DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE **RAPPORT 2021/34**

EU Geological CO_2 storage summary

Prepared by the Geological Survey of Denmark and Greenland for Clean Air Task Force

Karen Lyng Anthonsen & Niels Peter Christensen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

G E U S

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Content

Niels Peter Christensen is professor emeritus and an independent CCS adviser at CCS Consult (Oslo/Copenhagen).

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Introduction

The objective of this report is to give a summary of the EU Geological CO_2 storage potential based on the most recent European assessment, the CO2StoP project. The report includes locations of on-shore and off-shore CO_2 storage options in both Northern and Southern Europe, and prospective depleted offshore oil and gas fields (e.g. EOR prospects), based on processed data from the CO2StoP database.

One of the major tasks has been the production of European and regional maps with spatial extent of the sedimentary basins and fairways, indicating potential injection foci. For each of the 26 countries in the CO2StoP project, a brief summary on CO_2 storage capacity and emissions is given.

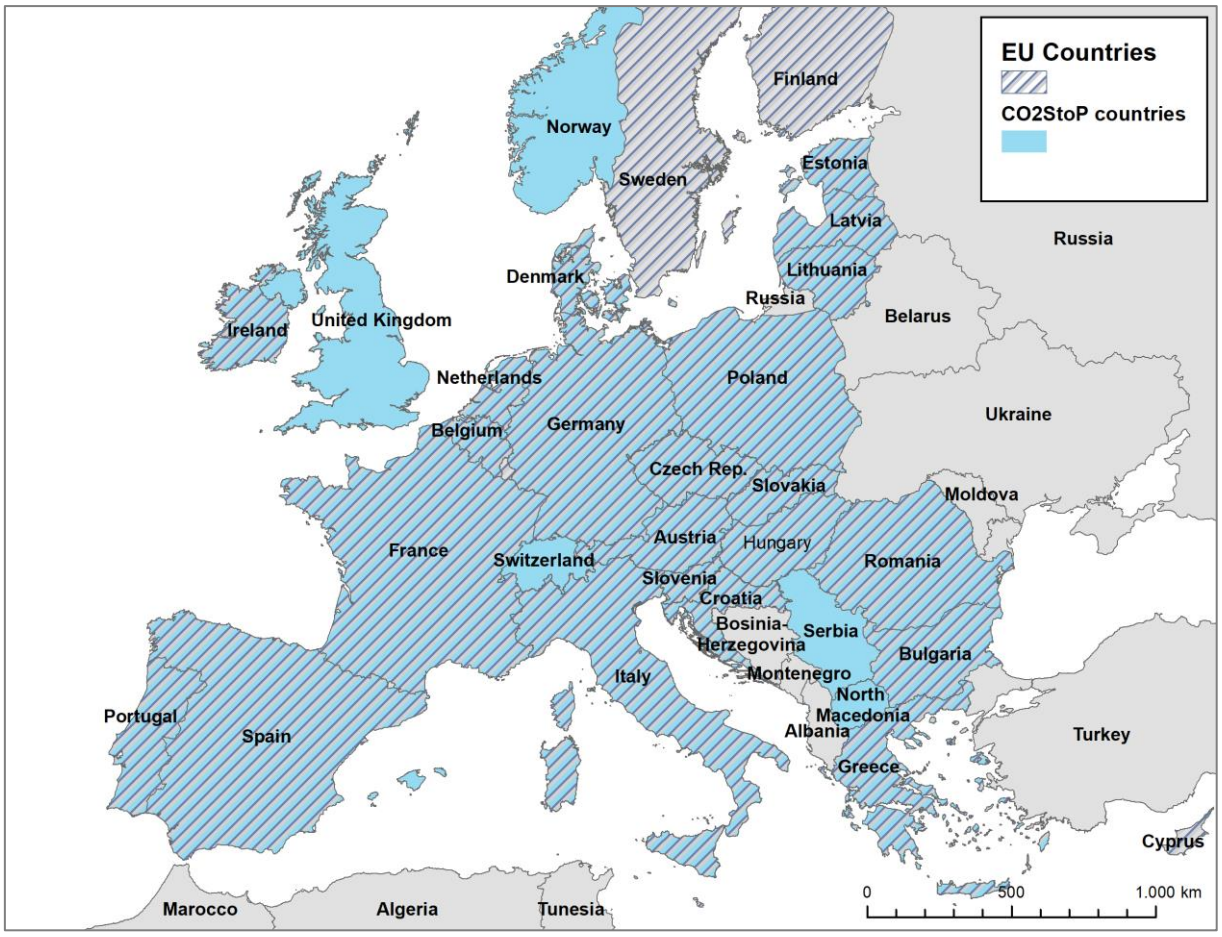


Figure 1. The countries in the CO2StoP project in blue colour, EU countries hatched.

European CO_2 storage assessments

Since the beginning of 1990ties, several studies have attempted to map and estimate the European storage capacity for CO_2. Among the most prominent are the Joule II project (Holloway et al. 1996), the GESTCO project (Christensen & Holloway, 2004), the CASTOR project (2006), the EU GeoCapacity project (Vangkilde-Pedersen et al. 2009) and the CO2StoP project (Poulsen et al. 2014).

These projects have in many ways been steppingstones to one another, but there are significant differences between the projects with respect to number of countries included, screening parameters, classification of storage sites and to some extent the assessment methodology. It is important to recognise the evolution of European CO_2 assessments and the challenges related to the methodology (static or probabilistic) for mapping and estimating storage capacities in Europe.

Apart from the European EU co-funded projects, Norway has published an atlas for the Norwegian continental shelf (Halland et al. 2014). The NORDICCS project made an assessment for the Nordic countries and released a joint Nordic CO_2 storage web-atlas in 2015 (Anthonsen et al. 2013). Additionally, United Kingdom and Spain have published national CO_2 storage atlases.

Joule II (1996)
The results from Joule II provided the theoretical CO_2 storage capacity for 13 European countries. The CO_2 storage capacity was estimated to 30 Gt in saline aquifer storage reservoirs (geological structures), 6 Gt in oil fields, 27 Gt in gas fields and 773 Gt in non-trapped major saline aquifers, a total of 836 Gt CO_2 storage capacity.

GESTCO (2004)
The GESTCO project (Geological Storage of CO_2 from Combustion of Fossil Fuel) mapped storage options as regional saline aquifers, storage reservoirs (geological structures), oil/gas fields and coal beds in 7 north-western European countries and Greece. The efficient storage capacity[1] was calculated for all storage options. GESTCO also made an inventory of stationary emission sources >100 Kt CO_2/year. All data was integrated in a GIS database. Only the summary report from the project is publicly available (Christensen & Holloway, 2004).

Castor WP 1.2 (2006)
The Castor project (CO_2 from Capture to Storage) mapped saline aquifers, storage reservoirs (geological structures), gas fields, oil fields, coal beds and emission sources

[1] The efficient storage capacity is calculated by introducing net/gross cut-off to the total storage formation thickness and multiplying with an efficiency factor, typically 0,02 for regional saline aquifers and 0,4 for storage in unconfined geological structures. For more details see EU GeoCapacity report D26 WP4 Report standards and site selection criteria.

from 8 eastern European countries and added data into the GESTCO GIS. Only a project summary is publicly available (CASTOR project, 2006).

EU GeoCapacity (2009)

The EU GeoCapacity (EU GeoCapacity – Assessing European Capacity for Geological Storage of Carbon Dioxide) updated the GESTCO GIS database and includes regional saline aquifers, storage reservoirs (geological structures), oil/gas fields, un-mineable coal beds and CO_2 emission sources >100 Kt CO_2/year for 25 European countries and two provinces in China (Fig. 2). The results from EU GeoCapacity provided the efficient CO_2 storage capacity based on the GIS data, but also a conservative estimate. The CO_2 storage capacity was estimated to 326 Gt in saline aquifers including the storage reservoirs (geological structures), 32 Gt in hydrocarbon fields and 2 Gt in un-mineable coal beds, in total 360 Gt storage capacity. The onshore storage capacity amounted 116 Gt and the offshore storage capacity 244 Gt (Vangkilde-Pedersen et al. 2009). Almost 200 Gt of this storage capacity is offshore Norway (http://www.geology.cz/geocapacity).The mapped areal extent of saline aquifers in Norway were not included in EU GeoCapacity, but Norway has subsequently produced a national CO_2 storage atlas for the Norwegian continental shelf in 2014 (Halland et al, 2014). Reports from the EU GeoCapacity project are partly available at The EU GeoCapacity Project: Home page (geology.cz), but not the GIS data.

