



# CO2StoP - a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe

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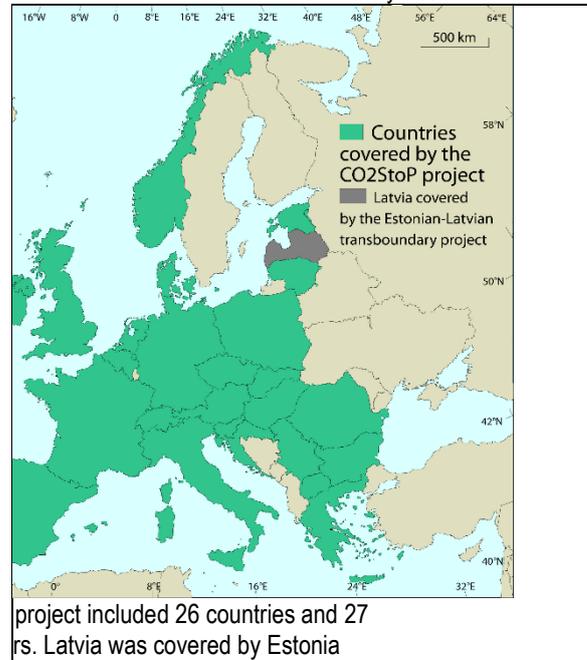
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CO2StoP is the acronym for the “CO<sub>2</sub> Storage Potential in Europe.” project. The CO2StoP project, which started in January 2012 and ended in December 2013, was funded by the European Commission (Project N°: ENER/C1/154-2011-SI2.611598). The CO2StoP project included 26 countries and 27 Partners. Further Latvia was covered by Estonia.

The results of the study are provided as a database of CO<sub>2</sub> storage locations throughout Europe, a Data Analysis/Interrogation Tool and GIS, and a tool to compute storage capacities and injection rates (StoreFit).

The database is now available on the website of the Joint Research Centre - European Commission, Petten, the Netherlands (<http://iet.jrc.ec.europa.eu/>) and will be available as an interactive web-based CO<sub>2</sub> Storage Atlas for Europe at the European Geological Data Infrastructure (EGDI), ([www.europe-geology.eu](http://www.europe-geology.eu)).

The CO2StoP database will be the first step towards a European Storage Atlas. Other databases are available for UK, the CO<sub>2</sub> Stored database (published 12 May 2016) ([www.co2stored.co.uk/home/index](http://www.co2stored.co.uk/home/index)) and the Nordic CO<sub>2</sub> storage atlas is produced by NORDICCS – the Nordic CCS Competence Centre (published November 2015) (<https://data.geus.dk/nordiccs/about.xhtml>). Spain has published Atlas of Geological Structures that uphold a CO<sub>2</sub> storage potential in Spain (ISBN: 978-84-7840-928-0 Año 2014).



## Background – methodologies

### *Introduction to CO<sub>2</sub> storage resource assessment*

A resource can be defined as anything potentially available and useful to man. The pore space in deeply buried reservoir rocks is a resource that can be used for CO<sub>2</sub> storage. It is of the utmost importance to be aware that the presence of a resource does not indicate that any fraction of it can be exploited, economically, now or in the future.

A reserve can be defined as that part of a resource that is available to be exploited economically now using currently available technology. Thus, in order to move from a resource estimate to a reserve estimate, a whole series of technical, economic, legal and socioeconomic criteria have to be applied to the resource. These criteria will then identify the fraction of the resource that can actually be economically exploited in a particular jurisdiction using presently available technology. Consequently, a very high level of technical assessment is required to demonstrate the existence of a CO<sub>2</sub> storage reserve. As a result, the resources required to achieve the level of technical assessment needed to define CO<sub>2</sub> storage reserves are, in most cases, only available within a demonstration or commercial storage project. For these reasons, it has not been possible to define any CO<sub>2</sub> storage reserves in the present project.

### *Storage mechanisms*

Carbon dioxide can be retained in reservoir rocks by the following mechanisms: 1) structural and stratigraphic trapping, 2) development of a residual saturation of gas, or supercritical phase CO<sub>2</sub> trapped in the pore space by capillary forces, 3) dissolution into the pore fluids present within the reservoir rock, 4) precipitation of carbonates or other carbon-rich minerals, 5) adsorption onto the surfaces of carbon-rich grains within the reservoir.

In typical porous and permeable saline water-bearing reservoir rocks (commonly described as deep saline aquifers in the CCS literature), mineral reaction and the dissolution of CO<sub>2</sub> into pore fluids are considered to be unimportant on short injection timescales (say 50 years or so) because the kinetics of these processes are relatively slow (van der Meer & van Wees, 2006). Therefore, they are unlikely to greatly affect storage capacity.

