

# CO<sub>2</sub> Storage Resource Catalogue

## Cycle 5 Report

### EUROPE

August 2025



HALLIBURTON



## Amounts of CO<sub>2</sub>

**Stored**  
**0.03** Gigatonnes

**Commercial**  
**1.6** Gigatonnes

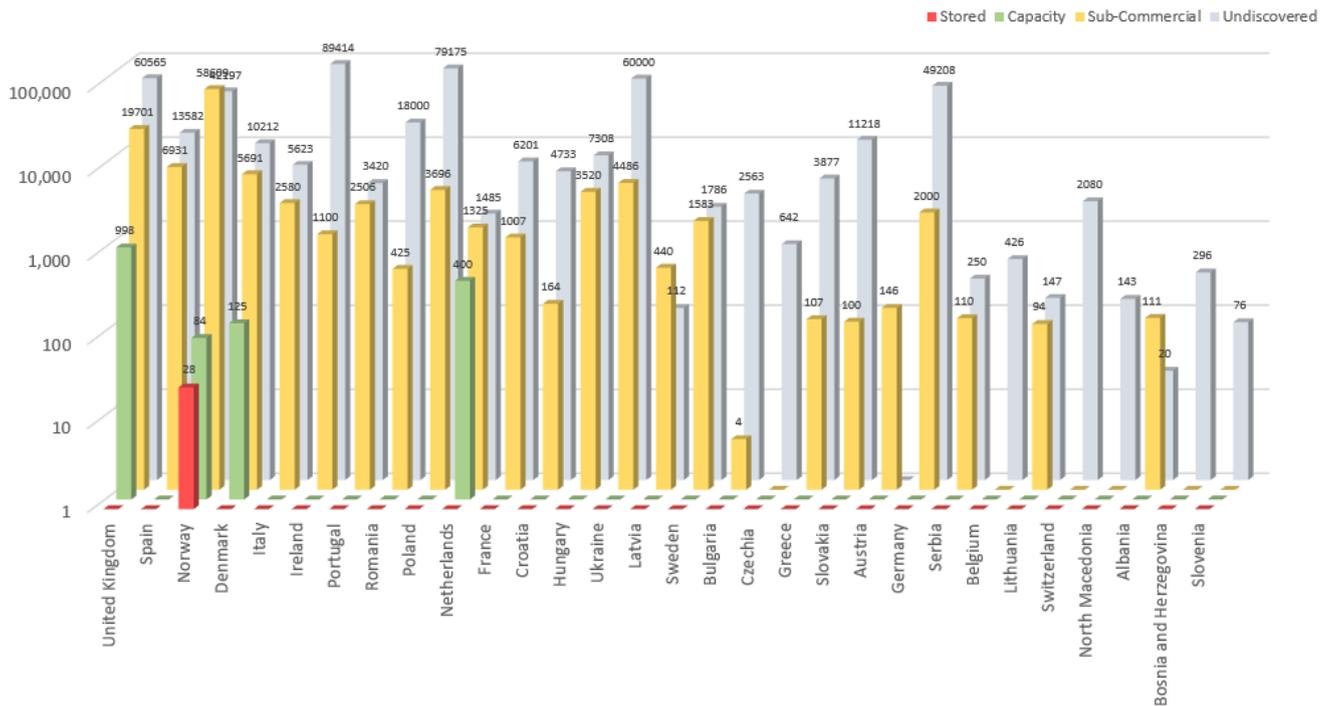
**Sub-commercial**  
**116** Gigatonnes

**Undiscovered**  
**474** Gigatonnes

## Appendix C: Europe

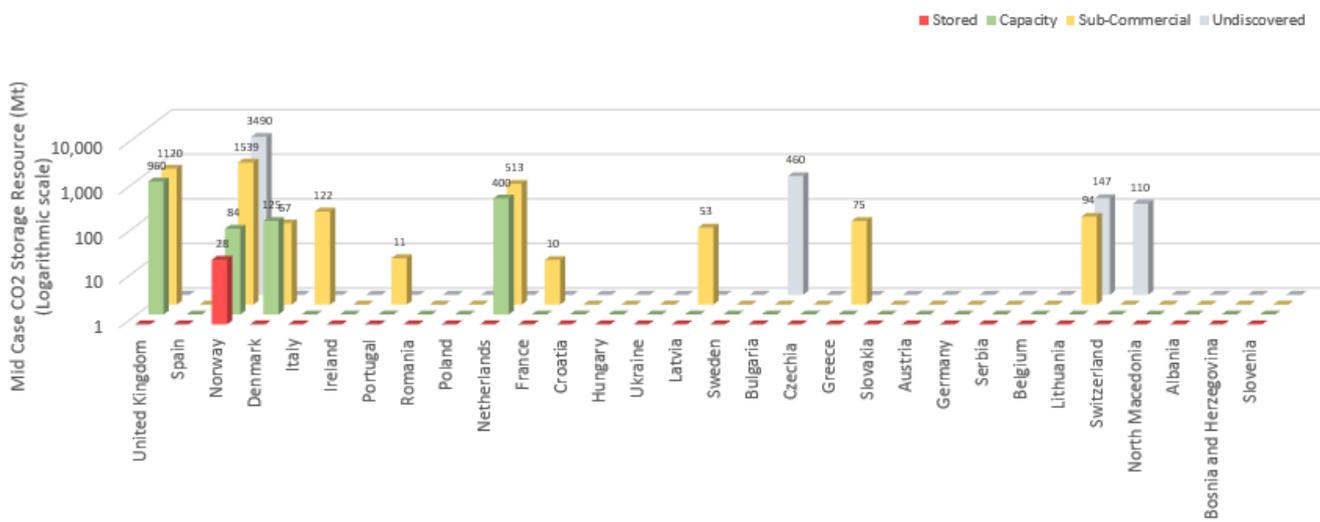
Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Kosovo, Latvia, Liechtenstein, Lithuania, Malta, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine and United Kingdom.

Global Storage Resource Maturity  
(Project and No Project)



Summary of Europe's CO<sub>2</sub> storage by capacity and maturity (project and no project) for each country assessed to date.

Global Storage Resource Maturity  
(Project specified)



Summary of Europe's CO<sub>2</sub> storage by capacity and maturity (project specified) for each country assessed to date.

<b>Document Summary</b>			
<b>Client</b>	Oil and Gas Climate Initiative (OGCI)		
<b>Title:</b>	CO <sub>2</sub> Storage Resource Catalogue – Appendix C: Europe		
<b>Distribution:</b>	OGCI, GCCSI, Halliburton	<b>Classification:</b>	Public
<b>Date of Issue:</b>	20/08/2025		
<b>Prepared by:</b>	Halliburton: Shelagh Baines, Kate Evans, Sonia Tetteh, Emily Firth, Joelle El Sayegh GCCSI: Aishah Hatta, Chris Consoli		

## Important notice

Halliburton Manufacturing and Services Limited have made every effort to ensure that the content of this report is accurate and up to date at the time of preparation. Halliburton Manufacturing and Services Limited makes no warranty, representation or undertaking whether expressed or implied, nor does it assume any legal liability, whether direct or indirect, or responsibility for the accuracy, completeness, or usefulness of any information. The reader shall be responsible for ensuring compliance with the appropriate legal requirements.

Halliburton does not warrant the accuracy or completeness of any materials supplied nor any interpretations, recommendations, or actions taken based on such use of this material by the recipient. Recipient acknowledges that it is accepting the material "as is," and that it agrees to the statement above. Recipient further agrees that Halliburton shall have no liability to recipient for any issues arising out of the recipient's use of the materials. Further recipient acknowledges that Halliburton does not accept responsibility for decisions by the recipient on matters of policy regarding any subsequent operations.

This report, including any further attached files, may contain confidential and privileged information for the sole use of the intended recipient(s). Any review, use, distribution or disclosure by others is strictly prohibited. If you are not the intended recipient (or authorized to receive information for the recipient), please contact the sender by reply email and delete all copies of this report.

## TABLE OF CONTENTS

<b>TABLE OF CONTENTS .....</b>	<b>3</b>
<b>1 Albania .....</b>	<b>8</b>
<b>2 Andorra .....</b>	<b>13</b>
<b>3 Austria .....</b>	<b>14</b>
<b>4 Belarus .....</b>	<b>19</b>
<b>5 Belgium .....</b>	<b>21</b>
<b>6 Bosnia and Herzegovina .....</b>	<b>27</b>
<b>7 Bulgaria .....</b>	<b>32</b>
<b>8 Croatia .....</b>	<b>37</b>
<b>9 Cyprus .....</b>	<b>44</b>
<b>10 Czechia .....</b>	<b>46</b>
<b>11 Denmark .....</b>	<b>52</b>
<b>12 Estonia .....</b>	<b>59</b>
<b>13 Finland .....</b>	<b>62</b>
<b>14 France .....</b>	<b>63</b>
<b>15 Germany .....</b>	<b>69</b>
<b>16 Greece.....</b>	<b>75</b>
<b>17 Hungary .....</b>	<b>81</b>
<b>18 Iceland .....</b>	<b>88</b>
<b>19 Ireland.....</b>	<b>90</b>
<b>20 Italy.....</b>	<b>96</b>
<b>21 Kosovo .....</b>	<b>102</b>
<b>22 Latvia .....</b>	<b>103</b>
<b>23 Liechtenstein.....</b>	<b>110</b>
<b>24 Lithuania .....</b>	<b>111</b>
<b>25 Malta .....</b>	<b>117</b>

## CO<sub>2</sub> Storage Resource Catalogue - Appendix C: Europe

---

26	Moldova .....	119
27	Montenegro .....	120
28	North Macedonia .....	121
29	Netherlands .....	127
30	Norway .....	134
31	Portugal .....	143
32	Poland .....	149
33	Romania .....	156
34	San Marino .....	162
35	Serbia .....	163
36	Slovakia .....	169
37	Slovenia .....	174
38	Spain .....	180
39	Sweden .....	186
40	Switzerland .....	193
41	Ukraine .....	199
42	United Kingdom .....	205
43	Bibliography .....	213

## Figures

FIGURE 1-1: ALBANIA SPREAD OF STORAGE SITES.	9
FIGURE 1-2: STORAGE RESOURCE SUMMARY FOR ALBANIA COMPILED IN THE CSRC.	10
FIGURE 3-1: AUSTRIA SPREAD OF STORAGE SITES.	15
FIGURE 3-2: STORAGE RESOURCE SUMMARY FOR AUSTRIA COMPILED IN THE CSRC.	16
FIGURE 5-1: BELGIAN SPREAD OF STORAGE SITES.	22
FIGURE 5-2: STORAGE RESOURCE SUMMARY FOR BELGIUM COMPILED IN THE CSRC.	23
FIGURE 6-1: BOSNIA AND HERZEGOVINIAN SPREAD OF STORAGE SITES.	28
FIGURE 6-2: STORAGE RESOURCE SUMMARY FOR BOSNIA AND HERZEGOVINA COMPILED IN THE CSRC.	29
FIGURE 7-1: BULGARIA SPREAD OF STORAGE SITES.	33
FIGURE 7-2: STORAGE RESOURCE SUMMARY FOR BULGARIA COMPILED IN THE CSRC.	34
FIGURE 8-1: CROATIA SPREAD OF STORAGE SITES.	38
FIGURE 8-2: STORAGE RESOURCE SUMMARY FOR CROATIA COMPILED IN THE CSRC.	39
FIGURE 10-1: CZECHIA SPREAD OF STORAGE SITES.	47
FIGURE 10-2: STORAGE RESOURCE SUMMARY FOR CZECHIA COMPILED IN THE CSRC.	48
FIGURE 11-1: DENMARK SPREAD OF STORAGE SITES.	53
FIGURE 11-2: STORAGE RESOURCE SUMMARY FOR DENMARK COMPILED IN THE CSRC.	54
FIGURE 14-1: FRANCE SPREAD OF STORAGE SITES.	64
FIGURE 14-2: STORAGE RESOURCE SUMMARY FOR FRANCE COMPILED IN THE CSRC.	65
FIGURE 15-1: GERMAN SPREAD OF STORAGE SITES.	70
FIGURE 15-2: STORAGE RESOURCE SUMMARY FOR GERMANY COMPILED IN THE CSRC.	71
FIGURE 16-1: GREECE SPREAD OF STORAGE SITES.	76
FIGURE 16-2: STORAGE RESOURCE SUMMARY FOR GREECE COMPILED IN THE CSRC.	77
FIGURE 17-1: HUNGARY SPREAD OF STORAGE SITES.	82
FIGURE 17-2: STORAGE RESOURCE SUMMARY FOR HUNGARY COMPILED IN THE CSRC.	83
FIGURE 19-1: IRELAND SPREAD OF STORAGE SITES.	91
FIGURE 19-2: STORAGE RESOURCE SUMMARY FOR IRELAND COMPILED IN THE CSRC.	92
FIGURE 20-1: ITALY SPREAD OF STORAGE SITES.	97
FIGURE 20-2: STORAGE RESOURCE SUMMARY FOR ITALY COMPILED IN THE CSRC.	98
FIGURE 22-1: LATVIAN SPREAD OF STORAGE SITES.	104
FIGURE 22-2: STORAGE RESOURCE SUMMARY FOR LATVIA COMPILED IN THE CSRC.	105
FIGURE 24-1: LITHUANIAN SPREAD OF STORAGE SITES.	112
FIGURE 24-2: STORAGE RESOURCE SUMMARY FOR LITHUANIA COMPILED IN THE CSRC.	113
FIGURE 28-1: NORTH MACEDONIAN SPREAD OF STORAGE SITES.	122
FIGURE 28-2: STORAGE RESOURCE SUMMARY FOR NORTH MACEDONIA COMPILED IN THE CSRC.	123
FIGURE 29-1: NETHERLANDS SPREAD OF STORAGE SITES.	128
FIGURE 29-2: STORAGE RESOURCE SUMMARY FOR THE NETHERLANDS COMPILED IN THE CSRC.	129
FIGURE 30-1: NORWAY SPREAD OF STORAGE SITES.	136
FIGURE 30-2: STORAGE RESOURCE SUMMARY FOR ITALY COMPILED IN THE CSRC.	137
FIGURE 31-1: PORTUGUESE SPREAD OF STORAGE SITES.	144
FIGURE 31-2: STORAGE RESOURCE SUMMARY FOR PORTUGAL COMPILED IN THE CSRC.	145
FIGURE 32-1: POLAND SPREAD OF STORAGE SITES.	150
FIGURE 32-2: STORAGE RESOURCE SUMMARY FOR POLAND COMPILED IN THE CSRC.	151
FIGURE 33-1: ROMANIA SPREAD OF STORAGE SITES.	157
FIGURE 33-2: STORAGE RESOURCE SUMMARY FOR ROMANIA COMPILED IN THE CSRC.	158
FIGURE 35-1: SERBIAN SPREAD OF STORAGE SITES.	164
FIGURE 35-2: STORAGE RESOURCE SUMMARY FOR SERBIA COMPILED IN THE CSRC.	165
FIGURE 36-1: SLOVAKIA SPREAD OF STORAGE SITES.	170
FIGURE 36-2: STORAGE RESOURCE SUMMARY FOR SLOVAKIA COMPILED IN THE CSRC.	171
FIGURE 37-1: SLOVENIAN SPREAD OF STORAGE SITES.	175
FIGURE 37-2: STORAGE RESOURCE SUMMARY FOR SLOVENIA COMPILED IN THE CSRC.	176
FIGURE 38-1: SPAIN SPREAD OF STORAGE SITES.	181
FIGURE 38-2: STORAGE RESOURCE SUMMARY FOR SPAIN COMPILED IN THE CSRC.	182
FIGURE 39-1: SPREAD OF SWEDISH STORAGE SITES	187
FIGURE 39-2: STORAGE RESOURCE SUMMARY FOR SWEDEN COMPILED IN THE CSRC.	188

FIGURE 40-1: SWITZERLAND SPREAD OF STORAGE SITES.	194
FIGURE 40-2: STORAGE RESOURCE SUMMARY FOR SWITZERLAND COMPILED IN THE CSRC.	195
FIGURE 41-1: UKRAINIAN SPREAD OF STORAGE SITES.	200
FIGURE 41-2: STORAGE RESOURCE SUMMARY FOR UKRAINE COMPILED IN THE CSRC.	201
FIGURE 42-1: UK SPREAD OF STORAGE SITES.	207
FIGURE 42-2 : STORAGE RESOURCE SUMMARY FOR THE UK REGION COMPILED IN THE CSRC.	208

## Tables

TABLE 1-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ALBANIA. ....	8
TABLE 2-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ANDORRA. ....	13
TABLE 3-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR AUSTRIA.....	14
TABLE 4-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR BELARUS. ....	19
TABLE 5-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR BELGIUM. ....	21
TABLE 6-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR BOSNIA AND HERZEGOVINA. ....	27
TABLE 7-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR BULGARIA. ....	32
TABLE 8-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR CROATIA. ....	37
TABLE 9-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR CYPRUS. ....	44
TABLE 10-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR CZECHIA. ....	46
TABLE 11-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR DENMARK.....	52
TABLE 12-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ESTONIA. ....	59
TABLE 13-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR FINLAND. ....	62
TABLE 14-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR FRANCE.....	63
TABLE 15-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR GERMANY.....	69
TABLE 16-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR GREECE.....	75
TABLE 17-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR HUNGARY.....	81
TABLE 18-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ICELAND.....	88
TABLE 19-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR IRELAND. ....	90
TABLE 20-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ITALY.....	96
TABLE 21-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR KOSOVO.....	102
TABLE 22-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR LATVIA. ....	103
TABLE 23-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR LIECHTENSTEIN.....	110
TABLE 24-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR LITHUANIA.....	111
TABLE 25-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR MALTA. ....	117
TABLE 26-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR MOLDOVA. ....	119
TABLE 27-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR MONTENEGRO. ....	120
TABLE 28-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR NORTH MACEDONIA. ....	121
TABLE 29-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR THE NETHERLANDS.....	127
TABLE 30-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR NORWAY. ....	134
TABLE 31-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR PORTUGAL.....	143
TABLE 32-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR POLAND. ....	149
TABLE 33-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR ROMANIA. ....	156
TABLE 34-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SAN MARINO. ....	162
TABLE 35-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SERBIA. ....	163
TABLE 36-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SLOVAKIA.....	169
TABLE 37-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SLOVENIA. ....	174
TABLE 38-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SPAIN.....	180
TABLE 39-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SWEDEN. ....	186
TABLE 40-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR SWITZERLAND. ....	193
TABLE 41-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR UKRAINE:.....	199
TABLE 42-1: STORAGE RESOURCE CLASSIFICATION SUMMARY FOR THE UK.....	205

## 1 Albania

### 1.1 Summary

Albania was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Albania as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.111	0.000
Undiscovered	0.020	0.000
Aggregated*	0.131	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Albania.

Table 1-1: Storage resource classification summary for Albania.

- Very limited evaluations have been performed on Albania and any that do exist are at a country level.
- Albania has a large salt dome that may hold potential for CO<sub>2</sub> storage and some depleted oil and gas fields. There is very limited research on any of these sites.
- Albania does not have any regulations in place for geological underground storage. At present the country is designing environmental legislation to align with EU policies and directives.

