ESTMAP.

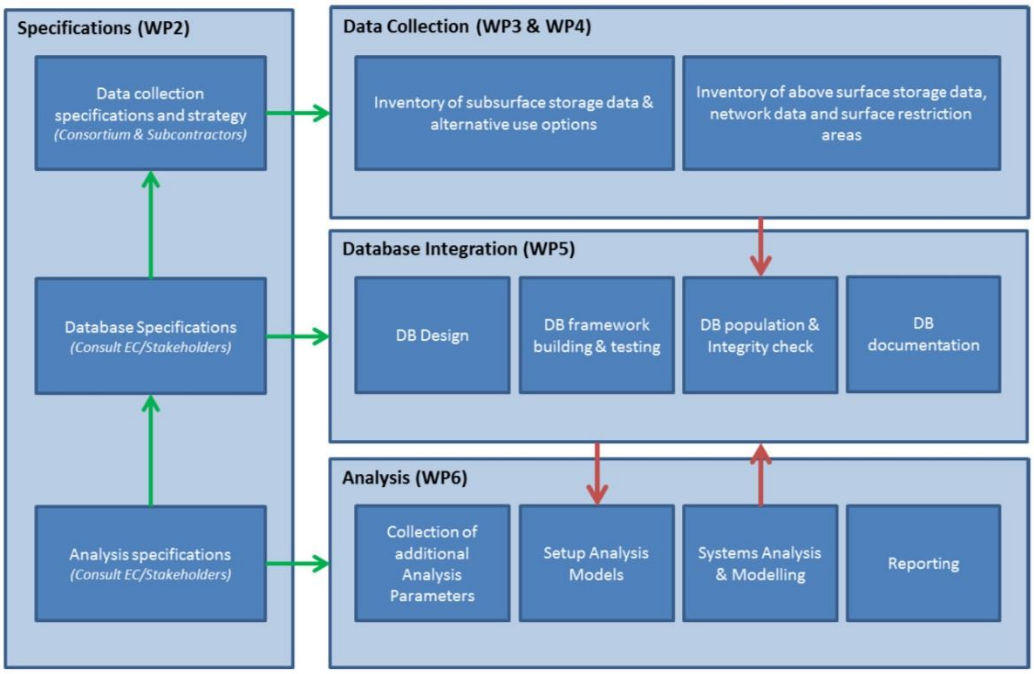

Figure 5-1 : Project logic and defined work packages.

The ESTMAP database covers readily and publicly available data from countries presented in Figure 5-2. They correspond to the EU member states (28 countries), the countries of the European Free Trade Association-EFTA (4 countries) and the Member of the Energy Community (8 countries). During the course of the project, Turkey accepted to participate as well.

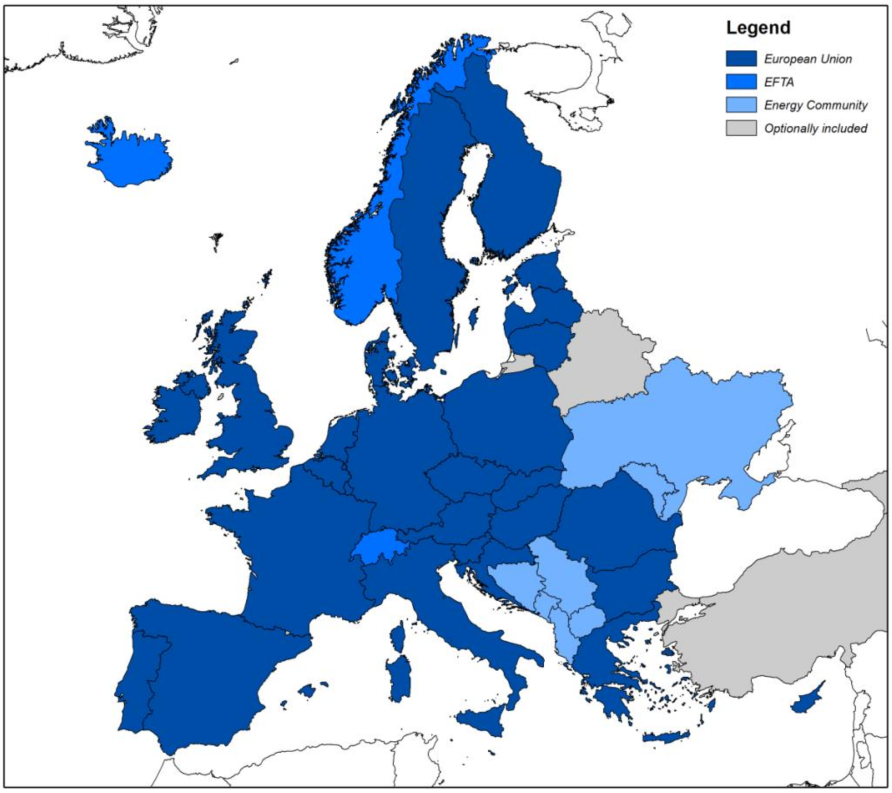

Figure 5-2: Geographical coverage as defined at the start of the ESTMAP project. Kalinigrad and Belarus were finally not covered by the project. Serbia and Kosovo are evaluated as separate countries

5.1. Subsurface data collection

5.1.1. Data scope and objectives

The main goal of the WP3 is to gather readily available and public data on existing and future potential storage reservoirs (Figure 5-3). These data involve all the aspects described in the reservoir specifications (Paragraph 4.3) and partly aspects of the storage facility specifications (Paragraph 4.2)

The scope of subsurface data collection includes the following features:

- aquifers
- hydrocarbon reservoirs
- salt formations and caverns
- rock formations, caverns and mines

These features are considered valid entries when they have an indication for feasibility for at least one of the following storage technologies:

- underground gas storage (natural gas or hydrogen)
- underground compressed air energy storage
- underground thermal energy storage
- underground pumped hydro storage

Features may be suitable for multiple energy storage technologies or may deliver other existing or potential functions such as geothermal energy, CO_2 storage, etc.

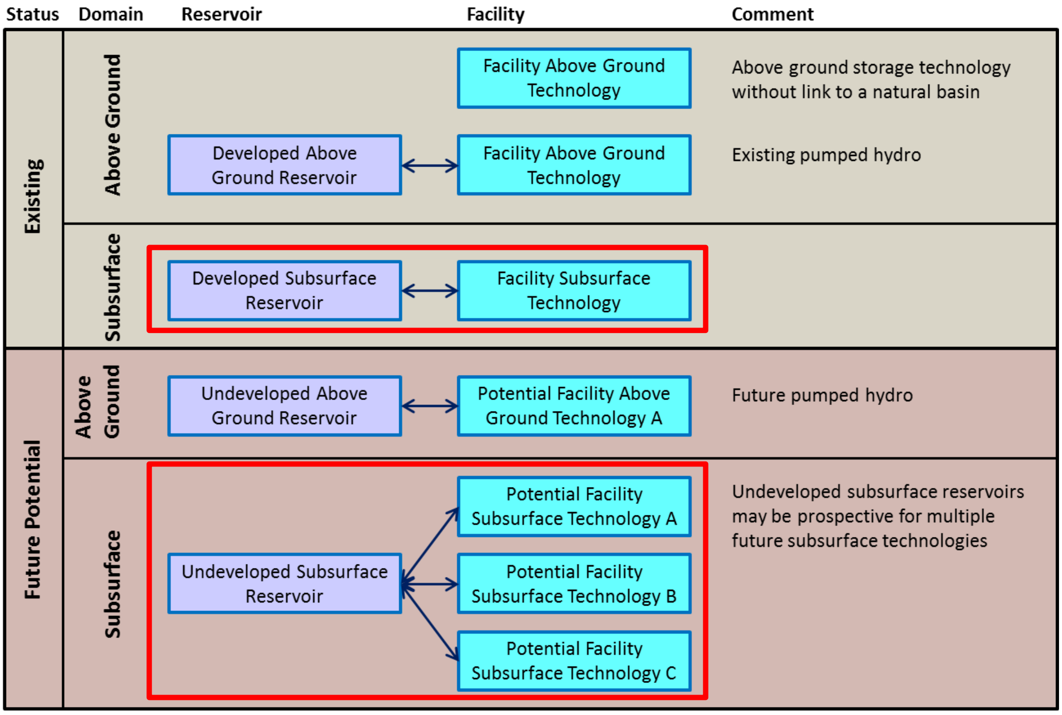

Figure 5-3: Focus areas of the subsurface data collection.

Data in ESTMAP must be public and comply to the technical specifications provided, meaning that all the obligatory data fields are filled out and that data has the right formatting and standards. Entries should at least have an theoretical indication for potential future energy storage development. It does not matter whether the potential is still regionally defined and relies on location specific assessment to prove feasibility.

It should furthermore be noted that it is unrealistic to assume that all potential included in ESTMAP could also be developed. Much information is still indicative. There may yet be technical, economical or societal barriers which will only come to light after a thorough assessment

5.1.2. Data sources and collection

In order to obtain a comprehensive, high quality and public dataset on European subsurface energy storage potential, the following three-tier approach was followed:

1. Obtain national or regional subsurface information on energy storage potential through subcontracted geosciences organizations and technical institutes.
2. Consult institutes from neighbouring countries when no partner could be found or contracted from the country itself
3. Consult public web database resources in case no further partners were available or willing to be subcontracted.

Subcontracted partner contributions

For most countries cooperation was established with the national geological organizations associated under EuroGeoSurveys (http://www.eurogeosurveys.org) or geotechnical institutes who are member of the ENeRG network (European Network for Research in Geo-Energy – http://www.energnet.eu) In countries not represented in these networks, national partners were sought individually.

Following introductory information on the ESTMAP project, each country was asked to fill-out a questionnaire (Annex 4) with the main objective to obtain a first impression of the potentially available public knowledge and information relevant to subsurface energy storage and the capability of the contacted organizations to deliver this information to ESTMAP. The questionnaire was accompanied by a draft of the proposed contract and a request to participate. Based on the outcomes of the questionnaire responses, each potential partner was contacted personally to discuss and clarify their expected contributions to ESTMAP as well as the conditions mentioned in the draft contract proposal.

After the reception of the questionnaires, all interested subcontractors were invited to a meeting in Vienna (ESTMAP, First subsurface data providers workshop, April 15th 2015), where the comprehensive data requirements were presented and discussed and as well as the contract details. Furthermore each subcontractor received a detailed description of the subsurface data specifications (ESTMAP D3.02).

Figure 5-4 shows the final countries from which data was retrieved and integrated in the ESTMAP database. Annex 3 provides a comprehensive list with further contact details. For a total of 26 countries cooperation was found from subcontracted partnering organizations. Netherlands, France the Czech Republic and partly Belgium (Flanders region) were assessed by the consortium partners. Germany, Ireland, Slovakia and Serbia were assessed from public sources by the consortium partners. Only for Iceland, Luxembourg, Cyprus, Switzerland, Former Yugoslavian Republic of Macedonia, Malta and Montenegro no further information on subsurface energy storage potential was found.

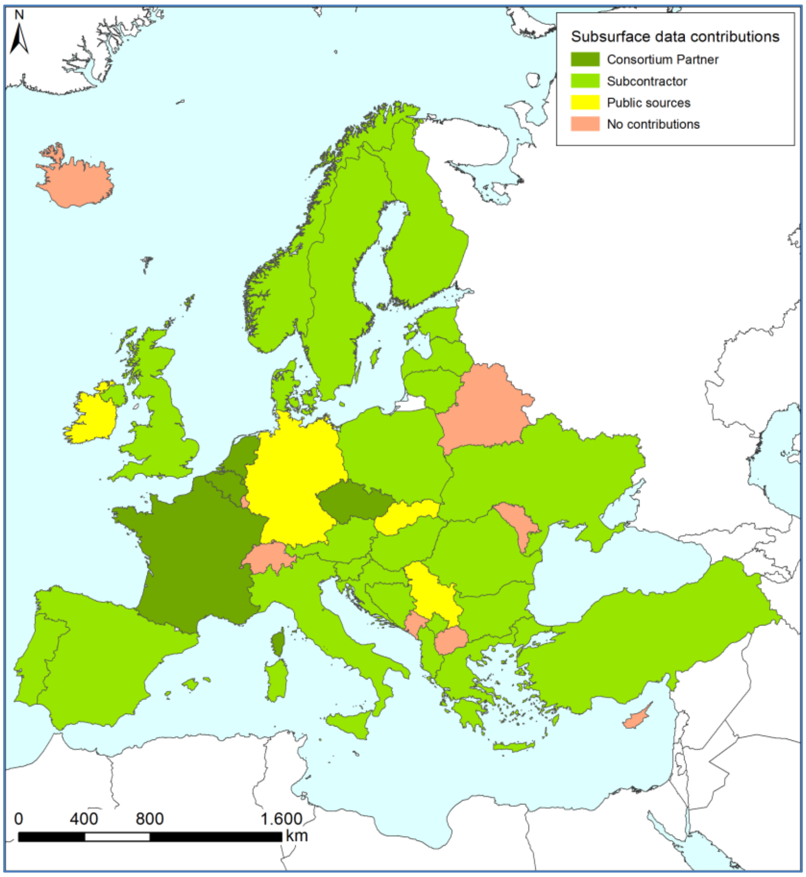

Figure 5-4: Overview of subsurface data contributions to the ESTMAP database

Upon the Vienna subsurface workshop, all subcontracted partners received a dedicated Excel form through which the data can be provided. This Excel form aligns with the ESTMAP data specifications (Annex 1) and was developed in order to facilitate the subcontractors in systematically gathering and compiling the information and to ensure that all contributions were compatible to the ESTMAP database model. Various checking mechanisms in the Excel form help in preventing incompatible entries (e.g. fixed reference values) and controlling internal consistency of all value entries.

Apart from the Excel data form, further spatial information on the location and extent of potential storage reservoirs was provided in ArcGIS shape files (ERTS-89 projection). The features in the shape files are linked to the Excel information through unique object identifiers (OBJECT_ID data field). In case the outline of the subsurface features could not be provided, the position is represented by an approximate mid-point (latitude, longitude).

The Excel form was accompanied by detailed instructions and a public version of the data specifications (ESTMAP-D3.02). At a later stage a Frequently Asked Questions document was established and shared with all data providers (ESTMAP-D3.03).

Annex 5 illustrates the Excel file filled-out for the French case. The file contains 10 sheets corresponding to the reservoir specifications:

- Reservoir identification (ID_QUAL sheet).
- Reservoir Location and Geometry (LOC sheet).
- Reservoir geological characterization (CHAR sheet).
- Current development status (DEV sheet).
- Reservoir properties. Fields to fill-out in this sheet are conditioned by the reservoir type (CHAR sheet).
- Five separate Assessment sheets for Underground Gas Storage (ASSESS_UGS), Hydrogen Storage (ASSESS_H2), Compressed Air Energy Storage (ASSESS_CAES), Underground Thermal Energy Storage (ASSESS_THERM) and Underground Pumped Hydro Storage (ASSESS_UPHS)[4]

Data collection for countries with no subcontractors

After settling the subcontracts, ten countries remained without a partner to contribute energy storage information:

- Cyprus
- Germany
- Iceland
- IrelandLuxembourg
- Macedonia
- Malta
- Montenegro
- Serbia

SwitzerlandFor these countries various public data sources have been accessed, including the DOE Global Energy Storage Database [19], the GIE Gas Storage Map Europe [20] and country-specific sources. For Iceland, Luxembourg, Switzerland, Montenegro, the Former Yugoslavian Republic of Macedonia, Cyprus and Malta, these efforts did not result in further information on subsurface energy storage.

[4] The ASSESS_UPHS was also used to compile and deliver information on existing and potential pumped hydro lakes above ground.

Details regarding the sources and contributions in each country are summarized in the country data review report (Report). The DOE and GIE databases are further explained in Paragraph 5.2.2 on the above-ground data collection.

5.1.3. Data processing and quality control

The primary quality checking procedure was conducted and coordinated by BRGM upon receiving the data files from the subcontracted data providers. The checks involved:

- Identification of internal consistency of related parameters (e.g. main and sub reservoir types, current/planned development and availability)
- Ensuring correct use of numerical value data (precision and accuracy, units, missing values, etc.)
- Completion of information on storage potential assessment
- Verification and processing of the GIS data (projection, coordinate conversion, consistency of mid-point locations, link between the geographic data and the Excel file data).

Upon clarification and revisions received from the data providers, BRGM incorporated all modifications in updated Excel data files.

A second quality procedure was performed at TNO and consisted of an upload test in the ESTMAP database model. Common issues detected in this phase concerned invalid entries (deviating from the specifications), incompatible field lengths and characters, inconsistent entries, units, uniqueness of record id-keys, etc. All issues were reported to BRGM who again consulted the data providers for further improvements.

During the course of the data collection process all subcontractors were invited to a meeting in Prague organized by CGS (ESTMAP Second subsurface data providers workshop, September 18th 2015). The aim of this workshop was to present a review of the already collected subsurface data and to directly answer further subcontractors' inquiries. The meeting also provided an opportunity to promote possible improvements to the data collected. During parallel discussion sessions each of the countries in a specific region of Europe discussed with its partner further potential additions to the datasets (e.g. on future potential). These contributions were finally included as well.

As the data were prepared for energy systems analysis input, further adjustments were made including some additions to the data model:

- Correcting unit conversion errors
- Filtering anomalous values
- Extending information categories related to defining hierarchical links between entries (e.g. individual salt caverns within a defined larger salt formation).
- Extending information categories related to future maturation and development requirements
- Extending information categories related to source database links (URL, table, field and id of source databases)
- Extending information categories related to links with similar data entries in the CO2StoP database [22]
- Adding new value categories for feasibility definitions and completing any missing values
- Adding and updating links between above-ground storage facilities and connected subsurface reservoirs
- Defining and adding a use-status field (for selecting records to be used in mapping and analysis)
- Specification of UGS surface locations to precisely match storage facility coordinates (performed on the basis of location descriptions, reported reservoir coordinates and Google-Earth and Google-Maps satellite images)

- Adding new values (late contributions from certain providers)

Before the finalization of the database, each subcontractor was given an extract of the data for his area, together with a request to fill out a questionnaire and data approval form (Annex 6). This last in-depth data check resulted in a significant improvement of the data quality and some new additions on reservoirs.

All the correspondence with a given subcontractor has been recorded in a follow-up form (listing the receipt of data, clarification requests, and answers. The resulting Frequently Asked Questions document [] was regularly updated and shared with the data providers. Once the validation of the data was found OK (Excel file and GIS data), the signed form was sent to the subcontractor in pdf format to give him the green light for initiating the invoicing (Example in Annex 7).

5.2. Above-ground data collection

5.2.1. Data scope and objectives

The main goal of the WP4 is to gather readily available and public data on existing and future planned storage facilities (the above-ground infrastructure that directly operates the energy storage and eventually connects with an above-ground or subsurface storage reservoir) as well as above-ground existing and future potential lakes for pumped hydro storage development (Figure 5-5). These data involve all the aspects described in the storage facility and reservoir specifications (Paragraph 4.2 & 4.3).

The scope of above-ground data collection includes the following facility types and technologies:
- Batteries
- Capacitors
- Compressed air energy storage
- Flywheels
- Hydrogen storage
- Natural gas storage (underground and LNG)
- Pumped hydro storage
- Thermal energy storage

Superconducting magnetic energy storage (SMES) is a technology which is still in development. Therefore there are no existing data on this storage technology and thus it has not been included in the database. However, since we consider it a relevant technology for future potential, a technology table for this technology was developed, allowing for inclusion as potential future storage option in the analysis part of the project.

Although the above-ground data collection (WP-4) includes facilities for subsurface technologies, it does not collect information on the subsurface reservoirs (only above-ground lakes). The appropriate connection between these facilities and the subsurface reservoirs is discussed in Paragraph 5.1.3.

In line with WP-3, the above-ground data in ESTMAP must be public and comply to the technical specifications provided, meaning that all the obligatory data fields are filled out and that data has the right formatting and standards. Entries for pumped hydro lakes should at least have an theoretical indication for potential future energy storage development. It does not matter whether the potential is still regionally defined and relies on location specific assessment to prove feasibility.

It should furthermore be noted that it is unrealistic to assume that all potential included in ESTMAP could also be developed. Much information is still indicative. There may yet be technical, economical or societal barriers which will only come to light after a thorough assessment.

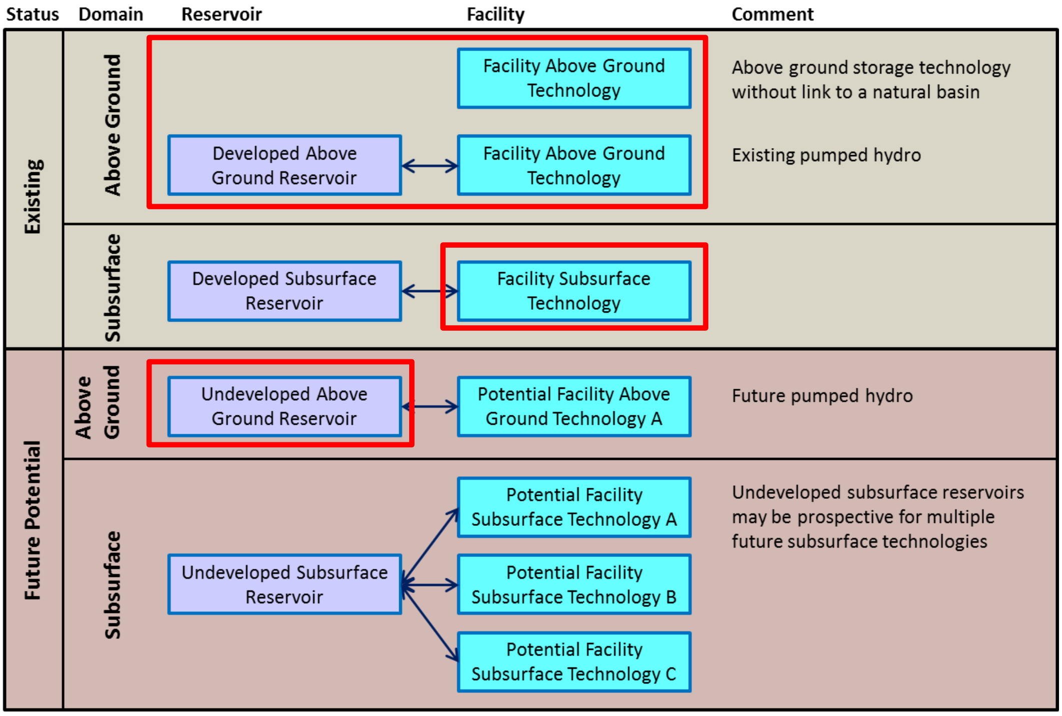

Figure 5-5: Focus areas of the above-ground data collection.

5.2.2. Data sources and collection

The approach chosen to collect data on subsurface and above-surface energy storage aims to produce a database that is as complete as possible and contains high quality open source and public data that can be shared with a minimum of restrictions. For the above-surface data collection, a tiered approach in five stages to identifying and collecting the relevant data on energy storage facilities and reservoirs has been used:

Tier 1: Collect available data within EC and JRC;
Tier 2: Collect data from open source and publicly available databases;
Tier 3: Data verification, upgrading and infilling via European geological networks and (State) geological institutes;
Tier 4: Data verification, upgrading and populating via specific energy sector organizations & networks;
Tier 5: Optional data populating from existing commercially available databases (depending on permission to include these data in this study).

In collecting the data under WP4, we have been able to tap into Tier 1 and/or Tier 2 databases for each energy storage technology. Table 5-1 provides an overview of these data sources that have been included in the ESTMAP database for the different energy storage technologies. Note that a considerably broader group of data sources has been considered and evaluated. Annex 8 provides an overview of all data sources that have been regarded, including comments on why they are include in the database or not.

Table 5-1: Overview of data sources included in final ESTMAP database

Technology	Data sources included in ESTMAP database

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Batteries		DOE			
Capacitors		DOE			
Compressed air energy storage		DOE			
Flywheels		DOE			
Hydrogen storage		DOE			
Natural gas storage		GLE, GSE			
Pumped hydro	JRC	DOE			
Thermal energy storage		DOE			

The data sources of which data has been included in the database are shortly described in the following sections.

DOE energy storage database

The DOE Global Energy Storage Database [19] provides free, up-to-date information on grid-connected energy storage projects and is funded by the US Department of Energy. The database is publicly available at http://www.energystorageexchange.org/ and was used as a key source of data due to its comprehensive coverage, detailed data included and consistency in approach across storage technologies. The DOE energy storage database has global coverage.

GLE LNG Investment database and GSE storage map

The LNG Investment Database [21] shows regasification and storage capacities of large-scale LNG terminals from 2005 as well as a forecast for the following years. The data is published by GLE (Gas LNG Europe), representing the LNG Terminal Operators, which is part of the umbrella organization GIE (Gas Infrastructure Europe). The database is publicly available at http://www.gie.eu/index.php/maps-data/lng-investment-database. Countries included in this database are Belgium, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Malta, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Turkey, UK and Ukraine.

Also GSE (Gas Storage Europe [20]) is part of the same GIE umbrella organisation. The GSE storage map is publically available at http://www.gie.eu/index.php/maps-data/gse-storage-map. Countries covered in this database are Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Serbia, Slovakia, Spain, Sweden, The Netherlands, Turkey, UK and Ukraine.

JRC PHS assessment data

A public version of the PHS assessment dataset was made available at https://setis.ec.europa.eu/node/3910, with corresponding reporting of the European assessment of pumped hydro storage potential [16]. The associated websites are maintained by The European Commission to enhance public access to information about its initiatives and European Union policies in general. The public version of this dataset excludes some data that could not be shared by JRC for reasons of confidentiality. Countries covered in this database are Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovenia, Sweden, Turkey and United Kingdom (Figure 5-6).

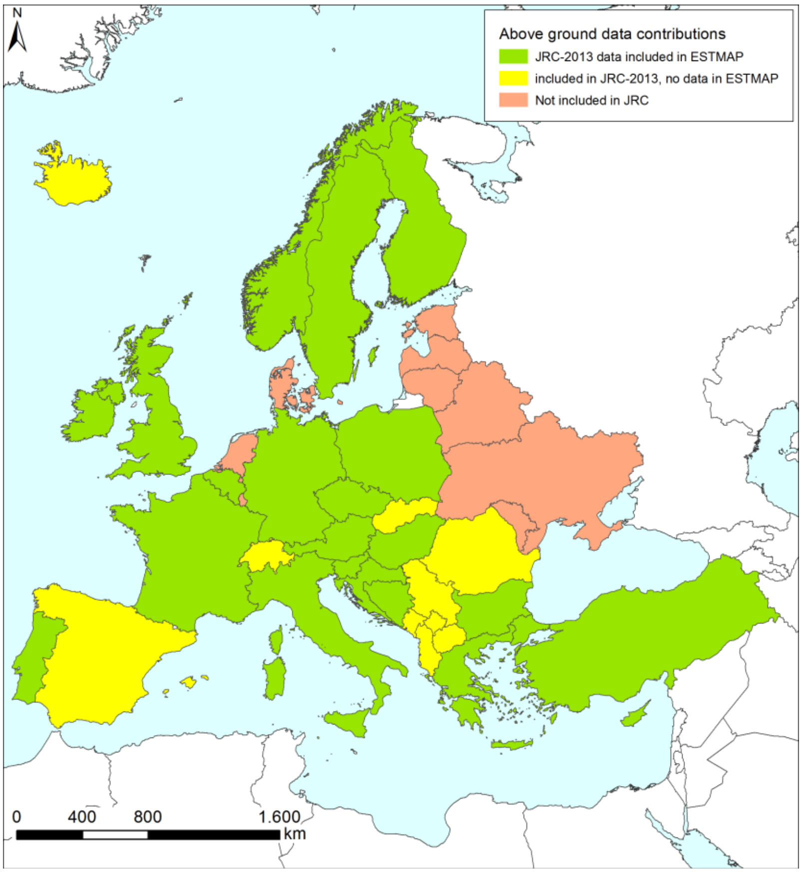

Figure 5-6: Overview of pumped hydro storage lake data included in JRC, 2013 [16]

5.2.3. Data processing

Energy storage facilities

The database with above-ground energy storage facilities was prepared based on publically available databases on Energy Storage projects in the ESTMAP countries. These publicly available datasets were imported into a database management system to create the final ESTMAP database. Based on discussions with experts within the consortium, Microsoft Access was selected as the main tool for data collection, since it allows for high transparency and traceability of data modifications while still being user friendly.

Each of the publically available databases undergo a number of cleaning and quality assurance operations before importing them in the ESTMAP dataset. These cleaning operations consist of:

- Renaming the original field names to ESTMAP format field names;
- Concatenating multiple fields into a single field, such as contact information (names, e-mail addresses etc.);
- Conversion of units, e.g. converting KW to MW;
- Calculation of empty parameter fields in records, e.g. energy storage capacity (MWh) by use of capacity (MW) and duration at rated capacity (hours);
- Remapping country names into consistent ESTMAP format as well as filtering records to show only ESTMAP country entries.

The cleaned up source databases were collated in one above-ground energy storage facility dataset. On this MS-Access dataset, an additional operation was carried out to create the final dataset to ensuring a consistent set of storage type names throughout the resulting database.

Moreover, duplicates were identified and filtered, based on the location of the facilities. In the filtering process of potential duplicates, entries were binned in a grid of 0.2 degrees latitude and 0.2 degrees longitude to identify facilities within a maximum of 15 km from each other. In each case of "co-location", it was verified whether both entries refer to the same facility. In case two entries refer to the same facility, additional data on this facility was used to select the most reliable entry. Subsequently, the least reliable entry was removed from the dataset.

The operations performed were implemented in database queries, for example a conversion query that uses the storage volume of the source database and calculates the storage volume in the units that are prescribed in the ESTMAP Data Specification (ESTMAP-D3.01). A schematic overview of the input, operations and output of the database is given in Figure 5-7

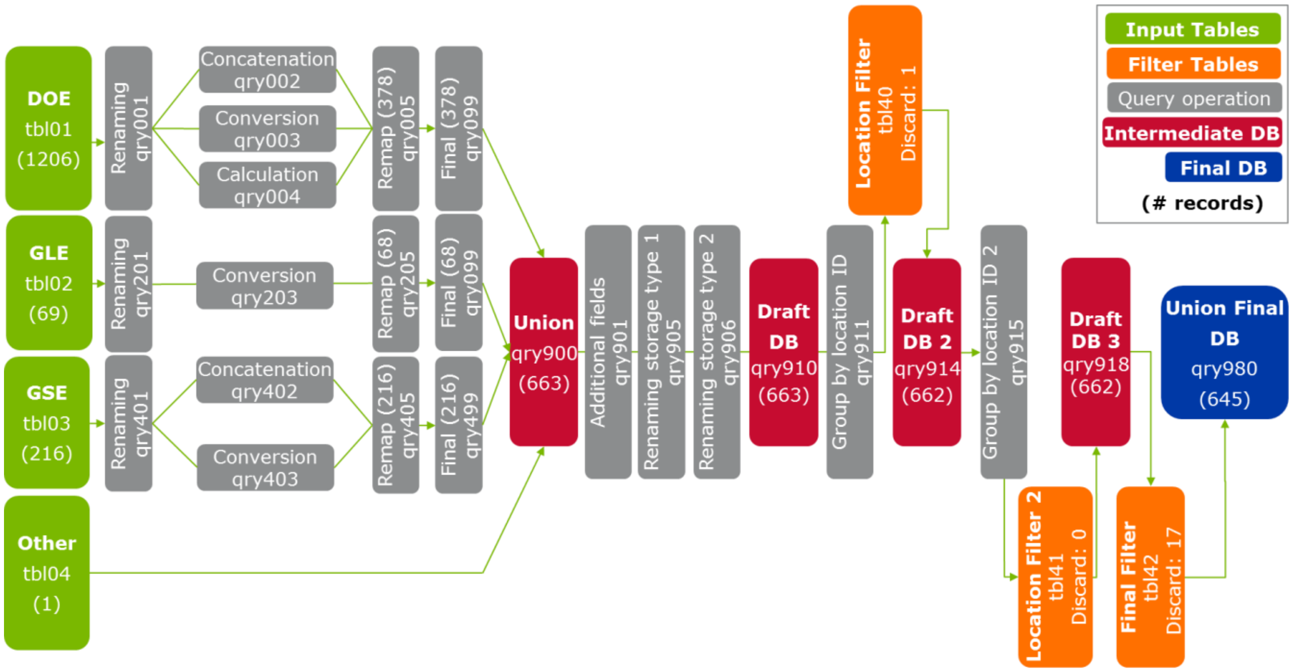

Figure 5-7: Schematic overview of database setup.

Above-ground lake reservoirs

The database with above-ground energy storage reservoirs consists of the publically available data sets on pumped hydro energy storage, as prepared by JRC. The structure of the data sets in this database is depicted in Figure 5-8. As shown in this figure, for each country in the database the study focuses on two types of topology [16]:

- (T1) when two reservoirs exist already with the adequate difference in elevation and within a feasible distance from one another so that they can be linked by a new penstock and electrical equipment
- (T2) based on one existing reservoir, when there is a suitable site sufficiently nearby as to build a second reservoir.