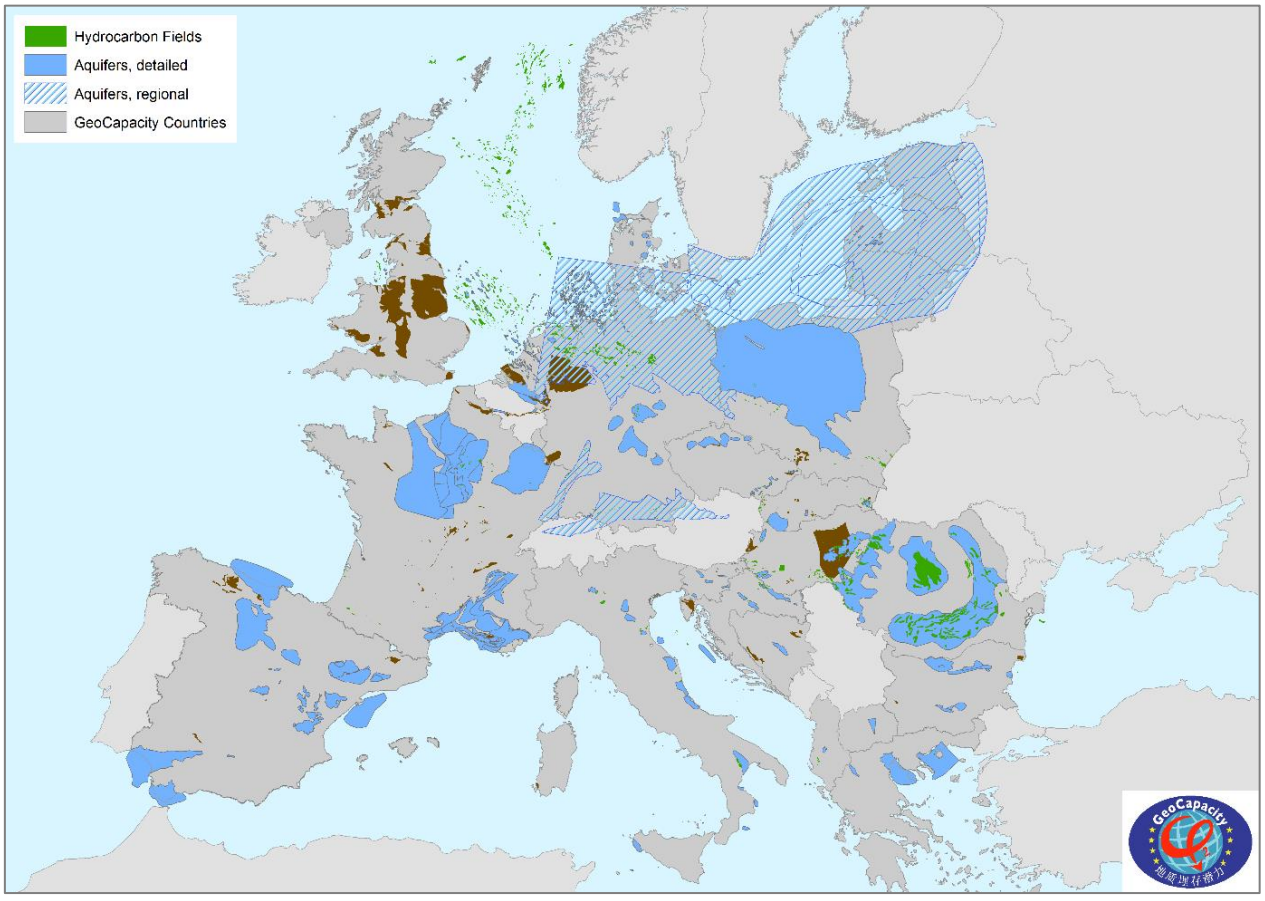


Figure 2. The mapped saline aquifers, gas fields, oil fields and coal beds in EU GeoCapacity. Darker grey coloured areas show the participating countries. Brown areas are the un-mineable coal beds.

The Nordic CO_2 Storage Atlas (2014)

The Nordic CO_2 Storage Atlas is available as a WebGIS Nordic CCS Competence Centre (geus.dk). The atlas includes potential storage options in saline aquifers, storage reservoirs (geological structures), hydrocarbon fields, porous basalts and ultramafic rocks. The CO_2 storage capacity in saline aquifers and hydrocarbon fields in Denmark, Norway and Sweden was estimated to 120 Gt in saline aquifers and 14 Gt in hydrocarbon fields, in total 134 Gt storage capacity. Iceland estimated that 60-330 Gt could be stored in porous basalts and Finland estimated 2-3 Gt questionable storage capacity in ultramafic rocks (Anthonsen et al. 2013). The atlas is a compilation of the data from the Norwegian CO_2 storage atlas by the Norwegian Petroleum Directorate (NDP), and new or updated data from Denmark, Finland, Iceland and Sweden.

CO2StoP (2015)

CO2StoP project harmonised the GIS-database from EU GeoCapacity and includes publicly available data from 27 European countries. The project introduced a revised approach to divide and subdivide potential geological storage formation into individual saline aquifers of assessment (probalistic approach) and further subdivisions of these into storage reservoirs i.e. hydrocarbon fields and potential structural storage reservoirs in saline aquifers DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/110 (europa.eu). The total storage capacity for all countries was estimated to 625 Gt. Norwegian data only covered the Norwegian North Sea area. Data is partly available through the European Geological Data Infrastructure at EGDI – European Geological Data Infrastructure (europe-geology.eu).

National CO_2 storage assessments have been produced and published by some of those European countries holding the largest storage potential.

Norway published the first CO_2 storage atlas in 2011 which covered the Norwegian North Sea co2-atlas-north-sea.pdf (npd.no) followed in 2012 by an atlas covering the Norwegian Sea co2-atlas-norwegian-sea-2012.pdf (npd.no) and an atlas for the Barents Sea in 2013 co2-atlas-barents-sea.pdf (npd.no). Finally a combined atlas for the entire Norwegian Continental Shelf was published in 2014 CO2 atlas for the Norwegian Continental Shelf - The Norwegian Petroleum Directorate (npd.no)

United Kingdom developed between 2013 and 2018 a database providing an overview of more than 500 potential storage sites in UK About CO2 Stored.

Spain published a CO_2 storage atlas in 2014, and this is available in Spanish at Almacenamiento geológico de CO2 | Publicaciones del IGME (igmepublicaciones.blogspot.com).

CO_2 emission sources

The EU GeoCapacity project made an inventory of emission sources and listed the annual CO_2 emissions from stationary CO_2 sources >100 Kt (emissions reported in 2005). The total emissions from all emission sources (>100 Kt) was 1988 Mt/y (almost 2 Gt) and the regions with highest emission is located in the western part of Germany, this region alone emitted 166 Mt/y (8% of total European emissions) (Fig. 3).

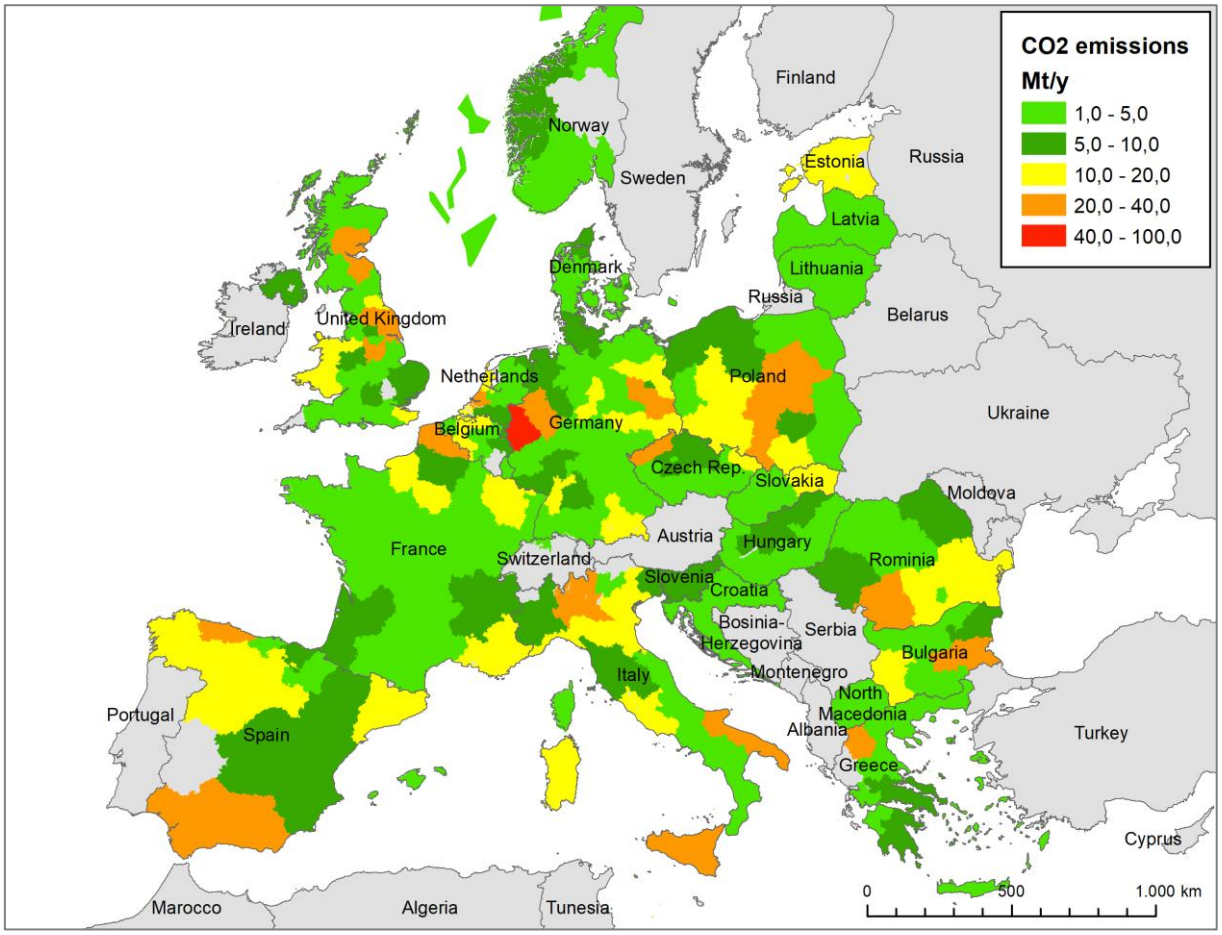
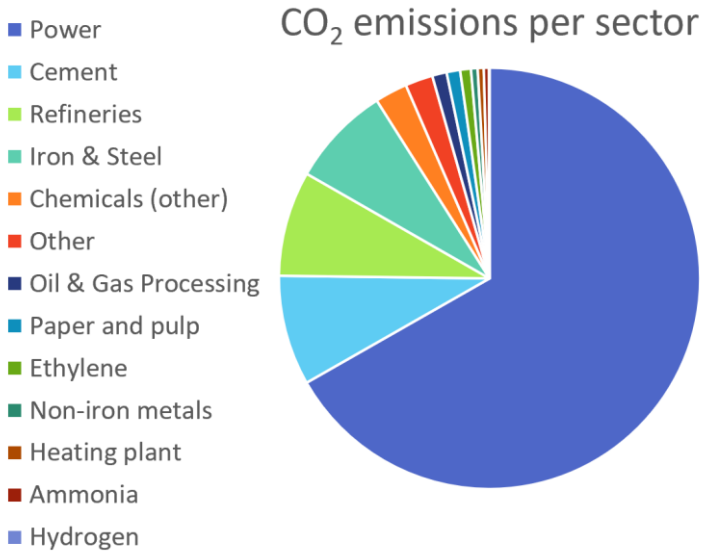