## A) Project and Non-Project Mid-Case Storage Resource



## B) Storage Resource by Type

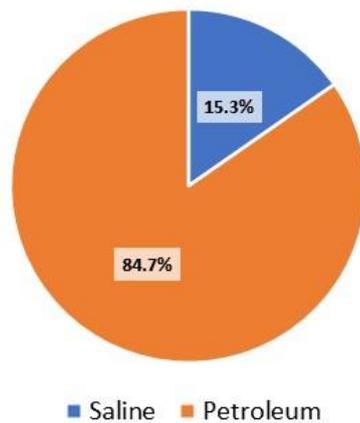


Figure 1-1: Albania spread of Storage Sites.

A) Spread of storage resource in all Albania sites across SRMS classifications; both project specified and not. B) Split of Albanian storage resources between saline aquifers and hydrocarbon fields, (including both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 1.2 Resource Statement



Figure 1-2: Storage resource summary for Albania compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 1.3 Evaluation History

The evaluation of storage sites in Albania is very limited. The country was part of the GeoCapacity Project [1] 2009, but limited literature exists on this study. This has resulted in evaluations at country level only.

## 1.4 Resource Review

Resources have been cited as being present in both saline aquifers and depleted oil and gas fields. The location of the saline aquifers is undetermined in the literature. The only structure that is identified is the Dumrea salt dome. Albania as a country has relatively low emissions and compared to other European countries and a comparatively low industrial sector. This has presumably been a contributing factor in the lack of effort needed to seek carbon mitigation strategies through CO<sub>2</sub> storage.

### 1.4.1 Major Projects

There are no projects reported on Albania's activity, either carbon storage or the CCS value chain.

### 1.4.2 Depleted Oil & Gas Fields

There is very limited literature on any studies performed for Albania's potential for CO<sub>2</sub> storage in hydrocarbon fields, but some research has been done for the GeoCapacity project [2].

Tertiary age reservoirs (e.g. Divjaka) and the Carbonates of Upper Cretaceous to Eocene (e.g. Cacran Mollaj fields) have been cited as potential sites. The total identified resource is listed as 110 Mt for hydrocarbon fields although the location of these is not specified.

### 1.4.3 Saline Aquifers

The Dumrea salt dome extends to a depth of 5000 m and has the potential for caverns in the diapiric salt body, usable for storage. The Dumrea diapir is an oval-shaped exposure that is 20 km in the north-south direction and 12 km in the east-west direction. A value of 20 Mt is cited as storage potential [2].

However, the dome is planned for natural gas storage so could pose a conflict to any future CO<sub>2</sub> storage. The natural gas project is planned to increase the security of energy supply and complement the gas supply originating from the Middle East and Caspian regions via the Trans Adriatic Pipeline (TAP) [3].

## 1.5 Regulatory Framework

Albania does not have any regulations in place for geological underground storage. At present the country is designing environmental legislation to align with EU policies and directives. Albania is also considering strategies such as EU Economic and Investment Plan, the EU Green Deal, and the National Plan for European Integration 2021-2023. Albania submitted its first

Nationally Determined Contribution (NDC) in 2015 and committed to reduce CO<sub>2</sub> emissions by 11.5 % between 2016 and 2030 [4].

### **1.6 Issues for the Assessment**

The main issue with the assessment is the lack of publicly available data. Low emissions, lack of regulatory framework and a stronger need to improve energy security with investigating stored gas has meant Albania has not considered CCS as a technology in reducing greenhouse gas emissions.

### **1.7 Future Updates**

#### **1.7.1 Future CRSC Cycles**

Any future updates should include information on Albania's regulatory stance on geological CO<sub>2</sub> storage and its position in the region with regards to any bilateral agreements on CO<sub>2</sub> transport and storage.

## 2 Andorra

### 2.1 Summary

Andorra was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Andorra.

Table 2-1: Storage resource classification summary for Andorra.

### 2.2 Evaluation History

There are no published reports that Andorra has areas suitable for geological storage of CO<sub>2</sub>. Neither are there any reports of future intention for Andorra to investigate geological CO<sub>2</sub> storage. Andorra is a small landlocked country in the Pyrenees Mountain range and therefore unlikely to have significant potential for domestic geological storage.

### 2.3 Regulatory Framework

There is no reported regulatory framework for geological storage of CO<sub>2</sub> in Andorra.

### 2.4 Future Updates

#### 2.4.1 Future CRSC Cycles

Due to the size of Andorra and unsuitable geological conditions for CO<sub>2</sub> storage, Andorra will not need future updates.

## 3 Austria

### 3.1 Summary

Austria was assessed by the CSRC for the first time in Cycle 4. A summary of the CO<sub>2</sub> Storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.146	0.000
Undiscovered	0.000	0.000
Aggregated*	0.146	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Austria.

Table 3-1: Storage resource classification summary for Austria

- Austria has a total of 6 sites that can be added to the CRSC.
- These sites are classified as discovered due to all sites being either an oil or gas fields but inaccessible due to legislation.
- CO<sub>2</sub> storage is currently prohibited in Austria. This status is reviewed every five years and assessed against the progress other countries have made.
- The identified sites are all carbonate formations in the Molasse or Vienna Basin.
- The storage potential of these fields was determined as 146Mt CO<sub>2</sub>.

## a) Project and Non-Project Mid-Case Storage Resource



## b) Storage Resource by Type

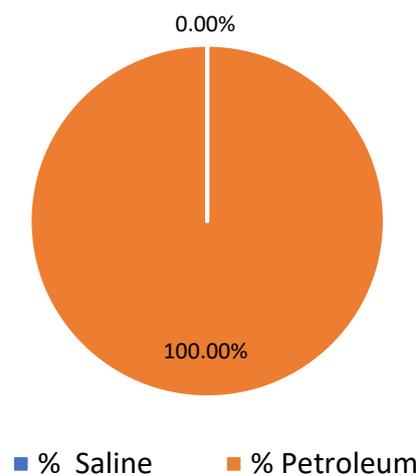


Figure 3-1: Austria Spread of Storage Sites.

a) Spread of storage resource in Austria all sites across SRMS classifications; both project specified and not. b) Split of Austrian storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

### 3.2 Resource Statement

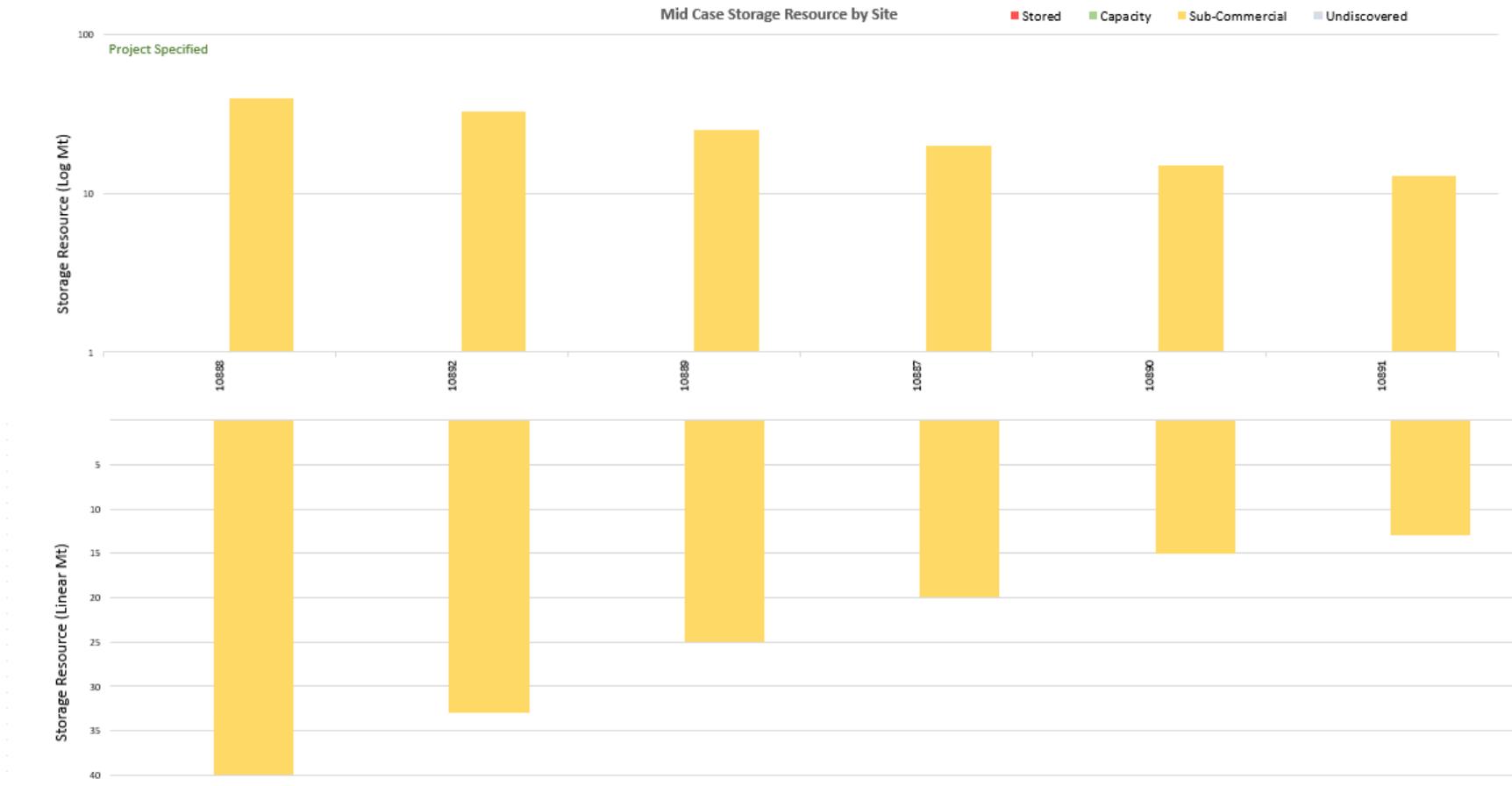


Figure 3-2: Storage resource summary for Austria compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 3.3 Evaluation History

Austria has extremely limited studies for CO<sub>2</sub> storage potential. This is likely due to the current ban on storing CO<sub>2</sub> in Austrian basins. Austria views CCS, and the uses of any natural CO<sub>2</sub> sink to reach climate neutrality negatively. As such, storage resource estimates hold great uncertainty. However, a brief study in 2006 by Sharf and Clemmens [1] identified potential areas that could have characteristics suitable for CO<sub>2</sub> storage in depleted oil and gas fields. This study built on Welkenhuysen et al.'s (2016) [2] work using a techno-economic approach that modelled different simulations to integrate a range of uncertainties to understand total and matched resources. Austria has a comprehensive and well-established hydrocarbon industry and is committed to reducing CO<sub>2</sub> emissions and being climate neutral by 2050; a change of direction regarding CCS legislation and more extensive studies may happen in the future.

### 3.4 Resource Review

#### 3.4.1 Major Projects

There are no storage projects in Austria due to CO<sub>2</sub> storage being prohibited. However, Austria does have projects in other parts of the CCS value chain. ViennaGreenCO<sub>2</sub> is a project set up to research and develop low cost, energy efficient CO<sub>2</sub> separation/capture technology. Austria has also considered CO<sub>2</sub>-EOR [3], which may help initiate a transition to CO<sub>2</sub> storage. In addition, the Lafarge Zementwerke, Verbund, OMV and Borealis are involved in a project called "Carbon2ProductAustria" (C2PAT), which aims to develop a full-scale CCU plant (CO<sub>2</sub>GeoNet (2021) [4].

#### 3.4.2 Depleted Oil & Gas Fields

Hydrocarbon fields in Austria deemed suitable for CO<sub>2</sub> storage are found in the Molasse and Vienna Basin. The most significant storage potential is in the Vienna Basin. The oil-producing Schenkirchen Tief reservoir includes 3 fractured reservoirs (Schoenkirchen Tief, Schoenkirchen Tief Gas and Prottes Tief), has 15 producing wells and good reservoir quality. Mid-range resource is estimated 20Mt. The Schenkirchen Ubertief is a sour gas reservoir of fractured dolomite and is estimated to provide a mid-range of 40Mt. The Aderklaa site is an abandoned gas reservoir with a reported mid-range of 25Mt storage potential. Two other reported sites are the Höflein gas condensate dolo-quarzenit with a mid-range of 15Mt and Reyersdorfer sour gas dolomite with a mid-range of 13Mt.

The Molasse Basin has the Atzbach Schwanenstadt Gas reservoir, which has an estimated mid-range storage resource of 7Mt and an upper of 18Mt, and the Voitsdorf Oil reservoir, which is estimated to have a mid-range resource of 33Mt.

There is concern cited that legacy wells may pose some of the most significant risks to CO<sub>2</sub> containment.

Whilst Austria may currently restrict activities for CO<sub>2</sub> storage, it does have a very active hydrogen storage industry. RAG Austria has several sites for hydrogen storage and operates 11 facilities. These include Puchkirchen/Haag, Haidach, Haidach 5, Aigelsbrunn, and the 7 Fields interconnected gas storage and facilities in Pilsbach and Rubensdorf. This active gas storage industry is encouraging in terms of technology and expertise for any future synergies with CO<sub>2</sub> storage.

### **3.4.3 Saline Aquifers**

Austria has no identified saline aquifers for CO<sub>2</sub> storage. However, this may change if there is a regulatory shift to permit CO<sub>2</sub> storage in Austria.

## **3.5 Regulatory Framework**

Austria's legal stance on domestic CO<sub>2</sub> storage is that it is prohibited within Austria. However, Austria has defined climate challenges to meet, and reviews how the country will achieve these regularly. It passed the Climate Act in 2011 and, in 2018, submitted its draft National Energy and Climate Plans (NECPs) to the European Parliament and the Council. In the "Long-Term Strategy 2050" - published by the Federal Ministry Republic of Austria, Sustainability and Tourism (2019), Austria plans to reduce greenhouse gas emissions. It notes a need for CCS in its plans. The strategy calculated and presented several pathways for Austria to use for greenhouse gas emissions and compensation from 2020 to 2050. Pathways proposed the use of CCS to varying degrees to meet the objectives, and some found routes to avoid CCS. Austria reviews its status and "Federal Act on the Prohibition of the Geological Storage of Carbon Dioxide" every 5 years [5]

Austria scores 30 on the CCS readiness scale as defined by the GCCSI [5].

## **3.6 Issues for the Assessment**

Limited research and very limited data availability for most of the CO<sub>2</sub> storage resources in Austria will affect the accuracy of storage estimates. All estimates at the current sites are based on hydrocarbon replacement volumes.

## **3.7 Future Updates**

### **3.7.1 Future evaluations**

Future evaluations should address any legislation updates and if this has helped encourage any projects or research.

### **3.7.2 Future CSRC cycles**

Future updates will be strongly dependent on Austria's regulations. Should CCS be permitted, any sites undergoing evaluation to transition to storage will need to be reviewed.

# 4 Belarus

## 4.1 Summary

Belarus was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Belarus.

Table 4-1: Storage resource classification summary for Belarus.

## 4.2 Evaluation History

Belarus has been sparsely investigated for storage resource and there is very limited literature in the public domain. A report by the UN [1] assessed the potential of geological storage in Eastern Europe, the Caucasus and central Asia and concluded that there was no opportunity for this in Belarus.

## 4.3 Resource Review

### 4.3.1 Major Projects

There are no reported storage projects in Belarus.

### 4.3.2 Depleted Oil & Gas Fields

There are no reported resources in Belarus. However, Belarus is reported as having potential for Advanced EOR+ [1]. "Advanced EOR+" is distinguished from "conventional" EOR. Where operations aiming to co-exploit oil production and storage could see a CO<sub>2</sub> utilization of ~0.6 tCO<sub>2</sub>/bbl [2].

### 4.3.3 Saline Aquifers

There are no reported resources in Belarus.

## 4.4 Regulatory Framework

Belarus does not report on having any regulations relating to geological carbon storage. However, it has set greenhouse gas emissions targets [3] which could contribute to the

adoption of CCS and any necessary regulations in the future, especially since EOR is cited as a possibility in the country. The oilfields in the Pripyat Trough may have suitable reservoirs for CO<sub>2</sub> storage; the basin has a succession of Devonian salt units with inter and intra sub salt deposits that serve as reservoir rocks for oil fields. These successions are up to 2000m thick.

## **4.5 Issues for the Assessment**

The main issue for assessment is the limited amount of research. At the time of Cycle 5, there is only one study available, and this was performed at a country level.

## **4.6 Future Updates**

### **4.6.1 Future CRSC Cycles**

Future cycles could investigate if any project is planned on cross border agreements for capture-transport-sink projects with neighboring states or if Advanced EOR+ projects have migrated into CO<sub>2</sub> storage projects.

# 5 Belgium

## 5.1 Summary

Belgium was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Belgium as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.426	0.000
Aggregated*	0.426	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Belgium.

Table 5-1: Storage resource classification summary for Belgium.

- Detailed studies on Belgium for CO<sub>2</sub> storage are limited and currently remain at a sequence level. Belgium has been part of three pan-European CO<sub>2</sub> Storage assessments; JOULE, GESTCO, and CO<sub>2</sub>STOP.
- CO<sub>2</sub> resources in Belgium are only reported at a sequence level. Saline aquifers and coal seams are the only geological storage options.
- Storage opportunities are in the Houthem and Maastricht formations, the Buntsandstein Formation, the Neeroeteren Formation, the Carboniferous Limestone Group (Dinantian) and the Devonian.
- Belgium is involved in several projects in the CCS value chain and is also part of storage transboundary cooperation projects.
- Both regions in Belgium have transposed the EU CCS Directive into various Acts.
- Belgium has a value of 47 on the GCCSI CCS Regulatory Indicator system, 2023.

A2) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

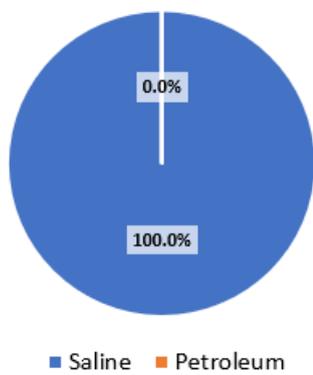


Figure 5-1: Belgian spread of Storage Sites.