For each topology, both theoretical and realizable potential have been analysed

- Theoretical potential includes all possible combinations of (potential) reservoirs
- Realizable potential takes constraints into account, for example by discounting potential sites close to a centre of population, protected natural areas or transport infrastructure

The scenarios modelled consist of different maximum distances possible between the two reservoirs of a prospective PHS:1, 2, 3, 5, 10 and 20 km. For the topology T2, both a filtered and an unfiltered data set have been published. The unfiltered data set contains all combinations of an existing reservoir and nearby potential future reservoirs, whereas the filtered list only includes the potential future reservoir that has the highest energy storage volume in combination with the existing reservoir.

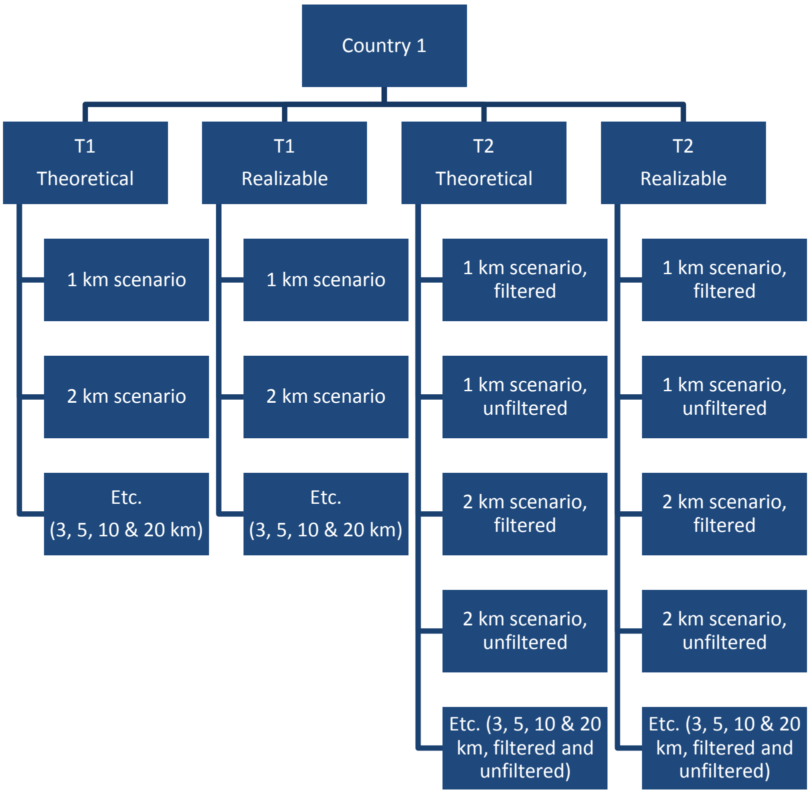

Figure 5-8: Schematic overview of JRC pumped hydro database

In the ESTMAP database, data sets for the T1 and T2 realizable potential for reservoirs with a maximum spacing of 10 km from each other have been included in order to capture the most realistic options. In the case of the T2 data set, the filtered list has been selected.

Matching lakes and pumped hydro facilities

Regarding pumped hydro energy storage, the ESTMAP database covers both facilities and reservoirs. Facility data is based on the DOE energy storage database and reservoir data based on the JRC pumped hydro database. The DOE energy storage database distinguishes closed and open loop pumped hydro energy storage facilities:

- **Closed loop** systems encompass two isolated reservoirs with a significant height difference between which water is exchanged to store or generate power;

- **Open loop** systems, include two variants:
  - a) A combination of two lakes with a significant height difference of which at least one lake is connected to a free stream, such as a river, between which water is exchanged to store or generate power
  - b) A combination of a lake and a free stream, such as a river, with a significant height difference between which water is exchanged to store or generate power

The JRC pumped hydro database has identified lakes within a certain proximity of each other and a significant height difference, between which water could be exchanged to store or generate power. The JRC analysis has not investigated current existing or planned facilities but has solely focussed on the combination of lakes. The following types of lake combinations can be identified in the JRC pumped hydro database:

T1: This type of lake combination comprises two existing lakes within a certain proximity of each other with a significant height difference.

T2: This type of lake combination consists of an existing lake, and a lake that could be developed within a certain proximity of the existing lake, with a significant height difference.

To determine which combinations of lakes allow the development of future pumped hydro energy storage facilities, it is critical to know if at a combination of lakes already an existing pumped hydro facility is present. Therefore, the pumped hydro facilities in the DOE database have been linked to lake combinations in the JRC database. This way, we identified which lakes are already in use, and thus are not available for potential future development.

The assigning of facilities to lake combinations has been done by:

1. First, identifying pumped hydro facilities (DOE) and lake combinations (JRC, T1 and/or T2 type combination) which are in the proximity of each other (within 0.2 degrees latitude, and 0.2 degrees longitude, corresponding to approximately 15 km);
2. Secondly, when a match has been found between the two databases, the following aspects are taken into account when deciding on whether a lake combination and facility are connected:
   a) Based on the facility description; For some PHS facilities in the DOE database, names of connected lake(s) are mentioned in the site specifications, based on which the facility can be linked to a JRC lake combination.
   b) Based on distance; Based on the geographical coordinates of both the DOE facility and the JRC lake combination, we assess if each lake combination in the JRC database could be connected to a specific facility.
      i. In case of multiple identified lake combinations, consisting of both T1 and T2 lake combinations with the same name, the T1 lake combination will be matched since this entry consists of two existing lakes.
      ii. If only a T2 lake combination can be found which is likely to correspond to the DOE facility, the T2 lake combination is matched to the facility.

Limitations

The JRC pumped hydro database covers a large number of potential reservoirs for pumped hydro energy storage, however, data limitations exist.

The ESTMAP database covers both open- and closed-loop pumped hydro facilities. Since open-loop facilities don't require connection to a combination of multiple lakes and the JRC database only covers combinations of multiple (potential) lakes, not all lakes where open-loop facilities operate are covered in the JRC database. Also, some open-loop pumped hydro facilities operate at lakes that are included in the T2 JRC dataset in combination with a lake that has to be developed. In this case, the facilities have been linked to this T2 type lake combination.

Furthermore, the accuracy of coupling of PHS facilities to reservoirs is highly dependent on the geographical location data of both the reservoirs and the facilities. Since the facilities are linked to the closest reservoir within a plausible maximum distance in case there is no clear similarity in the name of the reservoir and the facility, lack of precision in location data could lead to assignment of facilities to other reservoirs than the one where they actually operate.

5.2.4. Quality control

To ensure high quality of the above-ground data in the ESTMAP database, a range of quality control measures were applied.

Firstly, all queries that were used to clean up and merge the source databases have been thoroughly checked by a database expert, to confirm that each query does exactly what is stated in the reporting.

Next to that, spot checks were carried out on data in the resulting database. For each technology and data source, entries in the database were compared to the original data source, to verify if the raw data was correctly adopted in the ESTMAP database. Additionally to random spot checks, outliers in the ESTMAP database, e.g. in storage volume or output capacity, were also to the original data.

Note that quality of source data has not been verified at an entry level. Potential errors in source databases could be included in the ESTMAP database.

6. Data collection results

6.1. Introduction

This chapter presents and briefly reviews the storage information collected in the ESTMAP database. The last paragraph includes a discussion on the overall data content, quality and completeness, and future recommendations for improving, completing and extending energy storage data in ESTMAP.

All maps and statistics in this chapter are oriented at a pan-European scale. Report provides an in-depth review and discussion per country.

6.2. Storage reservoirs overview

6.2.1. General reservoir overview

Figure 6-2 shows the overall geographic distribution of the total of 4271 reservoir entries in the ESTMAP database across Europe. The contrasting high number of reservoir entries for some countries including Great-Britain, France, Italy, Turkey and to a lesser extend Norway, Czech Republic, Austria and Portugal are mainly related to the high number of lake reservoirs that have been included from the JRC databases [16]. The same reservoirs dominance is also visible in the chart in Figure 6-1 where ~ two-thirds of the defined reservoir are lakes. Although Germany is also characterized by a high number of reservoirs, the main contribution here is defined by subsurface reservoirs (Figure 6-3). The same is partly true for Czech Republic.

Figure 6-7 to Figure 6-14 show how the various types of reservoirs are distributed over the different countries. In particular aquifers and hydrocarbon reservoirs have broad distribution across Europe. Pumped hydro lakes are mainly restricted to regions with high surface relief. The other reservoir types are mostly bound to specific countries and regions. Details are discussed in Report ESTMAP-D3.05; Country storage data reviews.

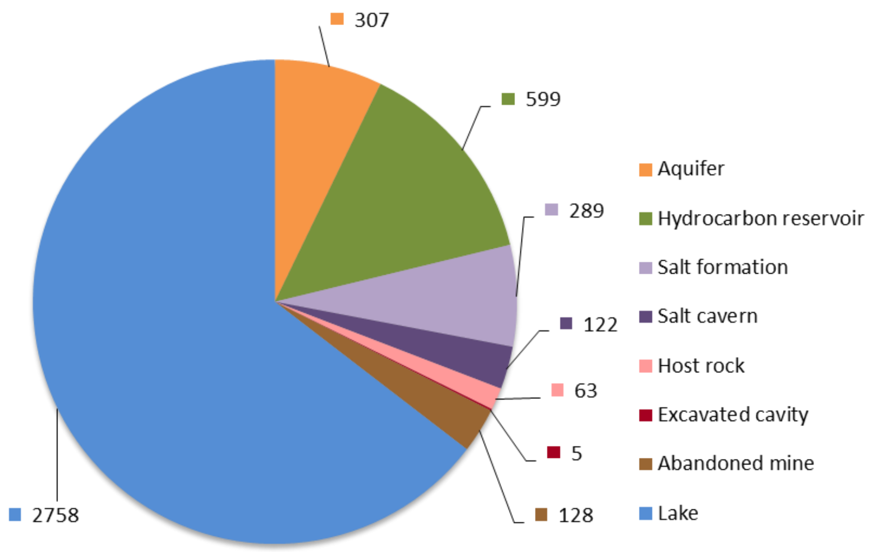

Figure 6-1: Total number of all energy storage reservoirs in ESTMAP, subdivided by main reservoir type.

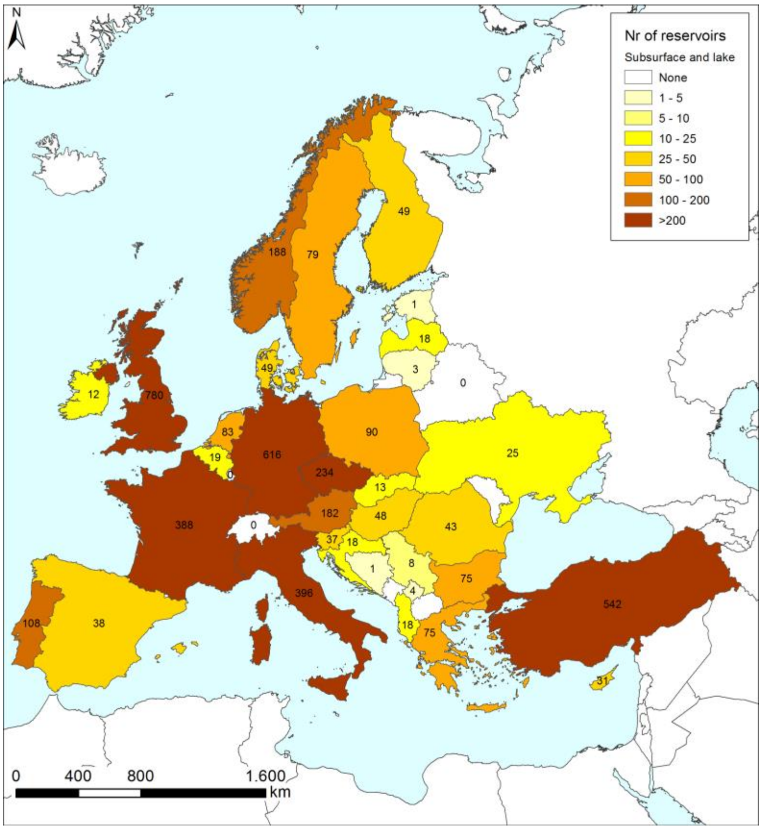

Figure 6-2: Distribution of subsurface and lake reservoirs, aggregated by country. Labels indicate the exact total number of reservoirs (subsurface and lake).

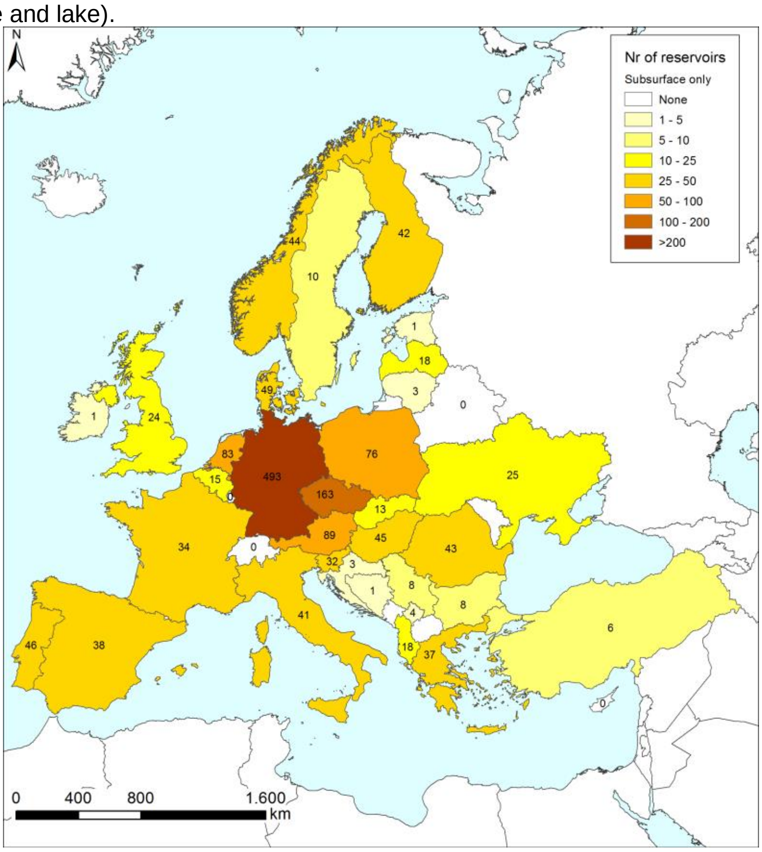

Figure 6-3: Distribution of subsurface reservoirs only, aggregated by country. Labels indicate the exact total number of subsurface reservoirs

6.2.2. Reservoir assessment and capacity

Figure 6-4 characterizes the overall level of assessment of each reservoir type. 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 assessment level. (e.g. with a total of 50 aquifers in the database and 10 of them being regionally defined, the bar will show a 20% share). The following assessment level categories are defined:

- **Local tested**: The reservoir is local defined (concrete site for development) and has been tested and considered proven for one or more storage technologies.
- **Local planned**: The reservoir is local defined (concrete site for development). One or more storage technologies are planned on this reservoir, but it is not unknown whether feasibility is fully confirmed yet.
- **Local evaluated**: The reservoir is local defined (concrete site for development). Feasibility for one or more technologies has been assessed but still remains unproven
- **Local indicative**: The reservoir is local defined (concrete site for development). Feasibility for one or more technologies is assumed and considered theoretically possible on the basis of quick scans or generic geological assumptions. There is no comprehensive assessment available (or known to the ESTMAP project) that has investigated the location-specific potential in further detail.
- **Regional tested**: The reservoir is regionally defined (without specific local defined sites for potential development). The reservoir is however successfully tested (proven development) for one of the storage technologies at one or more locations.
- **Regional planned**: The reservoir is regionally defined (without specific local defined sites for potential development). There are however known plans for development for one of the storage technologies at one or more locations. It is not unknown whether the feasibility is fully confirmed yet.
- **Regional indicative**: The reservoir is regionally defined (without specific local defined sites for potential development). Feasibility for one or more technologies is assumed and considered theoretically possible on the basis of quick scans or generic geological assumptions. There is no comprehensive assessment available (or known to the ESTMAP project) that has investigated the specific potential in further detail.

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.

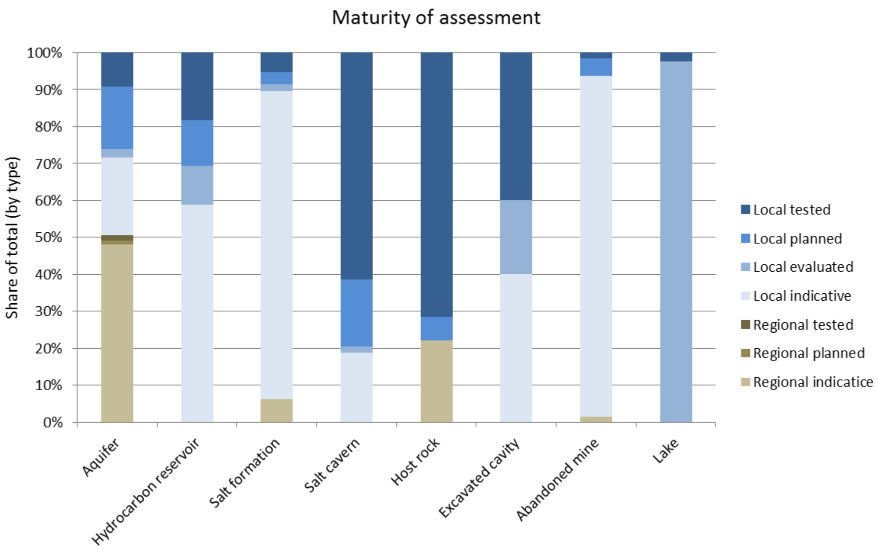

Figure 6-4: Maturity of assessment as interpreted for each reservoir category. Reported as a share of the total number of reservoirs per main reservoir type

Figure 6-5 summarizes the overall quality and level of capacity determination of each reservoir type. 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 regionally defined, the bar will show a 20% share). The following assessment level categories are defined:

- **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 (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 can only be roughly estimated from the total rock or pore volume. Many parameters are unknown or unconfirmed that could narrow down the uncertainty
- **Regional indicative**: Determination of local defined capacities is not possible. Reservoir parameters however do allow for estimation of gross rock or pore volumes (e.g. thickness x area).
- **None**: There are no indicative reservoir parameters available the can be used to estimate any volumes

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.

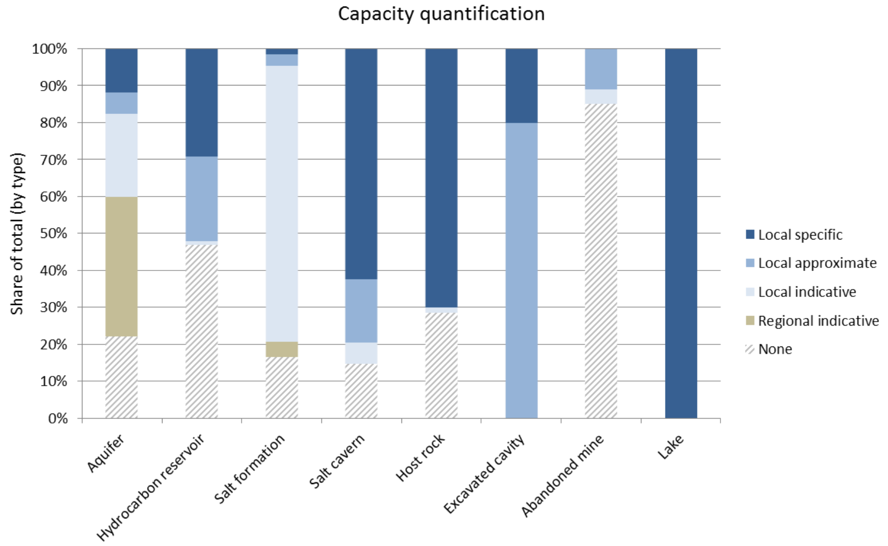

Figure 6-5: Quality of capacity determination for each reservoir category, as a share of the total number of reservoirs per main reservoir type

6.2.3. Technical feasibility

Figure 6-6 characterizes the feasibility for each 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**[5]: 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**[5]: 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).

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.

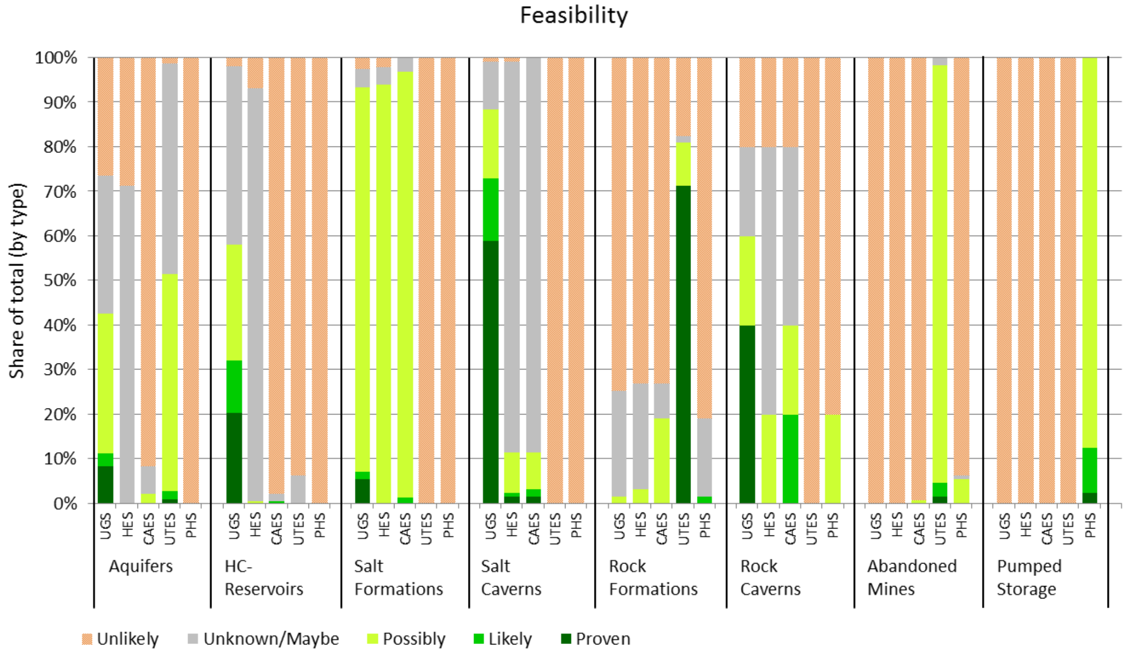

Figure 6-6: Determination of feasibility per reservoir type and technology, projected as a share of the total number of reservoirs for the given type (entire database).

6.2.4. Regional distribution of reservoir types

Pumped storage lakes are the most frequent reservoir type in the database (~ two thirds of the total dataset, Figure 6-1). The countries with most realisable potential sites (> 100, Figure 6-7) are UK, France, Germany, Norway, Italy Turkey, Spain and Switzerland (the latter two are not included in ESTMAP as data were not publicly available). All sites include estimated operational capacity indicators including lake volumes, elevation differences and energy storage capacities (Figure 6-5).

[5] 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”

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.) are not included (data is reported in JRC-2013, but not publicly available).

Aquifers are a common and widely distributed reservoir type across Europe (Figure 6-8). About half the sites in ESTMAP define site-specific potential (Figure 6-4). 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 6-5). The other half concerns regional formations without definitions of site-specific potential and capacities. Particularly in this case, capacity estimations are mostly lacking or specified to a very limited extent (area-thickness). These aquifers can be regarded as focus areas for further identification 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 6-6) with UTES as a second most occurring technology. Often HES and CAES are 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 6-9). The dominant storage technology is UGS (>30% is either developed or planned for development, Figure 6-6). HES is considered a good alternative but the suitability strongly relies on the sealing capacity (a major scope of investigation for this technology). Almost half of the sites has relatively good indications of capacity available (e.g. total or working gas volume, Figure 6-5). The other half is lacking capacity specifications which is possibly due to confidentiality issues.

Salt formations and associated **salt caverns** are in particular key targets for UGS, HES and CAES (Figure 6-6). The overall good suitability lies in the possibility to specifically engineer caverns for the storage purpose, the options for scaling 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. sufficient thickness of homogeneous salt quality limited depth range between ~300 – 2000m) that are less widely distributed across Europe. Especially in Germany there are many salt structures which have been identified after comprehensive regional mapping and assessment studies (Figure 6-10). UGS is the most commonly implemented technology (Figure 6-6). Database entries are mostly local defined and include in most cases good capacity indications (gas working volumes, cavern volumes, Figure 6-5). The regional defined formations still rely on further identification and confirmation of suitable sites.

Rock formations and **rock caverns** are a only sparsely defined as suitable options for energy storage across Europe (Figure 6-12 and Figure 6-13). 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. Especially Norway includes many rock formations which are used for UTES (Figure 6-6). Capacities are mostly well defined (thermal energy storage capacity, Figure 6-5). 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 primarily considered potential candidates in the Czech Republic and Finland (Figure 6-14). The overall level of assessment is still very pre-mature (suitability is theoretically assumed and to be confirmed by further subsurface assessment, Figure 6-4). Parameters for capacity estimation are mostly lacking (Figure 6-5). Mines are mainly considered for UTES development (two known existing operational sites in Europe, Figure 6-6).

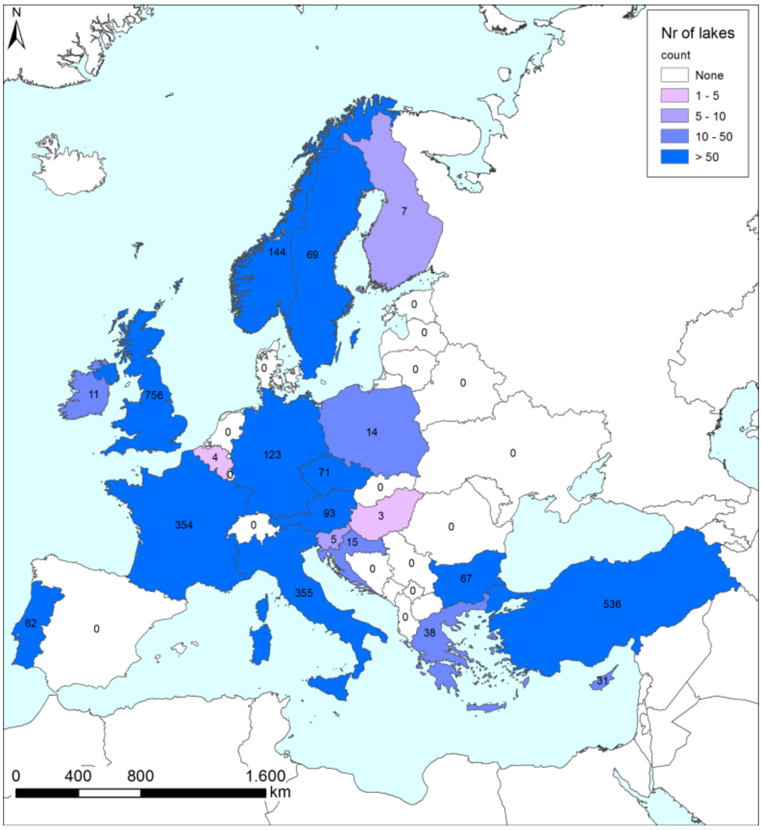

Figure 6-7: Number of above-ground lakes (for pumped hydro storage) per country, included in the ESTMAP database. Note that data for some countries (e.g. Spain, Switzerland) was not publicly available.

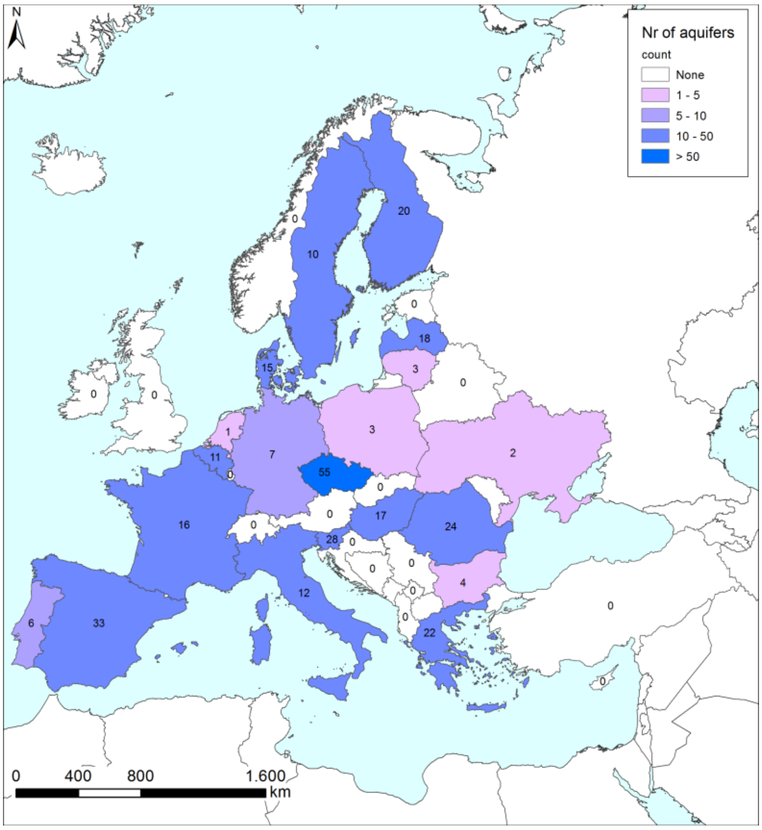

Figure 6-8: Number of subsurface aquifers per country, included in the ESTMAP database

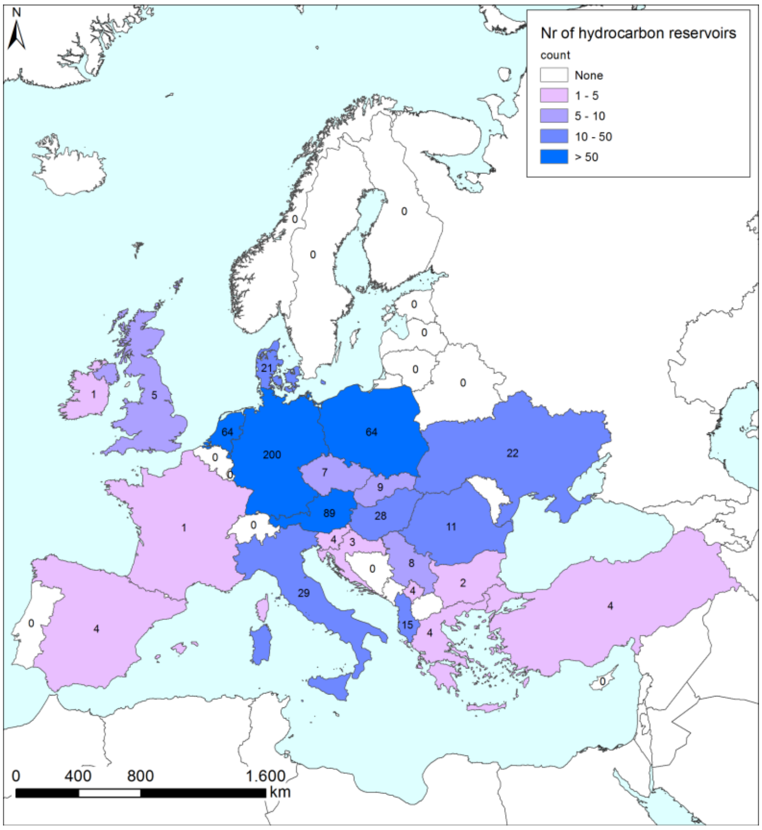

Figure 6-9: Number of subsurface hydrocarbon reservoirs per country, included in the ESTMAP database

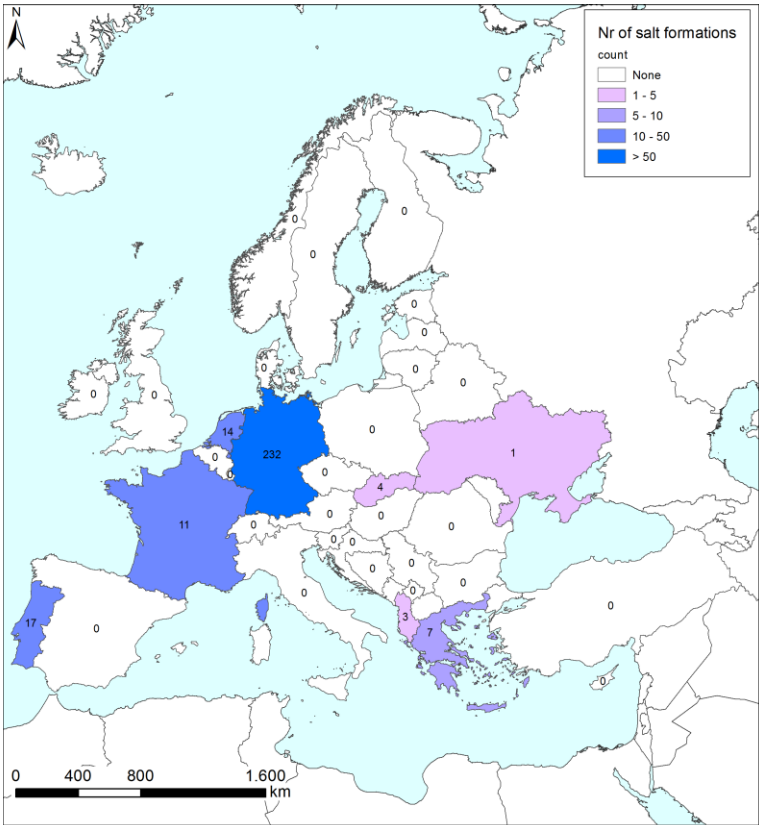

Figure 6-10: Number of subsurface salt formations per country, included in the ESTMAP database