### *Geological and physical constraints on CO<sub>2</sub> storage capacity*

Each jurisdiction contains a given amount of pore space within its subsurface. The total resource of pore space that is potentially available for CO<sub>2</sub> storage, in a jurisdiction, is that part of its total pore space that can be filled with, and will retain, injected CO<sub>2</sub>. Geology and physics dictate that this will be far less than the total pore space available in a jurisdiction. These limitations mean that only a small fraction of the total resource of pore space can be filled with CO<sub>2</sub>. Whilst geology varies greatly between jurisdictions, the underlying physical processes that dictate how much of the total pore space is



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theoretically available for CO<sub>2</sub> storage does not. Therefore, it is possible to define a common methodology that can be used to estimate the fraction of the total resource of pore space that could be used for storage. If appropriate CO<sub>2</sub> densities at reservoir conditions are applied to this volume, this allows estimation of the theoretical CO<sub>2</sub> storage resource.

### **Technical, legal, economic and social constraints on CO<sub>2</sub> storage capacity**

In practice, only a fraction of the theoretical CO<sub>2</sub> storage resource in any given jurisdiction can actually be utilised – for a variety of technical, economic, legal and social reasons. In the CO2StoP project, the pore space in a jurisdiction is subdivided into reservoir formations. These are mappable bodies of rock which are continuous in the subsurface and are both porous and permeable. Each reservoir formation contains one or more storage units. A storage unit is defined as a part of a reservoir formation that is at depths greater than 800 m and which is covered by an effective cap rock. These storage units are considered to have potential for CO<sub>2</sub> storage and they form the basis of the CO<sub>2</sub> storage estimates made in the CO2StoP project. Each storage unit may contain one or more daughter units. Daughter units are defined as structural or stratigraphic traps which have the potential to immobilise CO<sub>2</sub> within them, e.g. domes or proven oil and gas fields. Daughter units have the potential to store CO<sub>2</sub> at higher saturations than the remainder of a storage unit, so their storage potential can be estimated separately in CO2StoP.

### **Estimating the Technically Accessible CO<sub>2</sub> Storage Resource (TASR)**

The CO2StoP calculation engine is capable of producing a resource estimate that is very similar to the Technically Accessible CO<sub>2</sub> Storage Resource estimated by the US Geological Survey (Brennan et al. 2010), i.e. the fraction of the theoretical storage resource that can be accessed using all currently available technologies regardless of cost. The IEA has recommended that the first step in all CO<sub>2</sub> storage resource estimates should be to estimate the TASR (Heidug, 2013).

The CO2StoP estimate differs in one main respect from the TASR estimated by the USGS method. It adds the storage capacity of hydrocarbon fields to that of the saline aquifers. This has to be done because the pore volume of the hydrocarbon fields is not provided in the database, so it cannot be subtracted from the pore volume of the storage units before their storage capacity is estimated. There are other minor differences in the constraints and assumptions; nevertheless, it is considered that two methods produce results that are sufficiently similar to allow them to be compared.

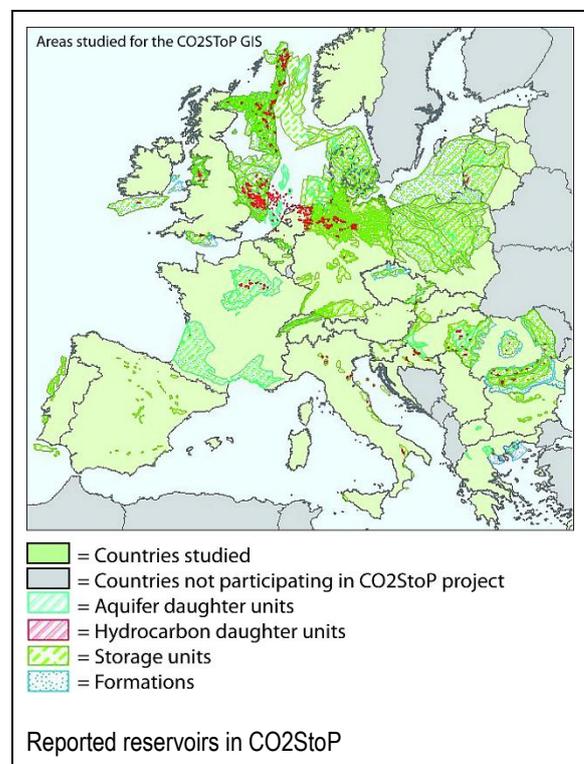
### **The CO2StoP methodology**

The CO2StoP project provides a database, GIS (ESRI's ArcGIS 10) and calculation engine capable of providing probabilistic estimates of CO<sub>2</sub> storage capacity. The Data Analysis/Interrogation Tool is a combination of Microsoft Access (Data Interrogation tool), and Excel (StoreFit tool) with external code (linked to Excel) to perform injection rate calculations. Calculations that can be done with the Database Analysis/Interrogation Tool include: storage capacity, injection rates and stochastic analyses of the storage capacity and injection rates.