A) Spread of storage resource in all Belgian sites across SRMS classifications; both project specified and not. B) Split of Belgian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 5.2 Resource Statement

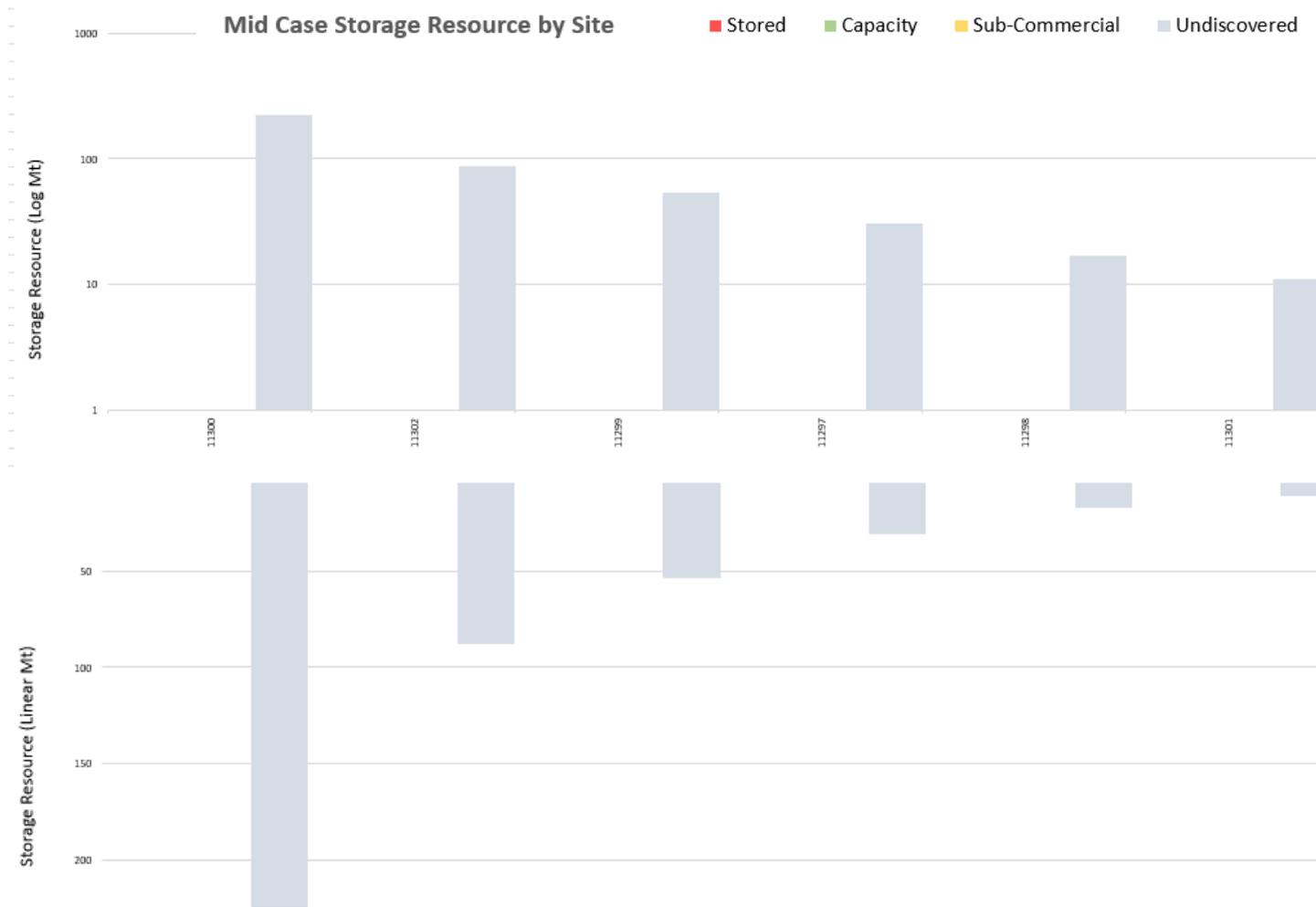


Figure 5-2: Storage resource summary for Belgium compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 5.3 Evaluation History

Detailed studies on Belgium for CO<sub>2</sub> storage are limited and currently remain at a sequence level. Belgium has been part of three pan-European CO<sub>2</sub> Storage assessments; JOULE in 1996, GESTCO in 2003, and CO<sub>2</sub>STOP in 2013 [1,2,3,4]. All assessments were at the sequence level and identified opportunities in saline aquifers and coal beds.

A paper published in 2009 [5] reviewed the potential CCS industry in Belgium from a policy perspective. It identified potential matters that could be targets for CCS projects, reviewed the current transport situation for CO<sub>2</sub> and finally provided some modelling for project costs. The assessment of storage sites was performed on a sequence level which considered both reservoir and seal characteristics but resources per site were not calculated. Later reports in 2009 and 2011 built on this research and provided further resource estimates although these were theoretical and did not use a comprehensive set of properties for the calculations [5,6,7]. The data from CO<sub>2</sub>Stop has been used for the CRSC since it is the most recent, has a reasonable set of properties and the methodology used to calculate the resource is consistent and therefore comparable with other European countries.

### 5.4 Resource Review

Belgium has several potential sites in saline aquifers at locations through the country which have been entered into the CRSC. It also has several coal formations and exhausted coal mines in the Campine Basin documented as having potential for CO<sub>2</sub> storage.

#### 5.4.1 Major Projects

Belgium does not have any domestic storage projects either in operation or in a planning stage. Belgium does, however, have projects in operation in the CCS value chain and is also part of storage transboundary cooperation projects.

The Antwerp@C/Kairos@C is a carbon transport and interim storage network located in the port of Antwerp which will be used to help decarbonise chemical and other industries. Antwerp@C plans to create an open access system to collect the CO<sub>2</sub>, liquify and then provide temporary storage. Consortium partners are Air Liquide, BASF, Borealis, ExxonMobil, INEOS, TotalEnergies, Fluxys, the Port of Antwerp-Bruges. The transport will be down by ship and transported to potential sites in Norway, the Netherlands, Denmark and the UK. It is currently in FEED status. A start of Phase 1 is foreseen in 2026 [8].

The Ghent Carbon Hub is another liquification, storage and transport network which received funding in 2022 from the EU Commission. The partners are Fluxys Belgium, North Sea Port and ArcelorMittal. The Pipeline network will connect the Walloon region to the hub in Ghent [9]. Fluxys also has a partnership with Wintershall Dea to undertake a feasibility study for the transport of CO<sub>2</sub> from Germany to Zeebrugge. The Walloon industry is also working on CCS projects. In June 2024, several leading Belgian industrial companies (Lhoist, Carmeuse,

ArcelorMittal, Holcim) confirmed their intention to boost the capture at source of the CO<sub>2</sub> they emit and then store it [9]. Flanders is also part of the North Sea Basin Task Force and is involved in the development of the Regional Plan.

Belgium is part of Project Greensand (Wintershall Dea, INEOS et al.) and is providing the CO<sub>2</sub> captured from the INEOS Oxide plant in Zwijndrecht, Belgium. A Memorandum of Understanding on Cross Border Transportation of CO<sub>2</sub> with the Purpose of Permanent Geological Storage was signed on the 26th of September 2022 between Belgium and Denmark [10].

#### **5.4.2 Depleted Oil & Gas Fields**

Belgium does not have any depleted oil and gas fields reported as potential storage sites due to the lack of a domestic oil and gas industry.

#### **5.4.3 Saline Aquifers**

Belgium has a few saline aquifer sites identified in the literature. Despite limited studies in the last 15 years there has been no advancement of the sites from a sequence level. Storage opportunities are in the Houthem and Maastricht Formations, the Buntsandstein Formation, the Neeroeteren Formation, the Carboniferous Limestone Group (Dinantian) and the Devonian, the latter two being in both the north and the south of the country. The Houthem and Maastricht formations do not have reported volumes large enough to enter in the CRSC. The Buntsandstein and the Dinantian reservoirs appear the most promising. Unmined coal sequences are also a potential option and could have very large capacities. In addition, abandoned coal mines have also been identified but may have pressure and sealing issues [7].

The Houthem and Maastricht Formations (Cretaceous to Palaeocene carbonates) occur at sufficient depth in the Roer Valley Graben and the north of the Campine Basin. The reservoir only just meets the 800 m depth for supercritical storage. Properties are favourable for injectivity, and the resource of the site is estimated at 8 Mt. This site does not make the cut-off for the CRSC. Trapping structures were not identified. The Buntsandstein sandstones (Lower Triassic) also occur in the Campine Basin and Roer Valley Graben. Issues may exist with sealing in the western areas of this formation. Included in this formation is the Verloren Kamp structure with a surface area of 7 km<sup>2</sup> and a height of about 100m. Storage capacity in this structure is estimated at 15 to 40 Mt CO<sub>2</sub> which is based on theoretical estimates in [7] without using a storage efficiency factor. Therefore, this is not entered in the CRSC since it is not possible to compare this resource with resource report from CO<sub>2</sub>Stop for the Bunsandstein as a whole. The Buntsandstein has an estimated mean resource of 31 Mt.

The Dinantian carbonate aquifers of the Carboniferous Limestone Group are found in both the Campine Basin and the Mons Basin. This formation has two parts: a lower dolomitised and an upper karstified part. Capacity is estimated at 54 Mt and some structures have been identified but the location is unspecified. The Dinantian aquifer in the Mons Basin is covered by thick coal

measures, potentially providing a good seal. This formation is used for gas storage at Loenhout and geothermal energy which may present a conflict to CO<sub>2</sub> storage. The Devonian carbonate aquifers in the Campine Basin and the Fagne-Famenne are the oldest. Very little is known on these reservoirs although a resource has been reported in CO<sub>2</sub>Stop [3,7].

Unmined coal sequences are found in both the Campine Basin and the Namur synclorium. The amount of coal in these sequences is relatively low. Research assumes most of the CO<sub>2</sub> will be adsorbed on coaly shales or stored in sandstone bodies, potentially creating storage resource of up to 1 Gt in the Campine Basin, and up to 700Mt or 1.56Mt/km<sup>2</sup> in the Namur synclorium. The deep coal mines have an estimated capacity of 30M t but pose technical difficulties with sealing due to shafts and mining induced fractures [7].

## 5.5 Regulatory Framework

**Flemish Region:** The Flemish Region has transposed the CCS Directive through the Act on the Deep Subsoil (*Decreet Diepe Ondergrond*) and the Decree of the Flemish Government on the Deep Subsoil (*Besluit Diepe Ondergrond*). This region is also in the process of updating the legislation on the transport of carbon dioxide for geological storage and for usage. The **Walloon Region** has also transposed the CCS directive through the decree of 10 July 2013 [11].

## 5.6 Issues for the Assessment

There is very little published and minimal research on storage sites in Belgium. Storage estimates are reliant on only basic parameters, and these do not represent the complexity of the aquifers. Hence, any resource estimates carry significant uncertainty. Some aquifers have an absence of areal extent so storage resource cannot be calculated.

## 5.7 Future Updates

### 5.7.1 Future CRSC Cycles

Belgium appears to be favoring the provision of a transport and storage hub at its ports within a wider consortium of capture-transport-storage projects to the North Sea. Domestic storage site updates are unlikely at this stage.

## 6 Bosnia and Herzegovina

### 6.1 Summary

Bosnia and Herzegovina was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Bosnia and Herzegovina as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.296	0.000
Aggregated*	0.296	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Bosnia and Herzegovina.

Table 6-1: Storage resource classification summary for Bosnia and Herzegovina.

- CO<sub>2</sub> storage research began in the mid-2000s, mainly through international projects like EU GeoCapacity, CO<sub>2</sub>GeoNet, ESTMAP, and UNECE studies. National involvement has been minimal.
- No storage projects have been implemented. Only high-level theoretical assessments exist, and there are no plans for future projects.
- A single aquifer (Sarajevo-Zenica Basin) has been assessed. No hydrocarbon fields were included due to lack of data and low storage potential.
- The Sarajevo-Zenica Basin provides a theoretical estimate of 293 Mt capacity, but this is based on limited data and broad assumptions.
- Bosnia and Herzegovina has no legal framework for CCS. Storage is not formally permitted or prohibited. Existing energy and mining laws may support future CCS regulation.
- Key challenges include poor data and tectonically complex geology, and absence of funding and regulatory support.
- Future updates depend on legal and policy developments, as current assessments lack the robustness needed for project development.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

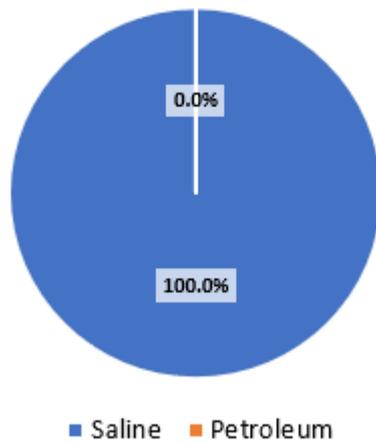


Figure 6-1: Bosnia and Herzegovinian spread of Storage Sites.

A) Spread of storage resource in all Bosnia and Herzegovinian sites across SRMS classifications; both project specified and not. B) Split of Bosnian and Herzegovinian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 6.2 Resource Statement



Figure 6-2: Storage resource summary for Bosnia and Herzegovina compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 6.3 Evaluation History

CO<sub>2</sub> storage research in Bosnia and Herzegovina began in the mid-2000s, primarily through international initiatives such as the EU GeoCapacity project, which provided the first high-level assessment of storage potential. Subsequent evaluations were conducted as part of regional collaborations like CO<sub>2</sub>GeoNet, ESTMAP, and UNECE-led studies, with limited national involvement. The only location assessed was the Sarajevo-Zenica Basin, where rough volumetric estimates were made. No hydrocarbon fields were included due to a lack of reliable data, and overall findings suggest limited storage potential. Research remained largely theoretical, constrained by poor data availability, geological challenges such as karstification and tectonic complexity, and the absence of a national CCS framework or dedicated funding.

## 6.4 Resource Review

In Bosnia and Herzegovina, assessment of CO<sub>2</sub> storage capacities is very limited with a lack of research for resource estimation. In the existing studies, no hydrocarbon fields were assessed due to lack of reliable data with all information indicating insignificant storage capacities. With respect to saline aquifers, only one basin was assessed, and the approach was restricted to high level theoretical estimation since no deep structures were defined [1].

### 6.4.1 Major Projects

There are no storage projects in Bosnia and Herzegovina due to the lack of regulations and a legislative framework for such activities. However, a first assessment of CCS opportunities including storage potential and capacities in Bosnia and Herzegovina were performed within the EU GeoCapacity project [1], which became the reference for future assessment like the Geologic CO<sub>2</sub> storage assessment by the United Nations Economic Commission for Europe [2] and the CO<sub>2</sub>GeoNet State-of-play on CO<sub>2</sub> geological storage [3]. Also, the Faculty of Mining, Geology and Civil Engineering, University of Tuzla, participated in the ESTMAP project in a further attempt to activate the issue of use and storage CO<sub>2</sub> through the project work [3].

### 6.4.2 Depleted Oil & Gas Fields

Despite the historical discoveries and limited production activity in northern Bosnia during the 1930s, no hydrocarbon fields were included in any of the assessments due to insufficient reliable data for storage estimation. Based on the country's hydrocarbon industry and information, even if properly assessed, these fields would not provide significant storage capacity [1].

### 6.4.3 Saline Aquifers

The only saline aquifer assessed in Bosnia and Herzegovina is the Sarajevo-Zenica Basin, where data from a previous oil exploration well enabled a rough estimation of aquifer properties and thickness, which in turn allowed for a capacity estimate. However, this estimate should be considered highly approximate due to several limitations: there was no detailed control over the subsurface reservoir geometry and the effective thickness and porosity were averaged

across the entire area. Using a storage efficiency factor of 3% and based on the theoretical volumetric calculations by GeoCapacity, a storage capacity of 293 Mt was calculated —primarily due to the basin's large size and thickness [1]. The area of the site is estimated at 793 km<sup>2</sup>, with a thickness of 250 m, a net/gross ratio of 0.4 and a porosity of 15%. In addition, the CO<sub>2</sub> density used to generate this result was estimated to be 0.830 t/m<sup>3</sup>. However, another value was also provided in this report, categorized as "Conservative estimate"=197 Mt, but with no further information on how it was calculated, or with which storage efficiency factor [1]. Therefore, the first estimated value was used in the database since it provides more clarity on efficiency value and aquifer properties considered.

## **6.5 Regulatory Framework**

Bosnia and Herzegovina currently lacks specific legislation for carbon capture and storage (CCS). CO<sub>2</sub> storage is neither explicitly allowed nor prohibited, as no dedicated legal framework exists. While the country adopted the "Climate Change Adaptation and Low Emission Development Strategy" in 2013 and ratified the Paris Agreement in 2017, implementation remains limited [3]. However, existing laws in energy, mining, and environmental protection could support future CCS regulation. Gas sector legislation—particularly on transport and storage—may be most relevant, though CO<sub>2</sub> pipeline transport is not yet covered [3]. Therefore, CCS regulation in Bosnia and Herzegovina is at an early stage, with legal gaps but potential foundations for development.

## **6.6 Issues for the Assessment**

In Bosnia and Herzegovina, research on CCS is extremely limited, with virtually no dedicated funding or ongoing studies. Data availability is also very scarce, restricting the accuracy of any estimates. Geologically, the country lacks favorable storage formations. The predominance of carbonate sedimentary rocks, combined with extensive karstification and tectonic disruption of their brittle layers, poses major challenges to secure CO<sub>2</sub> storage [1]. Furthermore, storage capacity figures reported are purely volumetric and do not account for geotechnical, regulatory, or socio-economic constraints, which are likely to significantly reduce usable storage potential. While the State has acknowledged the importance of CCS, particularly in the context of EU accession goals, progress in Bosnia and Herzegovina remains slow and uncoordinated [3].

## **6.7 Future Updates**

### **6.7.1 Future CRSC Cycles**

Future evaluations should address any legislation updates and if this has helped encourage any projects or research to have reliable storage sites assessments. CSRC updates will be strongly dependent on Bosnia and Herzegovina's regulations and low carbon strategy adoptions. Should CCS be permitted, any sites undergoing evaluation to transition to storage will need to be reviewed with more clarity and robust data assessment, unlike what is present currently.

# 7 Bulgaria

## 7.1 Summary

Bulgaria was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> Storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.004	0.000
Undiscovered	2.563	0.460
Aggregated*	2.567	0.460

\* The aggregated resource represents the summed storage resource across all maturity classes and, as such, should not be viewed as representative of the potential of Bulgaria.

Table 7-1: Storage resource classification summary for Bulgaria.

- Bulgaria has been assessed by several pan-European CO<sub>2</sub> storage assessment projects, namely Geocapacity, CASTOR and CO<sub>2</sub>Stop.
- Bulgaria has CO<sub>2</sub> storage potential in both depleted oil and gas reservoirs and saline basins. All assessments to date are volumetric.
- Bulgaria currently does not have any pilot/demonstration or commercial CO<sub>2</sub> storage projects. The ANARV project will be the first CO<sub>2</sub> capture in Bulgaria and store CO<sub>2</sub> in the Black Sea depleted gas field Galata, with an estimated CO<sub>2</sub> storage resource of 4Mt.
- A total of seven zonal aquifers are estimated as suitable for CO<sub>2</sub> storage. The majority are located in Northern Bulgaria and related to thick Phanerozoic sedimentary succession in the Moesian Platform
- Bulgaria follows the Directive 2009/31/EC on the Geological Storage of Carbon Dioxide.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



C) Storage Resource by Type

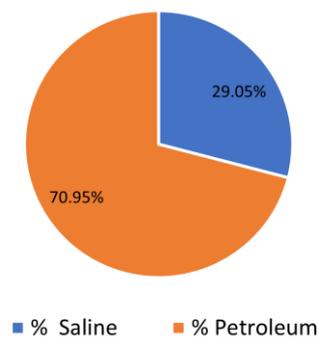


Figure 7-1: Bulgaria Spread of Storage Sites.