Figure 3. Illustrates the CO_2 emissions in most European regions. The region with highest emissions is shown in red. Emission data are from 2005 and is processed from the EU Geo-Capacity database.

An analysis of the sectors exposes that the dominating sector is the power generation sector, using much coal, counting for approximately 2/3 of the total reported emissions (Fig. 4). Other sectors with large emissions are cement, refineries and iron and steel production.



Sector	CO_2 emissions per year in Mt
Power	1327,4
Cement	168
Refineries	160,5
Iron & Steel	153,8
Chemicals (other)	49,5
Other	42,1
Oil & Gas Processing	22,1
Paper and pulp	20,6
Ethylene	16,4
Non-iron metals	10,2
Heating plant	9,2
Ammonia	7,9
Hydrogen	0,8
Total	1988,5

Figure 4. The CO_2 emissions distributed in sectors, based 2005 data and processed from the EU GeoCapacity GIS database.

Looking at the distribution of emission sources in Europe the largest concentrations are in the north-west (UK, Netherlands, Belgium and Germany), but also Poland and Italy have regions with high density of emission sources (Fig. 5).

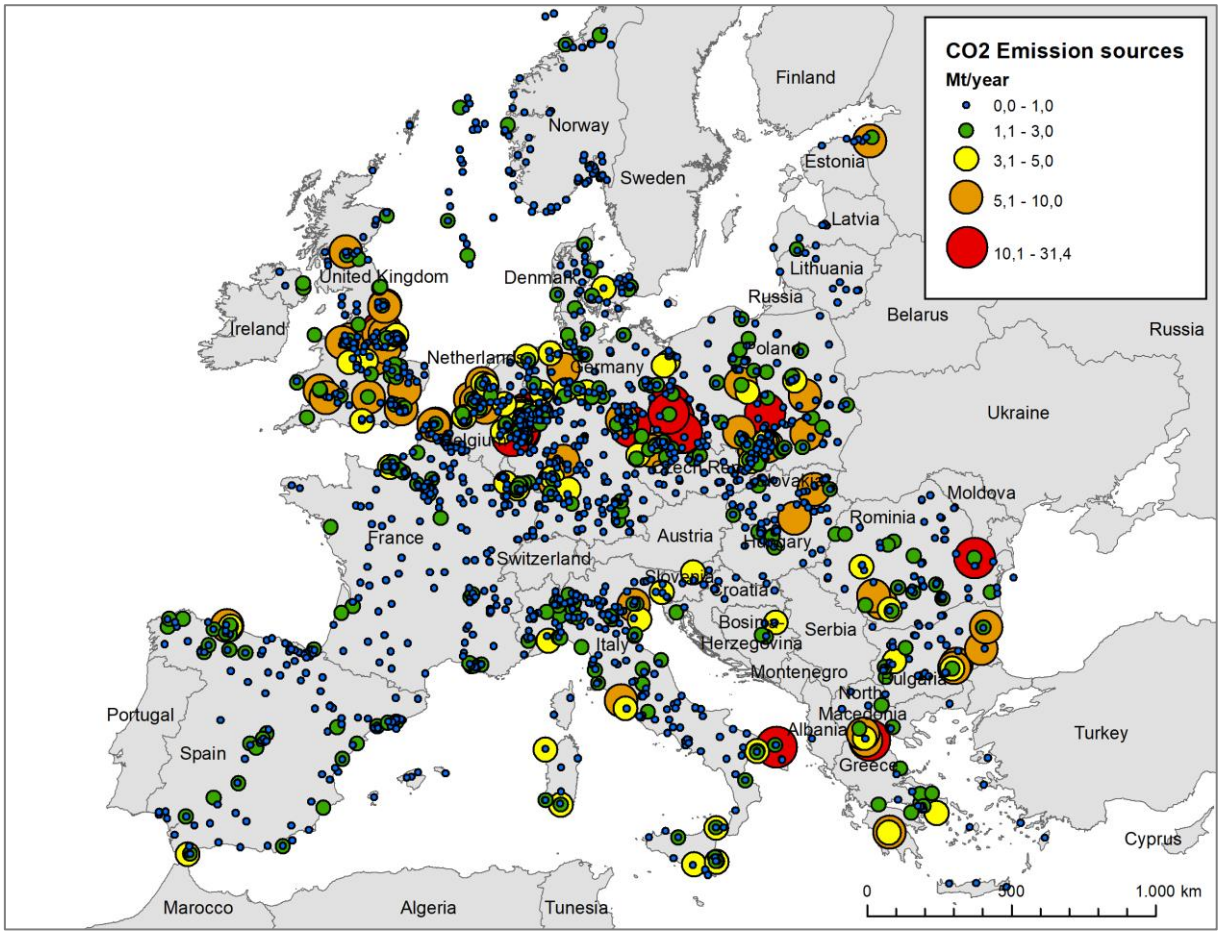


Figure 5. The location and yearly emissions from European emission sources based on the EU GeoCapacity inventory.

CO_2 storage in Europe

Since the Joule project all European CO_2 storage assessments have emphasised the large storage potential in the North Sea area. This storage potential is closely related to the location of some of the largest European sedimentary basins (Fig. 5). Storage regions in southern Europe are more scattered, due to the increased influence of the Alpine orogeny and subduction zone (Fig. 5).

Figure 5. European geological map. The sedimentary basins are in general located in the light-yellow coloured areas (Source: IGME 5000).

The CO2StoP project is a continuation of previous projects such as GESTCO, Castor and EU GeoCapacity, but only included publicly available data. The CO2Stop project

complied maps of CO_2 saline aquifer as well as storage reservoirs and hydrocarbon fields[2] (Poulsen et al. 2014).

Mapping of storage regions in CO2StoP show the large basin areas in northern Europe (Fig. 6). The project introduced a revised approach to divide and subdivide potential geological storage formation into individual saline aquifers of assessment (probalistic approach) and further subdivisions of these saline aquifers into hydrocarbon fields and potential storage reservoirs within saline aquifers. The storage capacities were in most cases calculated for both the saline aquifers and the storage reservoirs. An overview of the data entered into the CO2Stop database is given in table 1. The calculation methodology is described in Poulsen et al. 2014.