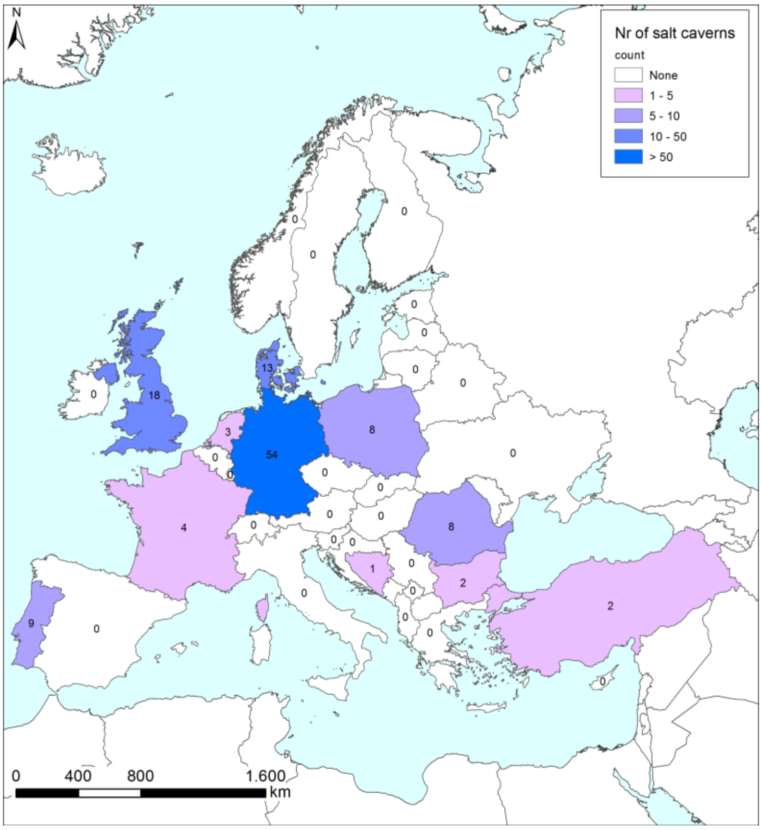

Figure 6-11: Number of subsurface salt caverns per country, included in the ESTMAP database

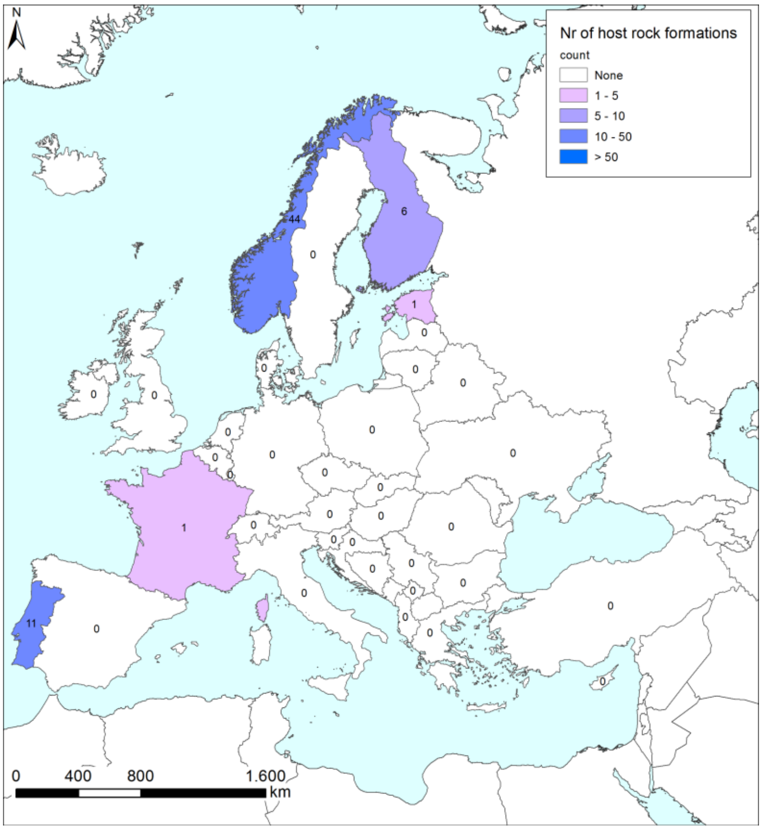

Figure 6-12: Number of subsurface host rock formations per country, included in the ESTMAP database

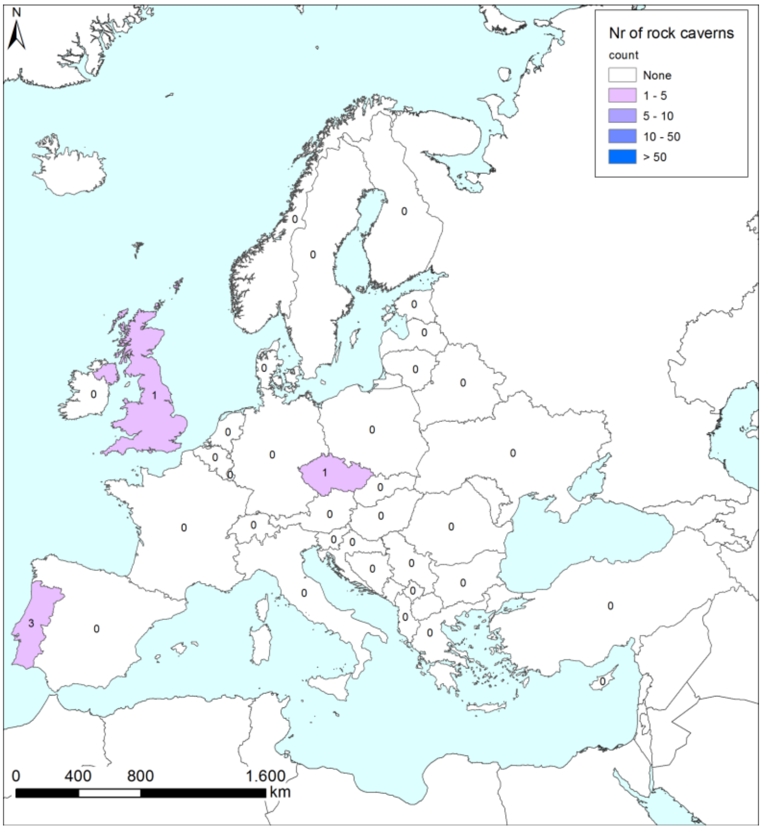

Figure 6-13: Number of subsurface rock caverns per country, included in the ESTMAP database

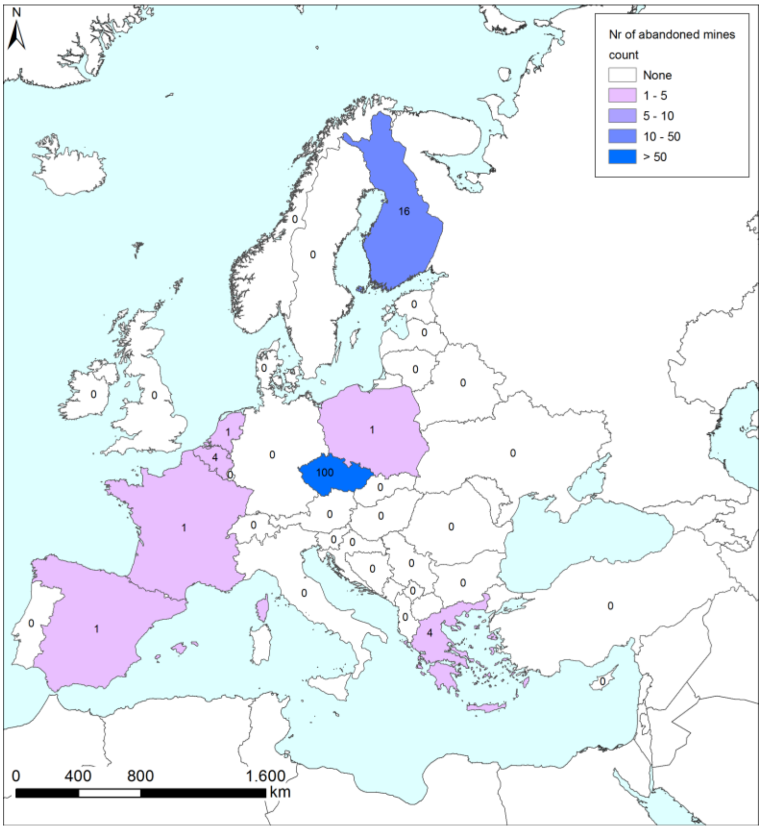

Figure 6-14: Number of subsurface abandoned mines per country, included in the ESTMAP database

6.2.5. Regional variations in reservoir characterization

The maps in Figure 6-15 to Figure 6-17 show how assessment maturity and quality of capacity determination for subsurface reservoirs are distributed across Europe. The legends in the maps represent the share of the total number of subsurface reservoirs.

From Figure 6-15 it is clear that in particular Ireland, UK, Norway, Estonia, Lithuania, Ukraine, Bulgaria, Croatia, Albania, Greece and Turkey have very low shares of future potential defined (i.e. most of the sites included in ESTMAP are either developed or planned for storage development). For these countries there is probably still much scope for extending information in ESTMAP.

Figure 6-16 shows that ESTMAP is mostly populated with location specific potential. Note that the regional potential in some countries covers a large share of the total country area (like for example in France, Hungary, Belgium and the Czech Republic, see Report **Error! Reference source not found.**). Particularly within the regional defined potential there is scope for site-specific research. Note that for many countries (especially those with sparse future potential defined), identification of regional potential may be an important first step towards extending the storage potential information in ESTMAP.

Figure 6-17 finally indicates that specific operational capacities (e.g. gas working volumes, energy storage capacity, thermal storage capacity) are comprehensively defined for a few countries only. Not surprisingly, these are the countries where mostly existing and planned sites are included. Especially this aspect requires significant efforts, e.g. by developing harmonized assessment methods and extending the critical parameter sets in ESTMAP.

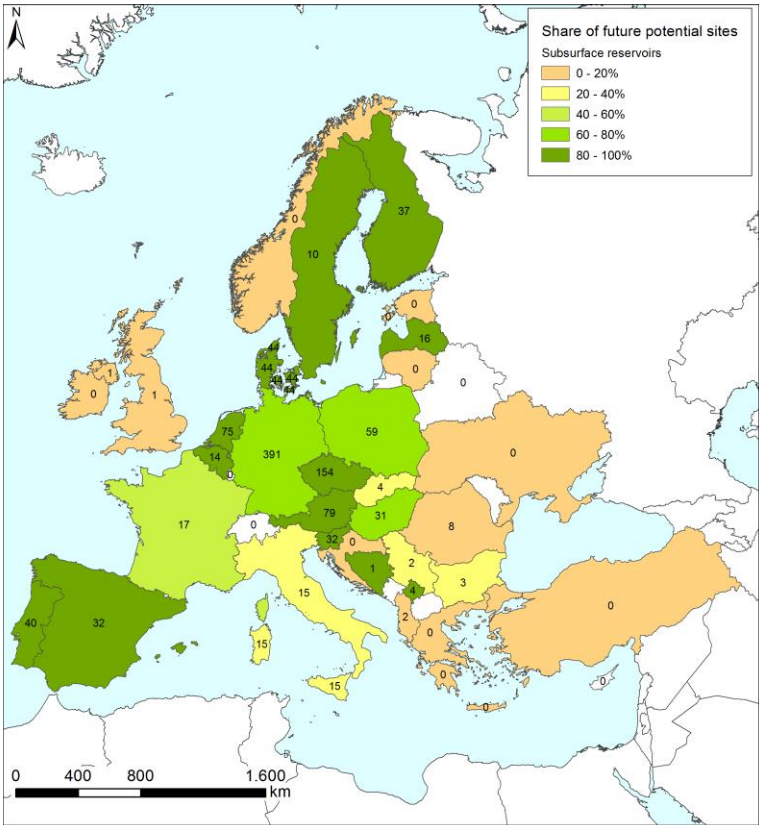

Figure 6-15: Share of total number of subsurface reservoirs representing future energy storage potential, aggregated by country. Labels indicate the exact number of reservoirs with future potential

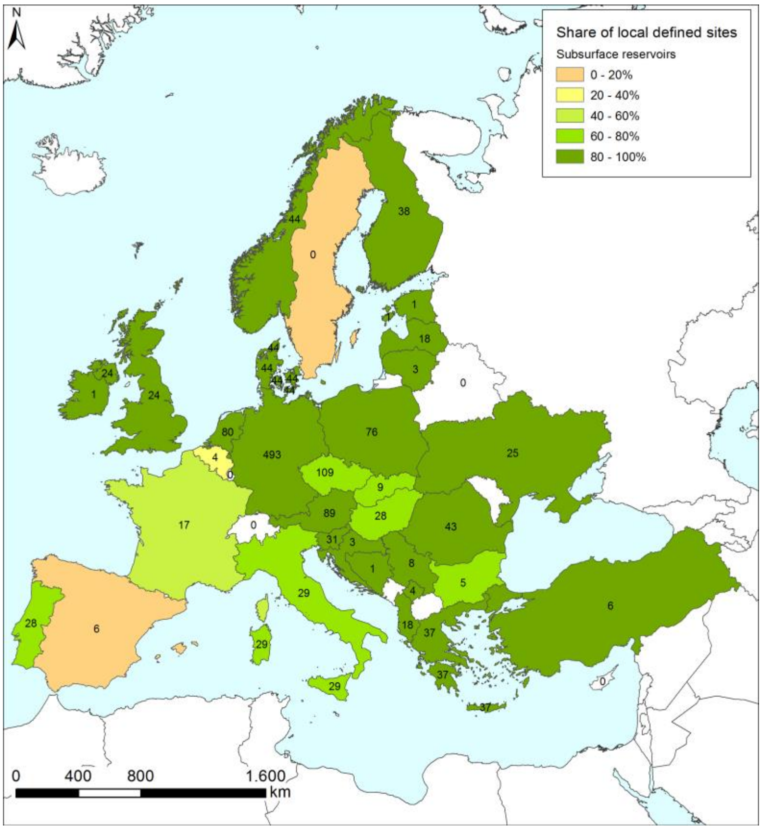

Figure 6-16: Share of total number of subsurface reservoirs representing local-defined storage potential, aggregated by country. Labels indicate the exact number of reservoirs with local-defined potential

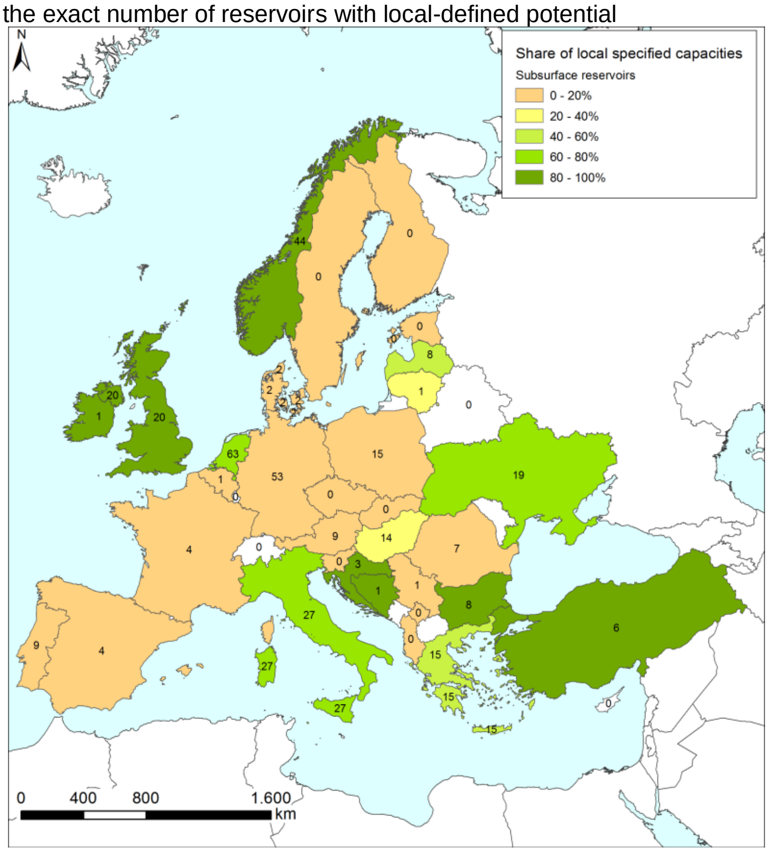

Figure 6-17: Share of total number of subsurface reservoirs with distinct storage capacity determination, aggregated by country. Labels indicate the exact number of reservoirs with distinct storage capacity

6.3. Energy storage facilities overview

Figure 6-18 and the maps in Figure 6-19 to Figure 6-21 show the overall geographic distribution of the total of 711 storage facility entries in the ESTMAP database across Europe. These facilities are either existing, planned or under construction. A minor part is reported offline. UGS facilities are a dominant category, with pumped hydro and batteries on second and third place. Especially UK, Germany, France and Italy have quite high numbers of subsurface developed energy storages online or planned.

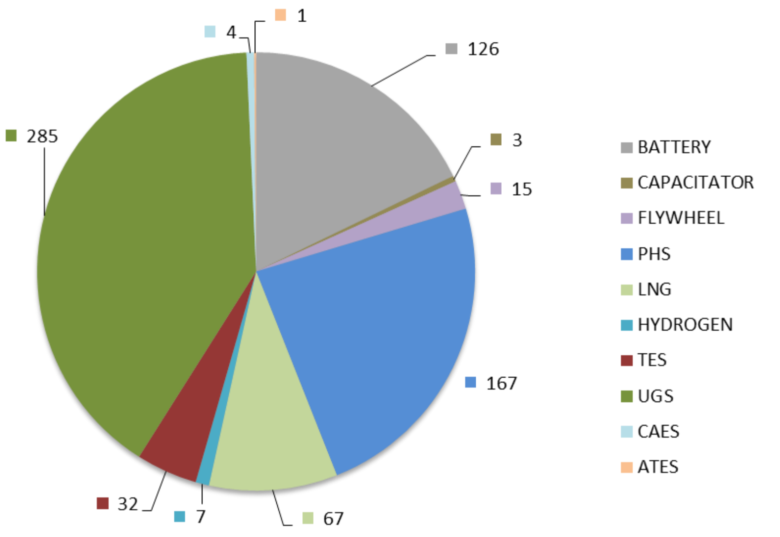

Figure 6-18: Total number of all energy storage facilities in ESTMAP, subdivided by technology type.

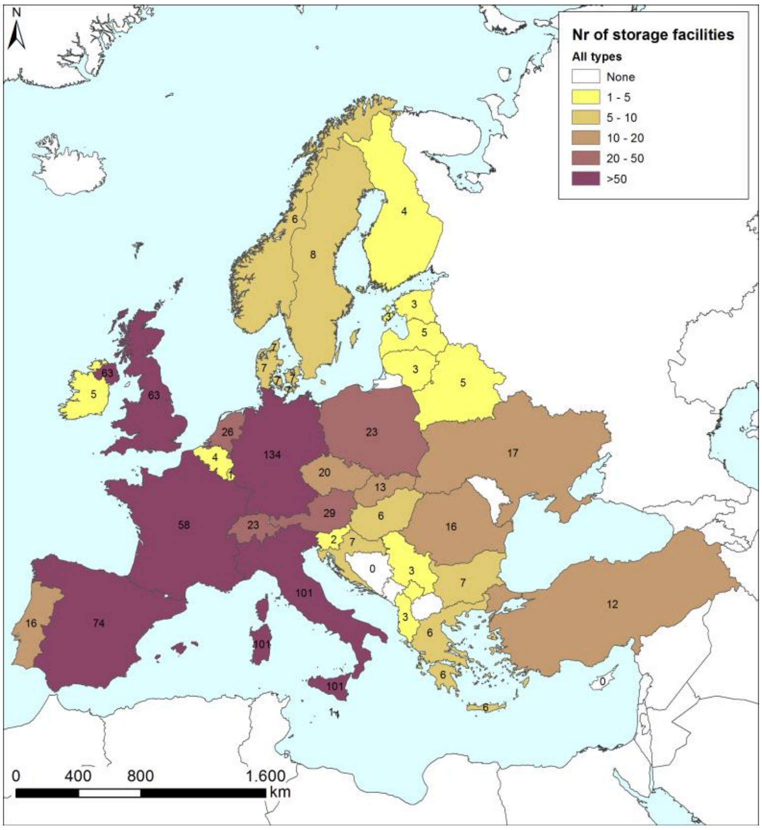

Figure 6-19: Distribution of all storage facilities, aggregated by country. Labels indicate the exact total number of storage facilities (all types).

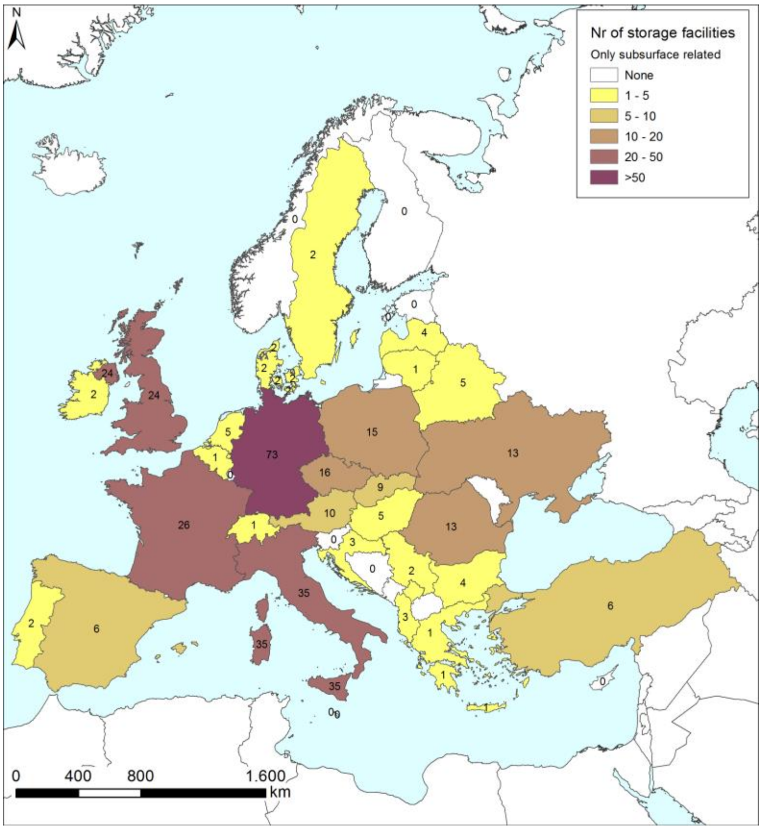

Figure 6-20: Distribution of subsurface related storage facilities, aggregated by country. Labels indicate the exact total number of subsurface related storage facilities.

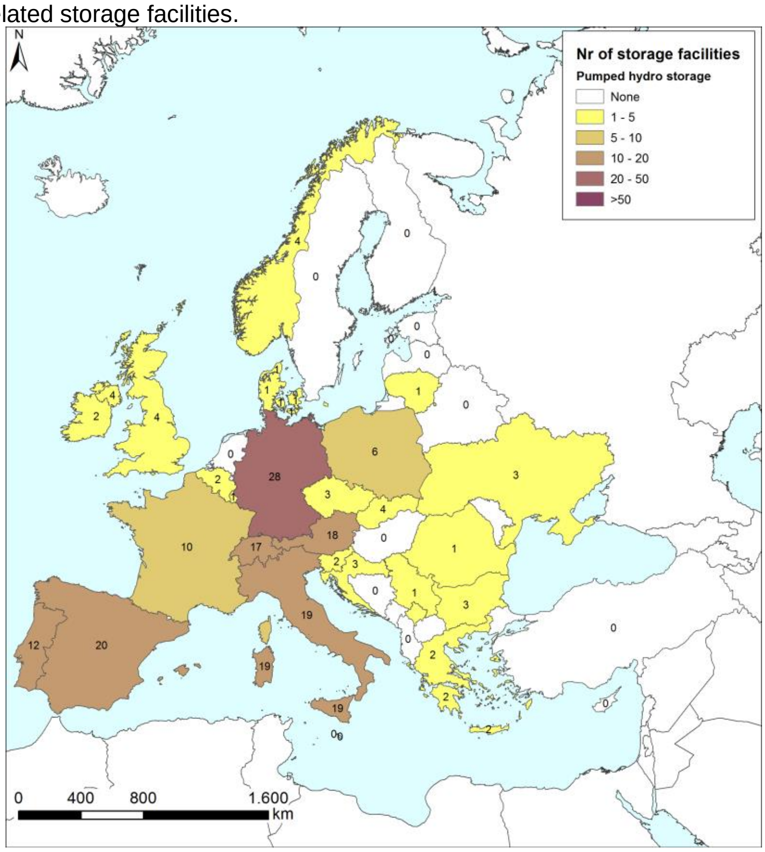

Figure 6-21: Distribution of pumped storage and hydro power facilities, aggregated by country. Labels indicate the exact total number of pumped storage and hydro power facilities.

6.4. Potential restrictions and conflicts

6.4.1. Natura 2000

A GIS analysis has been performed in order to determine potential overlaps with Natura-2000 areas. To this end the 2015 Natura-2000 area definitions were used [24]. Figure 6-23 shows the general outline of the energy storage reservoirs (dark grey) and the Natura-2000 areas (green). For each reservoir, the following classifications have been made:

- No overlap: No overlaps where determined on the basis of the Natura-2000 coverage
- Minor overlap: A reservoir has less than 20% overlap with Natura-2000 areas
- Moderate overlap: A reservoir has between 20% and 80% overlap with Natura-2000 areas
- Major overlap: A reservoir has >80% overlap with Natura-2000 areas
- Center overlap: The reservoir is defined as centre point location (no outline available). A Natura-2000 area is located within a 200m radius of the centre point location
- Overlap: Overlap has been identified by the data provider, but the extent is unspecified
- Unknown: No information regarding Natura-2000 areas was available

The graph in Figure 6-22 summarizes how these categories are defined for the reservoirs in the ESTMAP database

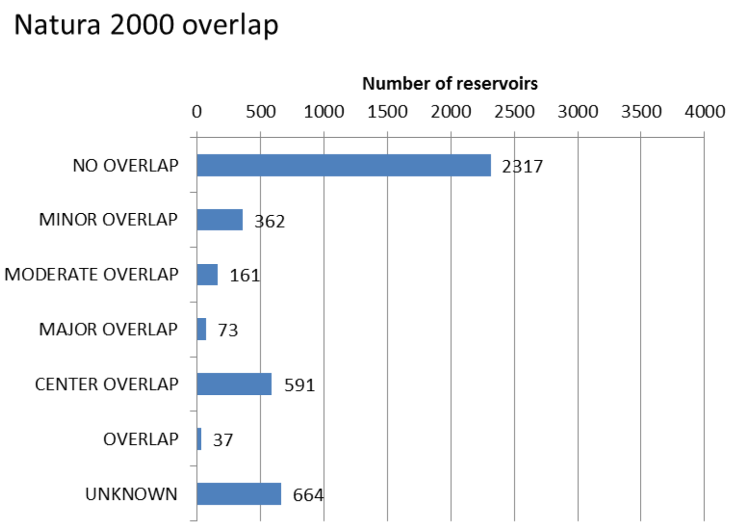

Figure 6-22: Evaluation of overlap between Natura-2000 areas (2015) and potential energy storage reservoirs.

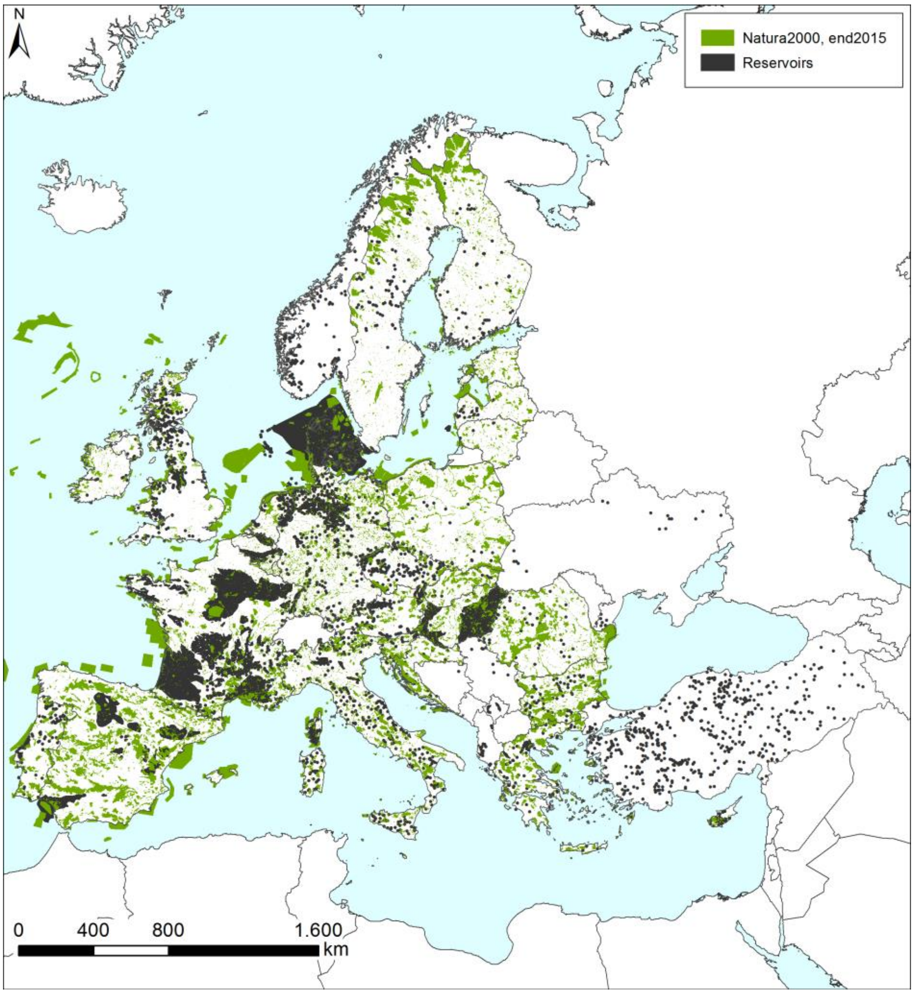

Figure 6-23: Overlay of Natura-2000 areas (end 2015) on potential energy storage reservoirs

6.4.2. CO_2 storage and other subsurface uses

Subsurface energy storage may interfere or compete with other subsurface functions. These functions may be related to production of resources or alternative storage. Figure 6-24 to Figure 6-26 summarize what is the current deployment of reservoirs in ESTMAP and what are the planned and potential future deployments identified. The sections below further discuss the potential conflicts for energy storage development.

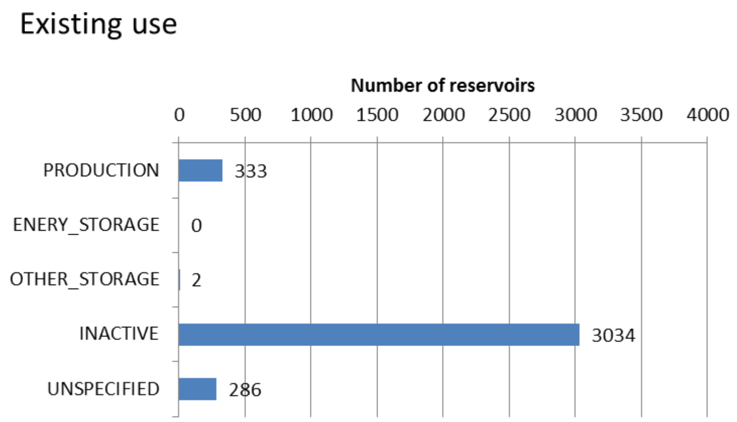

Figure 6-24: Number of reservoirs that are currently deployed for certain uses or that do not have any deployment ongoing.