The work to establish internationally recognised standards for capacity assessments was initiated by the Carbon Sequestration Leadership Forum (CSLF) about a year before the start of the EU GeoCapacity project and a CSLF Task Force has been active since. The paper "Estimation of CO<sub>2</sub> Storage Capacity in Geological Media - Phase 2" (Bachu et al., 2007) published by the CSLF presents comprehensive definitions, concepts and methodologies to be used in estimating CO<sub>2</sub> storage capacity. As in EU GeoCapacity, the CO2StoP methodology complies with the CSLF recommendations. The methods and calculations for determining the fractions of the resource, used in the CO2StoP project, also accord with the recent IEA proposals for harmonising CO<sub>2</sub> storage capacity estimation methodologies (Heidug 2013). The CO2StoP methodology can calculate the TASR and the storage resource in structural and stratigraphic traps (that latter divided into two subsets – hydrocarbon fields and aquifer daughter units), the storage resource assuming pressure management was not used.

### **Results**

The assessment of the various fractions of the CO<sub>2</sub> geological storage resource, performed in the CO2StoP project, is currently at a provisional level only. Unfortunately, large differences exist between the type and quality of data each country has available. Differences also exist with regards to





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how much of the relevant data is in the public domain and therefore can be reported. For example, there are major variations between countries where some only have data available from traps for buoyant fluids (where the TASR will be low because potential for storage outside such traps by residual saturation will not be accounted for) and some countries which have included aquifer formation data (where the TASR calculation will be more meaningful). In the great majority of countries, uncertainties also remain related to lack of reservoir parameter data. The

acquisition of such data will, potentially, require a sustained campaign of geological mapping and characterisation of storage capacity, or at least significantly more time and financial resources to assemble and enter all available data. These factors limit the results obtained from the CO<sub>2</sub>StoP project and it is recommended that further resources are targeted on improving the results. Both reporting and data could be improved if greater resources were made available.

In a European context, the Technically Accessible CO<sub>2</sub> Storage Resource (TASR) or theoretical storage resource should only be used for extra-European international resource comparisons because it is certain that the TASR is several times larger than the practical CO<sub>2</sub> storage capacity. Consequently quoting the TASR can be misleading, giving false impressions of capacity if there is not a critical distinction between resource and reserve estimates.

## Conclusions

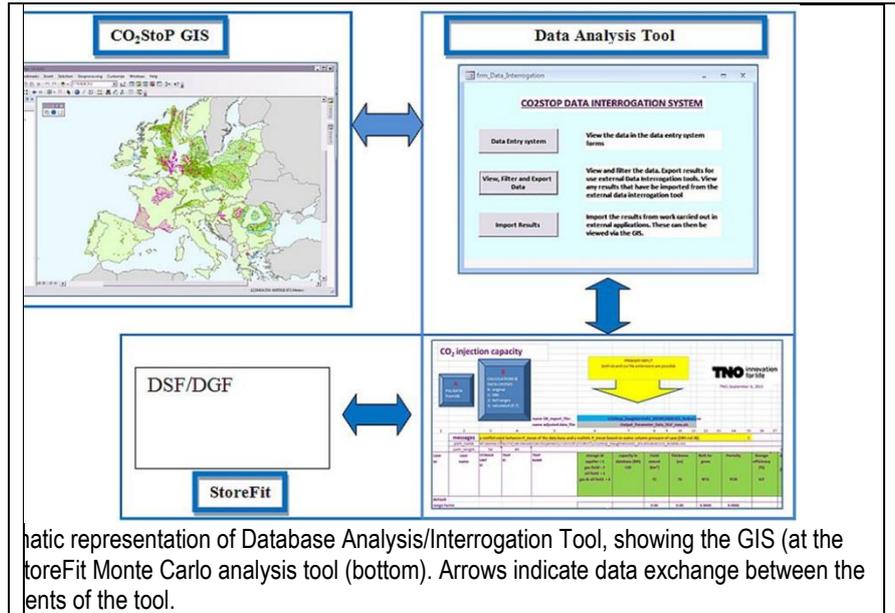
The calculations made in CO<sub>2</sub>StoP from the current project database of CO<sub>2</sub> storage locations throughout Europe paint a broad picture, but also identify the gaps in our knowledge. These gaps must be filled by further data entry, and, potentially, new geological studies, seismic surveys and drilling to make more precise data available.

It is critically important to understand the assumptions that lie at the basis of the storage capacity estimates entered in the database. These are especially relevant for saline formations, the capacities of which were derived without taking into account regulatory or economic limitations.

The CO<sub>2</sub>StoP methodology has made significant progress towards establishing probabilistic estimates of the CO<sub>2</sub> storage resource in Europe in a way that will allow comparisons with other regions of the world to be made, and which will also be useful to policy makers. However, the partial data entry into the project database does make clear that the current project marks the beginning of the process of resource estimation, and certainly not the end.

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Diagrammatic representation of Database Analysis/Interrogation Tool, showing the GIS (at the top left), the StoreFit Monte Carlo analysis tool (bottom left), and the CO<sub>2</sub> injection capacity (bottom right). Arrows indicate data exchange between the components of the tool.