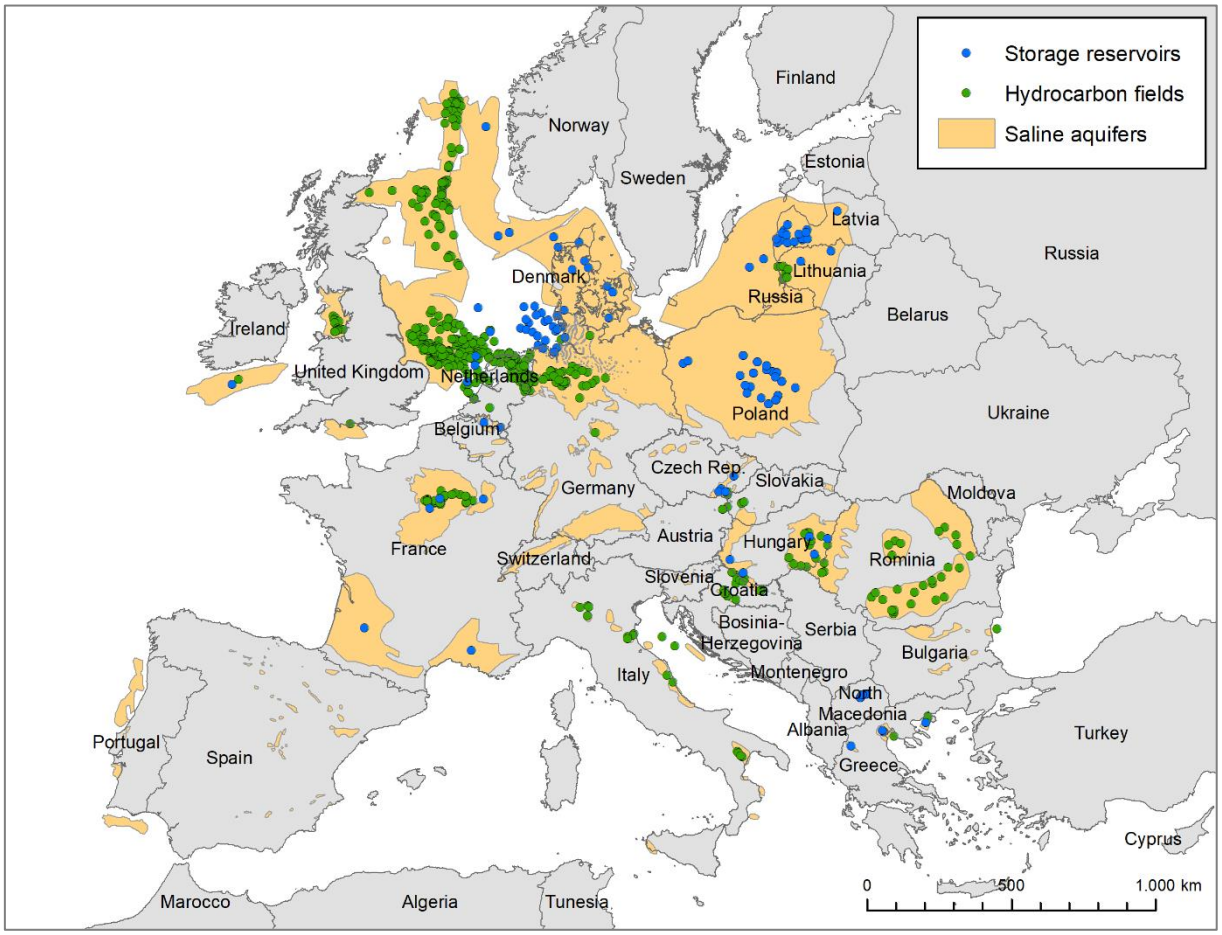


Figure 6. Location of Saline aquifers is illustrated as polygons and the hydrocarbon fields and storage reservoirs are illustrated as points.

[2] The CO2StoP uses the terms storage units and daughter units (traps). In this report the storage units are replace by saline aquifers and daughter unites are replaced with storage reservoirs.

Country	TASR	Resource assuming no pressure management	Resource in structural/stratigraphical traps	
			Saline aquifers	Hydrocarbon fields
Albania	-------	----------	----------	----------
Austria	X	X	N/A	X
Belgium	Mean only	Mean Only	Mean only	N/A
Bosnia and Herzegovina	-------	-------	-------	-------
Bulgaria	Yes	X	N/A	X
Croatia	Mean only	Some mean values	N/A	X
Czech Republic	Yes	All except 2 units		
Denmark	Yes	Yes	Yes	N/A
France	X	X	X	X
Germany	X	X	X	X
Greece	Yes	Yes	Yes	Yes
Hungary	Some mean values	X	Mean only	Mean only
Ireland	Yes	Mean only	Yes	X
Italy	Yes	Only 1 unit	Yes	Yes
Latvia	Yes	Yes	Yes	N/A
Lithuania	Yes	Yes	Yes	Yes
Macedonia (FYROM)	Yes	Yes	Yes	N/A
Netherlands	X	X	X	Yes
Norway	N/A	N/A	N/A	N/A
Poland	Yes	Yes	Yes	N/A
Portugal	X	X	N/A	N/A
Romania	Mean only	Mean only	N/A	x
Serbia	X	X	N/A	N/A
Slovakia	Yes	Yes	N/A	Yes
Slovenia	Mean only	X	N/A	N/A
Spain	Mean only	Mean only	N/A	N/A
Switzerland	Yes	Yes	N/A	N/A
UK	Yes	Yes	X	Yes

TASR = Technically Accessible CO_2 Storage Resource.
Yes = the data is available for recalculating the storage,
X = there is not enough data to recalculate (see section 4.1 for additional information on what storage capacity data is available)
N/A = not applicable i.e. the country has not provided this type of data

Table 1. Overview of which countries sufficient data has been entered to calculate each type of CO_2 storage resource estimate. Comments like 'Mean only' indicate that only a mean value is entered into the database rather than a range (min, mean, max). From Poulsen et al. 2014.

The CO2StoP database is limited to public available data, since in many countries data related to the subsurface is own by private companies and consequently more or less restricted. An overview of the data provided for the CO2StoP are listed in table 1.

The assessment of the various fractions of the CO_2 geological storage resource performed in the CO2StoP project is currently at a provisional level only. Unfortunately, large differences exist between what kind and quality of data each country has available, and what relevant data is in the public domain and therefore can be reported. In the great majority of countries, uncertainties also remain related to lack of reservoir parameter data, acquisition of which potentially will require a sustained campaign of geological mapping and characterisation of storage capacity (Poulsen et al. 2014).

CO_2 storage capacity

The CO2StoP projects distinguish between saline aquifers which is the part of a formation having reservoir properties suitable for CO_2 storage (Microsoft Word - D26 WP4 Report.doc (geology.cz)) and storage reservoirs which is a part of the saline aquifer (geological structure).

The mapped locations of the saline aquifers are illustrated both as merged polygons from the CO2Stop project showing the outline of the storage regions and as scaled points presenting the storage capacity for each saline aquifer (Fig. 7). In total the 418 mapped saline aquifers add up to a total storage capacity estimated at 482 Gt. Saline aquifers will in many cases be available in more than one stratigraphic level within the same area.

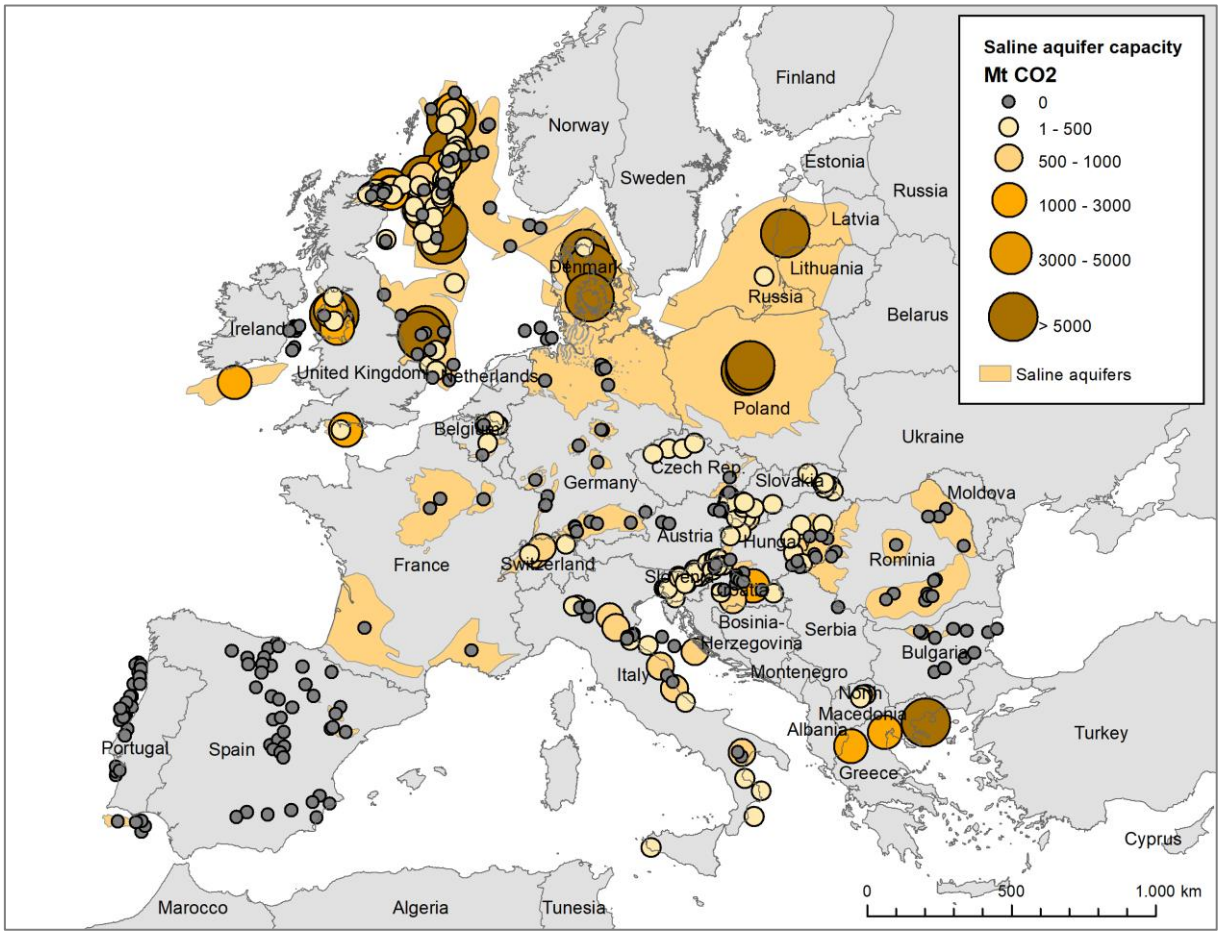


Figure 7. Location and outline of the saline aquifers and storage capacity illustrated as graduated symbols.