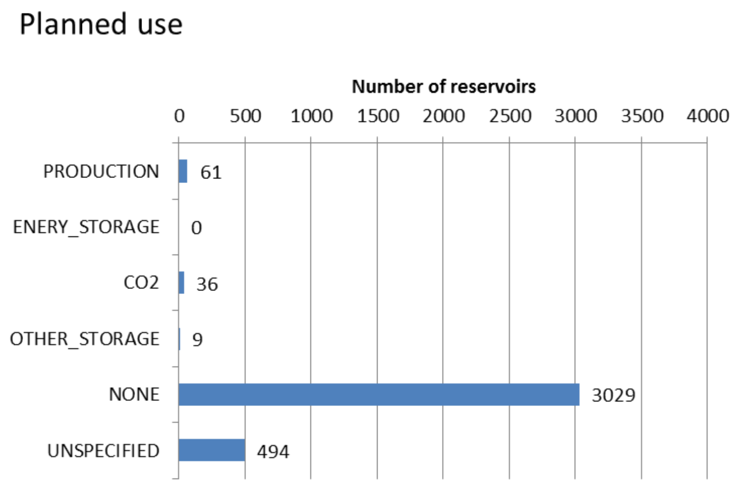

Figure 6-25: Number of reservoirs that are planned for certain uses or that do not have any plans for deployment.

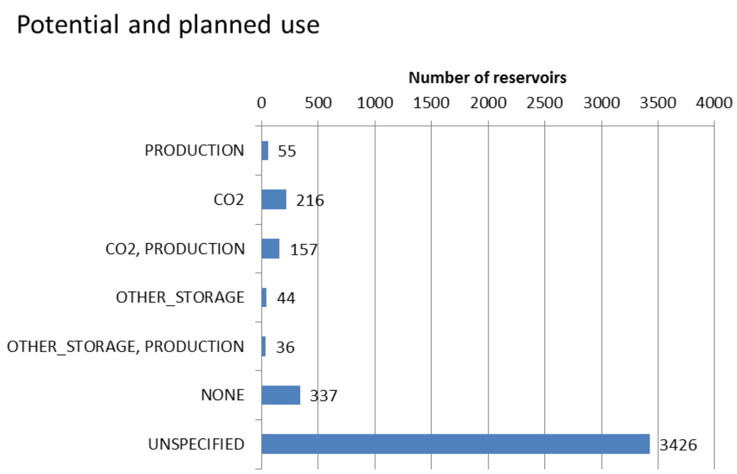

Figure 6-26: Number of reservoirs for which potential for other uses (including planned) has been identified.

CO_2 storage

Options for permanent subsurface sequestration of CO_2 have been investigated in various studies, including EU GeoCapacity [23] and CO2StoP [22]. Both aquifers as well as hydrocarbon reservoirs are typical candidates due to their large storage capacity and – at least for hydrocarbon reservoirs – the proven sealing capacity to contain fluids and gases over long geological time intervals. Salt caverns and rock caverns are mostly poor candidates because of the relatively limited storage volumes they can provide.

CO_2 storage is in direct competition with most energy storage functions in above reservoir types. Although they share common favourable conditions (e.g. high porosity and permeability, good sealing capacity), there are also some differences. For CO_2 the volume should preferably be as large as possible. For energy storage purposes this can be a negative aspect as the required amount of cushion gas (gas that is not included in the working volume but just serves to maintain sufficient pressure needed for operating the storage) is much higher.

Reservoirs that are deployed for CO_2 storage are in principle not available anymore for other subsurface. This is among other due to the permanent nature of CO_2 storage. One exception may be a new technology using CO_2 as a thermal energy carrier for UTES. This technology is still pre-mature however.

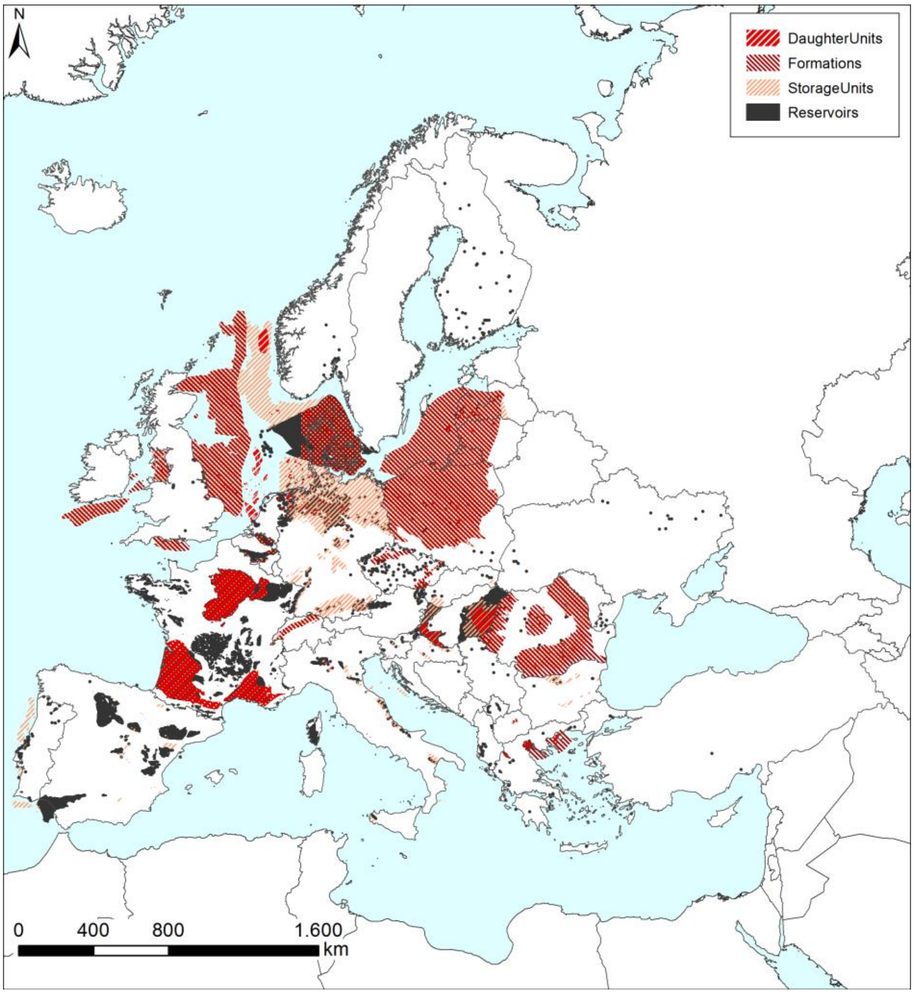

Figure 6-27: Potential energy storage reservoirs with an overlay of the traps and formations included in the CO2StoP database

Information regarding the potential for CO_2 sequestration has been included for most porous reservoirs. This information is either delivered by the data providers, or has been derived from the CO2StoP database. In the latter case the reservoirs in both the ESTMAP and CO2StoP database have been cross-linked. This has been done on the basis of the naming of the reservoir, the stratigraphic definitions and the overlap in geographic location. The identified cross-links have been reviewed by the data providers and adjusted where possible (note that not all providers were involved in the CO2StoP project, in which case they could not provide further information). The direct links to database entries in CO2StoP have been defined in ESTMAP. The map in Figure 6-27 shows an overlay of the potential CO_2 storage reservoirs on the ESTMAP reservoirs. Figure 6-25 and Figure 6-26 summarize the total amount of reservoirs in ESTMAP that are actually planned or found potentially suitable for CO_2 storage.

Conventional hydrocarbon production
In many cases the production of gas and oil are pre-requisites to developing an energy storage. The amount of gas or oil produced determines what volume is available for storage. In the case of natural gas storage, the reservoir does not necessarily have to be fully depleted. The amount of gas remaining after production will just be part of the storage (e.g. as cushion gas). For other forms of energy storage depletion may be necessary in order to prevent unwanted mixing of gases and fluids.

Unconventional hydrocarbon production
Shale gas and shale oil formations are in principle no candidates for energy storage functions as they lack the porous space needed to for storage. In specific cases there may be a conflict of use, for example when the shale layer defines a seal above the storage reservoir or when the drilling activities needed for shale gas and shale oil development hamper the operation of the energy storage site. So far the information to assess this interference is lacking or incomplete. An analysis of potential overlaps may be possible once the current European Unconventional Oil and Gas Assessment (EUOGA project [25]) has been finished and the results have been made available.

Salt production
Like hydrocarbon production, the production of salt is a pre-requisite to deploying energy storage functions in salt formations. At the time of salt production, it should preferably be known what type of energy storage function is envisioned in the resulting cavern, in order to ensure that the cavern is optimally designed for this function.

Geothermal production
For many energy storage functions a simultaneous development with geothermal production may be problematic. The nature and extent of the conflict or interference must be determined by site-specific investigations. Geothermal production sites could potentially be deployed as thermal storage once their production period has ended.

Other storage functions
Some sites are planned for brine storage, waste storage or buffering of other substances (e.g. Nitrogen). Each of these cases may potentially be in conflicts with future energy storage development. The nature and extent of the conflict or interference must be determined by site-specific investigations.

6.5. Conclusions

- 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[6] (PHS).

- Main contributing type of storage potential in the ESTMAP database is defined by hydro pumped storage lakes. The second most mentioned potential is UGS in hydrocarbon fields, aquifers and salt caverns.

- In general the distribution and types of storage reservoirs as well as the completeness of information on identified technologies and reservoirs in ESTMAP vary significantly across Europe. On the one hand this is due to the variable presence of natural conditions. On the other hand the still pre-mature status of energy storage assessment plays an important role here. Confidentiality is also influencing the extent to which capacities and technical parameters are defined in ESTMAP (public availability)

- Some key recommended actions to fill in major knowledge and information gaps are
  - Harmonizing and extending 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 elaborate sites that are primary targets for potential energy storage demonstration projects.

- ESTMAP strongly recommends to set up the appropriate procedures and means to maintain and regularly update the database with new contributions from third parties (industry) and national research. The overall results clearly show that there is scope for new data and upgrades in the coming years. Such updates will strengthen the position of the database as a one-stop location for obtaining actual information on energy storage.

- A better evaluation of various EU energy modelling results can be realized by stimulating the database to become a common agreed standard for such studies. Involvement from a broad user base will help in prioritizing and realizing the essential improvements required.

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Annex 1: Energy storage facility specifications

This Annex presents the detailed and updated specifications of the energy facilities that are related to both above-ground and subsurface storage technologies (originally reported in D3.01 and D3.02). The energy storage facilities are directly connected to the grid or to end-users and operate intake, output and conversion of the energy flows. For subsurface storage technologies the facilities are linked to subsurface reservoirs (described in Annex 2). For most above-ground technologies, the facility inherently integrates the means to store the energy and hence there is no link to a natural reservoir. Only for pumped hydro the facilities are linked to natural reservoir (i.e. lakes).

Figure A1-1 provides a simplified schematization of the different tables contained in the storage reservoir specification and the internal database relationships. Table A1-1 to Table A1-7 present all detailed specifications for each parameter.

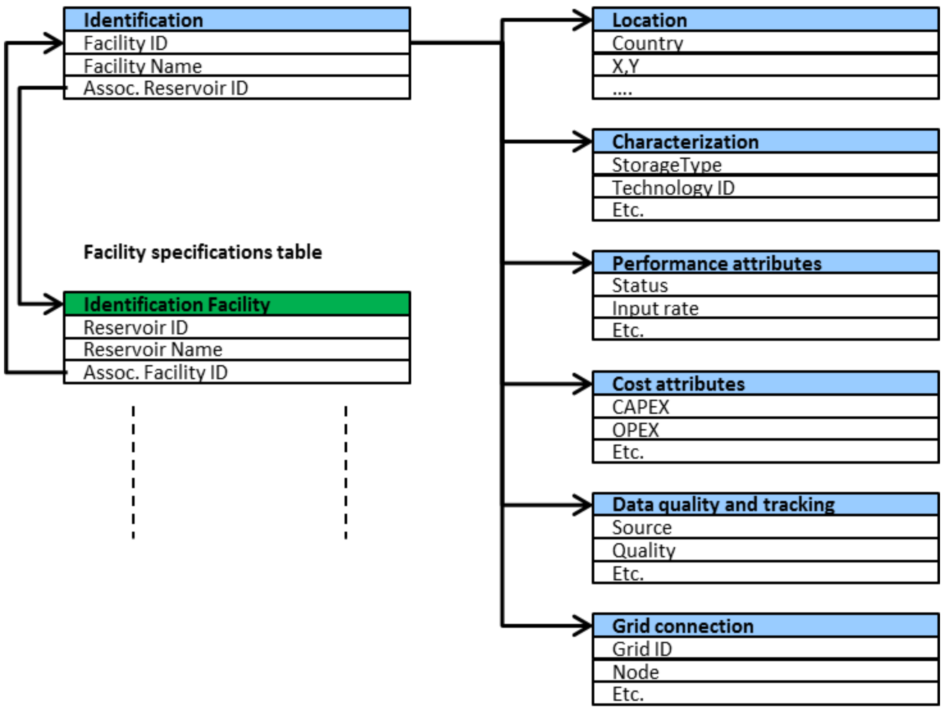

Figure A1-1: Schematic overview of the storage facility specification data tables and their relationships.

Facility identification

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Facility ID	ID	Single	text		Essential-DB
Facility Name	Name	Single	text		Essential-DB
Primary Reservoir ID	Name	Single	text		Optional
Secondary Reservoir ID	Name	Single	text		Optional

Table A1-1: Storage facility specifications: Identification

Facility ID: Unique (alpha-numeric) database identifier that will be assigned to each (existing) facility. This ID is not directly related to the name or identification of the data provider or source.

Facility Name: Name of the facility as defined by the data provider or source.

Primary Reservoir ID: This is a link to the main reservoir that is associated with this facility (in case applicable). The Reservoir ID is defined in the Reservoir Specification (Chapter 4.3). This value is set to "*Null*" if the facility cannot be coupled with a natural reservoir (i.e. it does not rely on an above-ground or subsurface reservoir for storage).

Secondary Reservoir ID: This is an optional link to a secondary reservoir that is associated with this facility (such as is the case for pumped hydro with two lake reservoirs). The Reservoir ID is defined in the Reservoir Specification (Chapter 4.3). This value is set to "*Null*" if the facility cannot be coupled with a natural reservoir (i.e. it does not rely on an above-ground or subsurface reservoir for storage) or if no secondary reservoir exists.

Storage facility characterization

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Energy carrier inbound	electricity, heat, gas, oil, coal	Single	text		Essential-DB
Energy carrier outbound	electricity, heat, gas, oil, coal	Single	text		Essential-DB
Storage type category 1	Mechanical, thermal, electro-chemical, gravitational potential energy, etc	list	text		Essential-DB
Storage type category 2	e.g. flywheel, battery type, pumped hydro etc	list	text		Essential-DB
Service type	Strategic reserves, load balancing, frequency and voltage control, time shifting, uninterrupted power supply, renewable integration, seasonal storage etc	list	text		Optional

Table A1-2: Storage facility specifications: Characterization

Energy carrier inbound: Describes energy carrier received and stored by the facility. Valid entries are:

- *Electricity*
- *Heat*
- *Gas*
- *Oil*
- *Coal*

Energy carrier outbound: Describes energy carrier exiting the facility (after conversion). Valid entries are:

- *Electricity*
- *Heat*
- *Gas*
- *Oil*
- *Coal*

Storage type category 1: Describes the form of energy in which energy is stored.

- *Natural gas storage*
- *Hydrogen storage*
- *Compressed air energy storage*
- *Liquid air energy storage*
- *Thermal storage*
- *Pumped hydro storage*
- *Batteries*
- *Fly wheels*
- *Super conductor*
- *…*

Storage type category 2: Describes type of energy storage concept, i.e. the specific technology concept.

Service type: Describes type of energy storage service for this specific facility. Note that a facility can serve various purposes.

Storage facility location

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Country	-	List	text		Optional
State/province	-	Single	text		Optional
City	-	Single	text		Optional
Operator	-	Single	text		Optional
Latitude	coordinate	Single	number; real		Essential-DB
Longitude	coordinate	Single	number; real		Essential-DB
Site specification	-	Single	text		Optional
Node	ID	Single	text or number		Optional

Table A1-3: Storage facility specifications: Location

Country: The country in which the facility is located. Defined as short name in English (geographical name), see http://publications.europa.eu/code/en/en-370100.htm.

State/Province: Name of the state or province in which the facility is located. If not available, this value is set to "*Null*".

City: Name of the city or municipality where the facility is located. If not available, this value is set to "*Null*".

Operator: Operator of the energy storage facility. If not available, this value is set to "*Null*".

Latitude: X-coordinate of the facility according to the ETRS-89 coordinate system

Longitude: Y-coordinate of the facility according to the ETRS-89 coordinate system

Site specification: Free text entry for site specificity.

Node: Node name in energy transport grid to which facility is coupled. If not available, this value is set to "*Null*".

Storage facility performance attributes

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Status	Prospect; Announced; Contracted; Operational; De-commissioned; Offline / repair; Under construction	List	text	Unknown	Essential-AN
Maximum intake capacity	MW (Mwe or MWth)	Single	number; real		Essential-AN
Minimum intake capacity	MW (Mwe or MWth)	Single	number; real		Optional
Maximum production capacity	MW (Mwe or MWth)	Single	number; real		Essential-AN
Minimum production capacity	MW (Mwe or MWth)	Single	number; real		Optional
Cycle efficiency storage	MWh in/MWh out	Range	number; integer		Essential-AN
Cycle efficiency influx	MWh in/MWh out	Range	number; integer		Optional
Cycle efficiency outlfux	MWh in/MWh out	Range	number; integer		Optional
Maximum annual cycle production volumes	n	Range	number; integer		Optional
Working volume	MWh	Range	number; real		Essential-AN
Exogenous charging	MWh/year	Range	number; real		Optional
Exogenous loss	MWh/year	Range	number; real		Optional
Duration	HH:MM	Single	number; time		Optional
Ramp up rate	% of max capacity per minute	Range	number; %		Optional
Ramp down rate	% of max capacity per minute	Range	number; %		Optional
Annual availability	hours	Range	number; integer		Optional
Required online time	hours	Range	number; integer		Optional
Required offline time	hours	Range	number; integer		Optional
Construction time of new facility	years	Range	number; integer		Optional
Technical life of the storage facility	years	Range	number; integer		Essential-AN
Technical life of the storage influx equipment	years	Range	number; integer		Optional
Technical life of the storage outflux equipment	years	Range	number; integer		Optional
Availability of the storage facility in terms of fraction of nominal capacity.	%	Range	number; %		Optional
Date in service	year	Single	Number:date		Optional
Date out of service	year	Single	Number:date		Optional

Table A1-4: Storage facility specifications: Performance attributes

Status: Defines the operational status of the facility. Valid entries are:

- *Prospect*: Facilities for which no development plans exist. Prospects may be defined by data providers but this category is mostly reserved for indicating hypothetical future facilities determined by ESTMAP. These facilities are defined and parameterized by undeveloped reservoir potential (reservoir specifications) in combination with the technology specifications (see also Chapter 0). The facilities and parameters are still considered speculative and uncertain.
- *Announced*: Facilities for which the technical outlines and development are known. Development is contingent. Parameters are contingent and based on information from data providers and other sources.
- *Contracted*: Facilities for which the technical outlines and development are known. Decision for development is firm and contracted. Parameters are firm and based on information from data providers and other sources.
- *Under construction*: Facilities for which the technical outlines and development are known. Development is in progress. Parameters are firm and based on information from data providers and other sources.
- *Operational*: Facilities that are currently operational. Parameters are proven by operation and based on information from data providers and other sources.
- *Offline*: Facilities that are temporarily out of production, e,g, due to repair activities. Parameters are proven by operation and based on information from data providers and other sources.
- *De-commissioned*: Facilities that are out of production and (being) de-commissioned. Parameters (if relevant) are based on information from data providers and other sources.
- *Unknown*: Information on the status is unavailable or restricted.

Maximum intake capacity: Upper limit to energy entering the storage facility in MW (MW_e in case of electricity and MW_{th} in case of other carrier)

Minimum intake capacity: Lower limit to energy entering the storage facility in MW (MW_e in case of electricity and MW_{th} in case of other carrier)

Maximum production capacity: Upper limit to energy leaving the storage facility in MW (MW_e in case of electricity and MW_{th} in case of other carrier)

Minimum production capacity: Lower limit to energy leaving the storage facility in MW (MW_e in case of electricity and MW_{th} in case of other carrier)

Cycle efficiency Storage: Round-trip storage efficiency. For storage technology this defines the storage loading and unloading efficiency.

Cycle efficiency Influx: For storage technology this defines the storage loading efficiency.

Cycle efficiency Outflux: For storage technology this defines the storage unloading efficiency.

Maximum annual cycle production volumes: Maximum amount of intake and production cycles per year.

Working volume: Maximum usable storage capacity expressed in energy content.

Exogenous charging: Exogenous charging of a storage facility in MWh per time period.

Exogenous loss: Exogenous loss of a storage facility in MWh per time period.

Duration: Duration of delivering energy at rated capacity.

Ramp up rate: upward ramping restriction when online (% of maximum generation).

Ramp down rate: Downward ramping restriction when online (% of maximum generation).

Annual availability: Number of hours available per year.

Required online time: required online time (does not include start-up period)

Required offline time: required offline time (does not include shut down period)

Construction time of new facility: The number of years it takes to get the facility up and running after investment has started.

Technical life of the storage facility: The number of years that the facility can be used without the need for reinvestment in capital goods.

Technical life of the storage influx equipment: The number of years that the facility influx equipment can be used without the need for reinvestment in capital goods.

Technical life of the storage outflux equipment: The number of years that the facility outflux equipment can be used without the need for reinvestment in capital goods.

Availability of the storage facility in terms of fraction of nominal capacity: If the basis could contain 100 MW worth of water but can only be depleted to a minimum water level worth 10 MW of water, then the availability would be 0.9. For gas storages this is defined by the working gas / total gas ratio.

Date in service: Date of coming online.

Date out of service: Date of de-commissioning.

Storage facility cost attributes

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Capital costs storage	Eur/MWh	Range	number; real		Essential-AN
Capital costs influx	Eur/MW	Range	number; real		Optional
Capital costs outflux	Eur/MW	Range	number; real		Optional
Decommissioning costs	Eur/MWh	Range	number; real		Optional
Fixed operation and maintenance cost storage	Eur/MWh/year	Range	number; real		Optional
Fixed operation and maintenance cost influx	Eur/MW/year	Range	number; real		Optional
Fixed operation and maintenance cost outlfux	Eur/MW/year	Range	number; real		Optional
Variable operation and maintenance cost storage	Eur/MWh or Eur/n	Range	number; real		Essential-AN
Variable operation and maintenance cost influx	Eur/MWh or Eur/n	Range	number; real		Essential-AN
Variable operation and maintenance cost outflux	Eur/MWh or Eur/n	Range	number; real		Essential-AN
Start-up costs	Eur/n	Range	number; real		Essential-AN
Shutdown costs	Eur/n	Range	number; real		Essential-AN
Total intake costs	Eur/MWh	Range	number; real		Optional
Total production costs	Eur/MWh	Range	number; real		Optional
Subsidy	Eur/MWh	Range	number; real		Optional

Table A1-5: Storage facility specifications: Cost attributes

Capital Costs Storage: Lump sum capital expenditure for the entire storage facility in euro per MWh of energy that can be stored.

Capital Costs Influx: Lump sum capital expenditure for the intake equipment in euro per MWh of energy that can be stored.

Capital Costs Outflux: Lump sum capital expenditure for the output equipment in euro per MWh of energy that can be stored.

Decommissioning costs: Cost of decommissioning the storage facility in euro per MW that can be stored.

Fixed Operation and Maintenance Cost Storage: Fixed yearly operating cost for exploitation of the entire storage facility in euro per MWh per year that can be stored.

Fixed Operation and Maintenance Cost Influx: Fixed yearly operating cost related to exploitation of intake in euro per MW per year that can be stored.

Fixed Operation and Maintenance Cost Outflux: Fixed yearly operating cost related to exploitation of output in euro per MW per year that can be stored.

Variable Operation and Maintenance Cost Storage: Overall variable facility cost per unit of energy stored in euro per MWh per n stored. The cost is expressed per time unit as chosen (yearly, seasonal or day-night)

Variable Operation and Maintenance Cost Influx: Variable cost per unit of energy stored in euro per MWh per n stored related to intake. The cost is expressed per time unit as chosen (yearly, seasonal or day-night)

Variable Operation and Maintenance Cost Outflux: Variable cost per unit of energy stored in euro per MWh per n stored related to output. The cost is expressed per time unit as chosen (yearly, seasonal or day-night)

Start-up costs: Costs for going online once

Shutdown costs: Costs for going offline once

Total intake costs: Sum of total intake costs (including CAPEX, FOPEX, VOPEX). Use this value if detailed estimates are not available

Total production costs: Sum of total production costs (including CAPEX, FOPEX, VOPEX). Use this value if detailed estimates are not available

Subsidy: Technology specific subsidy per generated MWh, "*Null*" if not present

Data quality and tracking

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Data source	-	Single	text		Essential-DB
Data quality label	-	Single	text		Essential-DB
Comment	-	Single	text		Optional
Date created	day:month:year	Single	Number:date		Essential-DB
Date last changed	day:month:year	Single	Number:date		Essential-DB

Table A1-6: Storage facility specifications: Data quality and tracking

Data Source: Specify the data source for this entry.

Data Quality Label: Expert estimate of data quality (see Section **Error! Reference source not found.** for details).

Comment: Free entry for data preparation and quality comments.

Date Created: Date of first record entry.

Date Last Changed: Date of last change.

Grid connection

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Grid ID	ID	Single	text or number		Optional
Categorisation of Grid	electricity; heat; gas; oil; coal	Single	text		Optional
Grid Interconnection	Transmission; Primary distribution, Secondary distribution	Single	text		Optional
Latitude	coordinate	Single	number; real		Optional
Longitude	coordinate	Single	number; real		Optional

Table A1-7: Storage facility specifications: Grid connection

Grid ID: ID of grid coupling if present.

Categorisation of Grid: Type of grid at which energy facility is coupled. The following entries are valid:

- *Electricity*
- *Heat*
- *Gas*
- *Oil*
- *Coal*

Grid Interconnection: Type of grid connection (in case of electricity)

Latitude: X-coordinate of grid node according to the ETRS-89 coordinate system

Longitude: Y-coordinate of the grid node according to the ETRS-89 coordinate system

Annex 2: Storage reservoir specifications

This annex describes the detailed specifications of natural and geographically bounded **subsurface** as well as **above-ground** (pumped hydro) energy storage reservoirs. These reservoirs may either already be connected to existing energy storage facilities or represent future potential for connection to new facilities.

For each storage reservoir the specifications describe some general attributes like reservoir type, location, current development, domain, etc. The typical geological or topographical properties related to feasibility, capacity and performance of each type of reservoir (e.g. salt caverns, aquifers, lakes) are further detailed in separate tables.

The major part of the energy storage reservoirs specified here are located in the subsurface. For the above surface only pumped hydro lakes are included. The following sections describe the main categories of parameters included and the definitions for each of the data entries.

Figure A2-1 provides a simplified schematization of the different tables contained in the storage reservoir specification and the internal database relationships. Table A2-1 to Table A2-16 present all detailed specifications for each parameter.

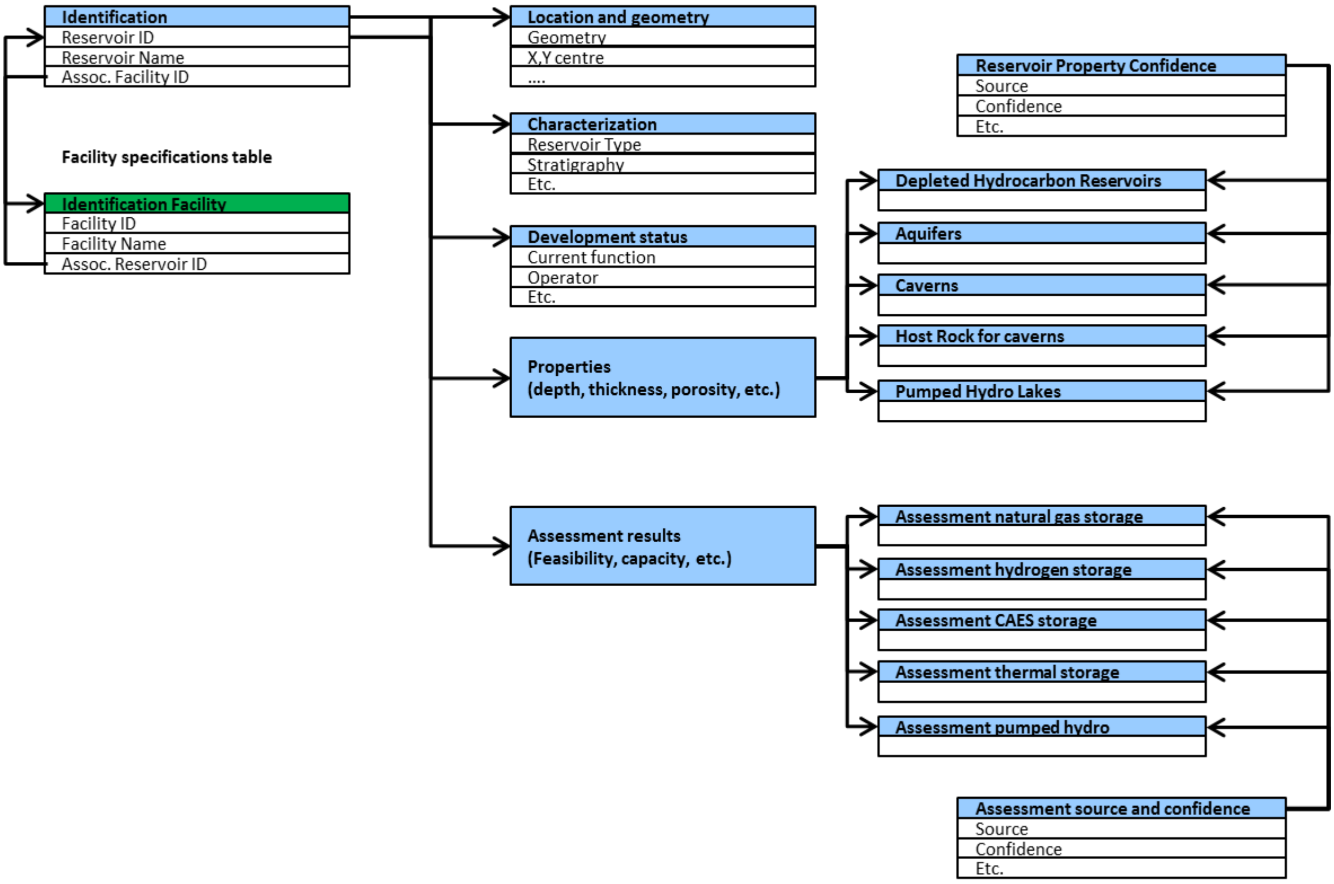

Figure A2-1: Schematic overview of the reservoir specification data tables and their relationships.

Reservoir Identification

Attribute	Unit / Entry	Single, Range, List	Format	Default value	Essential / Optional
Object ID	ID	Single	Text or Number		Essential-DB
Object Name	name	Single	Text	Null	Essential-DB
Sub code 1	ID	Single	Text or Number		Optional
Sub name 1	name	Single	Text	Null	Optional
Sub code 2	ID	Single	Text or Number		Optional
Sub name 2	name	Single	Text	Null	Optional
Parent ID	ID	Single	Text or Number	Null	Optional
Facility ID	ID	Single	Text or Number	Null	Optional

Table A2-1: Reservoir specifications: Identification

Object ID: Unique (alpha-numeric) database identifier that will be assigned to each reservoir or feature. This ID is not directly related to the name or identification of the data provider or source.

Object Name: Name of the reservoir or feature as defined by the data provider or source.

Sub Code1: Additional unique (alpha-numeric) database identifier for first sub-reservoir in case the reservoir definition consists of two sub-reservoirs (as is the case with Pumped Hydro Storage

Sub Code2: Additional unique (alpha-numeric) database identifier for second sub-reservoir in case the reservoir definition consists of two sub-reservoirs (as is the case with Pumped Hydro Storage

Sub Name1: Additional Name for first sub-reservoir in case the reservoir definition consists of two sub-reservoirs (as is the case with Pumped Hydro Storage

Sub Name2: Additional Name for second sub-reservoir in case the reservoir definition consists of two sub-reservoirs (as is the case with Pumped Hydro Storage

Parent ID: In case the reservoir is genetically linked to another (higher level) reservoir in the database, then this attribute can be used to register the ID of the higher (parent) reservoir. Examples are:

- Salt cavern (child) within a salt formation (parent)
- Aquifer trap (child) or depleted reservoir (child) within a larger regional aquifer (parent)

Facility ID: This is a back link to an existing or planned storage facility that is connected to this reservoir. The Facility ID is defined in the Storage Facility Specification (Chapter 0). This value is set to "*Null*" if the reservoir or feature is still undeveloped (i.e. no storage facility plan or development exists).