A) Spread of storage resource in all Bulgarian sites across SRMS classifications; project specified. B) Spread of storage resource in all Bulgarian sites across SRMS classifications; both project specified and not. C) Split of Bulgarian storage resources between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 7.2 Resource Statement

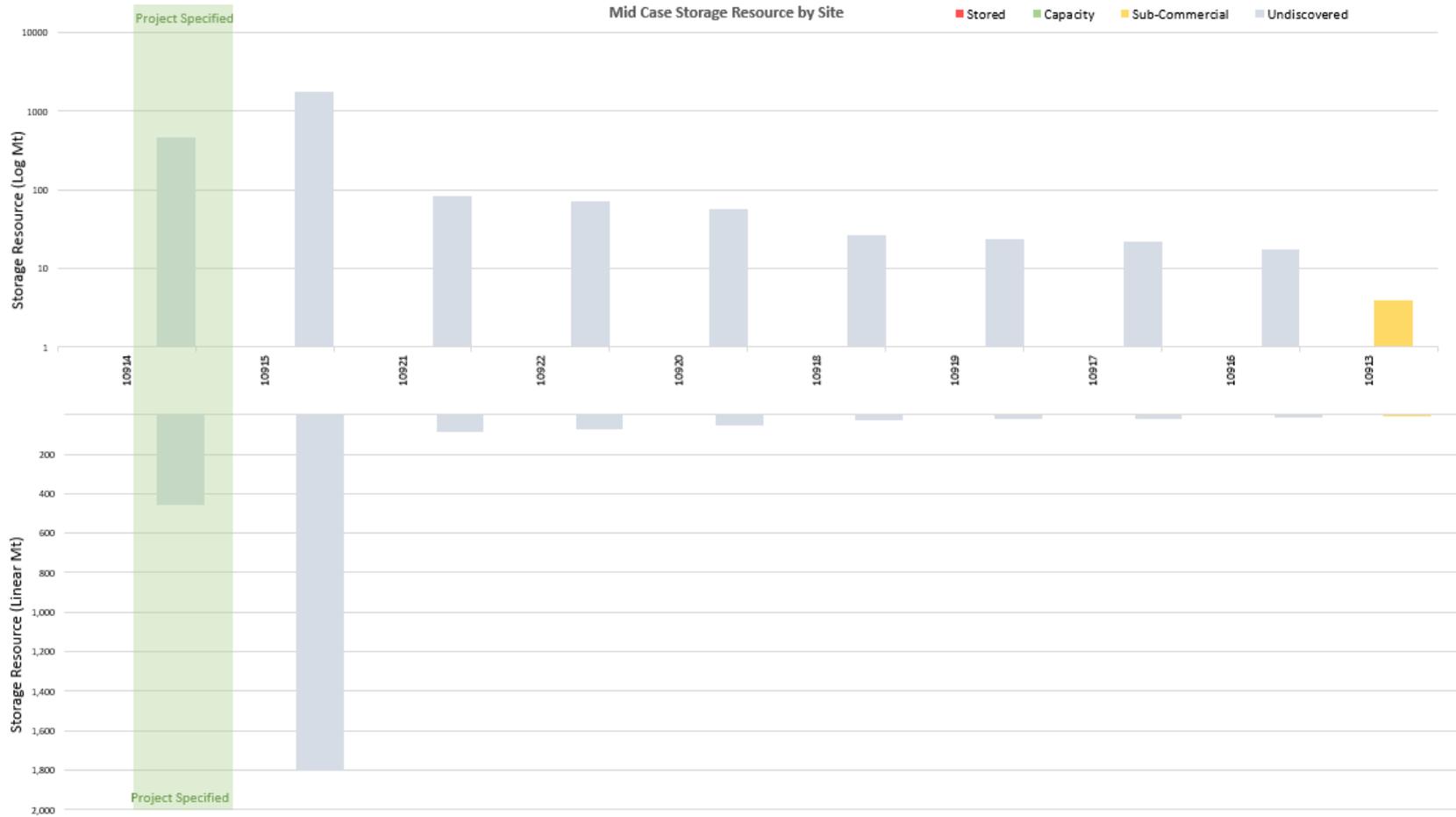


Figure 7-2: Storage resource summary for Bulgaria compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### **7.3 Evaluation History**

The first evaluation of potential storage resources in Bulgaria took place with the CASTOR project (2004 – 2005). This was updated and enlarged with the EU GeoCapacity project (2006-2008). During the GeoCapacity project, the CO<sub>2</sub> storage potential was estimated for onshore saline aquifers, depleted hydrocarbon fields and coal fields.

The most promising potential for CO<sub>2</sub> storage in Bulgaria is related to karstified and fractured carbonate reservoirs in the Devonian and Upper Jurassic - Valanginian, and coarse-grained clastic reservoirs in the Lower Triassic, Middle Jurassic and Middle-Upper Eocene stratigraphic units [1]. They have been proven by results from numerous drilled oil and gas exploration wells. The evaluation of CO<sub>2</sub> storage resources in Bulgaria's deep saline aquifers is based on estimating two individual structures and seven local zones. Six of the selected aquifers are in Northern Bulgaria, and the other two are in Southern Bulgaria [2].

All sites reported in the CRSC have used the GeoCapacity volumetric approach, hence carrying some uncertainty around over-estimation.

### **7.4 Resource Review**

The largest emission sources in Bulgaria are located near the Black Sea coast and in central Bulgaria. The storage regions are in the easterly part of the country, with a total storage resource of 2563Mt in deep saline aquifers and 4Mt in hydrocarbon fields [1].

#### **7.4.1 Major Projects**

Bulgaria has been involved in two CCS projects. The first is the Maritsa project. This was a proposed CCUS project and was due to start in 2013 but was cancelled due to the lack of budget. There is limited information available on this project. The second is the ANRAV project. This will be the first CCS Project in Eastern Europe and the first CO<sub>2</sub> capture project in Bulgaria. Storage of CO<sub>2</sub> will be in the Galata depleted oil field in the Black Sea. ANRAV, will link CO<sub>2</sub> capture facilities at Heidelberg Cement's (HEIG.DE) Devnya cement plant in north-eastern Bulgaria with offshore permanent storage in the depleted Black Sea gas field of Galata. Operations are expected to start in 2028, aiming to capture 800,000 tonnes of CO<sub>2</sub> yearly. The storage potential of the Galata field is estimated to be 2.0 billion m<sup>3</sup> at STP conditions [4], corresponding to 4Mt of CO<sub>2</sub>

#### **7.4.2 Depleted Oil & Gas Fields**

A review of storage potential in Bulgaria's depleted oil and gas fields is provided in the GeoCapacity project [5]. Most discovered economic oil and gas fields in Bulgaria are outside the depth range interval of 800-2500m (suitable for effective CO<sub>2</sub> storage). Only three gas fields (Pleven, Marash and Galata) are within the right depth interval. Bulgaria has an underground gas storage operation in Chiren, which started in 1974 and is still operating. Only

the Galata gas field, located offshore, was considered for CO<sub>2</sub> storage and has an estimated storage potential of 6Mt.

#### **7.4.3 Saline Aquifers**

Saline aquifers in Bulgaria have more promising CO<sub>2</sub> storage potential. A total of 7 aquifers are estimated as suitable for CO<sub>2</sub> storage. The majority were located in Northern Bulgaria and related to thick Phanerozoic sedimentary succession in the Moesian Platform. Good reservoirs with appropriate geological parameters for CO<sub>2</sub> storage are present in Devonian, Lower Triassic, Middle Jurassic, Valanginian and Eocene sedimentary sequences. In Southern Bulgaria, dominated by igneous and metamorphic rocks, the only aquifers with CO<sub>2</sub> storage potential are related to the narrow distribution of the Paleogene sedimentary sequence in the Thracian depression.

### **7.5 Regulatory Framework**

Carbon capture and storage EU laws were introduced in Bulgaria, with the draft legislation being approved by the Government on 22 September 2011 and sent to Parliament for further approval on 28 September 2011 [6]. Amendments and supplements from the third implementation of the Directive 2009/31/EC on the geological storage of carbon dioxide ("CCS Directive") have been transposed into Bulgarian legislation.

Bulgaria scores 34 out of 100 in the CCS readiness index as defined by the GCCSI [7].

### **7.6 Issues for the Assessment**

The only data available for Bulgaria on CO<sub>2</sub> storage potential is provided by G. Georgiev from Sofia University (as reported in the GeoCapacity project). Any subsequent publications found are still based on his estimations. Some show discrepancies in the storage resource values, but because no justification accompanies the published values, the GeoCapacity values are entered in the Cycle 4 CSRC database. A lack of dynamic modelling and ready access to site-specific data was the main issue for this assessment cycle and a limitation for understanding storage site potential in this country.

### **7.7 Future Updates**

#### **7.7.1 Future evaluations**

Future evaluations should seek to address if there are any refinements to the GeoCapacity estimates, which are now quite dated.

#### **7.7.2 Future CSRC cycles**

Should any further development in the Bulgaria storage systems occur, this should be reviewed annually to ensure the Global Storage Catalogue is up to date. Future updates should also include observations of progress with the ANRAV project.

# 8 Croatia

## 8.1 Summary

Croatia was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> Storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.164	0.000
Undiscovered	4.733	0.000
Aggregated*	4.897	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and, as such, should not be viewed as representative of the potential of the country.

Table 8-1: Storage resource classification summary for Croatia.

- Croatia has a total of 18 sites that can be added to the CSRC.
- Seven of these sites are classified as discovered due to a history of oil and gas production or drilling campaign.
- There are extensive pipeline networks, hydrocarbon fields and saline aquifers in close proximity to major emitters in the Sava and Drava depression regions, both of which have large saline aquifers. This area may hold potential for hub developments in the future.
- Additional saline aquifer storage is identified in defined structures in the Adriatic or in large saline basins in the north of the country.
- CCS is currently permitted in Croatia, and the country has an active research program on various aspects of the CCS life cycle. There are several projects underway through the full CCS value chain.
- Regulations are contradictory, which is a crucial reason for the advancement of limited storage assessments to date.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

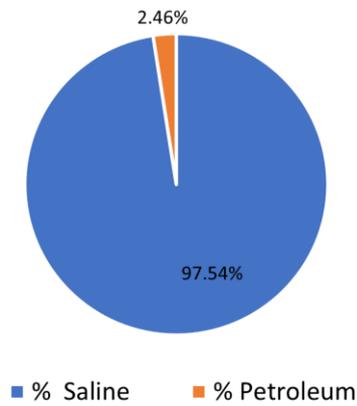


Figure 8-1: Croatia Spread of Storage Sites.

A) Spread of storage resources in Croatian sites across SRMS classifications; both project specified and not specified. B) Split of Croatian storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 8.2 Resource Statement

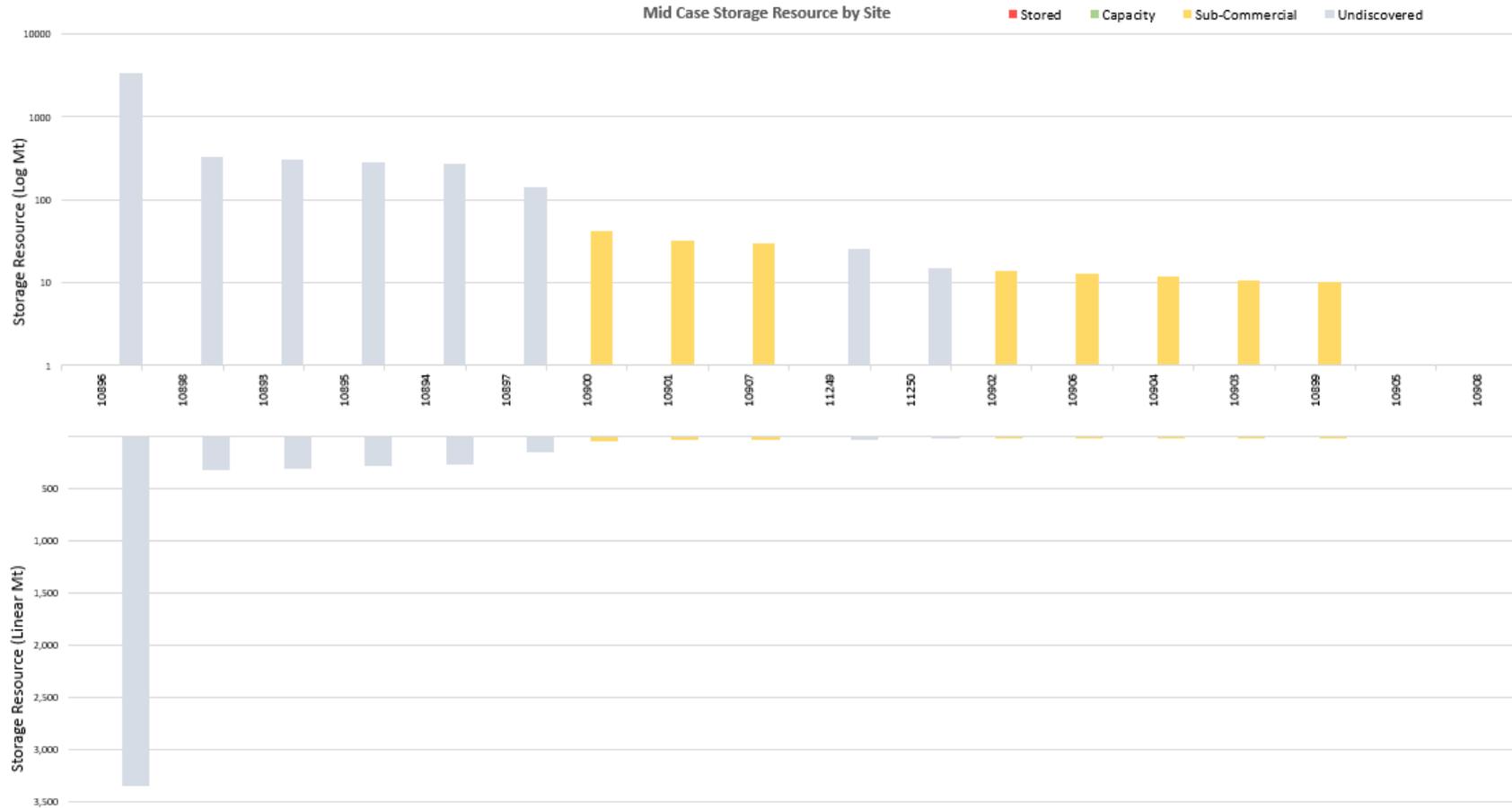


Figure 8-2: Storage resource summary for Croatia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 8.3 Evaluation History

Croatia has benefited from several of the pan-European assessment studies. Croatia was part of the GeoCapacity (2008) project and also underwent a comprehensive study for storage resources in the CASTOR (2008) project (<https://cordis.europa.eu/project/id/502586/reporting>). Since then, two extensive reports have used storage resource values similar to those reported in earlier studies but have attempted to revise some of these calculations or assess resource potential based on country advancement and emissions status. STRATEGY CCUS [1], a project completed in 2021, was funded by the EU. It assessed the storage resource data from each designated region and provided a maturity and readiness status for implementing CCUS projects. The report evaluated previous volumetric estimates with a qualitative assessment and then ranked the resources based on data maturity and understanding of resource potential. In most cases, this approach has increased Croatia's storage potential in saline aquifers. These values have been used in the CSRC. Croatia was also part of the CCS4CEE [2] study, which was completed in 2022. This report did not revise the estimates to any greater extent but did report many more hydrocarbon sites – most of which are too small to be included in the CSRC database. Other studies by Saftic et al. (2019) [3] published more extensive assessments of the Adriatic potential. Resources were based on volumetric methods incorporating compressibility calculations and have been used as the preferred values in the CSRC.

Plans have been made to establish a National Feasibility Study on CCS and evaluate a national CO<sub>2</sub> storage resource. However, no public reporting on this has been done to date.

## 8.4 Resource Review

### 8.4.1 Major Projects

Croatia is active in several areas of the CCS value chain. There are 3 projects operated by INA/MOL:

1. An active CO<sub>2</sub> EOR project has been in operation since 2014 and is run at the gas treatment plant at the Molve Municipality. The injection is onshore at the Ivanić & Žutica gas field.
2. A full chain CCS project at the Petrokemija Plant. Here, the Ammonia plant CO<sub>2</sub> will be captured and transported via pipeline to store at the depleted Ivanić & Žutica gas field. Injection is planned in 2026 [4].
3. A biorefinery project focused on industrial capture and underground storage aims to be operational by 2024 and capture 55,000 tonnes per year. The injection is in depleted oil and gas fields, although these are not specified. Collectively, these projects aim to capture 1.96Mt [4].
4. A further project is the CCGeo project (Closed Carbon Geothermal Energy), a full chain CCS project that intends to generate electricity and heat from geothermal brine. Then, the

produced CO<sub>2</sub> will be injected back into the same reservoir. This will be operated by AAT Geothermae, CLEAG. This site is in the Pannonian basin at Draškovec and started in 2022. To date, the project has completed the research phase [4]. An additional geothermal project, Velika Ciglena, has operated since 2018 and aims to capture 0.15Mt [2]. Finally, a large-scale project called KDeCO net Zero seeks to be the first net zero cement plant in Croatia and the Mediterranean. CO<sub>2</sub> will be captured and taken to the Mediterranean Sea for storage (the site is not yet named) [5].

#### **8.4.2 Depleted Oil & Gas Fields**

A total of 17 oil and gas fields have been identified as having CO<sub>2</sub> storage potential. However, due to their small size, only 6 have been added to the CSRC. Two prospective sites (which are currently CO<sub>2</sub> EOR projects) that have been identified as higher potential targets for CCS are the Ivanić and Žutica oil fields (central Croatia) and the Beničanci oil field (eastern Croatia). Both Beničanci and Ivanić are too small to be included in the CSRC. In addition, all these sites are close to both CO<sub>2</sub> emitters and pipeline infrastructure, so they could potentially present a hub and cluster solution in the future when combined with other sites in the vicinity. Most sites have targets in Upper Miocene formations - the Ivanić Grad, Kloštar Ivanić and Vinkovci Formations. There is limited data for these fields due to confidentiality. Most potential storage fields are in the Sava and Drava depressions, and three fields (Ida, Ika and Marica) are in the Adriatic. Marica's 9.7 Mt CO<sub>2</sub> storage potential is too small to be included in the CSRC database.

#### **8.4.3 Saline Aquifers**

Most of Croatia's potential storage sites sit within the Pannonian Basin, specifically the Sava and Drava Depressions. These depressions were formed during the Neogene–Quaternary tectonic evolution of the south-west part of Pannonian Basin. As with depleted oil and gas fields, all saline aquifer sites are in Upper Miocene sandstones. The Upper Miocene sediments are characterised by marls and sandstones initially deposited in a turbiditic pro-delta, then delta slope to delta plain environments. This area then developed into Lake Pannon. The Pliocene and Quaternary sediments are deposited in the terrestrial environment and comprise of fine-medium grain clastics. The Sava depression has three overlapping key units previously classified as one. They are the Iva, Okoli and Poljana aquifers. The Drava Depression has the Drava and Osijek aquifers. Combined with the Dugi Otok aquifer in the Adriatic, these three saline aquifers can potentially provide over 90% of Croatia's CO<sub>2</sub> storage resource. None of these resources have been extensively explored despite the presence of over 120 wells the Poljana area. It has not been possible to determine how many of these provide data for the aquifer. These sites are classified as Undiscovered due to great uncertainty surrounding data availability for such large areas. However, these sites are near several emission sources and pipeline networks, so they have the potential to present a hub and cluster solution if data is sought on their suitability.