Storage reservoirs are only identified in some countries (Fig. 8). All together 134 storage reservoirs are mapped with a total storage capacity between 31 and 54 Gt.

The majority of the European hydrocarbon fields (HC fields) are in the North Sea Basin, both the southern part (UK, the Netherlands, North Germany) and the northern part (UK) (no HC fields from Norway are included in this work) (Fig. 9). The total storage capacity is estimated to 25 Gt in 513 HC fields, and the Groningen field (7 Gt) in the Netherlands, accounts for 28 % of the total capacity.

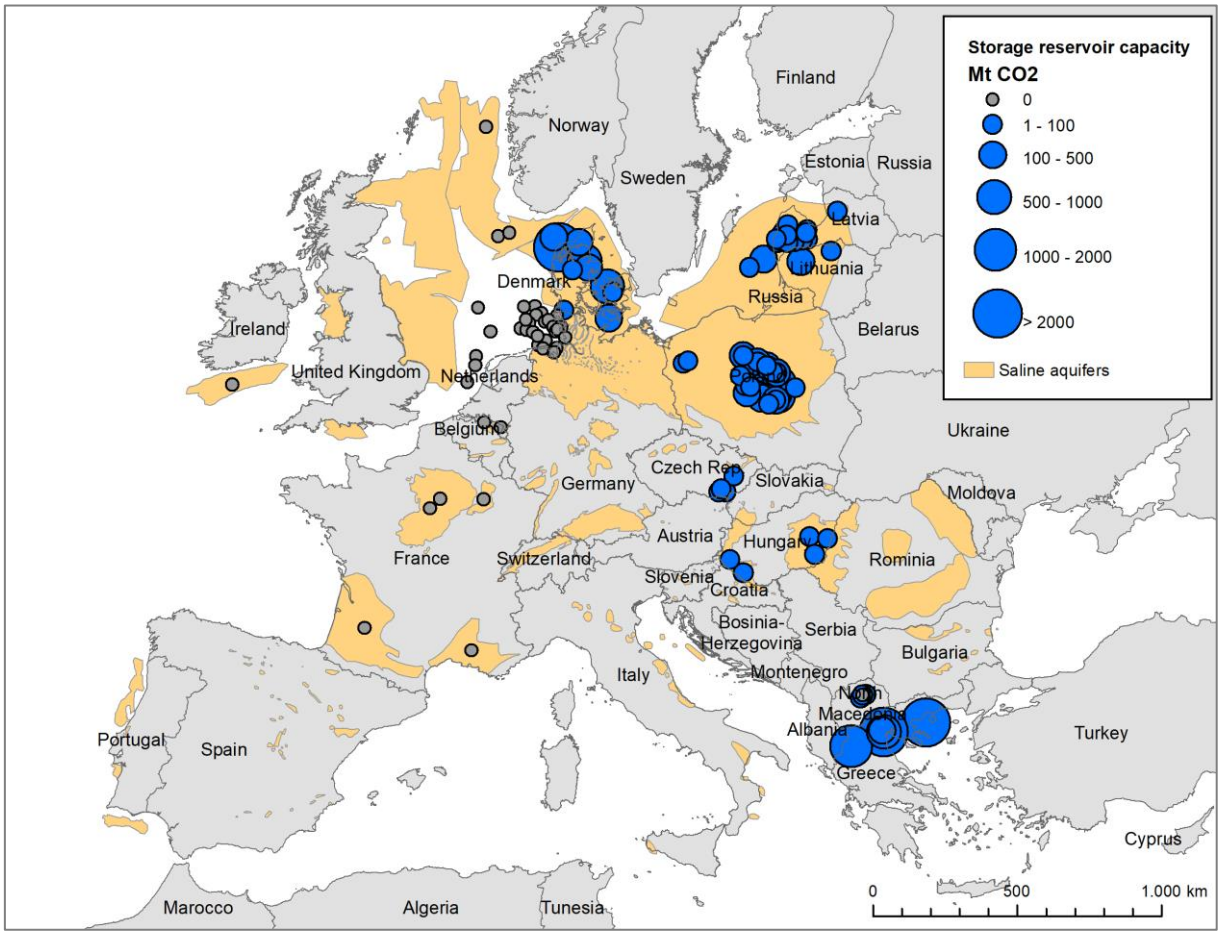


Figure 8. Location and storage capacity for the storage reservoirs.

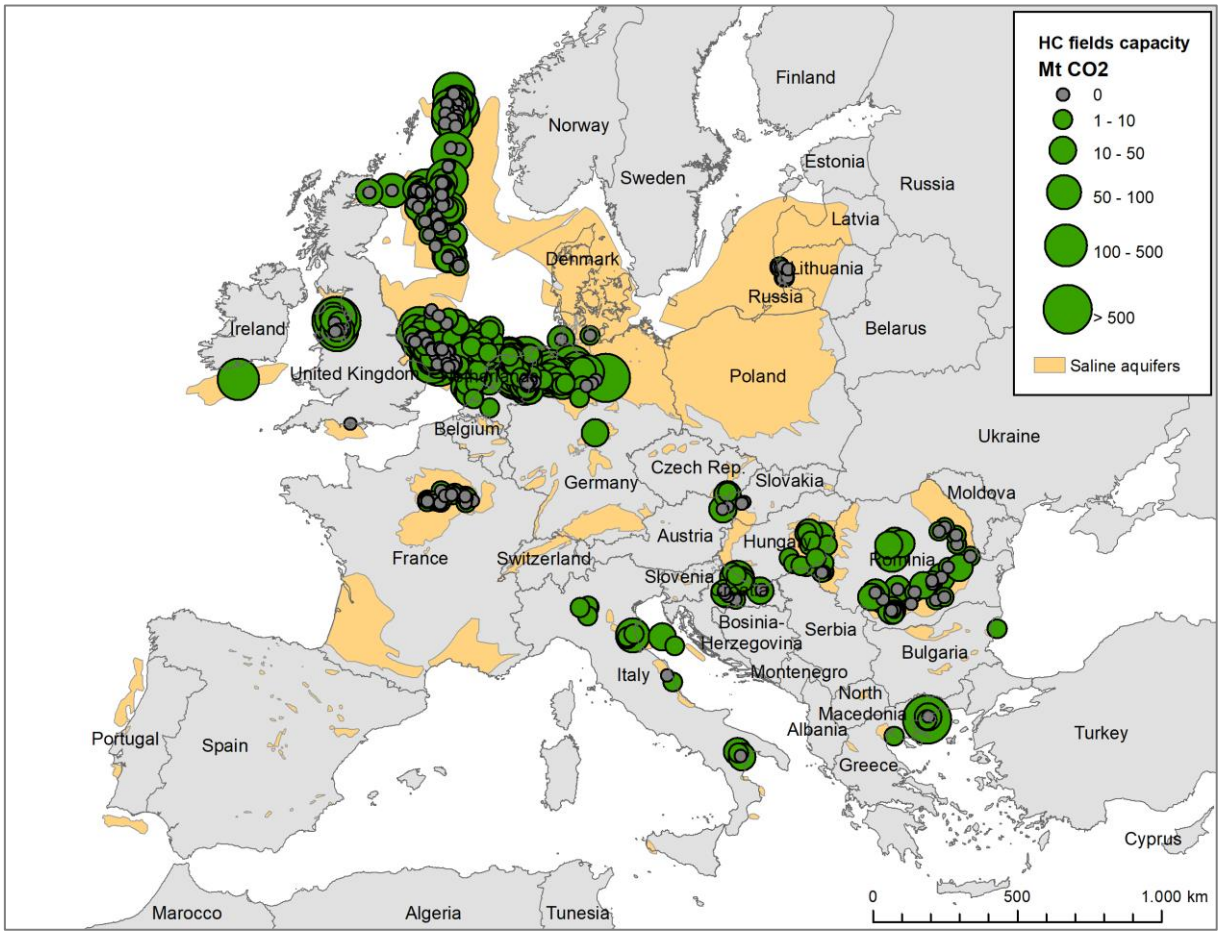


Figure 9. Location and storage capacity for the hydrocarbon fields.

Regional summary of CO_2 sources and sinks

This section provides a brief regional summary of CO_2 emission sources based on data from the EU GeoCapacity project together with CO_2 storage options mapped in CO2StoP. The storage capacities used in this section are based on the "user estimated capacity" given in the CO2StoP final report by Poulsen et al. 2014, in appendix D DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/110 (europa.eu) In case of updated national CO_2 storage capacities after finalisation of CO2StoP these estimates are included. For individually country information it is recommended to consult the EU GeoCapacity report D8 WP1 Report inventories and GIS Microsoft Word - D8 WP 1 Report_Final_230609.doc (geology.cz) from page 28 and onwards and D16 WP2 Report storage capacity Microsoft Word - D16 WP2 Report storage capacity.doc (geology.cz).

North-western Europe

Ireland, United Kingdom, Netherlands, Belgium, Norway and Denmark (Fig. 10).