Reservoir location and geometry

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Geometry	Polygon	Single	GIS-polygon		Essential-DB *
Domain	Subsurface or above-ground	Single	Text		Essential-DB
Spatial Hierarchy		Single	Text		Optional
Centre point latitude	Coordinate	Single	Number, real	Null	Essential-DB* (local reservoirs only)
Centre point longitude	Coordinate	Single	Number, real	Null	Essential-DB* (local reservoirs only)
Country	Country code	Single	Text		Optional
Secondary countries	Country code	List	Text	Null	Optional
State/province	Name	Single	Text	Null	Optional
City	Name	Single	Text	Null	Optional
Geological region	Name	Single	Text	Null	Optional

Table A2-2: Reservoir specifications: Location and geometry

Geometry: This is the spatial definition of the reservoir following the outline of the maximum extent (as given by the provider or source). The geometry is stored as a closed polygon (a set of interconnected vertices) according to the ORACLE spatial database definitions. The polygons and vertices are defined according to ETRS-89 projection. If possible, a reservoir unit should be entered as close as possible to a single coherent reservoir unit (e.g. individual trap structures within a aquifer). The Spatial Hierarchy attribute defines the hierarchical level of the spatial definition.

* If no geometry is available for a storage, then it should at least be defined by a centre point (see centre point definition in this table). A storage unit that has no spatial definition (i.e. if there is no definable outline or centre point) will not be entered into the database.

Domain: States whether this is a *subsurface* or an *above-ground* reservoir

Spatial Hierarchy: Specifies the level of precision and concreteness of the given geometry, for example whether the reservoir geometry defines a single storage unit (such as a storage cavern) or a global feature without a concrete local storage unit specification (such as a non-specific aquifer extent). Valid entries are:

- *Unique Unit*: E.g. single cavern or reservoir segment
- *Coherent Structure*: Genetically linked and spatially connected storage units such as two or more associated reservoir compartments within a single hydrocarbon field
- *Stacked Units*: Genetically linked and vertically stacked storage units such as separated zones in a single hydrocarbon field. May consist of multiple reservoir segments
- *Storage Group*: Group of different storage units that belong to a single development such as a group of salt caverns within a single salt structure, managed by one operator.
- *Regional Group*: Outline around multiple potential storage units or storage groups that belong to a specific geographic area / locality (e.g. multiple salt domes)
- *Non-specific Unit*: (Regional) reservoir without specifically defined internal storage units (e.g. large aquifer without definition of individual traps for storage).
- *Other*: Any other definition that does not comply to the above definitions

Centre Point Latitude: X-coordinate centre point of the reservoir or feature. This point will be defined based on the geometry (GIS calculation) or a coordinate given by the data provider (when no geometry is available). Compliant with the ETRS-89 coordinate system

Centre point Longitude: Y-coordinate centre point of the reservoir or feature. This point will be defined based on the geometry (GIS calculation) or a coordinate given by the data provider (when no geometry is available). Compliant with the ETRS-89 coordinate system

Country: The primary country covered by the extent of the reservoir or feature. Defined as short name in English (geographical name), see http://publications.europa.eu/code/en/en-370100.htm.

Secondary countries: A list (comma-separated) of all other countries covered by the feature. The coding is similar to the coding used for Country.

State/province: Name of the state or province linked to the reservoir or feature. If it is not possible to provide a unique link to a specific state or province, this value will be set to "*Unspecified*". If not determined, this value is set to "*Null*".

City: Optional name of the city linked to the reservoir or feature. If it is not possible to provide a unique link to a specific city, this value will be set to "*Unspecified*". If not determined, this value is set to "*Null*".

Geological Region: Optional name of a defined geological region such as a basin, structural element, orogen, etc. If it is not possible to provide a unique link to a specific geological region, this value will be set to "*Unspecified*". If not determined or unknown, this value is set to "*Null*".

Reservoir characterization

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Main Reservoir Type	Depleted reservoir, aquifer, rock salt formation, salt cavern, cavity host rock, excavated cavity, abandoned mine, pumped hydro reservoir	Single	Text		Essential-DB
Reservoir Subtype	e.g. salt pillar, bedded salt, aquifer trap, type of mine, etc.	Single	Text	Null	Optional
Chrono-stratigraphy	e.g. Zechstein, Permian, etc.	Single	Text	Null	Optional
Lithostratigraphy	e.g. Zechstein, Permian, etc.	Single	Text	Null	Optional
Lithotratigraphy Hierarchical Level	Group, Formation, Member, Layer/Bed	Single	Text	Null	Optional
Main Lithology	Sandstone, Carbonate, Rock salt, Coal, Clay stone, Granite, Basalt, etc.	Single	Text		Optional
Reservoir Seal Lithology	Salt, clay stone, anhydrite	Single	Text	Null	Optional
Fluid Fill	gas, oil, CO2, fresh water, saline water, brine, none	Single	Text	Null	Optional

Table A2-3: Reservoir specifications: Characterization

Main Reservoir Type: Describes on a main level the type of the reservoir or feature as described and defined in Chapter 3.4. Valid entries are:

- *Depleted reservoir*
- *Aquifer*
- *Rock salt formation*
- *Salt cavern*
- *Cavity host rock*
- *Excavated cavity*
- *Abandoned mine*
- *Pumped hydro reservoir*

Remark: The set of valid entries may be extended or adjusted during the project when this is needed to accommodate the collected reservoir data or to improve the database and analysis performance. A feature will not be entered into the database if the reservoir type is unknown or outside the project scope.

Reservoir Subtype: An additional definition of the reservoir or feature on a sublevel. The entries are optional and not restricted to a predefined value set. Examples are "*Salt pillar*", "*Bedded salt*", "*Aquifer trap*", "*Coal mine*", etc.

Chrono-Stratigraphy: Official chronostratigraphic (geological age) level. To be used for filtering and correlation. If possible, the unit should be defined at the lowest stratigraphic hierarchical level (e.g. stage / age). A "*Null*" value indicates that this parameter is unavailable (e.g. with pumped hydro lakes)

Litho-Stratigraphy: Official name of the stratigraphic unit to which the reservoir belongs (as defined by the data provider). If possible, the unit should be defined at the lowest stratigraphic hierarchical level (e.g. bed or layer). A "*Null*" value indicates that this parameter is unavailable (e.g. with pumped hydro lakes)

Litho-Stratigraphy Hierarchical Level: Indicates the hierarchical level of the lithostratigraphic unit. Valid entries according to the lithostratigraphic conventions are:

- *Super group*: Combination of associated groups
- *Group*: Succession of two or more formations
- *Subgroup*: Subunit within a group consisting of 2 or more formations
- *Formation*: Primary formal unit within stratigraphic classification, can be geologically mapped on regional scale)
- *Member*: Next in rank unit below formation, lithologically distinguishable from other parts of a formation
- *Bed*: Smallest formal unit representing a single lithological layer that can be distinguished from layers above and below
- *Flow*: Discrete extrusive volcanic body
- *Complex*: Combination of units of various rock types, levels, classes
- *Lithohorizon*: Boundary between two lithostratigraphic units such as top and base. Used for pumped hydro lakes which are defined as surface level
- *Informal*: Used for any other definition that does not conform to the above formal entries

Remark: Set to "*Null*" if not provided or unknown.

Main Lithology: Defines the main lithology (rock type) of the reservoir or storage feature. Valid entries are:

- *Sandstone*
- *Siltstone*
- *Clay stone*
- *Limestone*
- *Salt*
- *Granite*
- *Basalt*
- *Metamorphic rock*

Remark: The set of valid entries may be extended or adjusted during the project when this is needed to accommodate the collected reservoir data or to improve the database and analysis performance. A "*Null*" indicates that this parameter is unknown or unavailable (e.g. with pumped hydro reservoirs).

Reservoir Seal Lithology: Defines the main lithology (rock type) of the reservoir seal. Valid entries are:

- *Salt*
- *Clay stone*
- *Anhydrite - Gypsum*
- *Other*
- *Not applicable* (e.g. in case of pumped hydro lake)

Remark: The set of valid entries may be extended or adjusted during the project when this is needed to accommodate the collected reservoir data or to improve the database and analysis performance. A "*Null*" indicates that this parameter is unknown or unavailable (e.g. with pumped hydro reservoirs).

Fluid Fill: Determines the current type of fluid fill in the reservoir or basin. Valid entries are:

- *Oil*

- *Gas*
- *Mixed Oil and Gas*
- *Fresh water (e.g. used for pumped hydro reservoirs)*
- *Saline water - Brine*
- *CO2*
- *Air*
- *Hydrogen*
- *Gasoil*
- *Mixed*
- *None* (used for rock units in which no reservoir space has been developed yet, such as a salt formation)

Remark: The set of valid entries may be extended or adjusted during the project when this is needed to accommodate the collected reservoir data or to improve the database and analysis performance. A "*Null*" indicates that this parameter is unknown or unavailable.

Subsurface reservoir properties

The following tables specify the typical properties of subsurface reservoirs related to the feasibility, capacity and performance for (energy) storage. The tables are subdivided per reservoir type

(Depleted) hydrocarbon reservoirs

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Depth	m	Range/Single	Number; real	Null	Optional
Total Thickness	m	Range/Single	Number; real	Null	Optional
Total Area	m^2	Single	Number; real	Null	Optional
Total Bulk Volume	m^3	Range/Single	Number; real	Null	Optional
Net Porosity	%	Range/Single	Number; real	Null	Optional
Total Net Pore volume	m^3	Range/Single	Number; real	Null	Optional
Total GIIP	m^3	Range/Single	Number; real	Null	Optional
Total OIIP	m^3	Range/Single	Number; real	Null	Optional
Total UR Gas	m^3	Range/Single	Number; real	Null	Optional
Total UR Oil	m^3	Range/Single	Number; real	Null	Optional
Pressure	Bar	Range/Single	Number; real	Null	Optional
Permeability	Darcy	Range/Single	Number; real	Null	Optional
Transmissivity	Darcy.meter	Range/Single	Number; real	Null	Optional
Productivity	m^3/day	Range/Single	Number; real	Null	Optional

Table A2-4: Reservoir specifications: Properties

Aquifers

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Depth	m	Range/Single	Number; real	Null	Optional
Total Thickness	m	Range/Single	Number; real	Null	Optional
Total Area	m^2	Single	Number; real	Null	Optional
Total Bulk Volume	m^3	Range/Single	Number; real	Null	Optional
Net Porosity	%	Range/Single	Number; real	Null	Optional
Total Net Pore volume	m^3	Range/Single	Number; real	Null	Optional
Pressure	Bar	Range/Single	Number; real	Null	Optional
Permeability	Darcy	Range/Single	Number; real	Null	Optional
Transmissivity	Darcy.meter	Range/Single	Number; real	Null	Optional
Productivity	m^3/day	Range/Single	Number; real	Null	Optional
Temperature	°C	Range/Single	Number; real	Null	Optional
Total Heat in place	Joule	Range/Single	Number; real	Null	Optional

Table A2-5: Reservoir specifications: Properties

Caverns (Salt solution mined, Excavated rock, Mined)

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Depth	M	Range/Single	Number; real	Null	Optional
Total Cavern Height	M	Range/Single	Number; real	Null	Optional
Total Area	m^2	Single	Number; real	Null	Optional
Total Cavern Volume	m^3	Range/Single	Number; real	Null	Optional
Total Mined Volume	m^3	Range/Single	Number; real	Null	Optional
Number of caverns	-	Range	Number; integer	Null	Optional
Pressure	Bar	Range/Single	Number; real	Null	Optional

Table A2-6: Reservoir specifications: Properties

Host rock for cavern development (Salt formations, Host rock)

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Depth	m	Range/Single	Number; real	Null	Optional
Total Thickness	m	Range/Single	Number; real	Null	Optional
Total Area	m^2	Single	Number; real	Null	Optional
Total Bulk Volume	m^3	Range/Single	Number; real	Null	Optional
Number of caverns	-	Range	Number; integer	Null	Optional

Table A2-7: Reservoir specifications: Properties

General remark: Many attributes are indicated as Range/Single. This means that the attribute is represented by three values:

- The minimum and maximum values represented as a range
- The average value represented as a single
-

Depth: Top depth of the subsurface reservoir or rock unit. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average depths of individual units. The parameter unit is metres - True Vertical Depth – Ordinance Level.

Total Thickness: Total thickness of the subsurface reservoir or rock unit (summed thickness for stacked units). Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average thicknesses of individual units. The parameter unit is metres True Vertical Thickness.

Total Cavern Height: Height of the subsurface cavern. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average thicknesses of individual units. The parameter unit is metres True Vertical Thickness.

Total Area: This is the total area of the reservoir or storage unit group in m^2 (defined by the geometry / polygon).

Total Bulk volume: Bulk volume of the rock unit comprising the reservoir or feature. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual bulk volumes. The parameter unit is m^3.

Net Porosity: Net porosity of the reservoir or feature. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average porosities of individual units. For a single storage unit the range represents the estimation uncertainty range. The values are defined as percentages.

Total Net Pore Volume: Total net pore volume the reservoir or rock unit. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual net pore volumes. Represents the bulk volume times the average net porosity. The parameter unit is m^3.

Total Cavern Volume: Total net volume the cavern. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual net cavern volumes. The parameter unit is m^3.

Total Mined Volume: Total rock volume that has been mined. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual mined volumes. The parameter unit is m^3.

Total GIIP: Total gas volume initially in place. This value is only defined for individual gas reservoirs and determined by reservoir assessment. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual GIIP volumes. The parameter unit is m^3.

Total OIIP: Total oil volume initially in place. This value is only defined for individual oil reservoirs and determined by reservoir assessment. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, this parameter represents the summation of individual OIIP volumes. The parameter unit is m^3.

Total UR Gas: Ultimate recoverable (or recovered) gas volume. This value is only defined for gas reservoirs and determined by production forecast and/or production history. In case of a storage unit group, this parameter represents the summation of individual UR volumes. In many cases the UR volume may provide a good indication of the gas storage capacity. Can be entered as a range (min/max) as well as an average value (single). The parameter unit is m^3.

Total UR Oil: Ultimate recoverable (or recovered) oil volume. This value is only defined for oil reservoirs and determined by production forecast and/or production history. In case of a storage unit group, this parameter represents the summation of individual UR volumes. Can be entered as a range (min/max) as well as an average value (single). The parameter unit is m^3.

Number of caverns: This value provides the number of existing or planned caverns in a salt or host rock formation, or the number of caverns in a storage group. The minimum value in the range represents the total amount of existing caverns. The maximum value in the range includes the planned caverns.

Pressure: Can be entered as a range (min/max) as well as an average value (single). The max value represents the maximum allowable pressure in the storage reservoir as determined by the data provider. The min value represents the minimum allowable pressure or the pressure after depletion in the reservoir. In the case of a depleted hydrocarbon reservoir this pressure depends on the recovery of gas and the potential post-production influence of the attached aquifer. For salt caverns the minimum pressure may be defined as the pressure needed to prevent convergence. The average value represents the current pressure. This parameter can only be defined for single pressure regime reservoirs. The value unit is bar.

Permeability: Permeability of the reservoir. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average permeability of individual units. For a single storage unit the range represents the estimation uncertainty range. The values are defined as Darcy.

Transmissivity: Transmissivity of the reservoir or feature. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average permeability of individual units. For a single storage unit the range represents the estimation uncertainty range. The values are defined as Darcy.meter (average permeability times true vertical thickness).

Productivity: This parameter represents the expected maximum potential flow rate in m^3/hour as determined by existing infrastructure. The flow rate depends on geological factors as well as the well design and type of development. Therefore no proper values can be defined when these data are unavailable. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average productivity of individual units. For a single storage unit the range represents the uncertainty range. The productivity values can either be defined by production test data, production history or an assessment of geological and technical development parameters.

Temperature: Average temperature of the reservoir or feature and the fluids/gases therein. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum average temperatures of individual units. For a single storage unit the range represents the estimation uncertainty range. The values are defined as degrees Celsius.

Heat In Place: The estimated Heat In Place energy of the reservoir or feature and the fluids/gases therein. Can be entered as a range (min/max) as well as an average value (single). In case of a storage unit group, the range may be defined as the minimum and maximum estimated Heat In Place of individual units. For a single storage unit the range represents the estimation uncertainty range. The values are defined as MWHth.

Reservoir property confidence level

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Confidence	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional (only if property is provided)

Table A2-8: Reservoir specifications: Property confidence level

Confidence: The values in this parameter category provide an indication of the level of confidence for each of the parameters in the Reservoir Properties category. The set-up is similar for each entry and consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.
- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.
- *Unknown*: Not available. The assessment methodology and level of confidence are not known.

Reservoir natural gas storage performance

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Natural gas Storage Feasibility	Proven, Probable, Possible, Unsuitable, Unknown	Single	Text	Unknown	Optional
Total Gas Volume	Mm^3	Range	Number; real	Null	Optional
Area Specific Gas Volume	Mm^3/km^2	Range	Number; real	Null	Optional
Total Energy Capacity	MWh_e	Range	Number; real	Null	Optional
Area Specific Energy Capacity	MWh_e/km^2	Range	Number; real	Null	Optional
Effective Gas Working Volume	Mm^3	Range	Number; real	Null	Optional, single operational unit only
Working vs Cushion Volume Ratio	%	Range	Number; real	Null	Optional, single operational unit only
Effective Energy Storage Capacity	MWh_e	Range	Number; real	Null	Optional, single operational unit only
Assessment Source	Reference to assessment study	Single	Text	Unknown	Optional
Assessment Confidence Level	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional
Use Status	Yes / No	Single	Boolean		Optional

Table A2-9: Reservoir specifications: Natural gas storage performance

Natural Gas Storage Feasibility: This parameter determines the feasibility of the reservoir for natural gas storage. The feasibility is determined by the data provider and described by one of the following values:

- *Proven*: Exploration and development activities have proven the feasibility of the reservoir for storage. In most cases this means that the storage is developed and functional.
- *Probable*: It is expected that the reservoir is suitable for storage development. In most cases this means that the existence of the reservoir has been proven but that some other boundary conditions remain to be confirmed. A positive outcome can be expected on the basis of available data.
- *Possible*: There are good indications that a storage reservoir or a feature suitable for storage capacity development is present. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Assumed*: There are little indications that a storage reservoir or a feature may be suitable for storage capacity development. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Unsuitable*: Current information indicates that the reservoir is not suitable for this storage function.
- *Unknown Theoretical*: There is no information available on feasibility assessment but generic geological criteria suggest that there may be scope to investigate feasibility.
- *Unknown Unlikelyl*: There is no information available on feasibility assessment. Generic geological criteria suggest that feasibility is unlikely.

Total Gas Volume: The total amount of natural gas in Mm^3 that can be contained by the reservoir. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Gas Volume: The average amount of natural gas that can be contained in the reservoir per unit area. The values are represented as Mm^3/km^2. This parameter is mostly useful for specifying unrestricted storage reservoirs such as regional aquifers exceeding the scale of a single operation. The range represents minimum and maximum values from regional variation. "*Null*" means that this attribute is not available.

Total Energy Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the total natural gas volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Energy Capacity: The average electrical energy equivalent per unit area (MWh_e/km^2) as represented by the area specific gas volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Effective Gas Working Volume: The maximum amount of natural gas in the storage in Mm^3 that is available for output (i.e. working gas). The remainder of the gas in the storage (cushion gas) is fixed and used for maintaining minimum operational pressures and delivery rates. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Working Cushion Volume Ratio: The estimated ratio between working gas and cushion gas volume. A ratio of 1 means that all gas in the storage is available for output. The range represents minimum and maximum estimates. Only values between 0 and 1 are accepted. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Effective Energy Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the effective natural gas working volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Assessment Source: Identification of the assessment source. Either a report, scientific reference or an organization/institute.

Assessment Confidence Level: The values in this parameter category provide an indication of the level of confidence of the assessment parameters. Consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.

- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.
- *Unknown*: Not available. The assessment methodology and level of confidence are not known.

Use Status: Indicates whether this set of assessment values is preferred (more than one assessment from different sources can be entered for each feature, but only one is preferred)

Reservoir hydrogen storage performance

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Hydrogen Storage Feasibility	Proven, Probable, Possible, Unsuitable, Unknown	Single	Text	Unknown	Optional
Total Hydrogen Volume	Mm^3	Range	Number; real	Null	Optional
Area Specific Hydrogen Volume	Mm^3/km^2	Range	Number; real	Null	Optional
Total Energy Capacity	MWh_e	Range	Number; real	Null	Optional
Area Specific Energy Capacity	MWh_e/km^2	Range	Number; real	Null	Optional
Effective Hydrogen Working Volume	Mm^3	Range	Number; real	Null	Optional, single operational unit only
Working Cushion Volume Ratio	Fraction	Range	Number; real	Null	Optional, single operational unit only
Effective Energy Storage Capacity	MWh_e	Range	Number; real	Null	Optional, single operational unit only
Assessment Source	Reference to assessment study	Single	Text	Unknown	Optional
Assessment Confidence Level	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional
Use Status	Yes / No	Single	Boolean		Optional

Table A2-10: Reservoir specifications: Hydrogen storage performance

Hydrogen Storage Feasibility: This parameter determines the feasibility of the reservoir for hydrogen storage. The feasibility is determined by the data provider and described by one of the following values:

- *Proven*: Exploration and development activities have proven the feasibility of the reservoir for storage. In most cases this means that the storage is developed and functional.
- *Probable*: It is expected that the reservoir is suitable for storage development. In most cases this means that the existence of the reservoir has been proven but that some other boundary conditions remain to be confirmed. A positive outcome can be expected on the basis of available data.
- *Possible*: There are good indications that a storage reservoir or a feature suitable for storage capacity development is present. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Assumed*: There are little indications that a storage reservoir or a feature may be suitable for storage capacity development. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Unsuitable*: Current information indicates that the reservoir is not suitable for this storage function.
- *Unknown Theoretical*: There is no information available on feasibility assessment but generic geological criteria suggest that there may be scope to investigate feasibility.
- *Unknown Unlikelyl*: There is no information available on feasibility assessment. Generic geological criteria suggest that feasibility is unlikely.

Total Hydrogen Volume: The total amount of hydrogen in Mm^3 that can be contained by the reservoir. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Hydrogen Volume: The average amount of hydrogen that can be contained in the reservoir per unit area. The values are represented as Mm^3/km^2. This parameter is mostly useful for specifying unrestricted storage reservoirs such as regional aquifers exceeding the scale of a single operation. The range represents minimum and maximum values from regional variation. "*Null*" means that this attribute is not available.

Total Energy Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the total hydrogen volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Energy Capacity: The average electrical energy equivalent per unit area (MWh_e/km^2) as represented by the area specific hydrogen volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Effective Hydrogen Working Volume: The maximum amount of hydrogen in the storage in Mm^3 that is available for output (i.e. working gas). The remainder of the gas in the storage (cushion gas) is fixed and used for maintaining minimum operational pressures and delivery rates. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Working Cushion Volume Ratio: The estimated ratio between working gas and cushion gas volume. A ratio of 1 means that all gas in the storage is available for output. The range represents minimum and maximum estimates. Only values between 0 and 1 are accepted. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Effective Energy Storage Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the effective hydrogen working volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Assessment Source: Identification of the assessment source. Either a report, scientific reference or an organization/institute.

Assessment Confidence Level: The values in this parameter category provide an indication of the level of confidence of the assessment parameters. Consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.

- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.
- *Unknown*: Not available. The assessment methodology and level of confidence are not known.

Use Status: Indicates whether this set of assessment values is preferred (more than one assessment from different sources can be entered for each feature, but only one is preferred).

Reservoir CAES performance

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
CAES feasibility	Proven, Probable, Possible, Unsuitable, Unknown	Single	Text	Unknown	Optional
Total Air Volume	Mm^3	Range	Number; real	Null	Optional
Area Specific Air Volume	Mm^3/km^2	Range	Number; real	Null	Optional
Total Energy Capacity	MWh_e	Range	Number; real	Null	Optional
Area Specific Energy Capacity	MWh_e/km^2	Range	Number; real	Null	Optional
Effective Air Working volume	Mm^3	Range	Number; real	Null	Optional, single operational unit only
Working Cushion Volume Ratio	Fraction	Range	Number; real	Null	Optional, single operational unit only
Effective Energy Storage Capacity	MWh_e	Range	Number; real	Null	Optional, single operational unit only
Assessment Source	Reference to assessment study	Single	Text	Unknown	Optional
Assessment Confidence Level	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional
Use Status	Yes / No	Single	Boolean		Optional

Table A2-11: Reservoir specifications: CAES storage performance

CAES Feasibility: This parameter determines the feasibility of the reservoir for Compressed Air Energy Storage (CAES). The feasibility is determined by the data provider and described by one of the following values:

- *Proven*: Exploration and development activities have proven the feasibility of the reservoir for storage. In most cases this means that the storage is developed and functional.
- *Probable*: It is expected that the reservoir is suitable for storage development. In most cases this means that the existence of the reservoir has been proven but that some other boundary conditions remain to be confirmed. A positive outcome can be expected on the basis of available data.
- *Possible*: There are good indications that a storage reservoir or a feature suitable for storage capacity development is present. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Assumed*: There are little indications that a storage reservoir or a feature may be suitable for storage capacity development. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Unsuitable*: Current information indicates that the reservoir is not suitable for this storage function.
- *Unknown Theoretical*: There is no information available on feasibility assessment but generic geological criteria suggest that there may be scope to investigate feasibility.
- *Unknown Unlikelyl*: There is no information available on feasibility assessment. Generic geological criteria suggest that feasibility is unlikely.

Total Air Volume: The total amount of compressed air in Mm^3 that can be contained by the reservoir. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Air Volume: The average amount of compressed air that can be contained in the reservoir per unit area. The values are represented as Mm^3/km^2. This parameter is mostly useful for specifying unrestricted storage reservoirs such as regional aquifers exceeding the scale of a single operation. The range represents minimum and maximum values from regional variation. "*Null*" means that this attribute is not available.

Total Energy Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the total compressed air volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Area Specific Energy Capacity: The average electrical energy equivalent per unit area (MWh_e/km^2) as represented by the area specific air volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Effective Air Working Volume: The maximum amount of compressed air in the storage in Mm^3 that is available for output (i.e. working gas). The remainder of the gas in the storage (cushion gas) is fixed and used for maintaining minimum operational pressures and delivery rates. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Working Cushion Volume Ratio: The estimated ratio between working gas and cushion gas volume. A ratio of 1 means that all gas in the storage is available for output. The range represents minimum and maximum estimates. Only values between 0 and 1 are accepted. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Effective Energy Storage Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the effective air working volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available. This attribute only applies to reservoirs that can be operated as single storage units (e.g. specific depleted gas reservoirs, caverns, etc.).

Assessment Source: Identification of the assessment source. Either a report, scientific reference or an organization/institute.

Assessment Confidence Level: The values in this parameter category provide an indication of the level of confidence of the assessment parameters. Consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.

- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.
- *Unknown*: Not available. The assessment methodology and level of confidence are not known.

Use Status: Indicates whether this set of assessment values is preferred (more than one assessment from different sources can be entered for each feature, but only one is preferred).

Reservoir thermal energy storage performance

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Thermal storage feasibility	Proven, Probable, Possible, Unsuitable, Unknown	Single	Text	Unknown	Optional
Total Heat Energy Storage Capacity	MWh_{th}	Range	Number; real	Null	Optional
Area Specific Heat Energy Capacity	MWh_{th}/km^2	Range	Number; real	Null	Optional
Assessment Source	Reference to assessment study	Single	Text	Unknown	Optional
Assessment Confidence Level	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional
Use Status	Yes / No	Single	Boolean		Optional

Table A2-12: Reservoir specifications: Thermal energy storage performance

Thermal Storage Feasibility: This parameter determines the feasibility of the reservoir for thermal storage. The feasibility is determined by the data provider and described by one of the following values:

- *Proven*: Exploration and development activities have proven the feasibility of the reservoir for storage. In most cases this means that the storage is developed and functional.
- *Probable*: It is expected that the reservoir is suitable for storage development. In most cases this means that the existence of the reservoir has been proven but that some other boundary conditions remain to be confirmed. A positive outcome can be expected on the basis of available data.
- *Possible*: There are good indications that a storage reservoir or a feature suitable for storage capacity development is present. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Assumed*: There are little indications that a storage reservoir or a feature may be suitable for storage capacity development. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Unsuitable*: Current information indicates that the reservoir is not suitable for this storage function.
- *Unknown Theoretical*: There is no information available on feasibility assessment but generic geological criteria suggest that there may be scope to investigate feasibility.
- *Unknown Unlikelyl*: There is no information available on feasibility assessment. Generic geological criteria suggest that feasibility is unlikely.

Total Heat Energy Storage Capacity: The total heat capacity of the reservoir. The values are represented as MWh_{th}. The range represents minimum and maximum estimates. “*Null*” means that this attribute is not available.

Area Specific Heat Energy Storage Capacity: The average heat capacity of the reservoir per unit area. The values are represented as MWh_{th}/km^2. This parameter is mostly useful for specifying unrestricted storage reservoirs such as regional aquifers exceeding the scale of a single operation. The range represents minimum and maximum values from regional variation. “*Null*” means that this attribute is not available.

Assessment Source: Identification of the assessment source. Either a report, scientific reference or an organization/institute.

Assessment Confidence Level: The values in this parameter category provide an indication of the level of confidence of the assessment parameters. Consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.
- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.
- *Unknown*: Not available. The assessment methodology and level of confidence are not known.

Use Status: Indicates whether this set of assessment values is preferred (more than one assessment from different sources can be entered for each feature, but only one is preferred)

Reservoir pumped hydro storage performance

Note that the proposed performance parameters for pumped hydro will be highly will be scrutinized against the performance parameters included the JRC study on pumped hydro potential. The parameters discussed below should therefore be regarded as provisional.

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Pumped Hydro Storage Feasibility	Proven, Probable, Possible, Not feasible, Unknown	Single	Text	Unknown	Optional
Total lake volume reservoir 1	Mm^3	Range	Number; real	Null	Optional, single operational unit only
Total lake volume reservoir 2	Mm^3	Range	Number; real	Null	Optional, single operational unit only
Elevation lake reservoir 1	m	Range	Number; real	Null	Optional, single operational unit only
Elevation lake reservoir 2	m	Range	Number; real	Null	Optional, single operational unit only
Effective energy storage capacity	MWh_e	Range	Number; real	Null	Optional, single operational unit only
Assessment Source	Reference to assessment study	Single	Text	Unknown	Optional
Assessment Confidence Level	Assumption, Estimate, Assessment, Measurement, Unknown	Single	Text	Unknown	Optional
Use Status	yes/no	Single	Boolean		Optional

Table A2-13: Reservoir specifications: Pumped hydro storage performance

Pumped Hydro Storage Feasibility: This parameter determines the feasibility of the lake/basin for pumped hydro storage. The feasibility is determined by the data provider and described by one of the following values:

- *Proven*: Exploration and development activities have proven the feasibility of the basin/lake for storage. In most cases this means that the storage is developed and functional.
- *Probable*: It is expected that the reservoir is suitable for storage development. In most cases this means that the existence of the reservoir has been proven but that some other boundary conditions remain to be confirmed. A positive outcome can be expected on the basis of available data.
- *Possible*: There are good indications that a storage reservoir or a feature suitable for storage capacity development is present. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Assumed*: There are little indications that a storage reservoir or a feature may be suitable for storage capacity development. Existence and suitability for this storage function are yet unknown and based on assumptions.
- *Unsuitable*: Current information indicates that the reservoir is not suitable for this storage function.
- *Unknown Theoretical*: There is no information available on feasibility assessment but generic geological criteria suggest that there may be scope to investigate feasibility.
- *Unknown Unlikelyl*: There is no information available on feasibility assessment. Generic geological criteria suggest that feasibility is unlikely

Total Lake Volume Reservoir 1: The total amount of water in Mm^3 that can be contained by lake reservoir 1. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Total Lake Volume Reservoir 2: The total amount of water in Mm^3 that can be contained by lake reservoir 2. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Elevation Lake Reservoir 1: Height above ordinance level of lake reservoir 1. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Elevation Lake Reservoir 1: Height above ordinance level of lake reservoir 2. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Effective Energy Storage Capacity: The total amount of electrical energy equivalent (MWh_e) represented by the effective pumped hydro working volume. The value may follow from an assessment or can be determined by using a typical energy conversion factor and the height difference between lake level and outflow. The range represents minimum and maximum estimates. "*Null*" means that this attribute is not available.

Assessment Source: Identification of the assessment source. Either a report, scientific reference or an organization/institute.

Assessment Confidence Level: The values in this parameter category provide an indication of the level of confidence of the assessment parameters. Consists of the following predefined value set:

- *Assumption*: The values of the property represent a global assumption and are not supported by any quantitative estimation or assessment methodology
- *Estimate*: The values of the property represent an (uncertain) estimate based on a primitive estimation methodology and poor data.
- *Assessment*: The values of the property represent a well-founded estimate based on a comprehensive, scientifically robust assessment methodology and good data.
- *Measurement*: The values of the property are confirmed and derived from precise measurement or determination.