The Dugi Otok forland basin and 5 structures form the potential saline aquifer sites in the

Adriatic. Again, none of these sites have been extensively assessed. Three storage formations are found in this area:

1. Pliocene and Pleistocene sands (oil and gas reservoirs – see above)
2. Miocene sandstones (in Dugi Otok basin)
3. Triassic-Cretaceous Limestones (structures).

One structure is deemed too small to be counted in the CSRC database. Drilling activity is present in this region, and likely, some structures have been drilled, although the extent of this activity is unclear in the literature. One structure does have a well penetrating it (Kate-1), but limited data is available. This structure is classified as discovered.

Croatia is not tectonically benign, and earthquakes have been recorded in the CO<sub>2</sub> resource regions. However, the majority are concentrated in the south of the country, where there are currently no identified sites.

## **8.5 Regulatory Framework**

Croatia's legislative framework aligns with existing EU Directives on carbon capture and geological storage. The Hydrocarbon Exploration and Exploitation Law and the Law on Permanent carbon dioxide storage in geological formations represent the transposition of the Directive 2009/31/EC. Croatia's ordinance on 'Permanent carbon dioxide storage in geological formations (ordinance on permanent storage of gases in geological structures) outlines procedures and testing necessary for permanent storage of CO<sub>2</sub> within geological formations. It also defines the conditions under which CO<sub>2</sub> can permanently store in geological structures. The conditions for obtaining concessions, exploration and storage permits are in the Hydrocarbon Exploration and Exploitation Law. However, it is reported that these two laws can contradict each other, and this aspect has been deemed to be a limiting factor to Croatia's progression and implementation of CCS. Croatia scores 60.5 on the CCS readiness scale as defined by the GCCSI.

## **8.6 Issues for the Assessment**

Low research and a very limited amount of data for most of the CO<sub>2</sub> storage resources in Croatia will affect the accuracy of storage estimates. All estimates at the current sites are based on hydrocarbon replacement or theoretical volumes.

## **8.7 Future Updates**

### **8.7.1 Future evaluations**

Future evaluations should seek to address any updates to sites or potential projects. Future updates should also seek any insight from the planned national CO<sub>2</sub> storage assessment, which could provide more insight into the characteristics of potential storage sites.

### **8.7.2 Future CSRC cycles**

An update for all sites is recommended for future updates to the CRSC. Many sites currently at the formation level may have increased studies to evaluate the lead and prospect levels. The prospective nature of the northern area for hub and clusters and current EOR activity could make this area quite attractive for future storage development.

# 9 Cyprus

## 9.1 Summary

Cyprus was assessed during Cycle 4. The CSRC has identified that Cyprus has no published storage resource estimates, and so has zero sites to enter into the CSRC database:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.00	0.00
Undiscovered	0.00	0.00
Aggregated*	0.00	0.00

\* The aggregated resource represents the summed storage resource across all maturity classes and, as such, should not be viewed as representative of the potential of Cyprus.

Table 9-1: Storage resource classification summary for Cyprus.

## 9.2 Evaluation History

Cyprus was reviewed during Cycle 4. Cyprus is a gas-producing country with recent offshore discoveries undergoing development. No CO<sub>2</sub> storage evaluations have been carried out at the federal level, nor are any available in the public domain. Assessment of storage potential in the saline formations in the offshore Levantine Basin should form the subject of any future evaluation effort.

## 9.3 Regulatory Framework

The Cypriot government has a strategic goal to “participate proportionately in the commitment towards a climate-neutral economy at EU level and to contribute to the European Green Deal promoted by the European Commission” (Department of Environment Mistry of Agriculture, Rural Development and Environment, 2022 [Long-term low GHG emission development strategy Cyprus \(unfccc.int\)](#)). The roadmap to achieving these emissions’ goals is not yet established, and CCS is not highlighted as a potential technology. However, The EU CCS Directive was fully transposed to National Law in 2012 (Law L.71(I)/2012 and amended in 2015 by Law L.174(I)/2015. As of 2023, no assessment of the available storage potential in Cyprus has been undertaken ([Ap \(europa.eu\)](#)).

## 9.4 Future Updates

### 9.4.1 Future Updates for Evaluators

A comprehensive, country-wide assessment of Cyprus’ geologic CO<sub>2</sub> storage resources is

required for both saline formations and any future opportunities in depleted hydrocarbon fields.

#### **9.4.2 Future CRSC Cycles**

Updates to the Cycle 4 assessment should be completed if studies on Cyprus' CO<sub>2</sub> storage resources become available.

# 10 Czechia

## 10.1 Summary

Czechia was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.033	0.000
Undiscovered	0.753	0.000
Aggregated*	0.786	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Czechia.

Table 10-1: Storage resource classification summary for Czechia.

- There is limited information on storage sites in the literature and to date only 10 saline aquifer sites and sites exist to include in the CRSC. These numbers are considered to carry some uncertainty due to limited data availability in the saline aquifer sequences.
- Storage is estimated to be around 753 Mt in saline aquifers within Central Bohemian Upper Paleozoic Basins, Vienna Basin and the Carpathian Foredeep.
- Storage in hydrocarbon fields is estimated at 33 Mt CO<sub>2</sub> and 54 Mt CO<sub>2</sub> in coal fields (mainly in the Upper Silesian Basin).
- Despite limited published material on CO<sub>2</sub> resources in Czechia, the country has a very active history and participation in research projects across the full CCS value chain both nationally and with collaboration on European projects. This demonstrates a growing level of expertise and knowledge in the country for all components of a CCS project.
- The country has one commercial project identified in the Moravia region to capture CO<sub>2</sub> from cement production.

### A) Project and Non-Project Mid-Case Storage Resource



### B) Storage Resource by Type

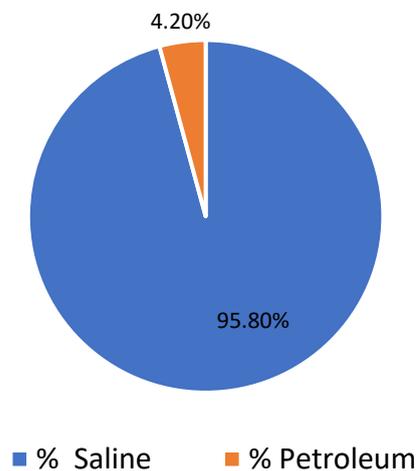


Figure 10-1: Czechia Spread of Storage Sites.

A) Spread of storage resources in Czechia sites across SRMS classifications; both project specified and not. B) Split of Czechia storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 10.2 Resource Statement

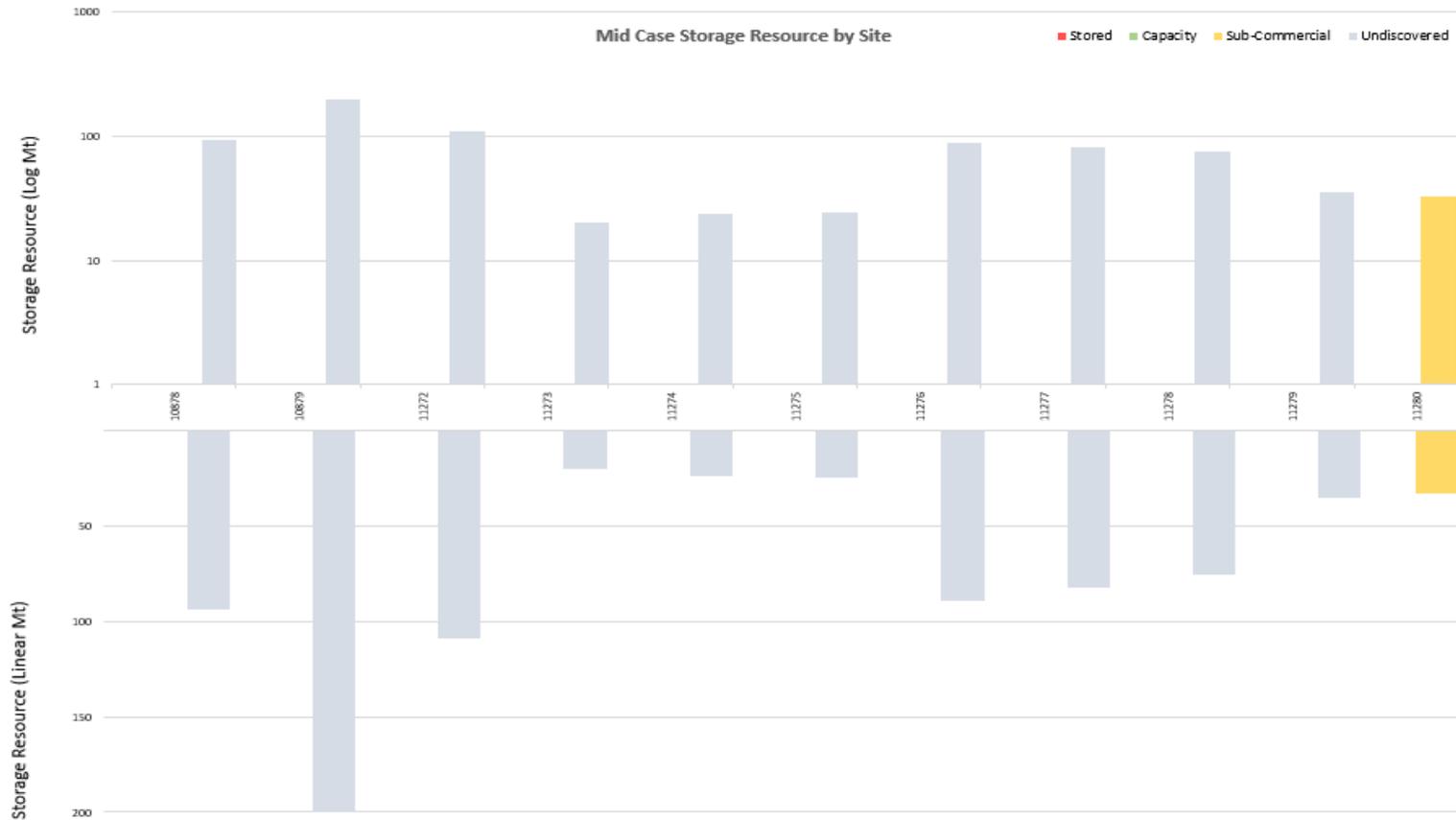


Figure 10-2: Storage resource summary for Czechia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 10.3 Evaluation History

There are very limited studies for CO<sub>2</sub> resources in Czechia. The main estimates for CO<sub>2</sub> storage resources in Czechia originate from the GeoCapacity project (2006-2008 [8]). Czechia was also part of the CASTOR project (2004-2005) and CO<sub>2</sub>Stop (2012-2013). CO<sub>2</sub>Stop [7] provides estimates for several sites in saline aquifers. However, most reports prefer to use GeoCapacity estimates when reporting on storage resource potential. The recent CCS4CEE reports [1] include a summary of storage potential estimated from the Czech Geological Survey's work for GeoCapacity. The storage resource estimates are variable due to varying storage efficiency coefficients and a lack of data for saline aquifers. The highest storage resource estimate in saline aquifers is 2863 Mt CO<sub>2</sub>, but more conservative estimates place this around 756 Mt CO<sub>2</sub>. An additional geological project was the TOGEOS project (2009-2010). This project targeted saline aquifer storage sites and was coordinated by the Czech Geological Survey and the Norwegian partner IRIS – the International Research Institute of Stavanger.

## 10.4 Resource review

### 10.4.1 Major Projects

Although a number of geological studies and research have been done in Czechia over the last 15 years, there are no CCS pilot projects to date. The research projects have covered a wide range of CCS topics in the CCS value chain and include many studies on capture, storage, and transport [1]. Despite limited reporting on CCS sites, this demonstrates that Czechia is building up expertise and knowledge readiness on CCS technologies for future opportunities.

Recent projects of note for CO<sub>2</sub> storage over the last 10 years include the following:

**The REPP-CO<sub>2</sub> project** aimed to advance the technology readiness of CO<sub>2</sub> storage in Czechia and update resource estimates in the Carpathian region. The project also focused on the Vienna Basin and identified a site (LBr-1) that could be prepared for a future pilot project (mainly for EOR and as such is not entered in to the CRSC). The ENOS project (2016-2020) [2,4] aimed to deepen the knowledge of onshore CO<sub>2</sub> storage and EOR options. The Czech Geological Survey participated in this consortium, and the site LBr-1 (as identified in REPP\_CO<sub>2</sub>) was chosen as one of the project test sites for simulation studies.

**The ENOS project** also studied the development of a possible cluster in the Czech Vienna Basin sector on the borders with Slovakia and Austria. This project at LBr-1 assessed a small-scale pilot with limited storage, full-scale storage, and CO<sub>2</sub>-EOR. It was also a key project to investigate and evaluate any transboundary issues that could arise from CO<sub>2</sub> storage in this field. Although this was a detailed study, only resource estimates of 70,000 tons were provided for a small-scale pilot. The main focus of this site is for EOR purposes.

**The CO<sub>2</sub>-Spicer Storage Pilot**, which ran from 2020 to 2024, was operated by the Czech Geological Survey, MND, and the Norce Norwegian Research Center. The project worked on

future steps toward realising the first CO<sub>2</sub> storage pilot project in Czechia. The Zarosice oil and gas field in SE Czechia was chosen. The naturally fractured Jurassic dolomite of the Vranovice Formation is considered a potential storage formation, sealed primarily with upper Jurassic marl (Mikulov Formation).

**The COREu project and Project CCS Moravia** are currently in the preparation stage. Project CCS Moravia is on a subsidy from the EU's Duty Program and part of the Green Deal commitment to reduce CO<sub>2</sub> emissions by 55% by 2030. The project partners are MND and Heidelberg Materials. The project aims to capture CO<sub>2</sub> from cement production and store it in saline aquifers in South Moravia. The project is planned to operate for 25 years. The total storage of the structure is 23.4 Mt, and injection is scheduled for 2034 [5]. This site may also be part of project COREu. This project's main objective is to develop CCS routes connecting emitters to storage sites and further support CO<sub>2</sub> capture, transport, and storage research. COREu links four potential routes together under the same project: Prinos/Kavala in Greece, South Moravia in Czechia, Baltic/Gdansk in Poland and Western Ukraine and plans to initiate an open-access, transnational network to connect emitters with European storage sites [5]. As there is no location the site is not entered in the CRSC, however it is hoped that future publications will provide more details on this project.

#### **10.4.2 Depleted Oil and Gas Fields**

In the south-eastern part of Czechia, a geological province of the Vienna Basin, there are several potential storage sites in oil and gas fields. According to EU GeoCapacity, the total storage resource of these fields was estimated at 33Mt CO<sub>2</sub>. The location and volume of exact fields is sparsely reported in the literature and as such depleted fields are entered as one site in the CRSC. Some fields in this basin, LB-1, have already been investigated for storage options (LBr-1 EOR) [3].

#### **10.4.3 Saline Basins**

The Central Bohemian Basin has CO<sub>2</sub> storage potential in upper Carboniferous and lower Permian clastic sediment. CO<sub>2</sub>Stop divided the basin into four subareas: the Zatec, Roudnice, Mnichovo-Hradiste, and Nova Paka. The combined storage resource for all these is 403 Mt. The entire basin is estimated at 471 Mt.

The Carpathian Foredeep contains storage potential in Neogene age formations. CO<sub>2</sub>Stop identified four sites with a resource estimated at 281 Mt. The entire basin has a resource estimate of 295 (this is derived from a total estimate of 766 Mt for all of Czechia from GeoCapacity [1] minus 471 Mt as estimated by [3] for the Central Bohemian Basin. One site in the South Moravia area is part of the Project CCS Moravia (the project is detailed in the Major Projects section above). This site will store CO<sub>2</sub> captured from the Mokrá Cement plant near Brno. The actual site name and location for storage are not reported in any literature at the time of cycle 4.

#### **10.4.4 Coal Fields**

In addition to saline aquifers and depleted hydrocarbon fields, there is also theoretical

methane storage in the Upper Silesian Coal Basin (NE Czechia in Ostrava province). A total storage of 54 Mt is estimated.

## **10.5 Regulatory Framework**

The CCS Act prohibited the storage of CO<sub>2</sub> over 100,000 tons until 01/01/2020. Since then, commercial storage restrictions have ceased to exist. However, the Act still limits storage to 1Mt CO<sub>2</sub>/yr. Czechia is not a party to the London Convention or London Protocol, so it must adopt similar standards and have bilateral agreements to export CO<sub>2</sub> for offshore storage. In addition, there may be issues with onshore transboundary and CO<sub>2</sub> storage is prohibited where leakage could occur [6].

The Czech National Energy and Climate Plan states that CCUS is one of its eight strategic priorities and that CCUS should be used for hard to abate industries such as cement manufacture.

Croatia scores 51.5 on the CCS readiness scale as defined by the GCCSI.

## **10.6 Issues for the Assessment**

Storage resource estimates across Czechia are limited for saline aquifers and depleted oil and gas fields. This made site identification challenging to verify and report on.

## **10.7 Future Updates**

### **10.7.1 Future evaluations**

If more studies are conducted on site identification, this would benefit more realistic resource estimates. In addition, updates on any project advancement will be beneficial.

### **10.7.2 Future CSRC cycles**

Any future submissions to the CSRC will improve the understanding of storage potential in Czechia.

# 11 Denmark

## 11.1 Summary

Denmark was previously assessed in Cycle 1 as part of the 'Baltic Countries'. In Cycle 4, Denmark was updated as an individual nation. A summary of the CO<sub>2</sub> storage resource is shown in Table 6-1.

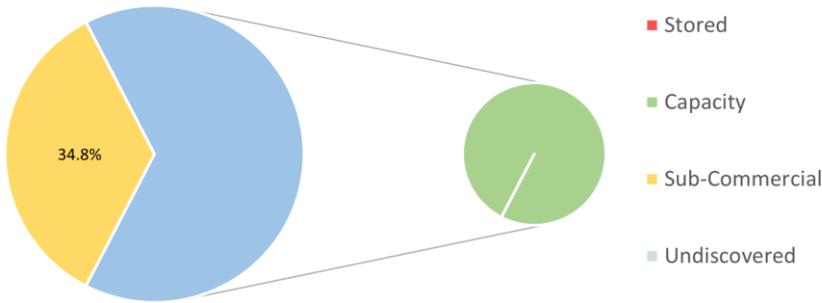
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.125	0.125
Sub-Commercial	5.691	0.067
Undiscovered	10.212	0.000
Aggregated*	16.028	0.192

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the country.