Ireland

Nine saline aquifers are mapped in Ireland with a total capacity of 500 Mt is given in Poulsen et al. 2014. One reported hydrocarbon field has a storage capacity of 332 Mt, and one storage reservoir has 40 Mt capacity (Fig 10).

United Kingdom

Most large emission sources are in mid-England. UK has not mapped onshore storage options most probably due to expected onshore restriction for CO_2 storage, limiting storage to offshore storage options (Fig. 10). No storage capacities are given for the 96 saline aquifers included. Neither is aquifer storage reservoir options mapped, but 192 hydrocarbon fields are included with a total storage capacity of 4 – 6 Gt, whereof several are either depleted or abandoned. EU GeoCapacity results shows that UK is one of most prospective countries in Europe for CO_2 storage (Table 2).

Netherlands

The Netherlands have a large storage capacity in hydrocarbon fields, total storage capacity is estimated to 10 Gt, but moderate in saline aquifers *c*. 1.4 Gt for 18 included saline aquifers. The concentration of emission sources is highest near the coastal areas offering many possibilities for storage in offshore depleted hydrocarbon fields (Fig. 10).

Belgium

The total storage capacity in saline aquifers is estimated to total 242 Mt (mean value) for 6 saline aquifers and between 15 – 40 Mt in two storage reservoirs. Most emission sources are located in the northern parts of Belgium (Fig. 10).

Norway

All assessments of the European CO_2 Storage capacity have concluded that the North Sea Basin and the Norwegian shelf are the most prospective area for CO_2 storage in Europe. The Norwegian CO_2 storage atlas mapped storage potential in saline aquifers on the Norwegian continental shelf at more than 80 Gt storage capacity including the hydrocarbon fields CO2 atlas for the Norwegian Continental Shelf - The Norwegian Petroleum Directorate (npd.no). Norway only have a few emissions sources on land and most Norwegian CO_2 emissions originates from offshore hydrocarbon production (Fig. 10).

Denmark

The largest emissions sources are located close to the coast of Denmark (Fig. 10). The most present assessment of the Danish storage capacity from 2020 concluded a capacity of 12 – 25 Gt in storage reservoirs and hydrocarbon fields (unpublished internal memorandum) based on current knowledge. This capacity is coherent with the previous European assessments.

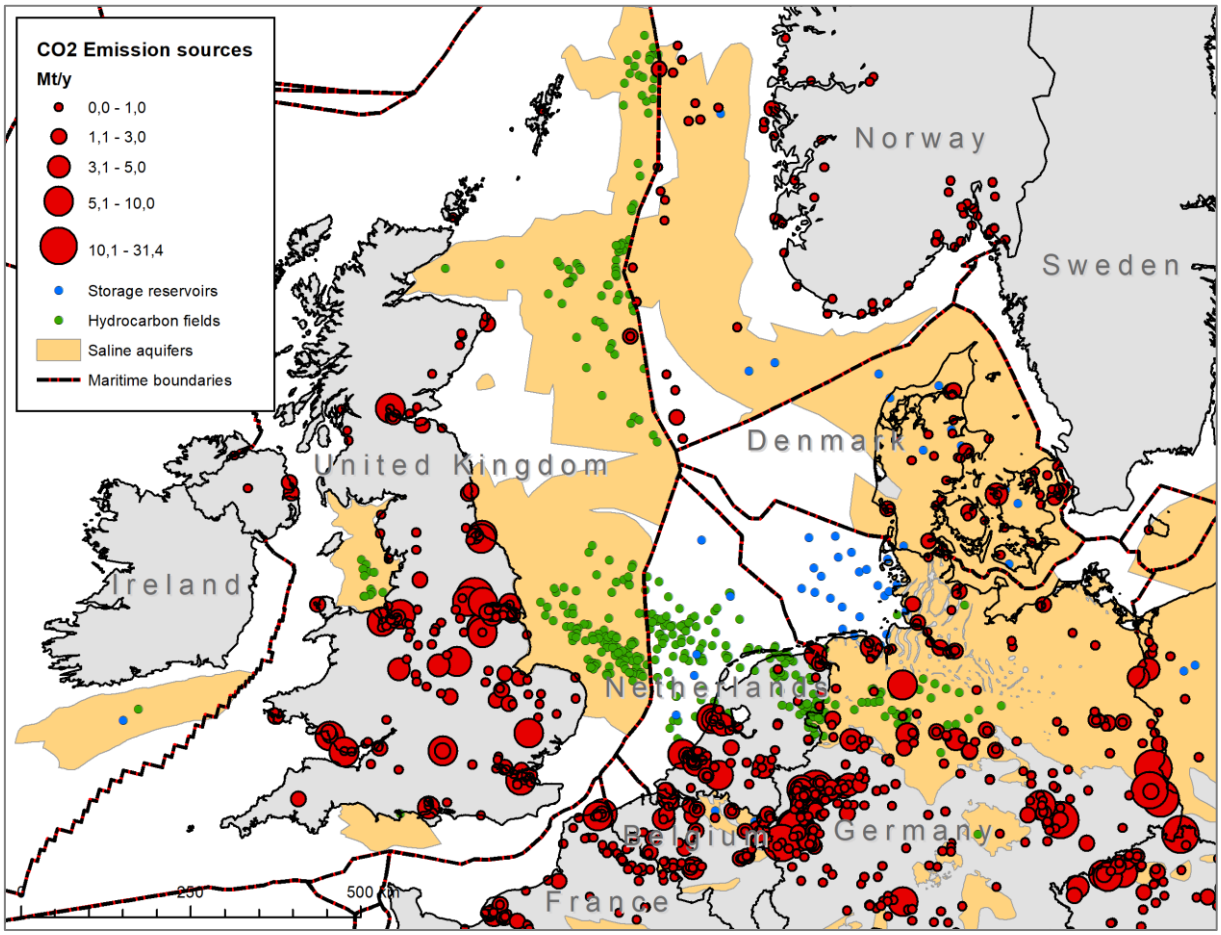


Figure 10. Location of emission sources > 100Kt/y (EU GeoCapacity data), the saline aquifers, storage reservoirs and hydrocarbon fields (CO2StoP data) in the north-western Europe.

Country	Annual total CO_2 emissions (Mt)	Annual CO_2 emissions from large point sources (Mt)	CO_2 storage capacity in deep saline aquifers (Mt)	CO_2 storage capacity in hydrocarbon fields (Mt)	CO_2 storage capacity in coal fields (Mt)
Slovakia	46	23	1716	-	-
Estonia	21	12	-	-	-
Latvia	4	2	404	-	-
Lithuania	18	6	30	7	-
Poland	325	188	1761	764	415
Czech Republic	128	78	766	33	54
Hungary	79	23	140	389	87
Romania	74	67	7500	1500	-
Bulgaria	52	42	2100	3	17
Albania	0	0	20	111	-
FYROM	6	4	390	-	-
Croatia	23	5	2710	189	-
Spain	423	158	14000	34	145
Italy	212	140	4669	1810	71
Slovenia	20	7	92	2	-
Bosnia-Herzegovina	-	9	197	-	-
Germany	864	465	14900	2180	-
Luxemburg	-	-	-	-	-
The Netherlands	180	92	340	1700	300
France	-	131	7922	770	-
Greece	110	69	184	70	-
United Kingdom	555	258	7100	7300	-
Denmark	52	28	2553	203	-
Norway	-	28	26031	3157	-
Belgium	-	58	199	-	-
Total	**-**	**1893**	**95724**	**20222**	**1089**

Table 2. The conservative storage capacities from the EU GeoCapacity project [Microsoft Word - D16 WP2 Report storage capacity.doc (geology.cz)]

North-eastern Europe

Northern Germany, Poland, Czech Republic, Estonia, Latvia and Lithuania (Fig. 11).

Germany (North)

The region with largest CO_2 emissions in Europe is in north-western Germany close to the borders of Belgium and the Netherlands (Fig. 3). The South Permian Basin (SPBA) covering most of northern Germany offers CO_2 storage options in this part of Germany and together with basins south of SPBA, Germany has several storage possibilities but only few closest to the region with highest emissions (Fig. 11). Storage capacities for saline aquifers are not included in the CO2StoP, but for whole Germany 24 storage reservoirs are reported in CO2StoP and they have a total capacity of 1 – 3 Gt and

additionally 2 Gt in hydrocarbon fields (Fig. 11). A conservative estimate from EU GeoCapacity mapped almost 15 Gt in German saline aquifers (Table 2).