Use Status: Indicates whether this set of assessment values is preferred (more than one assessment from different sources can be entered for each feature, but only one is preferred)

Reservoir development status

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Available	Yes, No, Unknown	Single	Text	Unknown	Optional
Current Development	E.g. gas production, salt production, storage, mining, etc.	Single	Text	Null	Optional
Planned Development	e.g. gas production, salt production, storage, mining, etc.	Single	Text	Null	Optional
Operator Name	Name	Single	Text	Null	Optional (only for developed reservoirs)
Licence Name	Name	Single	Text	Null	Optional
Country Ownership	Name	Single	Text		Optional
End Year	Year	Single	Date; year	Null	Optional (only for developed reservoirs)
Wells	-	Single	Number; integer	Null	Optional
Infrastructure Description	Description	Single	Text	Null	Optional
Natura-2000 Restriction	Description	List	Text	Null	Optional
Urban Restriction	Description	List	Text	Null	Optional
Groundwater Restriction	Description	List	Text	Null	Optional
Other Restriction	Description	List	Text	Null	Optional
Subsurface conflict	Description	List	Text	Null	Optional
Alternative Storage Potential	Description	List	Text	Null	Optional
CO2StoP trap id	Alpha-numeric	Single	Text	Null	Optional
CO2StoP storage unit id	Alpha-numeric	Single	Text	Null	Optional
CO2StoP formation id	Alpha-numeric	Single	Text	Null	Optional

Table A2-14: Reservoir specifications: Development status

Available: Indicates whether the reservoir or feature is currently available for storage development or not (e.g. because it is already developed or licenced for other uses).

Current Development: Describes the current function that has been developed in the reservoir or feature. "*Null*" is used when no functions are developed. "*Unknown*" is used when a development is in place, but no further details about its development are available.

Planned development: Describes a planned function development in the reservoir or feature. "*Null*" is used when there is no planned development. "*Unknown*" is used when no further details about planned development are available.

Operator Name: In case of an existing development, this parameter provides the name of the current operator or licensee. Also applies to planned development. "*Null*" is used when no development exists or has been planned. "*Unknown*" is used when a development is in place, but no further details about the operator are available.

Licence Name: Provides the name of a licence if the reservoir or feature falls under such a legal definition. "*Null*" is used when no licence exists or has been applied for. "*Unknown*" is used when no further details about an existing licence of licence application are available.

Country Ownership: The name of the country in case the storage reservoir or feature falls under such national state ownership. Defined as short name in English (geographical name), see http://publications.europa.eu/code/en/en-370100.htm. "*Null*" is used when the reservoir is not legally owned by a state . "*Unknown*" is used when no further details about state ownership are available.

End Year: The year until which a current development takes place or a licence claim is valid. After the end year the reservoir can be considered to be available for energy storage development. "*Null*" is used when the reservoir is already available. "*Unknown*" is used when no further details about the end date are available.

Wells: States the number of known (open) wells drilled into the reservoir. "*Null*" is used when no information is available on existing wells.

Infrastructure description: Description of infrastructure developments currently linked to the reservoir (e.g. compressors, gas treatment, grid connections, etc.). "*Null*" is used when no information is available on current infrastructure. "*None*" is used when no infrastructure is in place.

Natura-2000 Restriction: Mentions whether the geographic location of the reservoir potentially overlaps with a Natura-2000 area which may block the energy storage development in this reservoir. The parameter value represents the restriction type. "*None*" is used when no surface restrictions are known. The restrictions are determined by spatial GIS analysis or defined by the data provider.

Urban Restriction: Mentions whether the geographic location of the reservoir potentially overlaps with an urban area which may block the energy storage development in this reservoir. The parameter value represents the restriction type. "*None*" is used when no surface restrictions are known. The restrictions are determined by spatial GIS analysis or defined by the data provider.

Groundwater Restriction: Mentions whether the geographic location of the reservoir potentially overlaps with a groundwater protection area which may block the energy storage development in this reservoir. The parameter value represents the restriction type. "*None*" is used when no surface restrictions are known. The restrictions are indicated by the data provider.

Other Restriction: Mentions whether the geographic location of the reservoir potentially overlaps with any other restriction area which may block the energy storage development in this reservoir. The parameter value represents the restriction type. "*None*" is used when no surface restrictions are known. The restrictions are indicated by the data provider.

Subsurface Conflict: Mentions whether other potentially conflicting subsurface functions or uses are known (e.g hydrocarbon production or other storages), which may block the energy storage development in this reservoir. The parameter value represents the restriction type. "*None*" is used when no subsurface restrictions are known. The restrictions are determined from matches with other databases available to the project.

Alternative Storage Potential: Mentions whether the reservoir is identified as alternative storage potential other than the energy storage technologies mentioned in ESTMAP (e.g. CO2 storage). The parameter value represents the alternative identified storage potential. "*None*" is used when no alternative storage options are known. The alternative storage options are determined from matches with other databases available to the project (e.g. CO2StoP).

CO2StoP Trap ID: If this reservoir is also defined as a potential trap (for co2 storage) in the CO2StoP database (2014), then the associated trap ID is registered in this field. If not available, this value is "*Null*". The information can be used to directly link ESTMAP and CO2StoP

CO2StoP Storage Unit ID: If this reservoir is also defined as a potential storage unit (for co2 storage) in the CO2StoP database (2014), then the associated storage unit ID is registered in this field. If not available, this value is "*Null*". The information can be used to directly link ESTMAP and CO2StoP

CO2StoP Trap ID: If this reservoir is also defined as a formation (for co2 storage) in the CO2StoP database (2014), then the associated formation ID is registered in this field. If not available, this value is "*Null*". The information can be used to directly link ESTMAP and CO2StoP.

Technical Level of Readiness

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Regional assessment	Yes, No, Possibly	List	Text	Null	Optional
Local assessment	Yes, No, Possibly	List	Text	Null	Optional
Exploration	Yes, No, Possibly	List	Text	Null	Optional
Storage development planning	Yes, No, Possibly	List	Text	Null	Optional
Storage space engineering	Yes, No, Possibly	List	Text	Null	Optional
Facility engineering	Yes, No, Possibly	List	Text	Null	Optional
Storage Developed	No, Planned, Realized	List	Text	Null	Optional
Realized Primary Type	-	Single	Text	Null	Optional
Realized Alternative Type	-	Single	Text	Null	Optional
Planned Primary Type	-	Single	Text	Null	Optional
Planned Alternative Type	-	Single	Text	Null	Optional
Combined possible	Yes, No, Possibly	List	Text	Null	Optional
TLR	-	Single	Text	Null	Optional

Table A2-15: Reservoir specifications: Development status

Regional Assessment: "*Yes*" indicates that the identification of reservoir storage potential still depends on a regional assessment by which localized potential can be identified. "*No*" indicates this is not necessary. "*Possible*" indicates this may be necessary but it is not unconfirmed.

Local Assessment: "*Yes*" indicates that local (site specific) assessment is needed to determine the reservoir suitability and performance attributes. "*No*" indicates this is not necessary. "*Possible*" indicates this may be necessary but it is not unconfirmed.

Exploration: "*Yes*" indicates that the confirmation of presence of the reservoir and the determination of the reservoir properties still depends on exploration (i.e. drilling). "*No*" indicates this is not necessary (i.e. already drilled and explored). "*Possible*" indicates this may be necessary but it is not unconfirmed.

Storage development planning: "*Yes*" indicates that deployment of energy storage awaits the establishment of a development plan by the operator. "*No*" indicates this is not necessary (i.e. a plan is already available). "*Possible*" indicates this may be necessary but it is not unconfirmed.

Storage space engineering: "*Yes*" indicates that any storage deployment relies on the development of an artificial (man-made) storage space (e.g. cavern development). "*No*" indicates this is not necessary (i.e. in the case of existing caverns and reservoirs defined by porous formations such as aquifers). "*Possible*" indicates this may be necessary but it is not unconfirmed.

Storage facility engineering: "*Yes*" indicates that any storage deployment still relies on the development of an above-ground facility/infrastructure for operating the storage. "*No*" indicates this is not necessary (i.e. facility exists). "*Possible*" indicates this may be necessary but it is not unconfirmed.

Storage Developed: States the current development as energy storage. Valid entries are:

- *Realized*: Energy storage has been deployed
- *Planned*: Energy storage is planned
- *No*: Still undeployed and no plans for deployment known

Realized Primary Type: Identifies the currently realized primary (main) storage function (e.g. UGS, HES, CAES, UTES, etc.). Only determined if realized:

Realized Alternative Type: Identifies the currently realized alternative (secondary) storage function (e.g. UGS, HES, CAES, UTES, etc.). This may for example be the case for a salt formation with multiple caverns that host different storage functions.

Planned Primary Type: Identifies the planned primary (main) storage function (e.g. UGS, HES, CAES, UTES, etc.).

Planned Alternative Type: Identifies the planned alternative (secondary) storage function (e.g. UGS, HES, CAES, UTES, etc.). This may for example be the case for a salt formation with multiple caverns that host different storage functions.

Combined Possible: "*Yes*" indicates that the storage reservoir / site is capable of hosting multiple energy storage functions (e.g. multiple caverns in a salt formation). "*No*" indicates this is not posiible.

TLR: This is a free text attribute that summarizes the Technical Level of Readiness information in above attributes.

Data quality and tracking

Attribute	Unit/Entry	Single, Range, List	Format	Default value	Essential / Optional
Data source	-	Single	text		Essential-DB
Data quality label	-	Single	text		Essential-DB
Comment	-	Single	text		Optional
Date created	day:month:year	Single	Number:date		Essential-DB
Date last changed	day:month:year	Single	Number:date		Essential-DB
Source dbase name	-	Single	text		Optional
Source dbase link	URL	Single	text		Optional
Source dbase table	-	Single	text		Optional
Source dbase field	-	Single	text		Optional
Source dbase ID	-	Single	text		Optional

Table A1-16: Storage facility specifications: Data quality and tracking

Data Source: Specify the data source for this entry.

Data Quality Label: Expert estimate of data quality. Valid entries are:

- *Literature*: Literature source
- *Survey*: Data obtained from research or survey archives
- *Operator*: Data from operator website/source
- Quick Scan*: Quick evaluation on the basis of available data (not in-depth)*

Comment: Free entry for data preparation and quality comments.

Date Created: Date of first record entry.

Date Last Changed: Date of last change.

Source Dbase Name: If the reservoir is disseminated through a public dbase, then this attribute can be used to register the name.

Source Dbase Link: If the reservoir is disseminated through a public dbase with known URL, then this attribute can be used to register the URL.

Source Dbase Table: If the reservoir is disseminated through a public dbase, then this attribute can be used to register the table in which the reservoir ID data field/attribute is stored.

Source Dbase Field: If the reservoir is disseminated through a public dbase, then this attribute can be used to register the attribute/field in which the reservoir ID is stored.

Source Dbase ID: If the reservoir is disseminated through a public dbase, then this attribute can be used to register the specific reservoir ID used this database (can then be used to define a direct database link for eventual updates and review).

Annex 3: Overview of (subcontracted) national partners for subsurface data collection

Albania:

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

Austria:

GBA – Geologische Bundesanstalt
Subcontractor
Contact Person: Piotr Lipiarski

Bosnia and Herzegovina:

UNTZ– University of Tuzla
Subcontractor
Contact Person: Sanel Nuhanovic

Belgium:

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

Bulgaria:

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

Czech Republic:

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

Germany:

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

Denmark:

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

Estonia:

Tallinn University of Technology
Subcontractor
Contact Person: Alla Shogenova

Spain:

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

Finland:

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

France:

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

United Kingdom:

BGS– British Geological Survey
Subcontractor
Contact Person: David Evans

Greece:

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

Croatia:

University in Zagreb
Subcontractor
Contact Person: Dr. Domagoj Vulin

Hungary:

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

Ireland:

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

Italy:

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

Kosovo:

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

Lithuania:

Nature Research Centre
Subcontractor
Contact Person: Saulius Sliaupa

Latvia:

Tallinn University of Technology
Subcontractor
Contact Person: Alla Shogenova

Netherlands:

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

Norway:

Asplan Viak AS
Subcontractor
Contact Person: Henrik Holmberg

Poland:

PGI – Polish Geological Institute
Subcontractor
Contact Person: Adam Wójcicki

Portugal:

Universidade de Évora
Subcontractor
Contact Person: Júlio Ferreira Carneiro

Romania:

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

Serbia:

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

Sweden:

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

Slovenia:

Geoinzeniring
Subcontractor
Contact Person: Marjeta Car

Slovakia:

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

Turkey:

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

Ukraine:

Geoinform - State Research and Development Enterprise Ukraine
Subcontractor
Contact Person: Boris Malyuk

Annex 4: Template Questionnaire Public data availability

QUESTIONNAIRE TO BE RETURNED BY 27 FEBRUARY 2015. THANK YOU!
Please refer to the pdf document to get an overview of the project and of our requests.
Please note that only public data should be considered in your answers.

To be completed by the recipient

Organization:	
Name:	
Position:	
Email address:	
Phone number:	

PART 1: TECHNICAL DATA

1. *Current and planned **subsurface** energy storages (natural gas, compressed air, hydrogen, thermal…)*

- Are you: well-informed ☐ quite informed ☐ poorly informed ☐
  on the subsurface energy storages in your country?
- If you consider being poorly informed, do you know any institute to be contacted? ....
- How many subsurface energy storage sites are in your country?
  ………. existing storage sites ………. planned storage sites
- On current **and** planned storage sites, can you give the level of public information available.

	Most sites available	Varies strongly per location	Mostly unavailable or confidential
Current storage sites			
Geographic location of storage	☐	☐	☐
Type of stored energy	☐	☐	☐
Operational parameters (*)	☐	☐	☐
Geological formation and parameters	☐	☐	☐
Planned storage sites			
Geographic location of storage	☐	☐	☐
Type of stored energy	☐	☐	☐
Operational parameters (*)	☐	☐	☐
Geological formation and parameters	☐	☐	☐

(*) *energy capacity, output, grid, etc.*

Potential for subsurface energy storages

- Are you: well-informed ☐ quite informed ☐ poorly informed ☐
  on available subsurface geological data in your country?
- If you consider being poorly informed, do you know any institute to be contacted? ....
  ...

- Indicate in the following table with types of data you can provide us depending on the type of target storage reservoirs.

	General data ([1])	Subsurface attributes ([2])	Storage assessment ([3])	No data available
Depleted hydrocarbon reservoirs	☐	☐	☐	☐
Aquifers and traps	☐	☐	☐	☐
Salt structures and caverns	☐	☐	☐	☐
Abandoned mines	☐	☐	☐	☐
Rock cavities or suitable host rock units	☐	☐	☐	☐
Other *(specify)* …………………..	☐	☐	☐	☐

[1] General data: location, stratigraphic level, lithology …
[2] Subsurface attributes: thickness, volume, permeability …
[3] Storage assessment: technical evaluation of capacity and performance

- Do you have additional comments? ....
  ....
  ....

Please note that we will probably ask you to provide data in <u>shapefile format</u> and <u>in English language</u>. Note also that your data will afterwards be expected <u>by the end of June 2015</u>.

<u>PART 2: ADMINISTRATIVE DATA</u>

- If you are a state member of EU, what is your Community VAT number?

  ....

- What is your legal and social status?

  ....

- Who will be in charge of dealing with contracts in your institution (name, e-mail)?

  ....

THANK YOU FOR YOUR CONTRIBUTION!

Annex 5: Example of Subsurface data collection form (France)

IDENTIFICATION			DATA_QUALITY_AND_TRACKING		
OBJECT_ID	OBJECT_NAME	OBJ_CODE	SOURCE	QUALITY_LABEL	SOURCE_COMMENT
1	Beynes Supérieur	Beynes Sup.	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/beynes.html>
2	Beynes Inférieur	Beynes Inf.	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/beynes.html>
3	Saint-Illiers-la-Ville	St Illiers	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/saint-illiers-la-ville.html
4	Gournay sur Aronde	Gournay	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/gournay-sur-aronde.html
5	Chemery	Chemery	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/chemery-soing-en-sologne.html
6	Soings-en-Sologne	Soings	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/chemery-soing-en-sologne.html
7	Céré-la-Ronde	Céré	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/cere-la-ronde.html
8	Trois Fontaines l'Abbaye	Trois Fontaines	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/cerville-trois-fontaines.html
9	Cerville	Cerville	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/cerville-trois-fontaines.html
10	Germigny-sous-Coulombs	Germigny	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/germigny-sous-coulombs.html
11	Saint-Clair-sur-Epte	Saint Clair	Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/saint-clair-sur-epte.html
12	Tersanne		Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/tersanne-hauterives.html
13	Etrez		Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/etrez.html
14	Hauterive		Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/tersanne-hauterives.html
15	Manosque		Storengy	OPERATOR	https://www.storengy.com/countries/france/fr/nos-sites/manosque.html
16	Izaute		TIGF	OPERATOR	
17	Lussagnet		TIGF	OPERATOR	
18	Bassin de Paris - Muschelkalk salifère		Scientific reports	LITERATURE	BRGM, 1980 - Bourquin et al., 1997 - IFP, 2002
19	Bassin de Paris - Keuper salifère		Scientific reports	LITERATURE	BRGM, 1980 - Bourquin et al., 1997 - IFP, 2002
20	Fossé rhénan salifère		Scientific reports	LITERATURE	Blanc-Valleron, 1991
21	Fossé de Bresse salifère		Scientific reports	LITERATURE	Dumas, 1998
22	Bassin de Valence salifère		Scientific reports	LITERATURE	Moretto, 1987 - Dumas, 1988
23	Bassin du Sud-Est - Trias salifère		Scientific reports	LITERATURE	BRGM, 1984 - Curnelle and Dubois, 1986
24	Bassin du Sud-Est - Oligocène salifère		Scientific reports	LITERATURE	BRGM, 1984
25	Bassin d'Aquitaine -Trias salifère		Scientific reports	LITERATURE	BRGM, 1974 - Curnelle, 1983
26	Bassin d'Aquitaine - Lias salifère		Scientific reports	LITERATURE	BRGM, 1974 - Curnelle, 1983
27	Bassin d'Aquitaine - diapirs		Scientific reports	LITERATURE	Brunet, 1991
28	Fossé rhénan - diapirs		Scientific reports	LITERATURE	Lutz, 1999 - Benoiston, 2000
29	Roches métam et granites hors contraintes supérieurs à 50 km2		Geological map	LITERATURE	Geological Million map of France, Chantraine et al., 2003
30	Travaux miniers en roches compétentes (charbon+métal)		Data Base	LITERATURE	GEODERIS
31	Aquifère Dogger Bassin de Paris sup. à 1000m		Data Base	SURVEY	METSTOR Project (CO2)
32	Aquifère Trias Bassin de Paris sup. à 1000m		Data Base	SURVEY	METSTOR Project (CO2)
33	Aquifère Jurassique Bassin d'Aquitaine		Scientific reports	LITERATURE	Aquifère et eaux souterraines en France, BRGM, 2006
34	Aquifère Crétacé Bassin d'Aquitaine		Scientific reports	LITERATURE	Aquifère et eaux souterraines en France, BRGM, 2006

MAIN | ID_QUAL | LOC | CHAR | DEV | PROP | ASSESS_UGS | ASSESS_H2 | ASSESS_CAES | ASSESS_THERM | ASSESS_UPHS | REF | CTRL

ID		SPECIFICATION		CENTER_POINT		REGION			GEO	
OBJECT_ID	OBJECT_NAME	DOMAIN	SPATIAL_HIERARCHY	X (ETRS89)	Y (ETRS89)	COUNTRY_CD	STATE	CITY	GEOLOGICAL_REGION	STRUCTURAL_ELEMENT
1	Beynes Supérieur	SUBSURFACE	UNIQUE	1.876452	48.845097	FR	Yvelines	Beynes	Bassin de Paris	
2	Beynes Inférieur	SUBSURFACE	UNIQUE	1.876452	48.845097	FR	Yvelines	Beynes	Bassin de Paris	
3	Saint-Illiers-la-Ville	SUBSURFACE	UNIQUE	1.551293	48.985623	FR	Yvelines	Saint-Illiers	Bassin de Paris	
4	Gournay sur Aronde	SUBSURFACE	UNIQUE	2.703032	49.529132	FR	Oise	Gournay sur arond	Bassin de Paris	
5	Chemery	SUBSURFACE	GROUP	1.484223	47.389974	FR	Loir et Cher	Chémery	Bassin de Paris	
6	Soings-en-Sologne	SUBSURFACE	GROUP	1.499039	47.42666	FR	Loir et Cher	Soings	Bassin de Paris	
7	Céré-la-Ronde	SUBSURFACE	UNIQUE	1.218462	47.282749	FR	Indre et Loire	Céré	Bassin de Paris	
8	Trois Fontaines l'Abbaye	SUBSURFACE	UNIQUE	4.973056	48.699835	FR	Marne	Saint Dizier	Bassin de Paris	
9	Cerville	SUBSURFACE	UNIQUE	6.296046	48.702654	FR	Meurthe-et-Mosell	Nancy	Bassin de Paris	
10	Germigny-sous-Coulombs	SUBSURFACE	UNIQUE	3.173359	49.056294	FR	Seine-et-Marne	Meaux	Bassin de Paris	
11	Saint-Clair-sur-Epte	SUBSURFACE	STACKED	1.706278	49.203228	FR	Val-d'Oise	Mantes-la-Jolie	Bassin de Paris	
12	Tersanne	SUBSURFACE	GROUP	4.988789	45.208682	FR	Drome	Romans-sur-Isère	Bassin de Valence	
13	Etrez	SUBSURFACE	GROUP	5.211437	46.341197	FR	Ain	Bourg-en-Bresse	Fossé de la Bresse	
14	Hauterive	SUBSURFACE	GROUP	5.0518	45.238575	FR	Drome	Romans-sur-Isère	Bassin de Valence	
15	Manosque	SUBSURFACE	GROUP	5.781219	43.874509	FR	Alpes-de-Haute-Pr	Manosque	Bassin du Sud-Est	
16	Izaute	SUBSURFACE	UNIQUE	-0.110062	43.790813	FR	Gers	Mont-de-Marsan	Bassin d'Aquitaine	
17	Lussagnet	SUBSURFACE	UNIQUE	-0.220088	43.78005	FR	Landes	Mont-de-Marsan	Bassin d'Aquitaine	
18	Bassin de Paris - Muschelkalk salifère	SUBSURFACE	REGIONAL	6.84744	48.83035	FR			Bassin de Paris	
19	Bassin de Paris - Keuper salifère	SUBSURFACE	REGIONAL	5.25	48.68639	FR			Bassin de Paris	
20	Fossé rhénan salifère	SUBSURFACE	REGIONAL	7.63501	48.30778	FR			Fossé rhénan	
21	Fossé de Bresse salifère	SUBSURFACE	REGIONAL	5.17138	46.30591	FR			Fossé de la Bresse	
22	Bassin de Valence salifère	SUBSURFACE	REGIONAL	5.06592	45.14543	FR			Bassin de Valence	
23	Bassin du Sud-Est - Trias salifère	SUBSURFACE	REGIONAL	4.86875	43.92634	FR			Bassin du Sud-Est	
24	Bassin du Sud-Est - Oligocène salifère	SUBSURFACE	REGIONAL	4.15839	43.49962	FR			Bassin du Sud-Est	
25	Bassin d'Aquitaine -Trias salifère	SUBSURFACE	REGIONAL	-0.11361	43.7287	FR			Bassin d'Aquitaine	
26	Bassin d'Aquitaine - Lias salifère	SUBSURFACE	REGIONAL	-0.06655	43.98102	FR			Bassin d'Aquitaine	
27	Bassin d'Aquitaine - diapirs	SUBSURFACE	REGIONAL	-0.25972	43.72904	FR			Bassin d'Aquitaine	
28	Fossé rhénan - diapirs	SUBSURFACE	REGIONAL	7.48737	47.98621	FR			Fossé rhénan	
29	Roches métam et granites hors contraintes s	SUBSURFACE	REGIONAL	2.2811	45.7657	FR			France	
30	Travaux miniers en roches compétentes (cha	SUBSURFACE	REGIONAL	4.72193	46.12506	FR			France	
31	Aquifère Dogger Bassin de Paris sup. à 1000	SUBSURFACE	REGIONAL	2.95441	48.66935	FR			Bassin de Paris	
32	Aquifère Trias Bassin de Paris sup. à 1000m	SUBSURFACE	REGIONAL	2.87181	48.38519	FR			Bassin de Paris	
33	Aquifère Jurassique Bassin d'Aquitaine	SUBSURFACE	REGIONAL	-0.20695	44.21697	FR			Bassin d'Aquitaine	
34	Aquifère Crétacé Bassin d'Aquitaine	SUBSURFACE	REGIONAL	0.04712	44.39084	FR			Bassin d'Aquitaine	

MAIN | ID_QUAL | LOC | CHAR | DEV | PROP | ASSESS_UGS | ASSESS_H2 | ASSESS_CAES | ASSESS_THERM | ASSESS_UPHS | REF | CTRL

ID		RESERVOIR_TYPE		STRATIGRAPHY			LITHOLOGY_AND_FILL		
OBJECT_ID	OBJECT_NAME	MAIN_RESERVOIR_TYPE	RESERVOIR_SUBTYPE	LITHOSTRATIGRAPHY	LITHOSTRATIGRAPHY_LEVEL	CHRONOSTRATIGRAPHY	MAIN_LITHOLOGY	SEAL_LITHOLOGY	FLUID_FILL
1	Beynes Supérieur	AQUIFER	TRAP	Wealdien	FORMATION	Lower Cretaceous	SANDSTONE	CLAYSTONE	GAS
2	Beynes Inférieur	AQUIFER	TRAP	Sequanien	FORMATION	Upper Jurassic	SANDSTONE	OTHER	GAS
3	Saint-Illiers-la-Ville	AQUIFER	TRAP	Sequanien	FORMATION	Upper Jurassic	SANDSTONE	OTHER	GAS
4	Gournay sur Aronde	AQUIFER	TRAP	Sequanien	FORMATION	Upper Jurassic	SANDSTONE	OTHER	GAS
5	Chemery	AQUIFER	TRAP		FORMATION	Triassic	SANDSTONE	CLAYSTONE	GAS
6	Soings-en-Sologne	AQUIFER	TRAP			Triassic	SANDSTONE	CLAYSTONE	GAS
7	Céré-la-Ronde	AQUIFER	TRAP			Triassic	SANDSTONE	CLAYSTONE	GAS
8	Trois Fontaines l'Abbaye	DEPLETED_RESERVOIR	GAS	Muschelkalk	FORMATION	Triassic	SANDSTONE	CLAYSTONE	GAS
9	Cerville	AQUIFER	TRAP	Grès à Voltzias	FORMATION	Lower Triassic	SANDSTONE	CLAYSTONE	GAS
10	Germigny-sous-Coulombs	AQUIFER	TRAP	Wealdien	FORMATION	Lower Cretaceous	SANDSTONE	CLAYSTONE	GAS
11	Saint-Clair-sur-Epte	AQUIFER	TRAP	Kimmeridgien	FORMATION	Upper Jurassic	LIMESTONE	CLAYSTONE	GAS
12	Tersanne	SALT_CAVERN	BEDDED SALT	Rupélien	FORMATION	Oligocene	SALT	SALT	GAS
13	Etrez	SALT_CAVERN	BEDDED SALT	Rupélien	FORMATION	Oligocene	SALT	SALT	GAS
14	Hauterive	SALT_CAVERN	BEDDED SALT	Rupélien	FORMATION	Oligocene	SALT	SALT	GAS
15	Manosque	SALT_CAVERN	BEDDED SALT	Rupélien	FORMATION	Oligocene	SALT	SALT	GAS
16	Izaute	AQUIFER	TRAP	Sables de Lussagnet	FORMATION	Eocene	SANDSTONE	OTHER	GAS
17	Lussagnet	AQUIFER	TRAP	Sables de Lussagnet	FORMATION	Eocene	SANDSTONE	OTHER	GAS
18	Bassin de Paris - Muschelkalk salifère	SALT_FORMATION	BEDDED SALT	Formation salifère	FORMATION	Triassic	SALT	CLAYSTONE	NONE
19	Bassin de Paris - Keuper salifère	SALT_FORMATION	BEDDED SALT	Marnes Irisées	FORMATION	Triassic	SALT	CLAYSTONE	NONE
20	Fossé rhénan salifère	SALT_FORMATION	BEDDED SALT	Formation Salifère	FORMATION	Cenozoic	SALT	CLAYSTONE	NONE
21	Fossé de Bresse salifère	SALT_FORMATION	BEDDED SALT	Ensemble salifère	FORMATION	Cenozoic	SALT	CLAYSTONE	NONE
22	Bassin de Valence salifère	SALT_FORMATION	BEDDED SALT	Formation salifère	FORMATION	Cenozoic	SALT	CLAYSTONE	NONE
23	Bassin du Sud-Est - Trias salifère	SALT_FORMATION	BEDDED SALT	Trias salifère	FORMATION	Triassic	SALT	OTHER	NONE
24	Bassin du Sud-Est - Oligocène salifère	SALT_FORMATION	BEDDED SALT	Oligocène salifère	FORMATION	Cenozoic	SALT	OTHER	NONE
25	Bassin d'Aquitaine -Trias salifère	SALT_FORMATION	BEDDED SALT	Trias salifère	FORMATION	Triassic	SALT	OTHER	NONE
26	Bassin d'Aquitaine - Lias salifère	SALT_FORMATION	BEDDED SALT	Hettangien salifère	FORMATION	Hettangian	SALT	OTHER	NONE
27	Bassin d'Aquitaine - diapirs	SALT_FORMATION	SALT PILLAR	Trias salifère	FORMATION	Triassic	SALT	OTHER	NONE
28	Fossé rhénan - diapirs	SALT_FORMATION	SALT PILLAR	Formation salifère	FORMATION	Cenozoic	SALT	CLAYSTONE	NONE
29	Roches métam et granites hors contraintes supérieurs à 50 km2	HOST_ROCK	UNSPECIFIED						
30	Travaux miniers en roches compétentes (charbon+métal)	ABANDONED_MINE	UNSPECIFIED						
31	Aquifère Dogger Bassin de Paris sup. à 1000m	AQUIFER	UNSPECIFIED	Dogger calcaire	GROUP	Middle Jurassic	LIMESTONE	OTHER	SALINE_WATER
32	Aquifère Trias Bassin de Paris sup. à 1000m	AQUIFER	UNSPECIFIED		GROUP	Triassic	SANDSTONE	OTHER	SALINE_WATER
33	Aquifère Jurassique Bassin d'Aquitaine	AQUIFER	UNSPECIFIED		GROUP	Jurassic	LIMESTONE	OTHER	SALINE_WATER
34	Aquifère Crétacé Bassin d'Aquitaine	AQUIFER	UNSPECIFIED		GROUP	Upper Cretaceous	OTHER	OTHER	SALINE_WATER

MAIN | ID_QUAL | LOC | CHAR | DEV | PROP | ASSESS_UGS | ASSESS_H2 | ASSESS_CAES | ASSESS_THERM | ASSESS_UPHS | REF | CTRL

	A	B	C	D	E	F	G	H	I	J	K	L
1	ID		STATUS			OPERATION_AND_LEGAL				INFRASTRUCTURE		
2	OBJECT_ID	OBJECT_NAME	AVAILABLE	CURRENT_DEVELOPMENT	PLANNED_DEVELOPMENT	OPERATOR_NAME	LICENCE_NAME	OWNERSHIP	END_YEAR	STORAGE_FACILITY_NAME	GRID_CONNECTION	WELLS
3	1	Beynes Supérieur	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE		Beynes	GAS	27
4	2	Beynes Inférieur	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	35
5	3	Saint-Illiers-la-Ville	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	49
6	4	Gournay sur Aronde	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	74
7	5	Chemery	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	93
8	6	Soings-en-Sologne	YES	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE	2012		GAS	28
9	7	Céré-la-Ronde	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE	2017		GAS	26
10	8	Trois Fontaines l'Abbaye	YES	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	15
11	9	Cerville	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	54
12	10	Germigny-sous-Coulombs	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	52
13	11	Saint-Clair-sur-Epte	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	38
14	12	Tersanne	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	13
15	13	Etrez	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	21
16	14	Hauterive	NO	GAS_STORAGE	GAS_STORAGE	STORENGY		PRIVATE			GAS	2
17	15	Manosque	NO	GAS_STORAGE	GAS_STORAGE	GEOMETHANE		PRIVATE			GAS	7
18	16	Izaute	NO	GAS_STORAGE	GAS_STORAGE	TIGF		PRIVATE	2030		GAS	25
19	17	Lussagnet	NO	GAS_STORAGE	GAS_STORAGE	TIGF		PRIVATE	2018		GAS	28
20	18	Bassin de Paris - Muschelkalk salifère	YES	NONE	NONE						NONE	
21	19	Bassin de Paris - Keuper salifère	YES	NONE	NONE						NONE	
22	20	Fossé rhénan salifère	YES	NONE	NONE						NONE	
23	21	Fossé de Bresse salifère	YES	NONE	NONE						NONE	
24	22	Bassin de Valence salifère	YES	NONE	NONE						NONE	
25	23	Bassin du Sud-Est - Trias salifère	YES	NONE	NONE						NONE	
26	24	Bassin du Sud-Est - Oligocène salifère	YES	NONE	NONE						NONE	
27	25	Bassin d'Aquitaine -Trias salifère	YES	NONE	NONE						NONE	
28	26	Bassin d'Aquitaine - Lias salifère	YES	NONE	NONE						NONE	
29	27	Bassin d'Aquitaine - diapirs	YES	NONE	NONE						NONE	
30	28	Fossé rhénan - diapirs	YES	NONE	NONE						NONE	
31	29	Roches métam et granites hors contraintes supérieurs à 50 km2	YES	NONE	NONE						NONE	
32	30	Travaux miniers en roches compétentes (charbon+métal)	YES	NONE	NONE						NONE	
33	31	Aquifère Dogger Bassin de Paris sup. à 1000m	YES	NONE	NONE						NONE	
34	32	Aquifère Trias Bassin de Paris sup. à 1000m	YES	NONE	NONE						NONE	
35	33	Aquifère Jurassique Bassin d'Aquitaine										
36	34	Aquifère Crétacé Bassin d'Aquitaine										