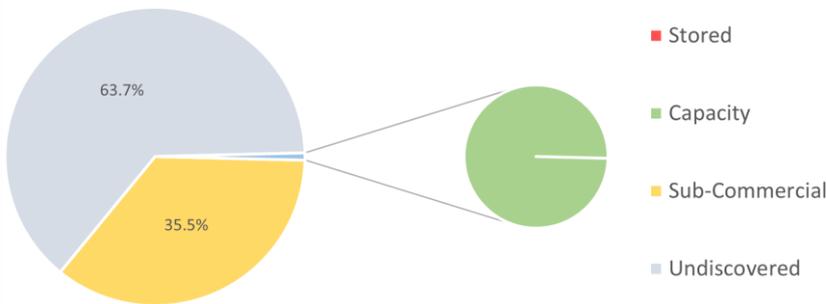
Table 11-1: Storage resource classification summary for Denmark.

- Denmark scored 66.5 within the 2023 CCS Chart of Legal and Regulatory Indicator system due to the country having specific CCS laws aligning with EU directives.
- Denmark has two pilot CCS projects at varying stages of development: Project Greensand and Project BiFrost. Both seek to use depleted hydrocarbon reservoirs at storage facilities. Testing of CO<sub>2</sub> injection took place in Project Greensand in 2023.
- Denmark's resources reside with both saline aquifers and depleted hydrocarbon reservoirs. Saline aquifers have been mainly reviewed at the formation level, and several onshore structures have been identified.
- There has been a significant effort at the national level to identify and characterise storage potential onshore and offshore.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



C) Storage Resource by Type

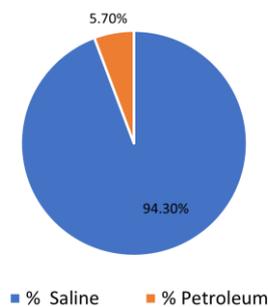


Figure 11-1: Denmark Spread of Storage Sites.

A) Spread of storage resource in all Danish sites across SRMS classifications; project specified.  
 B) Spread of storage resource in all Danish sites across SRMS classifications; both project specified and not.  
 C) Split of Danish storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 11.2 Resource Statement

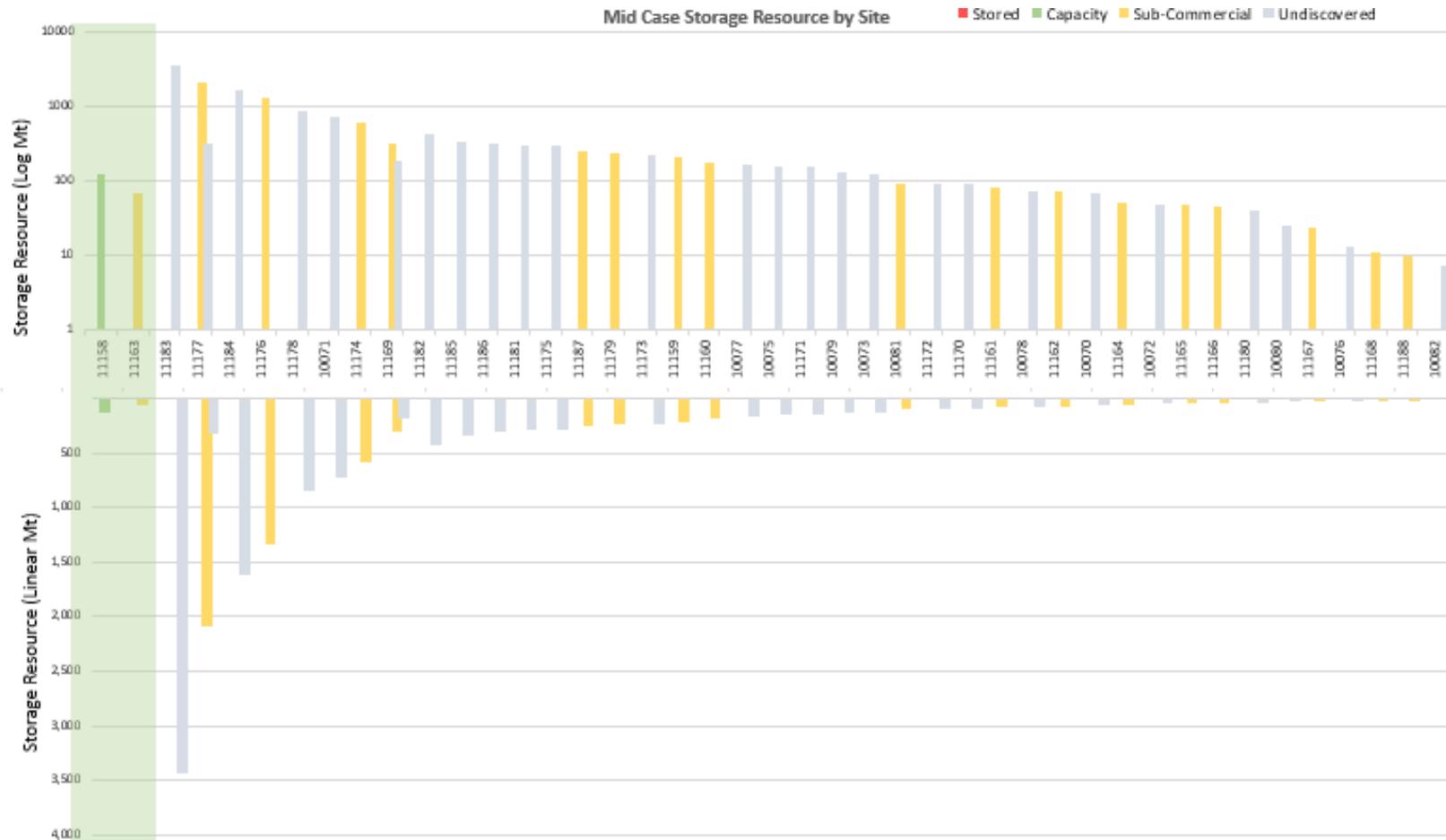


Figure 11-2: Storage resource summary for Denmark compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 11.3 Evaluation History

CCS has been identified as a key technology that will help Denmark reach its climate targets. The industrial and energy sectors, where alternative fuel sources or energy efficiency cannot meet targets, are the primary targets for CCS.

The storage potential was first evaluated by the JOULE II project (5600 Mt onshore aquifers and 590 Mt in offshore depleted fields). Following this, the EU GeoCapacity (2009) published country-wide evaluations of storage potential (16,672 Mt in identified aquifer structures and 810 Mt in hydrocarbon fields). In 2014, The NORDICCS project [1] mapped a series of aquifer structures and more recently, the Danish Geological Survey (GEUS) has undertaken a series of studies to identify and rank potential storage sites across Denmark, both onshore and offshore [2].

### 11.4 Resource Review

Storage potential has been identified in depleted fields and saline aquifers, and commercial projects are being developed in both types of storage.

#### 11.4.1 Major Projects

Denmark has two CCS pilot projects under development at the time of Cycle 4

**Project Greensand** is a joint venture between INEOS E&P and Wintershall Dea and is Denmark's first CCS project. Located 175 Km offshore, the project aims to utilise the depleted Nini-West field and re-purpose legacy infrastructure to develop the CO<sub>2</sub> storage facility. Ultimately, the plan is for CO<sub>2</sub> to be received by both pipelines and CO<sub>2</sub>-transporting vessels.

Project Greensand commenced in 2020, with the first phase focused on appraisal to validate the technical aspects of the project. In late 2020, the appraisal phase was completed, and DNV GL approved the Nini West field as theoretically suitable for CO<sub>2</sub> injection and storage of 0.45 Mt per year over 10 years. The Paleocene marine sandstone storage reservoir is estimated to have a storage volume of 100 – 150 Mt and is located within a four-way dip trapping closure at approximately 1600 – 2200 MBSL. The project's build-out, including the Nini East, Cecilie, and Siri field reservoirs, is under consideration and will expand storage potential to up to 4 Mtpa [3]. In early 2023, the project entered phase 2 which saw the pilot injection operations start and continue through March and beyond. This CO<sub>2</sub> injection pilot (15,000t over four months) received the first storage permit from the Danish Energy Agency in December 2022. project is expected to enter phase 3 for the full-scale project following FID.

**Project Bifrost** is a joint venture pilot project under the Danish Underground Consortium (TotalEnergies, Nordsøfonden and Noreco) along with Ørsted and DTU (Delft University of Technology). Located 260 Km offshore, the project aims to utilise the depleted Harald West and East field in the Søgne basin as a CO<sub>2</sub> storage facility. The Harald field has two developed

hydrocarbon reservoirs: the Harald East Cretaceous chalk reservoir with a porosity of 28-32% and permeability of 2.2 Darcys and the Middle Jurassic sandstone reservoirs of the Harald West. While the project will initially target the Harald West (and adjacent saline aquifer potential in the Oligocene Dagny permit area), the project aims to test storage in the Harald East carbonates reservoirs as a test of the potential of the Danish chalk reservoirs. The Bifrost project targets 5Mtpa injection by 2030 and potentially up to 15Mtpa from 2032 onwards. The consortium was awarded a CO<sub>2</sub> storage license in Q1 2023; however, no date has been set for project start-up.

#### **11.4.2 Depleted Oil & Gas Fields**

In addition to the Greensand and Bifrost, a small demonstration project named the “Stenlille Demo CO<sub>2</sub> storage” is being investigated by Gas Storage DK, who has published the aim to be operational by 2026 for a volume of 10 MT within the Gassum Sandstone formation.

Initially, the storage potential of Danish depleted fields was evaluated by the EU GeoCapacity project (810Mt) and the Nordic CCS Competence Centre (NORDICCS) [4]. A 2020 update [2] indicates a storage resource range 900-1300Mt within chalk fields. While the announced projects are focused on utilising clastic (sandstone) reservoirs, particularly within the Siri Canyon area (150-500Mt storage potential). Most Danish hydrocarbon fields sit within the chalk reservoirs (Cretaceous to Paleocene in age).

A study by Bonto et al. (2021) [5] focused on CO<sub>2</sub> storage in chalk formations. Using a reserves replacement approach, ten chalk fields were evaluated. The Tyra and Dan fields were the largest, with 211 and 174 Mt storage resources, respectively. Halfdan, Gorm, Harald East, and South Anne had estimated resources of 83 Mt, 73 Mt, 66 Mt and 52 Mt. Below 50 Mt, the Roar, Skjold and Valdemar fields were assessed to have storage of 48 Mt, 44 and 23 Mt, respectively. The Kraka field had a volume of 11 Mt.

#### **11.4.3 Saline Aquifers**

Several authors (for example, Larsen et al., (2007), Anthonsen et al., (2014) and Hjelm et al., (2022) [1,2,6] have studied the Danish subsurface independently assessing the same formations across the Danish basins, including the Norwegian-Danish basin and the northern rim of the North German basin. Screening and characterisation of saline aquifers across Denmark is challenged by low seismic density and generally poor-quality data [2]. However, it is suggested that a large storage opportunity sits within aquifers. Clastic (sandstone) formations are considered to carry the greatest storage potential, with the most prospective storage formations being the following:

- Bunter Sandstone and Skagerrak formations (Triassic)
- Gassum Formation (Upper Triassic – Lower Jurassic)

- Haldager Sand Formation (Middle Jurassic)
- Frederikshavn Formation (Upper Jurassic – Lower Cretaceous)

The most recent study [2] mapped 14 high-potential structures across onshore and offshore Denmark. These structures are estimated to hold a 12 Gt CO<sub>2</sub> storage resource, but the existing seismic database's sparse data may limit this.

Migration-assisted trapping in large, open aquifers of the Gassum formation in the Norwegian-Danish basin may contain up to 1Gt CO<sub>2</sub> storage resource. It should be noted that the published estimates are mostly derived from volumetric approaches, albeit using a Monte Carlo methodology to capture the considerable uncertainty associated with the estimates generated. The example provided in the Cycle 4 Global Summary report illustrates the issue whereby the difference between theoretical storage resources and pressure-limited storage resources from flow modelling reduced the named Hantsholm structure.

#### **11.4.4 Sites not evaluated as volumes below 10 Mt OGCI threshold:**

Bonto et al. (2021) published data for several sites that fall below the threshold for SRMS assessment. The Svend prospect was quoted as having a resource of 8.5 Mt. while the Siri prospect resource of 7.9 Mt, and Rolf is at 3.1 Mt. Lulita, Dagmar and Regnar all had a very small resource of 0.8 Mt.

## **11.5 Regulatory Framework**

Denmark received a promising evaluation under the 2023 GCCSI CCS readiness index, scoring 66.5.

Denmark has recently passed several amendments to acts of law dating to June 2022. This includes Act no. 803, which authorises the Minister for Climate, Energy and Utilities to institute regulation regarding the geological storage of CO<sub>2</sub> under 100 kilotonnes undertaken for research, development, or testing of new products and processes. The amendment to Act no. 803 also warrants the participation of the Danish State or a company owned by the Danish State in CO<sub>2</sub> storage operations.

Executive Order No. 1165 was passed in August 2022, which pertains to the continuous granting of permits for the exploration and storage of carbon dioxide concerning the area on the Danish continental shelf west of 6° 15' E and north of 56° 00' N. This executive order warrants that applications for permits for exploration and storage of carbon dioxide can be submitted to the Danish Energy Agency (DEA) annually from the 15th of August to the 1st of October in the same year.

Act no. 1592 was passed in December 2022 and entered into force in January 2023. This act warrants the participation of Nordsøfonden (a company owned by the Danish state) in any CO<sub>2</sub>

storage activities. As a result, Nordsøfonden will participate in every storage permit on behalf of the Danish state with a share of 20 percent [7].

In December 2022, the first CO<sub>2</sub> storage permit was awarded by the Danish Energy Agency to the Project Greensand Pilot phase for a 15,000 t, four-month test at the Nini West oilfield (developed by INEOS E&P and Wintershall Dea).

## **11.6 Issues for the Assessment**

Volumetric storage approaches dominate published storage resource estimates. This is partly driven by the limited subsurface database available across the country, but recent studies are looking to improve the understanding of more practical storage potential.

## **11.7 Future Updates**

### **11.7.1 Future CSRC cycles**

As pilot and commercial scale projects progress towards advanced development, future cycles should request updates from developers and ensure the CSRC maintains an accurate project representation.

# 12 Estonia

## 12.1 Summary

Estonia was assessed during Cycle 5. Due to the geology of Estonia being unsuitable for CO<sub>2</sub> storage, this country has been assessed as having no resources.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Estonia.

Table 12-1: Storage resource classification summary for Estonia.

- Estonian does not have any geological storage potential in either saline aquifers or depleted oil and gas fields due to any suitable formations being at depths too shallow for safe storage.
- There may be potential for cross border capture-transport-sink projects with neighbouring countries in the Baltic region that have geological storage options.
- Although storage projects are non-existent due to unfavourable geology, Estonia does have CO<sub>2</sub> capture research ongoing.
- Estonia currently has limited legislation regarding CCS, although at present storage is prohibited in both onshore and offshore environments

## 12.2 Evaluation History

Estonia has been assessed by various authors and research consortiums who have considered CO<sub>2</sub> storage in this country alongside other Baltic nations (Lithuania, Latvia, Sweden etc.). Estonia was part of GeoCapacity in 2009 [1] and GESTCO in 2004 [2]. Due to the nature of the position of Estonia in the Baltic Basin, the geological potential for carbon storage is very limited. The Baltic Basin extends over the three Baltic countries and varies in thickness, with Estonia being located on the eastern edge of this basin. The depth of any suitable storage does vary with the depth and may reach 800 metres in certain areas of Estonia, however research deems most of the geology unsuitable. The closest more suitable places for carbon capture and storage are in Latvia and Lithuania.

## **12.3 Resource Review**

### **12.3.1 Major Projects**

There are no storage projects in Estonia. However, the country does have a significant contribution to its CO<sub>2</sub> emissions from oil shale combustion. Power production is the biggest industry with the highest emissions in Estonia. The heating and power sector make up around 70% of all the CO<sub>2</sub> emissions in Estonia. [4] Based on the absence of suitable domestic storage and a high emissions contribution, if Estonia is to pursue CO<sub>2</sub> storage as a contribution to help decarbonisation, then it will likely need to be involved in cross border source-transport-sink projects. Several studies (e.g. [5,6]), have indicated that the most optimum location for the storage of Estonian emissions is in Latvia. However, theoretical proposals have suggested this would necessitate a pipeline that would extend over 800 km between the biggest cities of the two countries. This is cited as being a potentially very costly venture that may get limited public support [4].

There was a project funded by the RITA programme and completed in early 2016. The project was carried out by the Tallinn University of Technology and the project goal was to evaluate which CO<sub>2</sub> capture technologies could be used in the oil shale industry. The results of the study found that absorption and oxyfuel combustion is most suitable and depending on the capture technology selected, the CO<sub>2</sub> footprint of electricity production would fall from 1026 kg CO<sub>2</sub> eq/MWh to 169 kg CO<sub>2</sub> eq/MWh (absorption) or 146 kg CO<sub>2</sub> eq/MWh [4]. However, the research concluded that CO<sub>2</sub> capture is not financially feasible in Estonia due to the CO<sub>2</sub> emission quota tariffs being less costly in comparison to developing any CCS/CCU technologies [4].

Auvere Agropark is a planned project of the Ida-Viru County Industrial Areas Development Foundation (IVIA). This project involves the construction of a carbon dioxide (CO<sub>2</sub>) capture plant, to capture gas from the Auvere power plant, and then to be sold or reused in greenhouses for agriculture enterprises in the planned agropark. Preliminary estimates, state that annual consumption potential could reach almost 0.5 million tonnes of CO<sub>2</sub>. Operations are expected to start between 2027-2031 [4].

### **12.3.2 Depleted Oil & Gas Fields**

There are no reported depleted field storage resources in Estonia.

### **12.3.3 Saline Aquifers**

There are no reported saline aquifer storage resources in Estonia.

### **12.3.4 Other Storage options:**

Whilst there is unlikely to be any geological storage of CO<sub>2</sub>, a potential carbon capture and utilisation project is being investigated. There is project is based on ash valorisation technologies developed in Sweden. This technology is now being investigated for use in Estonia.

Estonian researchers and R-S OSA Service OÜ, a subsidiary of Ragn-Sells have developed a way to re-use Estonian leftover oil shale ash. The technology uses both leftover oil shale ash from the oil shale industry and captures the CO<sub>2</sub> from the burning process. The technology allows CO<sub>2</sub> to be captured and then directed to form precipitated calcium carbonate. A major feature of this technology is reducing the amount of ash that goes to landfill. And in addition, it can mitigate against the amount of limestone that needs to be mined. However, since the process does emit CO<sub>2</sub> during the energy it uses, the net gain of overall CO<sub>2</sub> sink is not able to be established yet [4].

## **12.4 Regulatory Framework**

Estonia currently prohibits the storage of CO<sub>2</sub> both onshore and offshore except for research and development purposes. Although it has amended existing legislation to implement Directive 2009/31/EC on the geological storage of CO<sub>2</sub> [7]. The 2030 National Energy and Climate Plan (NECP 2030) does include CCU and CCS as one route on how to mitigate carbon emissions, but it does not contain a more specific action plan that would allow implementing such solutions in Estonia [8].