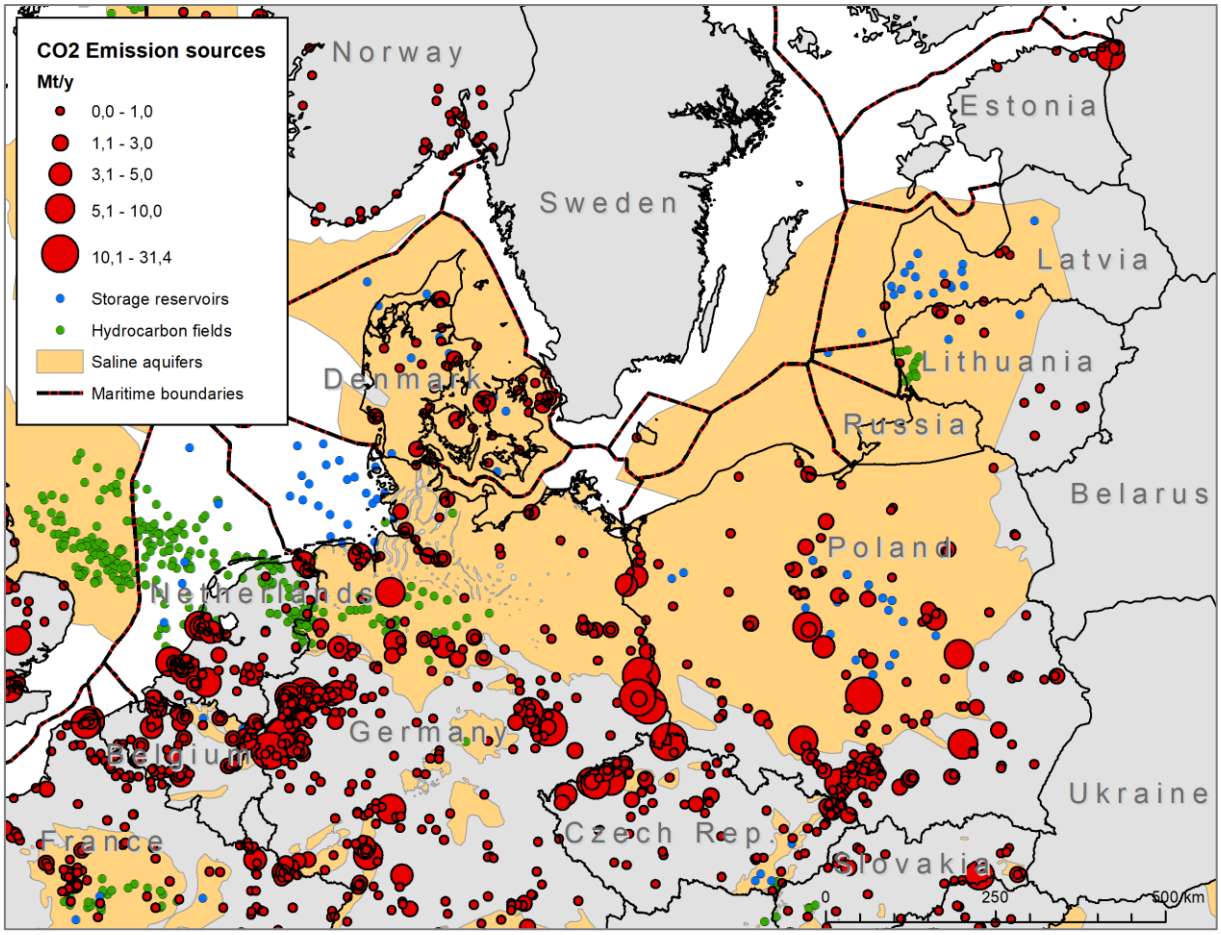


Figure 11. Location of emission sources > 100Kt/y (EU GeoCapacity data), the saline aquifers storage reservoirs and hydrocarbon fields (CO2StoP data) in the north-eastern Europe.

Poland

The largest emission sources in Poland are in the mid and southern part of the country (Fig. 11). A large basin area (SPBA) is present in almost the entire country offers many possibilities for CO_2 storage and the storage capacity for 4 saline aquifers are estimated to approximately 200 Gt (mean value). For 33 mapped storage reservoirs the capacity is estimated to 4 – 7 Gt. No storage assessment is provided for hydrocarbon fields.

Czech Republic

The highest concentration of emission sources is in the north-western part of the Czech Republic (Fig. 11). Likewise, are a few saline aquifers located close to these emission sources, and basins in the eastern parts offers storage opportunities for the emission sources located in the north eastern part of the Czech Republic. The storage capacity is moderate estimating *c*. 400 Mt in saline aquifers, hereof *c*. 190 Mt in storage reservoirs and 18 Mt in hydrocarbon fields.

Estonia, Latvia and Lithuania

Estonia has no storage options, but the largest CO_2 emissions of the three Baltic countries (Fig. 11). Latvia have storage options in storage reservoirs and the total capacity is estimated to 340 – 930 Mt in 18 reservoirs, but for the entire saline aquifer the capacity is estimated to be between 1 and 46 Gt. Lithuania has storage options in both storage reservoirs *c.* 80 Mt and in hydrocarbon fields 7 Mt.

South-western Europe

France, Spain, Portugal, Switzerland and Southern Germany (Fig. 12).

France

The remarkable absence of large emission sources in France is probably because a large part of the power production originates from nuclear power (Fig. 12). Most emission sources are located in northern France. Storage options are possible in three large basins, with five mapped saline aquifers with an estimated storage capacity of 29 Gt. No storage reservoirs capacity is given, but the capacity in hydrocarbon fields, located in the Paris Basin are 39 Mt.

Spain

Many emission sources are located at the coastal areas (Fig. 12). Spain has mapped 45 saline aquifers with a total capacity of around 6 Gt CO_2. Storage options are scattered and located primarily in the northern and eastern parts of Spain.

Portugal

No data on storage capacity is included in the CO2StoP database, although 32 saline aquifers are reported in Poulsen et al. 2014.

Switzerland

Four saline aquifers are mapped in the Swiz part of the Molasse Basin (Foreland basin to the Alps) with total capacity of *c.* 3 Gt (Fig. 12).

Germany (South)

The Molasse Basin (Foreland basin to the Alps) continues into the southern Germany and offers storage options in this part of Germany (Fig. 12). No estimates of storage capacity are given for the German part of the Molasse Basin.

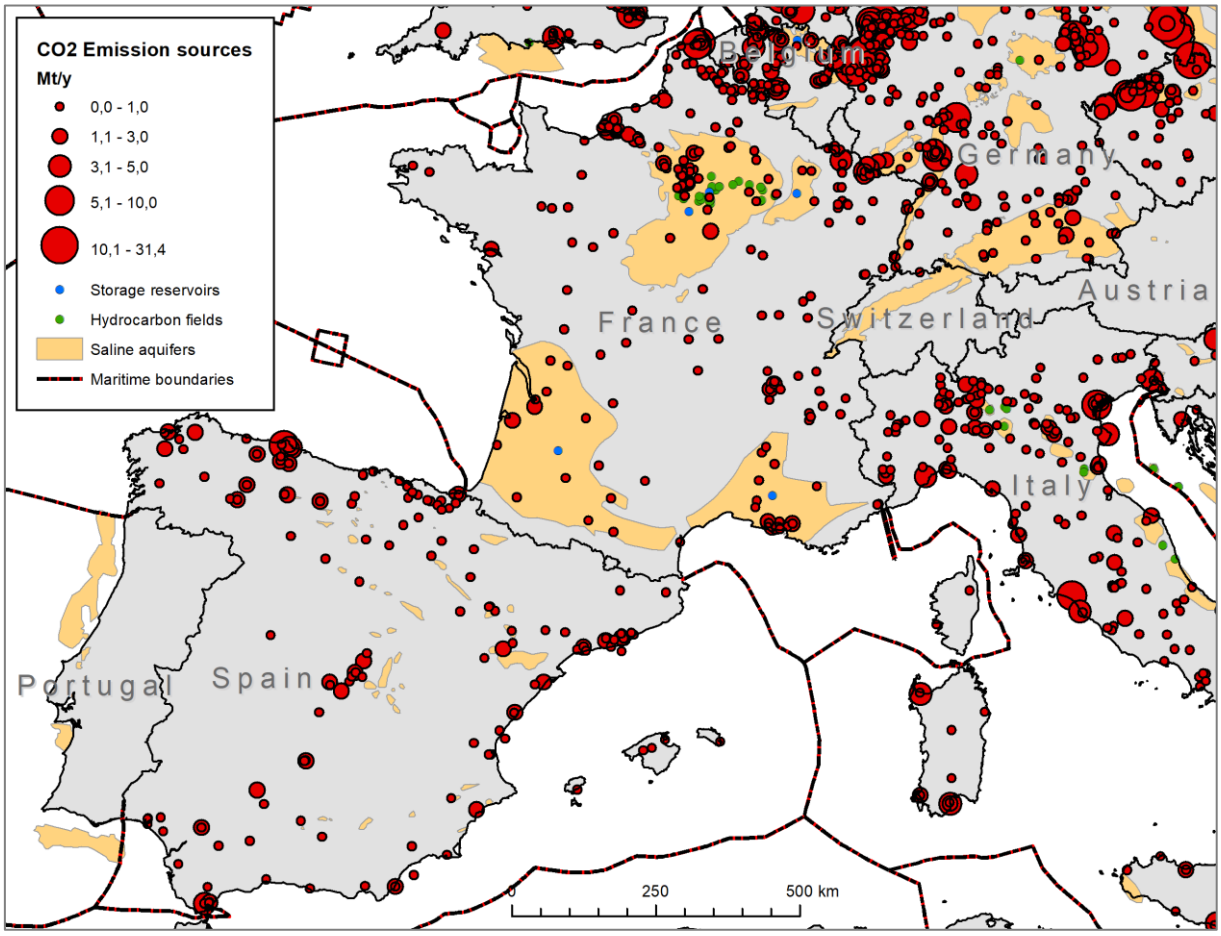


Figure 12. Location of emission sources > 100Kt/y (EU GeoCapacity data), the saline aquifers, storage reservoirs and hydrocarbon fields (CO2StoP data) in the south-western Europe.