MAIN | ID_QUAL | LOC | CHAR | DEV | PROP | ASSESS_UGS | ASSESS_H2 | ASSESS_CAES | ASSESS_THERM | ASSESS_UPHS | REF | CTRL

M	N	O	P	Q	R
RESTRICTION					
NATURA2000	URBAN	GROUNDWATER	OTHER_SURFACE_RESTRICTION	SUBSURFACE_CONFLICT	ALTERNATIVE_USE_POTENTIAL
	NO				
	NO				
	NO				
NO	NO				
NO	NO	NO			
YES	NO	NO			
NO	NO	NO			
YES	NO	NO			
NO	NO	NO			
NO	NO	NO			
YES	NO	NO			
NO	NO	NO			
NO	NO	NO			
NO	NO	NO			
YES	NO	NO	Parc Naturel Régional du Lubéron		
YES	NO	NO			
NO	NO	NO			
				STORAGE	
					CO2
					CO2
					Thermal springs
					Thermal springs

SESS_UPHS | REF | CTRL

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	ID			TOP_DEPTH				TOTAL_THICKNESS				TOTAL_CAVERNE_HEIGHT				TOTAL_AREA		
2	OBJECT_ID	OBJECT_NAME	Colonne1	AVG	MIN	MAX	CONFIDENCE	AVG	MIN	MAX	CONFIDENCE	AVG	MIN	MAX	CONFI	AVG	MIN	MAX
3	1	*Beynes Supérieur*	*AQUIFER*	430 m			MEASUREMENT	30 m			MEASUREMENT					17 400 000 m²		
4	2	*Beynes Inférieur*	*AQUIFER*	740 m			MEASUREMENT	30 m			MEASUREMENT					17 400 000 m²		
5	3	*Saint-Illiers-la-Ville*	*AQUIFER*	470 m			MEASUREMENT	30 m			MEASUREMENT					17 100 000 m²		
6	4	*Gournay sur Aronde*	*AQUIFER*	717 m			MEASUREMENT	45 m			MEASUREMENT					41 000 000 m²		
7	5	*Chemery*	*AQUIFER*		1 100 m		MEASUREMENT	50 m			MEASUREMENT					52 500 000 m²		
8	6	*Soings-en-Sologne*	*AQUIFER*	820 m			MEASUREMENT	16 m			MEASUREMENT					32 000 000 m²		
9	7	*Céré-la-Ronde*	*AQUIFER*	910 m			MEASUREMENT	70 m			MEASUREMENT					61 800 000 m²		
10	8	*Trois Fontaines l'Abbaye*	*DEPLETED_RESERVOIR*	1 700 m			MEASUREMENT	13 m			MEASUREMENT					180 000 000 m²		
11	9	*Cerville*	*AQUIFER*	450 m			MEASUREMENT	40 m			MEASUREMENT					28 400 000 m²		
12	10	*Germigny-sous-Coulombs*	*AQUIFER*	850 m			MEASUREMENT									252 200 000 m²		
13	11	*Saint-Clair-sur-Epte*	*AQUIFER*	700 m			MEASUREMENT									84 000 000 m²		
14	12	*Tersanne*	*SALT_CAVERN*	1 500 m	1 450 m		ESTIMATE	250 m				100 m				15 000 000 m²		
15	13	*Etrez*	*SALT_CAVERN*		1 200 m	1 900 m	MEASUREMENT	650 m			ESTIMATE					28 000 000 m²		
16	14	*Hauterive*	*SALT_CAVERN*	1 300 m			ESTIMATE	200 m				100 m				10 000 000 m²		
17	15	*Manosque*	*SALT_CAVERN*	1 000 m						366 m						29 000 000 m²		
18	16	*Izaute*	*AQUIFER*	510 m			MEASUREMENT									20 000 000 m²		
19	17	*Lussagnet*	*AQUIFER*	545 m			MEASUREMENT									15 500 000 m²		
20	18	*Bassin de Paris - Muschelkalk salifère*	*SALT_FORMATION*															
21	19	*Bassin de Paris - Keuper salifère*	*SALT_FORMATION*		200 m	1 500 m	ESTIMATE	80 m			ESTIMATE							
22	20	*Fossé rhénan salifère*	*SALT_FORMATION*	800 m			ESTIMATE	1 200 m			ESTIMATE					220 000 000 m²		
23	21	*Fossé de Bresse salifère*	*SALT_FORMATION*	1 000 m			ESTIMATE	1 000 m			ESTIMATE							
24	22	*Bassin de Valence salifère*	*SALT_FORMATION*		600 m	1 500 m	ASSESSMENT		75 m	150 m	ASSESSMENT							
25	23	*Bassin du Sud-Est - Trias salifère*	*SALT_FORMATION*		2 000 m		ESTIMATE	300 m			ESTIMATE							
26	24	*Bassin du Sud-Est - Oligocène salifère*	*SALT_FORMATION*			2 000 m	ESTIMATE		100 m									
27	25	*Bassin d'Aquitaine -Trias salifère*	*SALT_FORMATION*	2 500 m			ESTIMATE	500 m			ESTIMATE							
28	26	*Bassin d'Aquitaine - Lias salifère*	*SALT_FORMATION*	500 m			ESTIMATE	100 m			ESTIMATE							
29	27	*Bassin d'Aquitaine - diapirs*	*SALT_FORMATION*															
30	28	*Fossé rhénan - diapirs*	*SALT_FORMATION*	900 m			ESTIMATE	1 000 m			ESTIMATE							
31	29	*Roches métam et granites hors contraintes supérieurs à 50 km2*	*HOST_ROCK*															
32	30	*Travaux miniers en roches compétentes (charbon+métal)*	*ABANDONED_MINE*															
33	31	*Aquifère Dogger Bassin de Paris sup. à 1000m*	*AQUIFER*		1 000 m	1 900 m	ASSESSMENT	250 m			ASSESSMENT							
34	32	*Aquifère Trias Bassin de Paris sup. à 1000m*	*AQUIFER*		1 000 m	2 300 m	ASSESSMENT	350 m			ASSESSMENT							
35	33	*Aquifère Jurassique Bassin d'Aquitaine*	*AQUIFER*															
36	34	*Aquifère Crétacé Bassin d'Aquitaine*	*AQUIFER*															

MAIN ID_QUAL LOC CHAR DEV **PROP** ASSESS_UGS ASSESS_H2 ASSESS_CAES ASSESS_THERM ASSESS_UPHS REF CTRL

S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
	TOTAL_BULK_VOLUME				TOTAL_CAVERNE_VOLUME				TOTAL_MINED_VOLUME				NUMBER_OF_CAVERNS				TOTAL_PORE_VOLUME				GIIP			
CONFIDENCE	AVG	MIN	MAX	CONFIDENCE	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI
													14											
													21											
ASSUMED													2											
													7											
ESTIMATE																								

MAIN ID_QUAL LOC CHAR DEV **PROP** ASSESS_UGS ASSESS_H2 ASSESS_CAES ASSESS_THERM ASSESS_UPHS REF CTRL

AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS
OOIP				EUR_GAS				EUR_OIL				TOTAL_POROSITY				NET_POROSITY				PERMEABILITY				TRANSMISSIVITY			
AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFIDENCE	AVG	MIN	MAX	CONFIDE	AVG	MIN	MAX	CONFIDENCE	AVG	MIN	MAX	CONFI
													20%	30%	MEASUREMENT						0 D	1 D	MEASUREMENT				
												25%	20%	30%	MEASUREMENT					1 D	0 D	1 D	MEASUREMENT				
												23%	20%	34%	MEASUREMENT					1 D	0 D	1 D	MEASUREMENT				
												20%								1 D							
												25%			MEASUREMENT												
																23%	21%	26%	MEASUREMENT		0 D	1 D	MEASUREMENT				
												20%		24%						4 D							
												14%	11%	18%	MEASUREMENT					0 D	0 D	0 D	MEASUREMENT				
												22%									0 D	4 D	MEASUREMENT				
													3%	10%	ESTIMATE					0 D			ESTIMATE				
													20%	25%	ESTIMATE						2 D	5 D	ESTIMATE				
													20%	25%	ESTIMATE						2 D	5 D	ESTIMATE				
													0%	12%	ASSUMED												
													6%	18%	ASSUMED												

ID_QUAL LOC CHAR DEV **PROP** ASSESS_UGS ASSESS_H2 ASSESS_CAES ASSESS_THERM ASSESS_UPHS REF CTRL

BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CG	CH	CI
PRODUCTIVITY				HEAT_IN_PLACE				PRESSURE				TEMPERATURE			
AVG	MIN	MAX	CONFIDE	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI	AVG	MIN	MAX	CONFI
								70 bar							
29 600 000 m³/day								110 bar				35 °C			
17 600 000 m³/day			ESTIMATE					155 bar							
								160 bar							
								137 bar							
								60 bar							
								124 bar							
								100 bar							
								171 bar							
11 000 000 m³/day								71 bar				37 °C			
20 000 000 m³/day								76 bar				37 °C			

SESS_THERM ASSESS_UPHS REF CTRL

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	ID		FEASIBILITY	TOTAL_GAS_VOLUME			WORKING_GAS_VOLUME			CUSHION_GAS_VOLUME			WORKING_CUSHION_RATIO			ENERGY_STORAGE_CAPACITY		
2	OBJECT_ID	OBJECT_NAME	FEASIBILITY	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
3	1	Beynes Supérieur	PROVEN	475 Mm³									50%					
4	2	Beynes Inférieur	PROVEN	800 Mm³									50%					
5	3	Saint-Illiers-la-Ville	PROVEN	1 500 Mm³														
6	4	Gournay sur Aronde	PROVEN	3 130 Mm³			1 310 Mm³											
7	5	Chemery	PROVEN	7 000 Mm³														
8	6	Soings-en-Sologne	PROVEN	800 Mm³											50%			
9	7	Céré-la-Ronde	PROVEN	1 200 Mm³														
10	8	Trois Fontaines l'Abbaye	PROVEN	2 080 Mm³														
11	9	Cerville	PROVEN	1 500 Mm³			850 Mm³			650 Mm³								
12	10	Germigny-sous-Coulombs	PROVEN	2 800 Mm³														
13	11	Saint-Clair-sur-Epte	PROVEN	1 700 Mm³			1 000 Mm³											
14	12	Tersanne	PROVEN	262 Mm³														
15	13	Etrez	PROVEN	1 117 Mm³														
16	14	Hauterive	PROVEN	200 Mm³														
17	15	Manosque	PROVEN	496 Mm³			274 Mm³											
18	16	Izaute	PROVEN	3 000 Mm³														
19	17	Lussagnet	PROVEN	3 500 Mm³														
20	18	Bassin de Paris - Muschelkalk salifère	ASSUMED															
21	19	Bassin de Paris - Keuper salifère	ASSUMED															
22	20	Fossé rhénan salifère	ASSUMED															
23	21	Fossé de Bresse salifère	ASSUMED															
24	22	Bassin de Valence salifère	ASSUMED															
25	23	Bassin du Sud-Est - Trias salifère	ASSUMED															
26	24	Bassin du Sud-Est - Oligocène salifère	ASSUMED															
27	25	Bassin d'Aquitaine -Trias salifère	ASSUMED															
28	26	Bassin d'Aquitaine - Lias salifère	ASSUMED															
29	27	Bassin d'Aquitaine - diapirs	ASSUMED															
30	28	Fossé rhénan - diapirs	ASSUMED															
31	29	Roches métam et granites hors contraintes supérieurs à 50 km2	UNSUITABLE															
32	30	Travaux miniers en roches compétentes (charbon+métal)	UNSUITABLE															
33	31	Aquifère Dogger Bassin de Paris sup. à 1000m	ASSUMED															
34	32	Aquifère Trias Bassin de Paris sup. à 1000m	PROBABLE															
35	33	Aquifère Jurassique Bassin d'Aquitaine	ASSUMED															
36	34	Aquifère Crétacé Bassin d'Aquitaine	ASSUMED															
37																		

MAIN / ID_QUAL / LOC / CHAR / DEV / PROP / **ASSESS_UGS** / ASSESS_H2 / ASSESS_CAES / ASSESS_THERM / ASSESS_UPHS / REF / CTRL

S	T	U	V
ASSESSMENT_SOURCE_AND_QUALITY			
SOURCE	CONFIDENCE	QUALITY_LABEL	COMMENT
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
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	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	MEASUREMENT	OPERATOR	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	
	ASSUMED	QUICK_SCAN	

ASSESS_THERM / ASSESS_UPHS / REF / CTRL

Annex 6: Template ESTMAP Data Approval Form

Dear Mr./Ms. …….

First of all we want to thank you again for supporting the ESTMAP project as subcontracted participant. In your position as subsurface expert and geological institute you have provided the ESTMAP project with valuable information regarding potential and existing development of subsurface energy storage in your country or region. Your data is integrated into a pan-European Energy Storage database with subsurface information from other countries as well as above-ground information. This database shall be delivered to the EC and will be shared with all participants in the ESTMAP project.
Over the last few months the ESTMAP consortium has processed the data and made several changes in order to solves minor inconsistencies and data gaps. We have also attempted to complement the database with additional information elements which we consider as added value for further use and implementation of the data.
Before disseminating and sharing the information in the database we of course want to take great care to ensure that all data is correct and corresponding to the current state-of-art in each country. We therefore kindly ask you to perform checks on the processed data files and to fill in the accompanying questionnaire with questions concerning:

- *Specific sections of the data files that have been altered or added*
- *Your confirmation of changes/additions to the dataset as well as your approval to share and disseminate the data as is*
- *The current state of art of energy storage assessment in your country/region in relation to the contents of the database.*

In the attachment we provide you with the processed data from your country/region including an indication of the data elements that have been altered (yellow cells in the Excel file). We have deliberately used the original excel format used in the data collection phase in order to keep things easily recognizable.
Could you please perform the checks and fill-in the questionnaire before Friday, May 27th. We hope you are able to respond timely but in case you are experiencing problems or if you are not able to timely full-fill the requested checks, then please notify is as soon as possible.
Without your further notice we will consider the data approved and ready for dissemination after May 27th.

Kind regards

Serge van Gessel

Date: ______________________________________

Organization : _________________________________

Country : ____________________________________

PART I : DATA CHECK
The data provided by your organisation has been checked and in some cases adjusted or completed. The adjusted and additional parts are identified by yellow cells in the attached Excel data file. We hereby ask you to check and approve the changes we have applied to your country information and to provide corrections if necessary.

1. Links between reservoirs and facilities
In addition to the subsurface reservoir data, the ESTMAP project has collected information on existing and planned storage facilities (i.e. the above-ground infrastructure that is connected to the subsurface storage space). Where possible the database defines the connections between Facilities and associated Reservoirs:

- For Reservoirs: Sheet ID_QUAL, Column 3 (FACILITY_ID)
- For Facilities: Sheet FAC_ID, Column 3 (RESERVOIR_ID)

1.	Do you confirm the assigned links between reservoirs and associated facilities in your country/region?	YES/NO
Comments: *(please indicate incorrect links and/or additional information for correcting/improving information)*		

2. Link to source databases
With the development of the database we strive for transparency regarding the presentation of the origins of the included data. To that purpose we have defined additional data fields that can be used to incorporate links to published digital databases/sources (sheet: SOURCE_LINK). These links are described by the following parameters:

- **NAME** of the published database/source
- **URL** of the published database/source
- **TABLE** name containing the unique identifier
- Table **FIELD** name containing the unique identifier
- **ID** of the associated entry in the published database/source

2a.	If already filled-in, do you confirm the assigned links to the public database/source	YES/NO/N.A.[7]
2b.	Can you provide additional information that could help us to complete available links to relevant published databases/sources for the current entries in ESTMAP?	YES/NO
Comments: *(Please indicate where/how we can obtain these links or include the database link information in the attached Excel file)*		

[7] N.A. = Not Applicable

3. Integration on CO2StoP database

The ESTMAP project is required to integrate the data with CO2-Storage data. For this purpose, and on request of the EC we have included links to entries in the CO2StoP database (Project CO2StoP). The links are describe as follows in the sheet SOURCE_LINK:

- **TRAP_ID** (*CO2StoP*) in case the entry in ESTMAP relates to a Daughter Unit in CO2StoP
- **STORAGE_UNIT_ID** (*CO2StoP*) in case the entry in ESTMAP relates to a Storage Unit in CO2StoP
- **FORMATION_ID** (*CO2StoP*) in case the entry in ESTMAP relates to a Formation in CO2StoP

3a.	If already filled-in and relevant for your country/organisation, do you confirm the assigned links to the CO2StoP database entries?	YES/NO/N.A.
3b.	If relevant, can you provide additional information that could help us to complete further links to the CO2StoP data? If so, please enter this information in the attached Excel sheet	YES/NO
3c.	If relevant, could you indicate other entries in the CO2StoP database that may be valid as a potential entry for ESTMAP (e.g. entries in the CO2StoP database that could potentially be used for one of the energy storage functions defined in ESTMAP)?	YES/NO
Comments: *(Please indicate incorrect links for 3a or additional links for 3b/3c). Information can also be provided with the attached Excel file)*		

4. Feasibility classification

The information provided during data collection often lacked a complete indication of feasibility for all energy storage functions. We have attempted to provide a more complete classification by defining the feasibility for all entries and each subsurface storage function in ESTMAP. To that end we have extended the potential entries with following definitions:

- **THEORETICAL / UNKNOWN_THEORETICAL**: We have not obtained information on the suitability or the suitability has not been assessed yet. Based on generic geological assumptions we consider that the given storage function could theoretically be developed in this type of reservoir/formation. This is however still very uncertain and yet to be confirmed by further geological evaluation
- **UNLIKELY / UNKNOWN_UNLIKELY**: We have not obtained information on the suitability or the suitability has not been assessed yet. Based on generic geological assumptions however we consider it unlikely that technical or economic development of the given storage function is justifiable in this type of reservoir/formation.

4.	Do you confirm the classification of feasibility as now defined in ESTMAP? If not, please adjust the values in the attached Excel file: - ASSESS_UGS - ASSESS_H2 - ASSESS_CAES - ASSESS_THERM - ASSESS_UPHS	YES/NO
Comments: *(Please indicate corrections/improvements or adjust given information in the attached Excel file)*		

5. *Realization requirements*

We aim to adequately and more concretely represent the current state of knowledge and development of each of the defined entries in ESTMAP. To this end we have attempted to describe for each entry on a generic level what type activities and technical requirements would eventually be needed to confirm and deploy actual storage capacities. This information is included in the sheet TLR_CLASS and includes following elements:

- **REGIONAL_ASSESSMENT**: If marked as YES/POSSIBLE, this parameter indicates that there is still a need for determining unique and more site-specific storage prospects (e.g. traps) from a regional-defined potential in ESTMAP
- **LOCAL_ASSESSMENT**: If marked as YES/POSSIBLE, this parameter indicates that there is still a need for evaluating site-specific and more detailed geological and technical performance parameters for the given entry (i.e. up to a level that is regarded sufficient for progressing/approving further development)
- **EXPLORATION**: If marked as YES/POSSIBLE, this parameter indicates that there is still a need for drilling an exploration/appraisal well in order to prove and assess the suitability of the prospective storage site.
- **STORAGE_DEVELOPMENT_PLANNING**: If marked as YES/POSSIBLE, this parameter indicates that there is still a need for elaborating a development plan for the deployment of the identified storage capacity (e.g. as input for further corporate and legal decisions).
- **STORAGE_SPACE_ENGINEERING**: If marked as YES/POSSIBLE, this parameter indicates that the actual storage space should still be created, either through solution mining or excavation (i.e. this is not needed for storage capacities defined within natural porous systems).
- **FACILITY_ENGINEERING**: If marked as YES/POSSIBLE, this parameter indicates that there is still a need to develop/upgrade the above-ground facilities and infrastructures required to operate the storage.
- **STORAGE_DEVELOPED**: This parameter indicates whether an operational storage has been realized or planned.
- **REAL_PRIMARY_TYPE**: This parameter indicates the primary storage function that has been deployed on this reservoir.
- **REAL_ALTERNATIVE_TYPE**: This parameter indicates an eventual alternative storage function that has been deployed on this reservoir (e.g. multiple storage functions within one rock salt formation).
- **PLAN_PRIMARY_TYPE**: This parameter indicates the primary storage function that is planned for this reservoir.
- **PLAN_ALTERNATIVE_TYPE**: This parameter indicates an eventual alternative storage function that is planned for this reservoir (e.g. multiple storage functions within one rock salt formation).
- **COMBINED_POSSIBLE**: This parameter indicates whether the reservoir is suitable for combining multiple storage functions (e.g. by deploying multiple caverns in an identified rock salt formation) or not.
- **TLR**: Technical Level of Realization, summarizes the information from above parameters into a single description.

5.	Do you confirm the classifications in the sheet TLR_CLASS based on above definitions? If not, please adjust the values in the attached Excel file	YES/NO/N.A.
Comments: *(Please indicate corrections/improvements or adjust given information in the attached Excel file)*		

PART II : DATA APPROVAL

With the questions below we ask you to confirm and approve the data for your country/region/organization to be finalized and published in ESTMAP:

1.	Do you confirm that the overall data (as shown in the attached Excel file and including your eventual amendments) correctly represents your contribution on subsurface energy storage potential for your country/region?	YES/NO
Comments: *(Please specify reasons if you cannot confirm the data)*		

2.	Do you approve that the data contained in the attached Excel file (including your final amendments) is ready for further dissemination, publication and sharing?	YES/NO
Comments: *(Please specify reasons if you do not approve)*		

PART III : COUNTRY STATE OF ART

We acknowledge that the geological assessment and gathering of information on energy storage potential is in many cases still in an early and pre-mature state. In other cases there may be good knowledge available, but regional or national law and data property rights prevent further sharing with ESTMAP. With the delivery of the ESTMAP database we would like to clarify what is the state of art in each country and explain whether a lack of information on certain storage functions is either the result of information gaps or lacking subsurface potential. We also want to invite each organization to properly scope their information. We therefore ask you kindly to answer the questions below which we then will include in our final report (see next pages):

Underground Natural Gas Storage

1a. Does the data for your country/region provide a mostly complete and reliable overall representation of the current development and assumed potential for **Underground Natural Gas Storage**?

[ ] **Yes or mostly yes**: The data in the ESTMAP is as complete as possible/publicly available and based on a comprehensive regional geological assessment.
[ ] **Only partly**: ESTMAP contains a fairly broad indication of sites that are in theory suitable for storage potential, but the information is still founded on generic assumptions only and requires significant efforts on regional geological assessment.
[ ] **Only party**: ESTMAP includes selected (firm or confirmed) potential only. A broader regional evaluation will probably reveal significantly more potential.
[ ] **No or only partly**. Our country/region comprises significantly more storage capacity but this information is not included in ESTMAP due to restricted (public) data access or not being available yet.
[ ] **No or only partly**. Assessment in our country is still in a very early and premature state. For the major part of our country/region we do not know of any geological potential yet

1b. For **Underground Natural Gas Storage**, how do you consider the potential and completeness of information with regards to the individual types of reservoirs:

Hydrocarbon reservoirs :
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Aquifers:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Rock Salt (formations for solution mining and caverns):
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Other host rock (suitable for excavated caverns) and mines:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Underground Hydrogen Gas Storage

2a. Does the data for your country/region provide a mostly complete and reliable overall representation of the current development and assumed potential for **Underground Hydrogen Storage**?

[ ] **Yes or mostly yes**: The data in the ESTMAP is as complete as possible/publicly available and based on a comprehensive regional geological assessment.

[ ] **Only partly**: ESTMAP contains a fairly broad indication of sites that are in theory suitable for storage potential, but the information is still founded on generic assumptions only and requires significant efforts on regional geological assessment.

[ ] **Only party**: ESTMAP includes selected (firm or confirmed) potential only. A broader regional evaluation will probably reveal significantly more potential.

[ ] **No or only partly**. Our country/region comprises significantly more storage capacity but this information is not included in ESTMAP due to restricted (public) data access or not being available yet.

[ ] **No or only partly**. Assessment in our country is still in a very early and premature state. For the major part of our country/region we do not know of any geological potential yet

2b. For **Underground Hydrogen Storage**, how do you consider the potential and completeness of information with regards to the individual types of reservoirs:

Hydrocarbon reservoirs :

[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Aquifers:

[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Rock Salt (formations for solution mining and caverns):

[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Other host rock (suitable for excavated caverns) and mines:

[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Underground Compressed Air Energy Storage

3a. Does the data for your country/region provide a mostly complete and reliable overall representation of the current development and assumed potential for **Underground Compressed Air Energy Storage**?

[ ] **Yes or mostly yes**: The data in the ESTMAP is as complete as possible/publicly available and based on a comprehensive regional geological assessment.
[ ] **Only partly**: ESTMAP contains a fairly broad indication of sites that are in theory suitable for storage potential, but the information is still founded on generic assumptions only and requires significant efforts on regional geological assessment.
[ ] **Only party**: ESTMAP includes selected (firm or confirmed) potential only. A broader regional evaluation will probably reveal significantly more potential.
[ ] **No or only partly**. Our country/region comprises significantly more storage capacity but this information is not included in ESTMAP due to restricted (public) data access or not being available yet.
[ ] **No or only partly**. Assessment in our country is still in a very early and premature state. For the major part of our country/region we do not know of any geological potential yet

3b. For **Underground Compressed Air Energy Storage**, how do you consider the potential and completeness of information with regards to the individual types of reservoirs:

Hydrocarbon reservoirs :
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Aquifers:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Rock Salt (formations for solution mining and caverns):
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Other host rock (suitable for excavated caverns) and mines:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

<u>Underground Thermal Energy Storage</u>

4a. Does the data for your country/region provide a mostly complete and reliable overall representation of the current development and assumed potential for **Underground Thermal Energy Storage**?

[ ] **Yes or mostly yes**: The data in the ESTMAP is as complete as possible/publicly available and based on a comprehensive regional geological assessment.
[ ] **Only partly**: ESTMAP contains a fairly broad indication of sites that are in theory suitable for storage potential, but the information is still founded on generic assumptions only and requires significant efforts on regional geological assessment.
[ ] **Only party**: ESTMAP includes selected (firm or confirmed) potential only. A broader regional evaluation will probably reveal significantly more potential.
[ ] **No or only partly**. Our country/region comprises significantly more storage capacity but this information is not included in ESTMAP due to restricted (public) data access or not being available yet.
[ ] **No or only partly**. Assessment in our country is still in a very early and premature state. For the major part of our country/region we do not know of any geological potential yet

4b. For **Underground Thermal Energy Storage**, how do you consider the potential and completeness of information with regards to the individual types of reservoirs:

Aquifers:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Other host rock (suitable for excavated caverns) and mines:
[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Underground Pumped Hydro Storage

3a. Does the data for your country/region provide a mostly complete and reliable overall representation of the current development and assumed potential for **Underground Pumped Hydro Storage**?

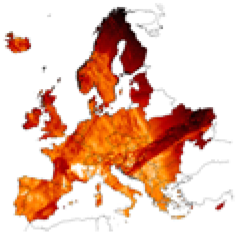
[ ] **Yes or mostly yes**: The data in the ESTMAP is as complete as possible/publicly available and based on a comprehensive regional geological assessment.
[ ] **Only partly**: ESTMAP contains a fairly broad indication of sites that are in theory suitable for storage potential, but the information is still founded on generic assumptions only and requires significant efforts on regional geological assessment.
[ ] **Only party**: ESTMAP includes selected (firm or confirmed) potential only. A broader regional evaluation will probably reveal significantly more potential.
[ ] **No or only partly**. Our country/region comprises significantly more storage capacity but this information is not included in ESTMAP due to restricted (public) data access or not being available yet.
[ ] **No or only partly**. Assessment in our country is still in a very early and premature state. For the major part of our country/region we do not know of any geological potential yet

3b. For **Underground Pumped Hydro Storage**, how do you consider the potential and completeness of information with regards to the individual types of reservoirs:

Other host rock (suitable for excavated caverns) and mines:

[ ] All/Most known potential for specific locations is included in ESTMAP
[ ] Only regional indications for potential are included in ESTMAP
[ ] There is well known potential, but information is not included in ESTMAP
[ ] Potential is unknown/not included in ESTAMP, but assumed to be present
[ ] Potential is (considered) absent of very limited

Annex 7: Data providers follow-up form: Example Poland



ESTMAP
Energy Storage Mapping and Planning

POLAND– Contract N°HADGR152701- 15

1-	**→ Receiving of data**	FJ : 2015/06/30, Excel + shapefiles
2-	← Acknowledgement of receipt	LB - 2015/07/02
3-	→ relance du contact: a-t-on vérifié les données ? 2015/07/10 then 2015/07/22	
4-	← Clarification request	LB 2015/07/22
5-	→ Clarification done	LB 2015/07/22
6-	← Acceptance of clarification, GIS in progress	LB 2015/07/22
7-	→ Acceptance of clarification	LB 2015/07/22
8-	← Clarification request regarding the GIS	LB 2015/07/23
9-	→ Clarification done	LB 2015/07/23
10-	VALIDATION OK	LB 2015/07/24

OK for invoicing

Annex 8: Above-ground data sources consulted

Data source	Included in database	Comments	URL
DOE Energy Storage Database	Yes	Please note that the database dates from February 2015. More recent versions are available but could not be included in this project	http://www.energystorageexchange.org/
GLE LNG Investment database	Yes	Please note that the database dates from June 2014. More recent version became available in April 2015, but could not be included in this project	http://www.gie.eu/index.php/maps-data/lng-investment-database
GSE (storage map)	Yes	Please note that the database dates from July 2015. More recent versions are available but could not be included in this project	http://www.gie.eu/index.php/maps-data/gse-storage-map
EASE European Energy storage Database	No	EASE does not allow use of the database for the ESTMAP project. The database has been thoroughly analysed to confirm that the EASE database only includes a limited (2) number of entries which are not included in the DOE energy storage database which were used.	http://www.ease-storage.eu/demonstrator.html
GLE small-scale LNG (2014)	No	No coordinates and capacities available in the database	http://www.gie.eu/index.php/maps-data/gle-sslng-map
FESTA	No	No coordinates available. Website offline now	http://www.fetsa.org/facts.php
Tankterminals.com	No	Commercial database of which data could not be included in the public ESTMAP database	www.tankterminals.com
Inogate	No	Data does not cover EU countries	http://www.inogate.org/contact/?lang=en
Industrial info	No	Commercial database of which data could not be included in the public ESTMAP database	http://www.industrialinfo.com/database/
IRENA	No	No database available	http://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E17%20Thermal%20Energy%20Storage.pdf
HYDI	No	Contains potentials for hydro power storage on a national level	http://streammap.esha.be/18.0.html
European Small Hydropower Association	No	Data is limited to hydropower and does not include storage	http://www.esha.be/de/projects/projects/hydropower-map.html
Hydro wiki	No	Source contains few EU entries for pumped hydro storage which are not all referenced	http://en.wikipedia.org/wiki/List_of_pumped-storage_hydroelectric_power_stations
Enipedia	No	Source describes technologies and products, not storage facilities	http://enipedia.tudelft.nl/wiki/Electricity_Storage#Technologies

Annex 9: Detailed overview of database input

Databases

The publically available databases are available in Excel format and are imported as a table in Access.

Database name	Database source	Actions performed prior to import
DOE	http://www.energystorageexchange.org/	1. “Duration” field converted to HH:MM format in “Duration_calculated_HHMM” field. 2. Extracted “Performance_RTE” field from “Performance” field. 3. Extracted “Performance_available” field from “Performance” field. 4. Trimming field names to exclude spaces. 5. “ID_ESTMAP” included as “unique key”.
GLE	http://www.gie.eu/index.php/maps-data/lng-investment-database	1. “Last update” converted to “Date_Last_update” 2. “ID_ESTMAP” included as ‘unique key’ 3. “Latitude” and “Longitude” included based on manual Google Maps search on “Company” and “Name of facility”
GSE	http://www.gie.eu/index.php/maps-data/gse-storage-map	1. Included separate field “Country”, derived from country names in original database. 2. “ID_ESTMAP” included as ‘unique key’ 3. Included separate field “Comment” based on footnotes for a number of gas storage locations. 4. “Latitude” and “Longitude” included based on manual Google Maps search on “Facility/Location”.
DEM	http://www.dem.si/en-gb/Development-opportunities/Pumped-storage-hydroelectric-PP	5. “ID_ESTMAP” included as ‘unique key’ 6. Filled in as many fields as possible for the single entry in the database based on available information, so the database can be merged directly into the union of databases (qry900).