## **12.5 Issues for the Assessment**

Due the limitations Estonia has for long term CO<sub>2</sub> storage there is a limited amount of research. It is not expected that further research will be conducted based on the unstable geological conditions for CO<sub>2</sub> storage.

## **12.6 Future Updates**

### **12.6.1 Future CRSC Cycles**

Future cycles could investigate if any project is planned on cross border agreements for capture-transport-sink projects with neighboring Baltic states.

# 13 Finland

## 13.1 Summary

Finland was assessed during Cycle 4. The CSRC has identified that Finland has no published storage resource estimates, and so has zero sites to enter into the CSRC database:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.00	0.00
Undiscovered	0.00	0.00
Aggregated*	0.00	0.00

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Finland.

Table 13-1: Storage resource classification summary for Finland.

## 13.2 Evaluation History

Finland was reviewed during Cycle 4. Finland is not a hydrocarbon-producing country. No CO<sub>2</sub> storage evaluations have been carried out at the federal level, nor are any available in the public domain. Finland's geology is unsuitable for conventional CO<sub>2</sub> storage and is dominated by pre-Cambrian shield igneous and metamorphic rocks. More recent sediments are restricted to thin, unconsolidated Quaternary glacial deposits.

## 13.3 Regulatory Framework

Finland has issued the Finnish Act on Carbon Capture and Storage (the "CCS Act"; 416/2012). According to this Act, geological storage of CO<sub>2</sub> is banned in Finland and its exclusive economic zone (EEZ). The driver for this was the unsuitable geology for CO<sub>2</sub> storage. However, new, temporary (2023-2026) legislation has been introduced, which gives permitting priority to green transition projects, which can include CCS but must adhere to a "do no significant harm" principle.

## 13.4 Future Updates

### 13.4.1 Future Updates for Evaluators

Given Finland's unsuitable geology, no future conventional CO<sub>2</sub> storage projects are anticipated, and therefore, no future updates should be required.

### 13.4.2 Future CRSC Cycles

Not applicable

# 14 France

## 14.1 Summary

France was assessed in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

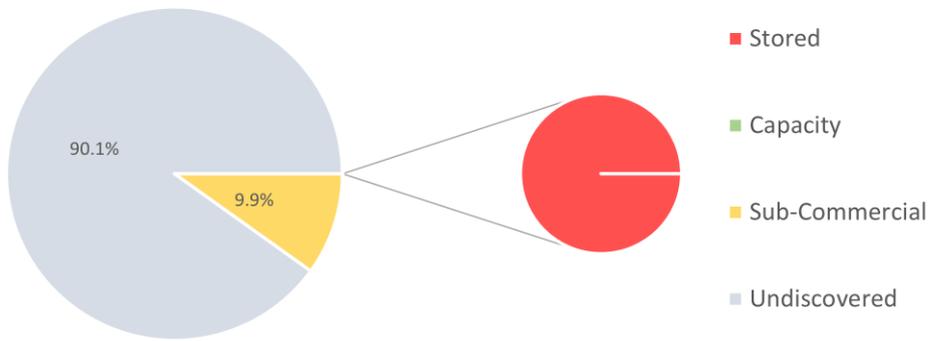
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	1.007	0.000
Undiscovered	6.201	0.010
Aggregated*	7.208	0.010

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of France.

Table 14-1: Storage resource classification summary for France

- France has been an active player in CCUS, participating in and pioneering research in carbon capture, transport, and storage and many European and worldwide research projects.
- A total of 19 sites have been identified in France (10 saline aquifers and 9 depleted oil and gas fields).
- The majority of the sites are rarely able to be assessed beyond basin or sequence classification.
- There are some historical projects in France, and some are ongoing. Two historical research projects in Lacq-Rousse and one in Saint-Emillion are now terminated. The four ongoing projects relate to a more involved CCUS and energy transition supply chain: Dunkirk, Pycasso, H2020 STRATEGY CCUS and CO<sub>2</sub>SERRE
- Volumes in saline aquifers are mainly reported at a basin level, with some smaller volumes at a prospect level.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

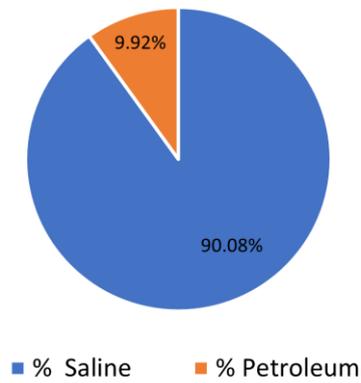


Figure 14-1: France Spread of Storage Sites.

A) Spread of storage resource in all French sites across SRMS classifications; both project specified and not. B) Split of French storage resources between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 14.2 Resource Statement

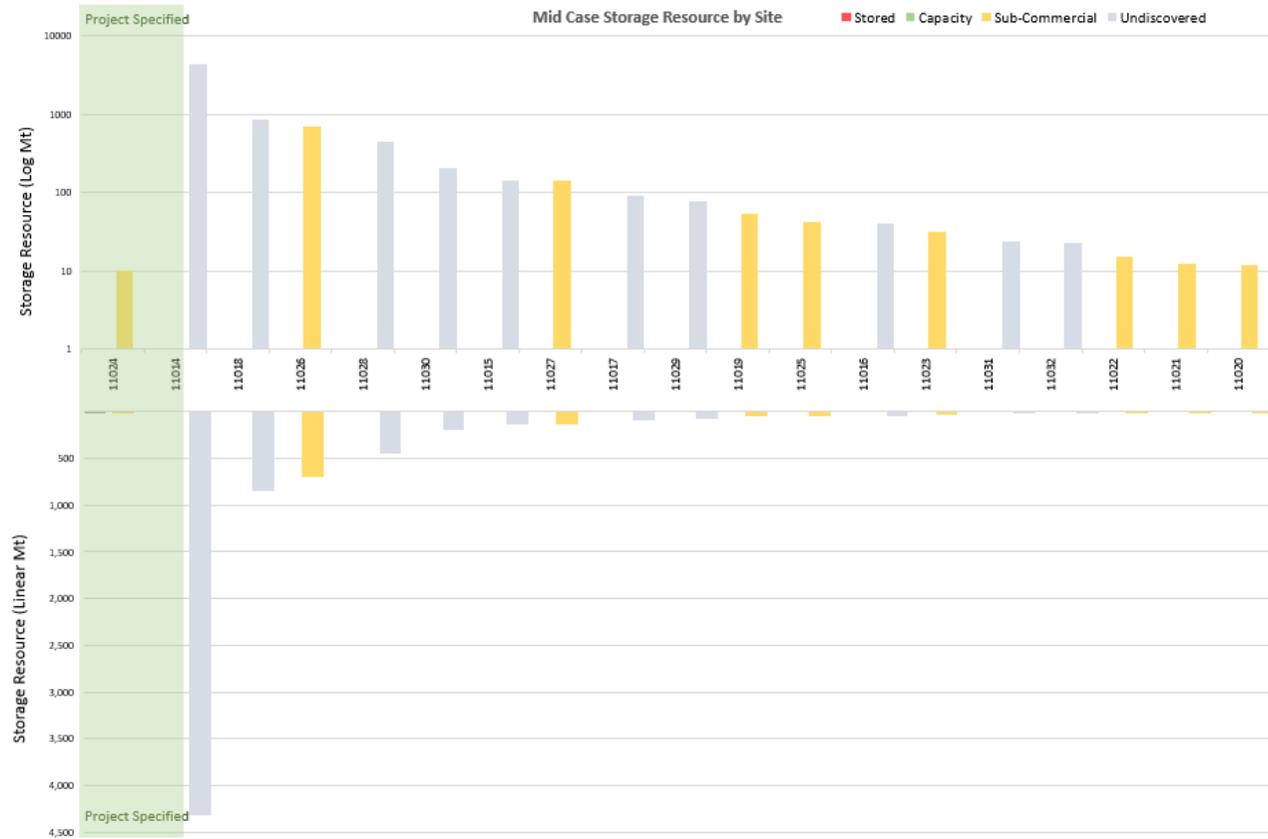


Figure 14-2: Storage resource summary for France compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 14.3 Evaluation History

Since the 1990s, several European projects have estimated the CO<sub>2</sub> storage resource in France's saline aquifers and depleted hydrocarbon field. The first evaluation was performed during the Joule project in 1996, and a second was conducted during the GESTCO project in 2003. The latter was updated during the EU GeoCapacity in 2009. GeoCapacity estimates for saline aquifers ranged from 800Mt to 27Gt of CO<sub>2</sub> (a factor of 30 between the lowest and highest estimations). For hydrocarbon fields, they estimated in the range from 770Mt (low) to 1007.6Mt (high). France was also part of the CO<sub>2</sub>StoP project in 2012-2013 [1]. Other research projects at the basin scale are the France Nord and ULCOS TGR-BF, which resulted in a more in-depth assessment of two potential storage resource areas in the Paris Basin and the Vasco project in the Marseille area.

The European project STRATEGY CCUS [2,3,4], which started in 2019 and was coordinated by BRGM (Bureau de Recherches Géologiques et Minières), gathered existing data in eight different regions. The aim of this research was to compile and develop a common methodology to evaluate CO<sub>2</sub> storage resources.

### 14.4 Resource Review

The potential for CO<sub>2</sub> storage in France lies in three onshore sedimentary basins: the Paris Basin, the Aquitaine Basin, and the Sud-East Basin. These basins have both aquifers and depleted hydrocarbon fields. Both the Aquitaine Basin and the South-East Basin extend offshore, where offshore possibilities are mentioned in [5]. However, limited publications have been found on offshore France's CO<sub>2</sub> storage potential.

#### 14.4.1 Major Projects

Currently, there are no ongoing carbon geological storage operations in France.

##### **Dunkirk**

The Dunkirk project is a low-carbon hydrogen production in Port Jerome (Port Jerome CO<sub>2</sub> capture plant), a CCS-equipped steel-making plant in Dunkirk. The project is part of a study to develop a future European Dunkirk North Sea Capture and Storage Cluster [6].

##### **Lacq-Rousse**

The CCS pilot-scale project in Lacq-Rousse, a depleted field in the Aquitaine basin, was operated by Total (2006-2013) and injected more than 51 Kt of CO<sub>2</sub> from 2010 to 2013 [7,8].

##### **Saint-Emilion**

This experimental site in underground limestone in Saint-Emilion, in Nouvelle Aquitaine (France), was exploited by using "the rooms and pillars" method. It is currently terminated [9].

##### **CO<sub>2</sub>SERRE**

A three-year study (2019-2022), led by BRGM (Bureau De Recherches Geologiques Et Minières),

which investigates the techno-economic and environmental feasibility of implementing a “BCCUS” (i.e. CCUS for CO<sub>2</sub> of biomass origin) pilot in France, in the Centre-Val de Loire Region. The Life Cycle Analysis (LCA) objective is to compare the environmental impacts of biomass transformation activities with and without CCUS [10].

#### **Pycasso**

The PYCASSO Project aims to capture, use and store CO<sub>2</sub> in the depleted fields of the Aquitaine Basin. At the beginning of 2021, 30 institutions, universities and industrial companies teamed up to form PYCASSO, a territories project and operational consortium focused on advancing CCUS development studies onshore SW France and NE Spain to reach the net zero emissions European objective in 2050 [11]. PYCASSO aims to bring CCUS solutions to scale and implement a complete 1Mt (million tons)/year CO<sub>2</sub> abatement chain in 2030 to be further extended to 5 Mt/y in 2035.

#### **H2020 STRATEGY CCUS**

Scenarios for local CCUS development schemes in the Rhône Valley in the short, medium, and long term are being studied as part of the H2020 STRATEGY CCUS project (2019-2022), which is elaborating strategic plans from 2025 to 2050 for deploying CCUS in eight promising regions of Southern and Eastern Europe, including the Paris Basin and the Rhone Valley for France [3].

#### **14.4.2 Depleted Oil & Gas Fields**

A review of storage potential in France’s depleted oil and gas fields is provided in the GeoCapacity project (2010). Many of the 32 identified fields in the Paris basin are too small in volume to be included in the CRSC. Four have volumes above 10 Mt (Coulommès, Donnemarie, Chailly, and Vilemer fields). The Aquitaine basin has a storage resource of just over 880 Mt. These include the only the pilot project at Lacq-Rousse. Other fields in this basin are the St. Marcet ( 41.10Mt), Laq Profond (691.90Mt) and Meillon (139.90Mt).

#### **14.4.3 Saline Aquifers**

Saline aquifers in France have a promising CO<sub>2</sub> storage potential. However, there is very limited research to delineate the sites beyond the formation level. The historic CO<sub>2</sub> storage resource projects provided an estimate for the CO<sub>2</sub> resource for the Paris Basin saline aquifers, where 4 formations have been identified. The Aquitaine basin has potential in the North Aquitanian in Triassic to Early Jurassic sediments, while the Jurassic-Cretaceous units of the South Aquitanian basin are also considered to carry some potential. The South-East basin has 8 CO<sub>2</sub> sites but there are limited assessment details to classify these sites; of those identified, only 2 make the volume cut off for the CRSC.

Offshore potential for CO<sub>2</sub> storage (offshore Aquitaine and offshore Mediterranean) has been cited, but these possibilities have not yet been studied.

### **14.5 Regulatory Framework**

France established a regulatory framework for the storage of CO<sub>2</sub> as early as 2010. In addition, it has industrial competence covering the whole CCS chain, with all the necessary conditions and technical knowledge to start CCS projects.

According to the national low-carbon strategy, the legislative framework for CCS activities in France is ready. The CCS Directive was implemented into national law in 2011 (French national decree on the geological storage of CO<sub>2</sub> - Decree n°2011-1411). Further relevant legislation states from 2009 that any new coal-fired power plant must be CCS-ready and have a full-scale demonstration program.

## **14.6 Issues for the Assessment**

Even though France has been a pioneer in the CCUS, just one pilot project (Le Lacq-Rousse) has been run, and the possible saline storage sites in the Aquitaine basin and the Southeast Basin haven't been assessed. Overall, data related to site assessment is very limited in the public domain. Large pan-European projects are still the only sources to define sites. This renders France's CO<sub>2</sub> storage resource highly uncertain.

## **14.7 Future Updates**

### **14.7.1 Future evaluations**

Future evaluations should check for updates on developing projects or new evaluations that can provide more insight into France's CO<sub>2</sub> storage potential.

### **14.7.2 Future CSRC cycles**

A focus for future cycles should be on the current projects and their progression.

# 15 Germany

## 15.1 Summary

Germany was previously assessed by the CSRC in Cycle 1 as part of the Baltic Region (including Denmark). In Cycle 4 Germany was assessed as a single country.

A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	2.000	0.000
Undiscovered	49.208	0.000
Aggregated*	51.208	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Germany.

Table 15-1: Storage resource classification summary for Germany.

- There have been limited and very varying assessments for Germany with respect to understanding CO<sub>2</sub> storage resources: JOULE 1996 (2-3 Gt), GESTCO 2003 (25-44 Gt), BGR 2005 (18-41 Gt), and GeoCapacity 2009 (17-29 Gt) projects. Research in the last decade has also been limited.
- Four additional sites have been identified in Cycle 4, adding to the offshore site reported in Cycle 1. These sites provide a cumulative total of just over 49Gt for saline aquifers (at basin scale) and 2Gt cumulative for hydrocarbon reservoirs.
- Germany has no major CO<sub>2</sub> storage projects underway, but it has several projects in the CCS value chain including capture and transport. It ran a pilot CO<sub>2</sub> injection and monitoring project from 2008 to 2013 at the Ketzin gas storage field.
- Germany's historical regulations restrict CO<sub>2</sub> storage projects. However, in early 2023, The Federal Ministry for Economic Affairs and Climate Action initiated stakeholder dialogue aimed at developing a strategy for CCS.
- Germany's most recent strategy, 'The German Carbon Management Strategy' hails a significant step towards its CCS deployment. The strategy will enable the legislative revisions needed to establish CO<sub>2</sub> pipeline networks and allow offshore storage of CO<sub>2</sub> under Germany's North Sea.
- If Germany's storage capacity remains restricted to permitting domestic storage, it will

need to ratify Article 6 of the London Protocol to transport CO<sub>2</sub> to other countries to facilitate storage projects outside its jurisdiction.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

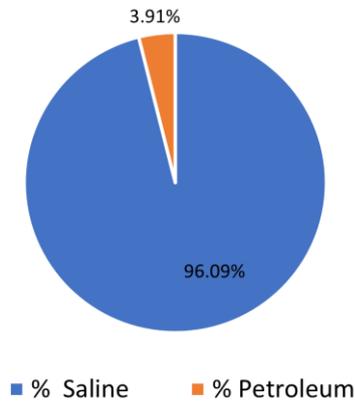


Figure 15-1: German Spread of Storage Sites.

A) Spread of storage resource in all German sites across SRMS classifications; both project specified and not. B) Split of German storage resources between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 15.2 Resource Statement



Figure 15-2: Storage resource summary for Germany compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 15.3 Evaluation History

There have been several assessments to understand the CO<sub>2</sub> storage potential in Germany, which includes oil and gas fields and onshore and offshore saline aquifers. The earlier European reports JOULE II, GESTCO, BGR and GeoCapacity estimated storage resource (which included oil and gas fields and onshore and offshore saline aquifers) in the following ranges – JOULE 1996 (2-3Gt), GESTCO 2003 (25-44Gt), BGR 2005 (18-41Gt) and GeoCapacity 2009 (17-29Gt). These summaries are reported in Holler and Viebahn (2011) [2]. The authors provide their ranges for total German resources, with a minimum of 4 Gt, a mid estimate of 5 Gt, and a maximum estimate of 15 Gt. The much lower estimates are based on cautious efficiency factors that they apply to the volumetric calculations from the earlier studies. Germany was also reviewed for saline aquifer potential in the European CO<sub>2</sub>Stop Project. However, no volumes were reported for the 25 formations identified; instead, an overall 1-3Gt range for saline aquifers and 2Gt for hydrocarbon fields were reported [3]. The saline formations were identified in the German North Sea, North German Plain, Central Uplands, South German Scarplands and Alpine Foreland. In addition, there are projects by the Storage Catalogue of Germany and GPDN; however, these are published in German and have not been reviewed. [6&7].

Bense and Jähne-Klingberg (2017) [4] performed a detailed geological review of the offshore potential in the German North Sea. No resource volumes were published, but the trapping and suitability of various stratigraphic intervals were investigated via a structural model.

The most recent and more involved study by Knopf and May (2017) [5] assessed aquifers using a 'regional aquifer-based method'. This study was built on results [6&7] using a volumetric approach but considered distinct reservoir-barrier units with storage resources based on net thickness and porosity. Monte Carlo simulations were run with efficiency values between 0.9 and 4.6 to provide P10, P50 and P90 ranges. The study also compared the potential of structures within the units. This assessment has been favoured by the CRSC since it considers potential sites in Germany on a more containment basis (by considering both reservoir and barrier) and refines the resource estimates from previous studies. The estimates also provide higher storage volumes than earlier studies.