South-eastern Europe

Italy, Austria, Slovakia, Hungary, Romania, Bulgaria, Slovenia, Croatia, Serbia, North Macedonia and Greece (Fig. 13).

Italy

Emission sources are primarily concentrated in northern Italy, but several large point sources are located in the southern part (Fig. 13). The storage region follows a trend from mid-north Italy along the eastern coast to southern Italy. Altogether are 26 saline aquifers mapped with a total capacity of 5 Gt. No information about storage reservoirs are included, but the storage capacity in hydrocarbon fields are estimated to 134 Mt.

Austria

Altogether, are 6 saline aquifers with a total capacity of 20 Gt reported in Poulsen et al. 2014.

Slovakia

Emission sources are manly located in the northern Slovakia and in the south-eastern parts of the country. Storage options are in the western and eastern Slovakia (Fig. 13). In total 2 – 13 Gt storage capacity is estimated for 37 saline aquifers, and for the hydrocarbon fields in west Slovakia the storage capacity is estimated to *c.* 1 Mt.

Hungary

The emission sources are mainly found in the northern Hungary (Fig. 13). Storage regions are in the western and south-eastern Hungary. The storage capacity estimated for 16 mapped saline aquifers is 311 Mt (mean value). Further are 450 Mt storage capacity reported for 5 storage reservoirs and *c*. 100 Mt in 14 hydrocarbon fields.

Romania

In Romania, the emission sources are primarily located in the southern parts (Fig. 13). The storage options are related to basins in connection with the Carpathian mountain range. Altogether, 15 saline aquifers are mapped with total storage capacity between 21 – 53 Gt. The hydrocarbon fields have a storage capacity of around 400 Mt.

Bulgaria

The largest emission sources are located near the Black Sea coast and in the central Bulgaria (Fig. 13). Storage regions are located in the easterly part of the country, with a total storage capacity of 2 – 3 Gt in 11 saline aquifers and 4 – 6 Gt in hydrocarbon fields.

Slovenia

One large emission source is located in the northern Slovenia (Fig. 13). Several storage options are mapped and distributed quit evenly throughout the country. The capacity is estimated to a total storage capacity of 154 Mt in 37 saline aquifers.

Croatia

Only minor emission sources are mapped in Croatia (Fig. 13). Storage options are in the Adriatic Sea and in the eastern part of the country. A total storage capacity of 4 Gt in 14 saline aquifers and 175 Mt in 17 hydrocarbon fields.

Serbia

Even though Serbia participated in CO2StoP, no data was provided.

North Macedonia

North Macedonia has a few emission sources scattered throughout the country and one storage region in the central part (Fig. 13). Altogether, 3 saline aquifers have an estimated storage capacity of 21 Mt and 17 storage reservoirs have between 15 and 131 Mt capacity.

Greece

Emission sources are concentrated in northern Greece and in the southern part of the country (Fig. 13). Storage options are located in northern Greece, were three saline aquifers have a total storage capacity of 1 – 2 Gt and the 5 storage reservoirs have a mean capacity at 2 Gt. Storage capacity in 3 hydrocarbon fields is estimated to around 37 Mt.

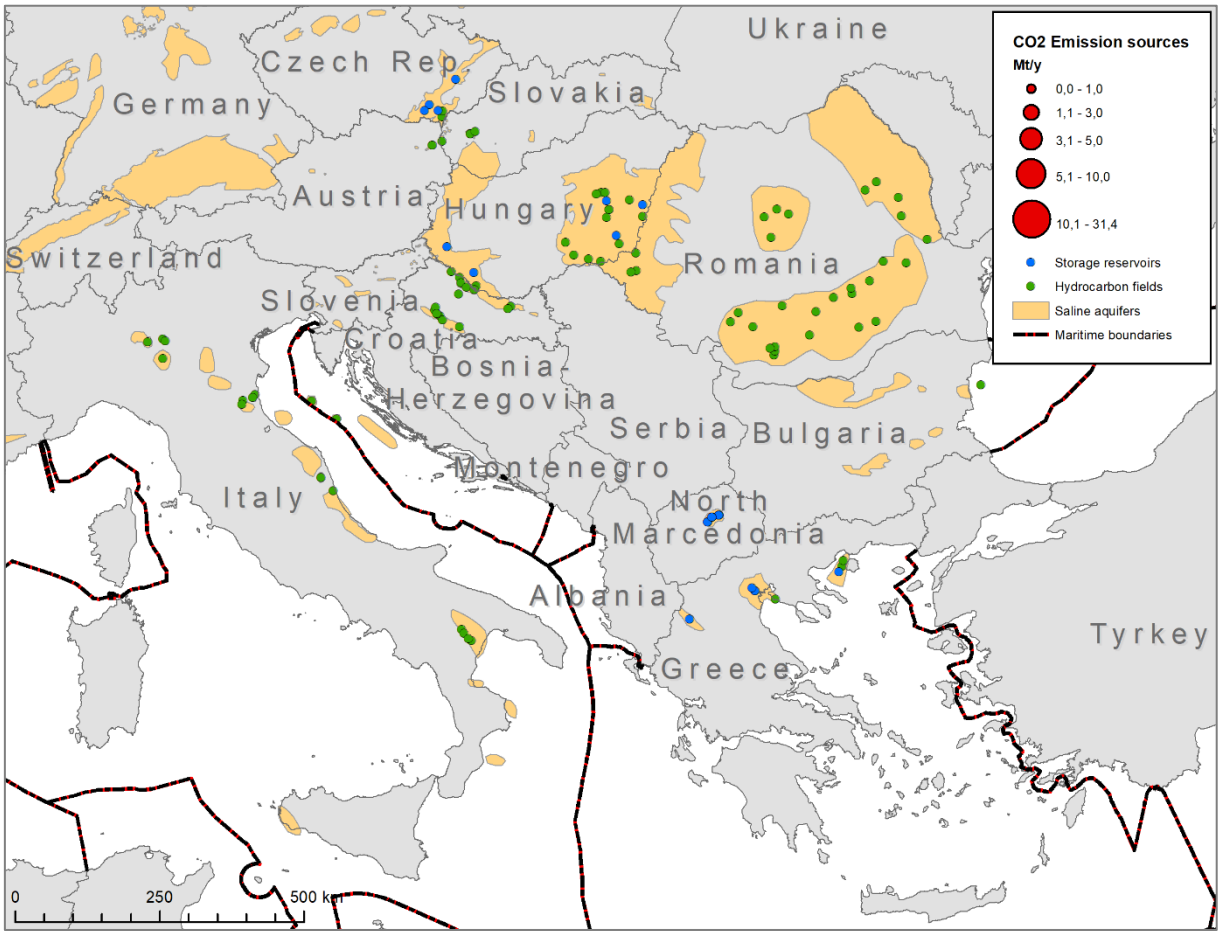


Figure 13. Location of emission sources > 100Kt/y (EU GeoCapacity data), the saline aquifers, storage reservoirs and hydrocarbon fields (CO2StoP data) in the south-eastern Europe.

Regulations

The EU Directive 2009/31/EC on the geological storage of carbon dioxide provides the overall regulatory framework for CO_2 storage in the EU and the associated countries; Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (europa.eu). The directive has been transposed into national legislation by all EU member states. Even the CO_2 storage directive has been implemented EU-wide, many countries will still lack supporting national rules and regulations for CO_2 storage licenses, monitoring and liability considerations as well as economic and environmental responsibilities.

References & links

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Castor project. 2006: Final Report Summary - CASTOR (CO_2 from Capture to Storage) Project ID: 502586 Funded under: FP6-SUSTDEV http://cordis.europa.eu/result/rcn/47842_en.html

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Vangklide-Pedersen, T. (ed) 2009: EU GeoCapacity – Assessing European Capacity for Geological Storage of Carbon Dioxide. GeoCapacity Final Report. EU Project no. SES6-518318.

Links

The Norwegian CO_2 Storage Atlases:
Carbon storage - The Norwegian Petroleum Directorate (npd.no)
co2-atlas-north-sea.pdf (npd.no)
co2-atlas-norwegian-sea-2012.pdf (npd.no)
co2-atlas-barents-sea.pdf (npd.no)
CO2 atlas for the Norwegian Continental Shelf - The Norwegian Petroleum Directorate (npd.no)

UK CO_2 Storage Evaluation Database:
About CO2 Stored

EU GeoCapacity:
The EU GeoCapacity Project: Home page (geology.cz)

The Nordic CO_2 Storage Atlas:
Nordic CCS Competence Centre (geus.dk)

CO2StoP Final report
DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/110 (europa.eu)

The Spanish CO_2 storage atlas:
Almacenamiento geológico de CO2 | Publicaciones del IGME (igmepublicaciones.blogspot.com)

European Geological Data Infrastructure:
EGDI – European Geological Data Infrastructure (europe-geology.eu)

Pan-European coordination action on CO_2 Geological Storage:
CGS Europe - Home Page

The European network of excellence on the geological storage of CO_2:
Co2Geonet

EU Emissions Trading System:
EU Emissions Trading System (EU ETS) | Climate Action (europa.eu)

The EU CO_2 Storage directive:
Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (europa.eu)