Mapping tables

Several mapping tables have been used to perform cleaning operations on the source databases.

tbl11_MappingCountries

This mapping table names the countries according to the ESTMAP format. The table also serves as filter to only include ESTMAP countries in the ESTMAP database.

Loc_Country_raw	Loc_Country
Albania	ALBANIA
Austria	AUSTRIA
Belarus	BELARUS
Belgium	BELGIUM
Bosnia/Herzegovina	BOSNIA/HERZEGOVINA
Bulgaria	BULGARIA
Croatia	CROATIA
Cyprus	CYPRUS
Czech Republic	CZECH REPUBLIC
Denmark	DENMARK

Estonia	ESTONIA
Finland	FINLAND
France	FRANCE
Germany	GERMANY
Greece	GREECE
Hungary	HUNGARY
Iceland	ICELAND
Ireland	IRELAND
Italy	ITALY
Kosovo	KOSOVO
Latvia	LATVIA
Liechtenstein	LIECHTENSTEIN
Lithuania	LITHUANIA
Lituania	LITHUANIA
Luxembourg	LUXEMBOURG
Macedonia	MACEDONIA
Malta	MALTA
Moldova	MOLDOVA
Montenegro	MONTENEGRO
Netherlands	NETHERLANDS
Norway	NORWAY
Poland	POLAND
Portugal	PORTUGAL
Romania	ROMANIA
Russia	RUSSIAN FEDERATION
Serbia	SERBIA
Slovakia	SLOVAKIA
Slovenia	SLOVENIA
Spain	SPAIN
Sweden	SWEDEN
Switzerland	SWITZERLAND
the Netherlands	NETHERLANDS
Turkey	TURKEY
UK	UNITED KINGDOM
Ukraine	UKRAINE
United Kingdom	UNITED KINGDOM

tbl12_MappingEnergyCarrierInOutDOE

This mapping table is used in qry005_RemappingDOE to map the energy inflow and outflow characteristics based on “ID_ESTMAP”. Most projects in the DOE database have electricity as incoming as well as outgoing energy carrier. A number of Hydrogen Storage projects is differentiated from the other projects in the DOE DB because they have electricity as incoming energy carrier, but hydrogen as outgoing energy carrier.

ID_ESTMAP	Char_Ene_car_in	Char_Ene_car_out
DOE00650	Electricity	Hydrogen
DOE00854	Electricity	Hydrogen
DOE00855	Electricity	Hydrogen
DOE00884	Electricity	Hydrogen
DOE00904	Electricity	Electricity/Hydrogen

Input tables

The following table gives an overview of the input values used in the queries e.g. for conversions or calculations. The values are given with source (if applicable) and description.

Table name	Value	Unit	Source	Description
tbl30_InputConvUSD ToEUR	0.75	€/$	World Bank ('09-'14)	Converts USD to Euro's.
tbl31_InputNumberOf SecondsInHour	3600	seconds/ho ur	-	Converts hours to seconds.
tbl33_InputMJtoMWh	1/3600= 0.00027777 7778	MWh/MJ	-	Converts MJ to MWh
tbl36_InputNumberOf HoursInDay	24	hours/day	-	Converts days to hours.

tbl37_InputNumberOfHoursInYear	8760	Hours/year	-	Converts years to hours.
tbl38_InputNumberOfDaysInYear	365	Days/year	-	Converts years to days

Filter tables

These tables are used for filtering out records, e.g. in case of duplicates or out of (geographical) scope records.

Table name	Description	Manual modifications
tbl40_DuplicateLocationFilter	This filter is filled by qry913_Fill_Table40 and contains potential duplicates identified through qry911_DraftFinalDBwithLocationID and qry912_DraftFinalDB_duplicateList. It is used to point out which records are (not) to be discarded.	The “Discard” column is manually added and checked. No records to merge are identified.
tbl41_DuplicateLocationFilter2	This filter is filled by qry917_Fill_Table41 and contains potential duplicates identified through qry915_DraftFinalDB_2_withLocationID and qry916_DraftFinalDB_2_duplicateList. It is used to point out which records are to be merged and which ones are (not) to be discarded.	The “Discard” column is manually added and checked. No records to merge are identified.
tbl42_FinalFilter	This filter can be used to filter out other records, e.g. if a record location appears to be in the (Kingdom of the) Netherlands, but in reality is located on the island of Bonaire.	The “Discard” column is manually added and checked.

Annex 10: Detailed overview queries on database input

DOE

This sections covers the queries for the DOE database.

qry001_RenamingDOE

This query renames the columns of the raw DOE input data.

Target field	Source field(s)	Action
ID_ESTMAP	ID ESTMAP	Collect
Fac_Name	Project Name	Renaming
Char_cat1_sto_type	Technology Type Category 2	Renaming
Char_cat2_sto_type	Technology Type	Renaming
Loc_Country	Country	Renaming
Loc_State	State_Province	Renaming
Loc_City	City	Renaming
Loc_Operator	Utility	Renaming
Loc_Lat	Latitude	Renaming
Loc_Long	Longitude	Renaming
Loc_Site_spec	Description	Renaming
Perf_Status	Status	Renaming
Perf_Duration	Duration_calculated_HHMM	Renaming
Perf_Fac_tech_time	Projected Project Lifetime years	Renaming
Perf_Service_date_in	Commissioning Date	Renaming
Perf_Service_date_out	Decommissioning Date	Renaming
Data_date_create	Record Created	Renaming
Data_date_change	Last Updated	Renaming
Grid_connect	Grid Interconnection	Renaming
Perf_eff_storage	Performance_RTE	Renaming

qry002_Concatenation

This query concatenates columns and stores them in a new field name.

Target field	Source field(s)	Action
Char_serv_type	tbl01_DOE2015.Service_Use Case 1, tbl01_DOE2015.Service_Use Case 2, tbl01_DOE2015.Service_Use Case 3, tbl01_DOE2015.Service_Use Case 4, tbl01_DOE2015.Service_Use Case 5, tbl01_DOE2015.Service_Use Case 6, tbl01_DOE2015.Service_Use Case 7, tbl01_DOE2015.Service_Use Case 8, tbl01_DOE2015.Service_Use Case 9, tbl01_DOE2015.Service_Use Case 10, tbl01_DOE2015.Service_Use Case 11, tbl01_DOE2015.Service_Use Case 12	Concatenation

qry003_Conversions

This query converts columns to the ESTMAP units (e.g. kW to MW).

Target field	Unit	Source field(s)	Action
Perf_Cap_in_max	MW	tbl01_DOE2015.Rated Power in kW	Convert “Rated Power in kW” to MW by dividing by 1000.
Perf_Cap_prod_max	MW	tbl01_DOE2015.Rated Power in kW	Convert “Rated Power in kW” to MW by dividing by 1000.
Perf_status	[-]	qry001_RenamingDOE.Perf_status	Convert fields to match ESTMAP Perf_status options through nested IIF statements.

qry004_Calculations

This query performs calculations with columns to arrive at ESTMAP parameters.

Target field	Unit	Source field(s)	Action
Perf_Volume_work	MWh	tbl01_DOE2015.Duration_calculated_hours, qry003_ConversionsDOE.Perf_Cap_in_max	Duration_calculated_hours*Perf_Cap_in_max. If equation results in zero, "null" is used to give an "empty" cell.
Perf_Fac_constr_time	years	tbl01_DOE2015.Commissioning Date, tbl01_DOE2015.Construction Date	(Commissioning Date- Construction Date)/365
Perf_Availability_hours	Hours	tbl37_InputNumberOfHoursInYear.NumberOfHoursInYear, tbl01_DOE2015.Performance_available	NumberOfHoursInYear*Performance_available
Ex_cap_storage	€/MWh	tbl01_DOE2015.Duration_calculated_hours, qry003_ConversionsDOE.Perf_cap_in_max, tbl01_DOE2015.CAPEX, tbl30_InputConvUSDToEUR.USDtoEUR Conversion	CAPEX*INPUTConvUSDtoEUR/(Duration_calculated_hours*Perf_Cap_in_max). If equation results in zero, "null" is used to give an "empty" cell.
Exe_ope_fix	€/MWh/year	tbl01_DOE2015.OPEX usd_kWh Capacity_year, tbl30_InputConvUSDToEUR.USDtoEUR Conversion	OPEX usd_kWh Capacity_year*USDtoEURConversion/1000

qry005_Remapping

This query remaps the energy carriers as well as the country of the entry (and filters by country).

Target field	Source field(s)	Action
Loc_country	Tbl1_MappingCountries.Loc_Country, Tbl1_MappingCountries.Loc_Country_raw, qry001_RenamingDOE.Loc_country	Remapping on tbl11_MappingCountries.Loc_Country_raw and qry001_RenamingDOE.Loc_Country Only keeping records where joined fields from both tables are equal.
Char_Ene_car_in	Tbl12_MappingEnergyCarrierInOutDOE.ID_ESTMAP, Tbl12_MappingEnergyCarrierInOutDOE.Char_Ene_car_in, qry001_RenamingDOE.ID_ESTMAP	Remapping on Tbl12_MappingEnergyCarrierInOutDOE.ID_ESTMAP and qry001_RenamingDOE.ID_ESTMAP Including all records from qry001_RenamingDOE and only those records from 'tbl12_mappingEnergyCarrierInOutDOE' where the joined fields are equal.
Char_Ene_car_out	Tbl12_MappingEnergyCarrierInOutDOE.ID_ESTMAP, Tbl12_MappingEnergyCarrierInOutDOE.Char_Ene_car_out, qry001_RenamingDOE.ID_ESTMAP	Remapping on Tbl12_MappingEnergyCarrierInOutDOE.ID_ESTMAP and qry001_RenamingDOE.ID_ESTMAP Including all records from qry001_RenamingDOE and only those records from 'tbl12_mappingEnergyCarrierInOutDOE' where the joined fields are equal.

qry099_DOE_final

This query collects the columns from the specific queries.

Target field	Source field(s)	Action
ID_ESTMAP	qry001_RenamingDOE.ID_ESTMAP	Collect
Fac_Name	qry001_RenamingDOE.Fac_Name	Collect
Loc_Country	qry005_RemappingDOE.Loc_Country	Collect
Char_cat1_sto_type	qry001_RenamingDOE.Char_cat1_sto_type	Collect
Char_cat2_sto_type	qry001_RenamingDOE. Char_cat2_sto_type	Collect
Char_Ene_car_in	qry005_RemappingDOE.Char_Ene_car_in	Collect
Char_Ene_car_out	qry005_RemappingDOE.Char_Ene_car_out	Collect
Loc_State	qry001_RenamingDOE.Loc_State	Collect
Loc_City	qry001_RenamingDOE.Loc_City	Collect
Loc_Operator	qry001_RenamingDOE.Loc_Operator	Collect
Loc_Lat	qry001_RenamingDOE.Loc_Lat	Collect
Loc_Long	qry001_RenamingDOE.Loc_Long	Collect
Loc_Site_spec	qry001_RenamingDOE.Loc_Site_spec	Collect

Perf_Status	qry003_ConversionsDOE.Perf_Status	Collect
Perf_Duration	qry001_RenamingDOE.Perf_Duration	Collect
Perf_Fac_tech_time	qry001_RenamingDOE. Perf_Fac_tech_time	Collect
Perf_Service_date_in	qry001_RenamingDOE.Perf_Service_date_in	Collect
Perf_Service_date_out	qry001_RenamingDOE.Perf_Service_date_out	Collect
Data_date_create	qry001_RenamingDOE.Data_date_create	Collect
Data_date_change	qry001_RenamingDOE.Data_date_change	Collect
Grid_connect	qry001_RenamingDOE.Grid_connect	Collect
Perf_Volume_work	qry004_CalculationsDOE.Perf_Volume_work	Collect
Perf_Fac_constr_time	qry004_CalculationsDOE.Perf_Fac_constr_time	Collect
Ex_cap_storage	qry004_CalculationsDOE.Ex_cap_storage	Collect
Ex_ope_fix	qry004_CalculationsDOE.Ex_ope_fix	Collect
Perf_Cap_in_max	qry003_ConversionsDOE.Perf_Cap_in_max	Collect
Perf_Cap_prod_max	qry003_ConversionsDOE.Perf_Cap_prod_max	Collect
Char_Serv_type	qry002_ConcatenationDOE.Char_Serv_type	Collect
Perf_Availability_hours	qry004_CalculationsDOE.Perf_Availability_hours	Collect
Perf_Eff_storage	qry001_RenamingDOE.Perf_Eff_storage	Collect

GLE

This sections covers the queries for the GLE database.

qry201_RenamingGLE

This query renames the columns of the raw GLE input data.

Target field	Source field(s)	Action
ID_ESTMAP	tbl02_GLE2014.ID_ESTMAP	Renaming
Data_date_change	tbl02_GLE2014.Date_Last_Upd ate	Renaming
Fac_Name	tbl02_GLE2014.Name of facility	Renaming
Loc_Country	tbl02_GLE2014.Country	Renaming
Loc_Lat	tbl02_GLE2014.Latitude	Renaming
Loc_Long	tbl02_GLE2014.Longitude	Renaming
Data_comm	tbl02_GLE2014.Source of information	Renaming

qry203_Conversion

This query converts columns to the ESTMAP units (e.g. kW to MW).

Target field	Source field(s)	Action
Perf_Cap_prod_max	-	Leave empty (input is provided in m^3 per hour in Perf_Cap_prod_max_nm3perHour)
Perf_Cap_prod_max_nm3 perHour	tbl02_GLE2014. Max Send-Out Capacity (Nm3_h) Current, tbl02_GLE2014.Max Send-Out Capacity (Nm3_h) Future	If Max Send-Out Capacity (Nm3_h) **Current** is not empty, then Max Send-Out Capacity (Nm3_h) **Current** Otherwise Max Send-Out Capacity (Nm3_h) **Future**
Perf_Volume_work	-	Leave empty (input is provided in m^3 LNG in Perf_Volume_work_m3_LNG)
Perf_Volume_work_m3_L NG	tbl02_GLE2014.Storage Capacity (m3 LNG) Current, tbl02_GLE2014.Storage Capacity (m3 LNG) Future	Storage Capacity (m3 LNG) **Current** is not empty, then Storage Capacity (m3 LNG) **Current** Otherwise Storage Capacity (m3 LNG) **Future**
Perf_Service_date_in	tbl02_GLE2014.Status _ start of operation, tbl02_GLE2014.Expected	If Status _ start of operation is 19* or 20* then take Status _ start of operation, otherwise take Expected.
Perf_Status	tbl02_GLE2014.Status _ start of operation	Convert fields to match ESTMAP Perf_status options through nested IIF statements.

qry205_RemappingGLE

This query remaps the energy carriers as well as the country of the entry (and filters by country).

Target field	Source field(s)	Action
Country	tbl11_MappingCountries.Loc_Country, tbl02_GLE2014.Country	Remapping on Loc_Country and Country Only keeping records where joined fields from both tables are equal.
Char_Ene_car_out	Default value for all records: “Gas”	Char_Ene_car_out defined as “Gas” for all records.
Char_Ene_car_in	Default value for all records: “Gas”	Char_Ene_car_in defined as “Gas” for all records.

qry299_GLE_final

This query collects the columns from the specific queries.

Target field	Source field(s)	Action
ID_ESTMAP	qry201_RenamingGLE.ID_ESTMAP	Collect
Data_date_change	qry201_RenamingGLE.Data_date_change	Collect
Fac_Name	qry201_RenamingGLE.Fac_Name	Collect
Loc_Lat	qry201_RenamingGLE.Loc_Lat	Collect
Loc_Long	qry201_RenamingGLE.Loc_Long	Collect
Data_comm	qry201_RenamingGLE.Data_comm	Collect
Perf_Cap_prod_max	qry203_ConversionsGLE.Perf_Cap_prod_max	Collect
Perf_Volume_work	qry203_ConversionsGLE.Perf_Volume_work	Collect
Perf_Service_date_in	qry203_ConversionsGLE.Perf_Service_date_in	Collect
Loc_Country	qry205_RemappingGLE.Loc_Country	Collect
Char_Ene_car_out	qry205_RemappingGLE.Char_Ene_car_out	Collect
Char_Ene_car_in	qry205_RemappingGLE.Char_Ene_car_in	Collect
Perf_Status	qry203_ConversionsGLE.Perf_Status	Collect
Perf_Cap_prod_max_nm3 perHour	qry203_ConversionsGLE.Perf_Cap_prod_max_ nm3perHour	Collect
Perf_Volume_work_m3_L NG	qry203_ConversionsGLE.Perf_Volume_work_ m3_LNG	Collect

GSE

This sections covers the queries for the DOE database.

qry401_RenamingGSE

This query renames the columns of the raw GSE input data.

Target field	Source field(s)	Action
Fac_Name	tbl03_GSE2014.Facility_Location	Renaming
Char_cat1_sto_type	tbl03_GSE2014.Type	Renaming
Loc_Country	tbl03_GSE2014.Country	Renaming
Loc_City	tbl03_GSE2014.Facility_Location	Renaming
Loc_Operator	tbl03_GSE2014.Company	Renaming
ID_ESTMAP	tbl03_GSE2014.ID_ESTMAP	Collect
Loc_Lat	bl03_GSE2014.Latitude	Renaming
Loc_Long	tbl03_GSE2014.Longitude	Renaming

qry402_ConcatenationGSE

This query concatenates columns and stores them in a new field name.

Target field	Source field(s)	Action
Data_comm:	tbl03_GSE2014.Access, tbl03_GSE2014.Comments	Concatenate Access and Comments if Access has a value, otherwise use just Comments.

qry403_ConversionGSE

This query converts columns to the ESTMAP units (e.g. kW to MW).

Target field	Source field(s)	Action
Perf_Cap_prod_max_nm3	-	Leave empty (input is provided in m^3 per hour in Perf_Cap_prod_max_nm3perHour).
Perf_Cap_prod_max_nm3perHour	tbl03_GSE2014.Withdrawal Capacity TPA, tbl03_GSE2014.Withdrawal Capacity nTPA, tbl36_InputNumberOfHoursInDay.NumberOfHoursInDay,	Capacities are converted from million m^3 per day to m^3 per hour. If Withdrawal Capacity TPA and Withdrawal Capacity nTPA are not empty: (Withdrawal Capacity TPA + Withdrawal Capacity nTPA) / (NumberOfHoursInDay) * 1000 * 1000 If Withdrawal Capacity TPA is not empty and Withdrawal Capacity nTPA is empty: Withdrawal Capacity TPA/ (NumberOfHoursInDay) * 1000 *1000 If Withdrawal Capacity TPA is empty and Withdrawal Capacity nTPA is not empty: Withdrawal Capacity nTPA/ (NumberOfHoursInDay) * 1000 * 1000
Perf_Volume_work	-	Leave empty (input is provided in m^3 Gas in Perf_Volume_work_m3_Gas).
Perf_Volume_work_m3_Gas	tbl03_GSE2014.Working Gas TPA, tbl03_GSE2014.Working Gas nTPA,	Volumes are converted from million m^3 to m^3. If Working Gas TPA and Working Gas nTPA are not empty: (Working Gas TPA + Working Gas nTPA) * 1000 * 1000 If Working Gas TPA is not empty and Working Gas nTPA is empty: Working Gas TPA * 1000 * 1000 If Working Gas nTPA is empty and Working Gas nNTPA is not empty: Working Gas nTPA * 1000
Perf_Status	tbl03_GSE2014.Working Gas TPA, tbl03_GSE2014.Working Gas nTPA, tbl03_GSE2014.Working Gas Project	If Working Gas TPA or Working Gas nTPA is not empty then field is Operational. If Working Gas project is not empty then field is Announced
Perf_Cap_in_max	-	Leave empty (input is provided in m^3 per hour in Perf_Cap_prod_max_nm3perHour).
Perf_Cap_in_max_nm3perHour	tbl03_GSE2014.Injection Capacity TPA, tbl03_GSE2014.Injection Capacity nTPA, tbl36_InputNumberOfHoursInDay.NumberOfHoursInDay,	Capacities are converted from million m^3 per day to m^3 per hour. If Injection Capacity TPA and Injection Capacity nTPA are not empty: (Injection Capacity TPA + Injection Capacity nTPA) / (NumberOfHoursInDay) * 1000 * 1000 If Injection Capacity TPA is not empty and Injection Capacity nTPA is empty: Injection Capacity TPA/ (NumberOfHoursInDay) * 1000 *1000 If Injection Capacity TPA is empty and Injection Capacity nTPA is not empty: Injection Capacity nTPA/ (NumberOfHoursInDay) * 1000 * 1000

qry404_RemappingGSE

This query remaps the energy carriers as well as the country of the entry (and filters by country).

Target field	Source field(s)	Action
Country	tbl11_MappingCountries.Loc_Country, tbl03_GSE2014.Country	Remapping on Loc_Country and Country Only keeping records where joined fields from both tables are equal.
Char_Ene_car_out	Default value for all records: “Gas”	Char_Ene_car_out defined as “Gas” for all records.
Char_Ene_car_in	Default value for all records: “Gas”	Char_Ene_car_in defined as “Gas” for all records.

qry499_GSE_final

This query collects the columns from the specific queries.

Target field	Source field(s)	Action
Loc_Country	qry404_RemappingGSE.Loc_Country	Collect
Char_ene_car_in	qry404_RemappingGSE.Char_ene_car_in	Collect
Char_Ene_car_out	qry404_RemappingGSE.Char_Ene_car_out	Collect
Perf_Status	qry403_ConversionGSE.Perf_Status	Collect
Perf_Volume_work	qry403_ConversionGSE.Perf_Volume_work	Collect
Perf_cap_prod_max	qry403_ConversionGSE.Perf_cap_prod_max	Collect
Data_comm	qry402_ConcatenationGSE.Data_comm	Collect
Loc_Operator	qry401_RenamingGSE.Loc_Operator	Collect
Loc_City	qry401_RenamingGSE.Loc_City	Collect
Char_cat1_sto_type	qry401_RenamingGSE.Char_cat1_sto_type	Collect
Fac_Name	qry401_RenamingGSE.Fac_Name	Collect
ID_ESTMAP	qry401_RenamingGSE.ID_ESTMAP	Collect
Loc_Lat	qry401_RenamingGSE.Loc_Lat	Collect
Loc_Long	qry401_RenamingGSE.Loc_Long	Collect
Perf_Cap_in_max	qry403_ConversionGSE.Perf_Cap_in_max	Collect
Perf_Cap_prod_max_nm3perHour	qry403_ConversionGSE.Perf_Cap_prod_max_nm3perHour	Collect
Perf_Volume_work_m3_Gas	qry403_ConversionGSE.Perf_Volume_work_m3_Gas	Collect
Perf_Cap_in_max_nm3perHour	Perf_Cap_in_max_nm3perHour.qry403_ConversionGSE	Collect

Intermediate DB

This section presents the queries used for the union of the individual data sources and it’s post processing.

qry900_UnionAll_DOE_GSE_GLE_DEM

Target field	Source field(s)	Action
ID_ESTMAP Fac_Name Data_date_create Perf_Cap_in_max Char_cat1_sto_type Char_cat2_sto_type Loc_Country Loc_State Loc_City Loc_Operator Loc_Lat Loc_Long Loc_Site_spec Perf_Status Perf_Duration Perf_Fac_tech_time Perf_Service_date_in Perf_Service_date_out Data_date_change Grid_connect Char_Serv_type Data_Comm Perf_Cap_prod_max	qry099_DOE_final.* qry299_GLE_final.* qry499_GSE_final.*	Union of all four DB final queries. If a final DB does not contain the target field, “” is used for text fields, NULL is used for number fields.

Perf_Volume_work Perf_Fac_constr_time Ex_cap_storage Ex_ope_fix Char_Ene_car_in Perf_Eff_storage Perf_Availability_hours Perf_Rate_up Ex_subsid Char_Ene_car_out Perf_Cap_prod_max_nm3perHour Perf_Volume_work_m3_Gas Perf_Cap_in_max_nm3perHour Perf_Volume_work_m3_LNG		

qry901_Union_with_additional_fields

This query adds two columns to the union query, the data source and a label for data quality.

Target field	Source field(s)	Action
*	qry900_UnionAll_DOE_GSE_GLE_DEM.*	Collect
Data_source	qry900_UnionAll_DOE_GSE_GLE_DEM.ID_ESTMAP	Collect data source from ID ESTMAP: Left(qry900_UnionAll_DOE_GSE_GLE_DEM.ID_ESTMAP,Len([qry900_UnionAll_DOE_GSE_GLE_DEM.ID_ESTMAP)-5)
Data_quality	-	Set all to "Operator". Could still be subject to be updated.

qry905_Renaming_StorageType1

This query renames the primary storage type, to comply with ESTMAP standards.

Target field	Source field(s)	Action
Char_cat1_sto_type	qry901_Union_with_additional_fields.Char_cat1_sto_type, qry901_Union_with_additional_fields.Char_cat2_sto_type	Transform Char_cat1_sto_type to ESTMAP storage types based on contents of qry901_Union_with_additional_fields.Char_cat1_sto_type and qry901_Union_with_additional_fields.Char_cat2_sto_type through (nested) IIF statements.

qry906_Renaming_storageType2

This query renames the secondary storage type, of GSE and GLE entries.

Target field	Source field(s)	Action
Char_cat2_sto_type	qry901_Union_with_additional_fields.Char_cat1_sto_type,	Determine Char_cat2_sto_type based on contents of qry901_Union_with_additional_fields.Char_cat1_sto_type through (nested) IIF statements.

qry910_DraftFinalDB

This query collects the relevant columns from the previous four queries.

Target field	Source field(s)	Action
ID_ESTMAP	qry901_Union_with_additional_fields.ID_ESTMAP	Collect
Fac_Name	qry901_Union_with_additional_fields.Fac_Name	Collect
Data_date_create	qry901_Union_with_additional_fields.Data_date_create	Collect
Perf_Cap_in_max	qry901_Union_with_additional_fields.Perf_Cap_in_max	Collect
Char_cat1_sto_type	qry905_Renaming_StorageType1.Char_cat1_sto_type	Collect
Char_cat2_sto_type	qry906_Renaming_StorageType2.Char_cat2_sto_type	Collect
Loc_Country	qry901_Union_with_additional_fields.Loc_Country	Collect
Loc_City	qry901_Union_with_additional_fields.Loc_City	Collect
Loc_Operator	qry901_Union_with_additional_fields.Loc_Operator	Collect
Loc_Lat	qry901_Union_with_additional_fields.Loc_Lat	Collect
Loc_Long	qry901_Union_with_additional_fields.Loc_Long	Collect
Loc_Site_spec	qry901_Union_with_additional_fields.Loc_Site_spec	Collect
Perf_Status	qry901_Union_with_additional_fields.Perf_Status	Collect

Perf_Duration	qry901_Union_with_additional_fields.Perf_Duration	Collect
Perf_Fac_tech_time	qry901_Union_with_additional_fields.Perf_Fac_tech_time	Collect
Perf_Service_date_in	qry901_Union_with_additional_fields.Perf_Service_date_in	Collect
Perf_Service_date_out	qry901_Union_with_additional_fields.Perf_Service_date_out	Collect
Data_date_change	qry901_Union_with_additional_fields.Data_date_change	Collect
Grid_connect	qry901_Union_with_additional_fields.Grid_connect	Collect
Char_Serv_type	qry901_Union_with_additional_fields.Char_Serv_type	Collect
Data_Comm	qry901_Union_with_additional_fields.Data_Comm	Collect
Perf_Cap_prod_max	qry901_Union_with_additional_fields.Perf_Cap_prod_max	Collect
Perf_Volume_work	qry901_Union_with_additional_fields.Perf_Volume_work	Collect
Perf_Fac_constr_time	qry901_Union_with_additional_fields.Perf_Fac_constr_time	Collect
Ex_cap_storage	qry901_Union_with_additional_fields.Ex_cap_storage	Collect
Ex_ope_fix	qry901_Union_with_additional_fields.Ex_ope_fix	Collect
Char_Ene_car_in	qry901_Union_with_additional_fields.Char_Ene_car_in	Collect
Perf_Eff_storage	qry901_Union_with_additional_fields.Perf_Eff_storage	Collect
Perf_Availability_hours	qry901_Union_with_additional_fields.Perf_Availability_hours	Collect
Perf_Rate_up	qry901_Union_with_additional_fields.Perf_Rate_up	Collect
Ex_subsid	qry901_Union_with_additional_fields.Ex_subsid	Collect
Char_Ene_car_out	qry901_Union_with_additional_fields.Char_Ene_car_out	Collect
Data_source	qry901_Union_with_additional_fields.Data_source	Collect
Data_quality	qry901_Union_with_additional_fields.Data_quality	Collect
Perf_Cap_prod_max_nm3perHour	qry901_Union_with_additional_fields.Perf_Cap_prod_max_nm3perHour	Collect
Perf_Volume_work_m3_Gas	qry901_Union_with_additional_fields.Perf_Volume_work_m3_Gas	Collect
Perf_Cap_in_max_nm3perHour	qry901_Union_with_additional_fields.Perf_Cap_in_max_nm3perHour	Collect
Perf_Volume_work_m3_LNG	qry901_Union_with_additional_fields.Perf_Volume_work_m3_LNG	Collect

qry911_DraftFinalDBwithLocationID

This query adds an extra column to the previous query introducing a LocationID based on a combination of the coordinates of the location.

Target field	Source field(s)	Action
Loc_ID	qry910_DraftFinalDB.Loc_Lat, qry910_DraftFinalDB.Loc_Long	Binning by rounding Loc and Lat on 0.2 Longitude and Latitude degrees (~15 km longitude and ~22 km latitude at 47 degrees latitude) and create Loc_ID: Round(qry910_DraftFinalDB.Loc_Lat*5,0)/5*10+ Round(qry910_DraftFinalDB.Loc_Long*5,0)/5*10 000

qry912_DraftFinalDB_duplicateList

This query creates a list of entries with an identical LocationID.

Target field	Source field(s)	Action
*	qry911_DraftFinalDBwithLocationID.*	Collect and find duplicates based on Loc_ID

qry913_Fill_Table40

This query fills table40 with the list of duplicates out of the previous query.

Target field	Source field(s)	Action
Tbl40_DuplicateLocationFilter	qry912_DraftFinalDB_duplicateList.*	Fill Table 40 with content of query 912.

qry914_DraftFinalDB_2

This query creates a new draft database by discarding the entries indicated in table 40.

Target field	Source field(s)	Action
*	Qry912_DraftFinalDB.*, tbl40_DuplicateLocationFilter.Discard	Show only the records from qry910 that are not indicated as 'to discard' in Table 40.

qry915_DraftFinalDBwithLocationID

This query introduces again a location ID, however the binning is shifted by half a bin size in order to include entries that were not included in qry911 due to rounding.

Target field	Source field(s)	Action
Loc_ID	qry914_DraftFinalDB_2.Loc_Lat, qry914_DraftFinalDB_2.Loc_Long	Binning by rounding Loc and Lat on 0.2 Longitude and Latitude degrees (~15 km longitude and ~22 km latitude at 47 degrees latitude) and create Loc_ID (this time shifted half a bin size 0.1): (Round((qry914_DraftFinalDB_2.Loc_Lat+0.1)*5,0)/5-0.1)*10+(Round((qry914_DraftFinalDB_2.Loc_Long+0.1)*5,0)/5-0.1)*10000

qry916_DraftFinalDB_2_DuplicateList

This query creates a list of entries with a unique LocationID.

Target field	Source field(s)	Action
*	qry915_DraftFinalDBwithLocationID.*	Collect and find duplicates based on Loc_ID

qry917_Fill_Table41

This query fills table 41 with the list of duplicates out of the previous query.

Target field	Source field(s)	Action
tbl41_DuplicateLocationFilter2	qry916_DraftFinalDB_2_duplicateList.*	Fill Table 41 with content of query 916.

qry918_DraftFinalDB_3

This query creates a new draft database by discarding the entries indicated in table 41.

Target field	Source field(s)	Action
*	Qry914_DraftFinalDB_2.*, tbl41_DuplicateLocationFilter2.Discard	Show only the records from qry914 that are not indicated as ‘to discard’ in Table 41.

qry919_Fill_Table42

This query fills table 42 with the records from query 918 in order to facilitate manual deletion of unwanted records.

Target field	Source field(s)	Action
tbl42_FinalFilter	qry918_DraftFinalDB_3.*	Fill Table 41 with content of query 916.

qry930_FinalDB

This query creates the final database by discarding the entries indicated in table 42.

Target field	Source field(s)	Action
*	qry918_DraftFinalDB_3.*, tbl42_FinalFilter.Discard	Show only the records from qry918 that are not indicated as ‘to discard’ in Table 42.

qry980_Make_output_table

This query creates an output table by pasting the content of qry930 in table 50.

Target field	Source field(s)	Action
tbl_50_Output_table.*	qry930_FinalDB.*	Collect and export to Table 50.