## 15.4 Resource Review

### 15.4.1 Major Projects

In Germany, there are currently no major storage projects. However, there are five projects in progress for various stages of the CCS value chain: H2Morrow is a project that aims to develop clusters and projects from industry and coalfields and then develop a CO<sub>2</sub> pipeline grid for export options at major ports. The LEILAC 2 Pilot aims to capture CO<sub>2</sub> from the Heidelberg Cement's Hanover plant with a capture capacity of 25,000 tonnes per year. The WESTKÜSTE100 project is a real-world laboratory to develop a regional hydrogen economy on an industrial scale, with CO<sub>2</sub> being separated from cement production and then used in methanol synthesis. The CO<sub>2</sub> liquefaction and buffer storage in Wilhelmshaven project aims to

capture 4.3Mt per annum from the European Energy logistics park and export it. The Downstream CO<sub>2</sub> pipeline Hastedt – Bremen aims to investigate a pilot CO<sub>2</sub> pipeline infrastructure connecting the industrial hub in Bremen to the Energy Park in Wilhelmshaven.

The Pilot CO<sub>2</sub> Injection project at Ketzin (called COMPLETE), which was injected from 2008 until 2013, saw 67,271 t of CO<sub>2</sub> injected through 5 wells. The project was extensively monitored and aimed to help a rigorous understanding of post-closure site behaviour and monitoring knowledge. Ketzin was a natural gas storage site [1].

#### **15.4.2 Depleted Oil & Gas Fields**

Very little information surrounds the potential for storage in Germany's oil and gas fields. CO<sub>2</sub>Stop assessed the potential via reporting saline aquifer locations with hydrocarbon fields and reported an overall storage resource estimate of 2Gt. Due to a significant absence of reporting and literature on German potential in depleted hydrocarbon fields, an undifferentiated storage estimate is added to the CSRC of 2Gt. This is currently classified as Inaccessible due to regulations and Undiscovered due to absence of any further details relating to formation or basin locations.

#### **15.4.3 Saline Aquifers**

The largest potential is in the Mesozoic (Triassic) formations in North Germany in the German-Polish Lowland (or Middle European Plain) and the south of Germany. Triassic strata have the greatest CO<sub>2</sub> storage potential in the middle and lower Bunterstain and Volprehausen formations, with a 10-25% porosity and a 100-300 mD permeability range. The Alpine orogenic belt limits the extent of the aquifer from the South. Most assessments have a considerable lack of geological data; hence, there is a great deal of uncertainty surrounding saline aquifer storage estimates for CO<sub>2</sub> in Germany.

### **15.5 Regulatory Framework**

The Carbon Capture and Storage Act (KSpG) 2012 came into force in August 2012 and was intended to test the first demonstration projects for the long-term storage of CO<sub>2</sub> in the ground in Germany. Specifically, it stipulated an annual storage of no more than 1.3m tons of CO<sub>2</sub>, a maximum storage volume of 4m tons of CO<sub>2</sub> per year in Germany, and that permits could only be granted if an application for a CO<sub>2</sub> storage facility was made by 31 December 2016. By the end of the application, only one demonstration project had been applied for and built. Since then, no further applications have been made, and CCS is not considered possible in Germany. However, several actions may change the future of the CCS for Germany. Firstly, Germany is now considering CCS as a key component of climate action. The German Government have been pushing these discussions since 2021. In early 2023, The Federal Mistry for Economic Affairs and Climate Action initiated stakeholder dialogue to develop a CCS strategy (released in early 2024). Further to this, the Green House Gas (GHG) neutrality studies from 2021 evaluated a need to deploy CCS to meet climate targets and found that technologies for the full CCS value

chain are mature enough. However, the legal framework in Germany currently prevents the deployment of any technology for CCS. Lastly, The Langfristszenarian Project (Long-term Scenarios for the Transformation of the Energy System in Germany) is being modelled on behalf of the German Federal Ministry for Economic Affairs and Climate Action. These scenarios model how the country's energy and climate policy goals can be achieved. A number of goals have proposed several scenarios that include CCS as a key component. Germany will need to ratify Article 6 of the London Protocol to transport CO<sub>2</sub> to other countries if storage in the country remains legally restricted and has been in discussion with other European countries for transboundary movement of CO<sub>2</sub>.

The recent German Carbon Management Strategy (released in early 2024) will hopefully help Germany move towards more research in all aspects of the CCUS value chain and encourage the rest of Europe to advance in CCUS and CO<sub>2</sub> management strategies.

Germany scores 57.5 on the CCS readiness scale as defined by the GCCSI.

## **15.6 Issues for the Assessment**

The most challenging issue with Germany is the lack of geological data and static or dynamic modelling to accurately define storage resource estimates. The country's regulations to date are likely to have hindered this. However, with a renewed interest from the government, further rigorous assessments may be conducted in the future.

## **15.7 Future Updates**

### **15.7.1 Future evaluations**

Future evaluations should seek to address any updates to sites or potential projects in light of the more progressive legislation for CO<sub>2</sub> storage.

### **15.7.2 Future CSRC cycles**

Future cycles will need to focus on collating information from studies that provide a greater insight into the quality and resources of saline aquifers in Germany's jurisdiction.

# 16 Greece

## 16.1 Summary

Greece was assessed by the CSRC in Cycle 4. A summary of the CO<sub>2</sub> Storage resource is shown in the Table below.

A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.107	0.075
Undiscovered	3.877	0.000
Aggregated*	3.984	0.075

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Greece.

Table 16-1: Storage resource classification summary for Greece

- Greece has seven sites that can be added to the CRSC, ranging from undiscovered to sub-commercial.
- Greece has an active and positive approach to CCS, and although early in its deployment, it has awarded a storage exploration license in the Prinos Basin.
- As a country, it is actively supporting European research projects, seeking out further storage sites within its borders, and funding CCS initiatives.
- Greece has been assessed by GESTCO and GeoCapacity in the past which identified several sites. Limited studies have been conducted since then but have helped to refine some resource estimates, namely those in the Messohelinic Trough.
- Greece has two hydrocarbon sites (Prinos and Kallirachi) and several saline basins suitable for CO<sub>2</sub>, some of which are close to industrial centres like the Messohelinic Trough, where the Kozani and Ptolemaida industrial areas are. These include coal/lignite-fired power plants, waste incinerator, cement plants and biomass plants.
- Prinos is currently a storage project in the early stages of assessment with a license granted by HEREMA in 2022. Energean are the license holders.
- Further saline storage sites are in the Thessaloniki Basin and Ptolemais-Kozani Basin.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



C) Storage Resource by Type

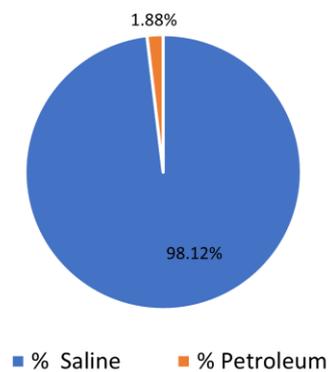


Figure 16-1: Greece Spread of Storage Sites.

A) Spread of storage resources in Greece across SRMS classifications, where a project has been specified. B) Spread of storage resources in all Greek sites across SRMS classifications; both project specified and not. C) Split of Greek storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 16.2 Resource Statement

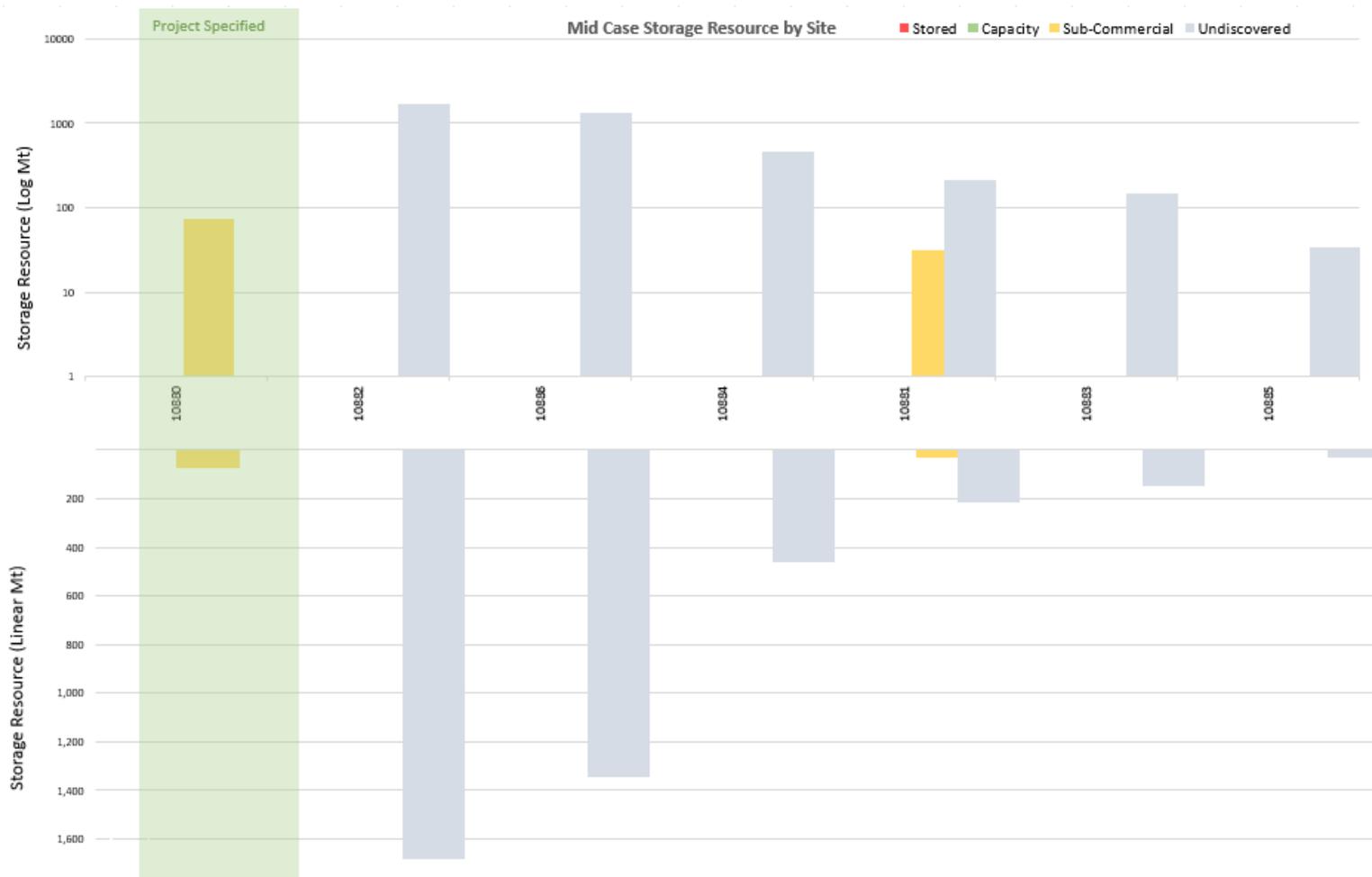


Figure 16-2: Storage resource summary for Greece compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 16.3 Evaluation History

Greece participated in the GESTCO project (2000-2003) [1] and was evaluated for CO<sub>2</sub> storage potential for saline aquifers and oil and gas fields. Overall storage potential in saline aquifers was estimated at 2.2Gt and 17Mt in hydrocarbon fields. The Geocapacity Report of 2009 [2], in which Greece was also a participating country, estimated resources for the country's saline aquifers in the region of 184Mt and hydrocarbon fields of around 70Mt.

More recent studies by universities and research institutions have provided a greater understanding of some of the potential sites in Greece. These publications have provided a more concise view of individual storage site resources and have been used in this assessment. This research has been used to understand storage potential in the Ptlomais, Mesohellenic Trough, Thessaloniki Basin, Alexandria Anticline and the Loudias and Agriossykia Synclines and Volos region. These assessments still rely on a volumetric approach based on estimates provided by Geocapacity. All sites, except for Prinos, are classified as Undiscovered at a basin or sequence level (depending on the assessment resolution) due to an absence of data to determine well locations in the saline aquifers.

## 16.4 Resource Review

### 16.4.1 Major Projects

The first exploration license for the Prinos field was awarded by the Hellenic Hydrocarbons and Energy Resources Management (HEREMA) to Energean in late September 2022. The project is a key part of the Mediterranean CCS Strategic Plan. This plan was developed by France, Italy, and Greece and aims to create the first CO<sub>2</sub> storage hub in the Southeast Mediterranean. CO<sub>2</sub> is planned to be transported by both ship and pipeline. The first phase of the project aims to inject 1Mt CO<sub>2</sub> /yr as a compressed form and then later accommodate liquid CO<sub>2</sub> by 2027. The second phase aims to increase injection rates to 3Mt CO<sub>2</sub>/yr for 25 years. Greece is also part of the European Horizon 2020 STRATEGY CCUS project, which aims to support the development of low-carbon energy and industry in Southern and Eastern Europe. The West Macedonia Region was selected due to high industrialisation, lignite production and a CO<sub>2</sub> capture plant developed by the Centre for Research and Technology-Hellas (CERTH). The Mesohellenic Trough has been identified as a storage site in this area.

### 16.4.2 Depleted Oil & Gas Fields

The Prinos Basin in the North Aegean Sea is the only area in Greece active in hydrocarbon production and is now licensed for exploration for CO<sub>2</sub> Storage. It is a rift basin with a thick sedimentary fill of clastics and evaporites. The pre-evaporitic sequence provides a suitable storage formation and overlays a thick sequence of evaporitic and clastics (Messinian-Quaternary), providing an excellent seal. Both structural and stratigraphic traps exist throughout the basin. In contrast to other areas of Greece, this site is tectonically stable and poses a much-reduced risk to containment issues. Recent studies to the license award have

resulted in much refined estimates of storage potential. The resource estimate is taken from a recent white paper published by HEREMA and whilst this cites an upper value of 100 Mt, a value of 75Mt is included in the CRSC (based on injection of 3Mt/yr for 25 years from the development plan).

The Kallirachi oil field is another potential site for CO<sub>2</sub> storage when hydrocarbon production has ceased. It has a thick sandstone reservoir and, like Prinos, a very thick seal of salt. No storage values are available for this field yet.

### **16.4.3 Saline Aquifers**

Greece has some saline aquifer sites that hold CO<sub>2</sub> storage potential. They are generally sparse in data availability, which impacts storage estimates. The Mesohellenic Trough in Western Macedonia, which was studied by Tasianas and Koukouzas (2016) [3], estimates significant storage potential in two formations: the Pentolofos and Eptachori. They used a geological model to understand potential resources built from 2D and 3D data and estimated over 700Gt of storage. This was re-evaluated by Koukouvis et al. (2021) [4] and provided P90, P50 & P10 estimates for the storage resource of the main formations using a methodology (US-DOE-NETL) as adopted in the STRATEGY CCUS project [5 in 4]. This approach gave P10 for both formations in the region of 3400Mt resource. In North-Eastern Greece, the Thessaloniki Basin has a few onshore Eocene age storage opportunities in saline sandstone aquifers and structures such as the Alexandria Anticline and the Loudias and Agriossykia Synclines. Total storage resources are reported at ~640Mt. The Bellona Foundation [6] summarises storage potential in these areas based on the GETSCO report. The Ptolemais-Kozani Basin, situated between the Mesohellenic Trough and Thessaloniki Basin, holds a storage resource estimate reported by The Bellona Foundation of 1343 Mt. Lastly, Arvanitis et al. (2020) [7] reported potential in basalts of the Volos region with a resource of ~43,200 tons (not included in the CRSC database). Smaller volumes are also cited as having potential in the Klepa-Nafpaktia sandstones in Western Greece, with a storage resource of 18 x10<sup>5</sup> tons.

## **16.5 Regulatory Framework**

Greece is positive in its approach to promoting solutions for CCS through initiatives, partnerships, and collaboration and is at an early stage in CCS deployment. In April 2022, HEREMA was appointed as the licensing authority for the geological storage of CO<sub>2</sub> in Greece. This also covered the overall management of the rights of the Hellenic state for the storage of CO<sub>2</sub> and other gases and liquids, such as natural gas and hydrogen (Law 4920/2022, Government Gazette A '74/ 15.04.2022). Greece has transposed The EU CCS Directive 2009/31/EC into Greek law. A recent implementation report on the Directive 2009/31/EC indicates that in addition to licensing authority changes, Greece plans to determine additional storage sites for CO<sub>2</sub>, has programs in place to support the deployment of CCS financially and is actively involved in European research projects. Greece scores 57.5 on the CCS readiness scale as defined by the GCCSI [8].

## **16.6 Issues for the Assessment**

Low research and a very limited amount of data for most of the CO<sub>2</sub> storage resources in Greece will affect the accuracy of storage estimates. Prinos is now a well-studied area; however, due to the proprietary nature of the studies, the storage volume estimates are reliant on published press release data by Energean.

## **16.7 Future Updates**

### **16.7.1 Future evaluations**

Future evaluations should seek updates to the Prinos project and any updates to the Messohelinic Trough area based on any outcomes of the STRATEGY CCUS project.

### **16.7.2 Future CSRC cycles**

An update for all sites is recommended for future updates to the CRSC. Many sites that are currently at the formation level may have increased studies to be able to evaluate the lead and prospect levels.

# 17 Hungary

## 17.1 Summary

Hungary was assessed by the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	3.520	0.000
Undiscovered	7.308	0.000
Aggregated*	10.828	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Hungary.

Table 17-1: Storage resource classification summary for Hungary

- Hungary's national oil company, Mol Group, has a long history of experience with CO<sub>2</sub>-EOR with potential with the country itself having very sizeable potential for CCS/CO<sub>2</sub> storage within deep saline aquifers and depleted oil and gas fields.
- In 2010, the MOL group collaborated with ELGI (Hungarian National Research Institute) to conduct a screening study to evaluate 180 hydrocarbon reservoirs for CCUS productivity. Despite this, no evidence in the public domain demonstrates that the country has any active or firm future plans for CCS storage projects. Additionally, Hungary has yet to establish a CCUS pilot project.
- Although storage resource is reported as being present in both saline aquifers and oil and gas fields, the greatest potential by a sizeable margin exists within deep saline aquifers.
- According to the literature, the most prospective areas for CCUS storage are within the Jászág Sub-basin of the wider Pannonian Basin in the southwest of the country. The primary prospect across this region is the prolific Szolnok formation. Various authors have quoted volumes ranging from 97Mt to 2000Mt for this formation.
- MOL has expressed an intention to apply EOR in depleted hydrocarbon reservoirs in the region, potentially paving the way for a Hungarian CCS project to become financially feasible.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

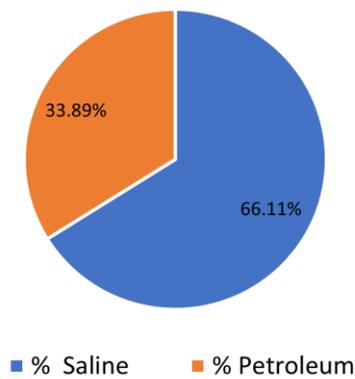


Figure 17-1: Hungary Spread of Storage Sites.

A) Spread of storage resource in all Hungarian sites across SRMS classifications; both project specified and not. B) Split of Hungarian storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 17.2 Resource Statement

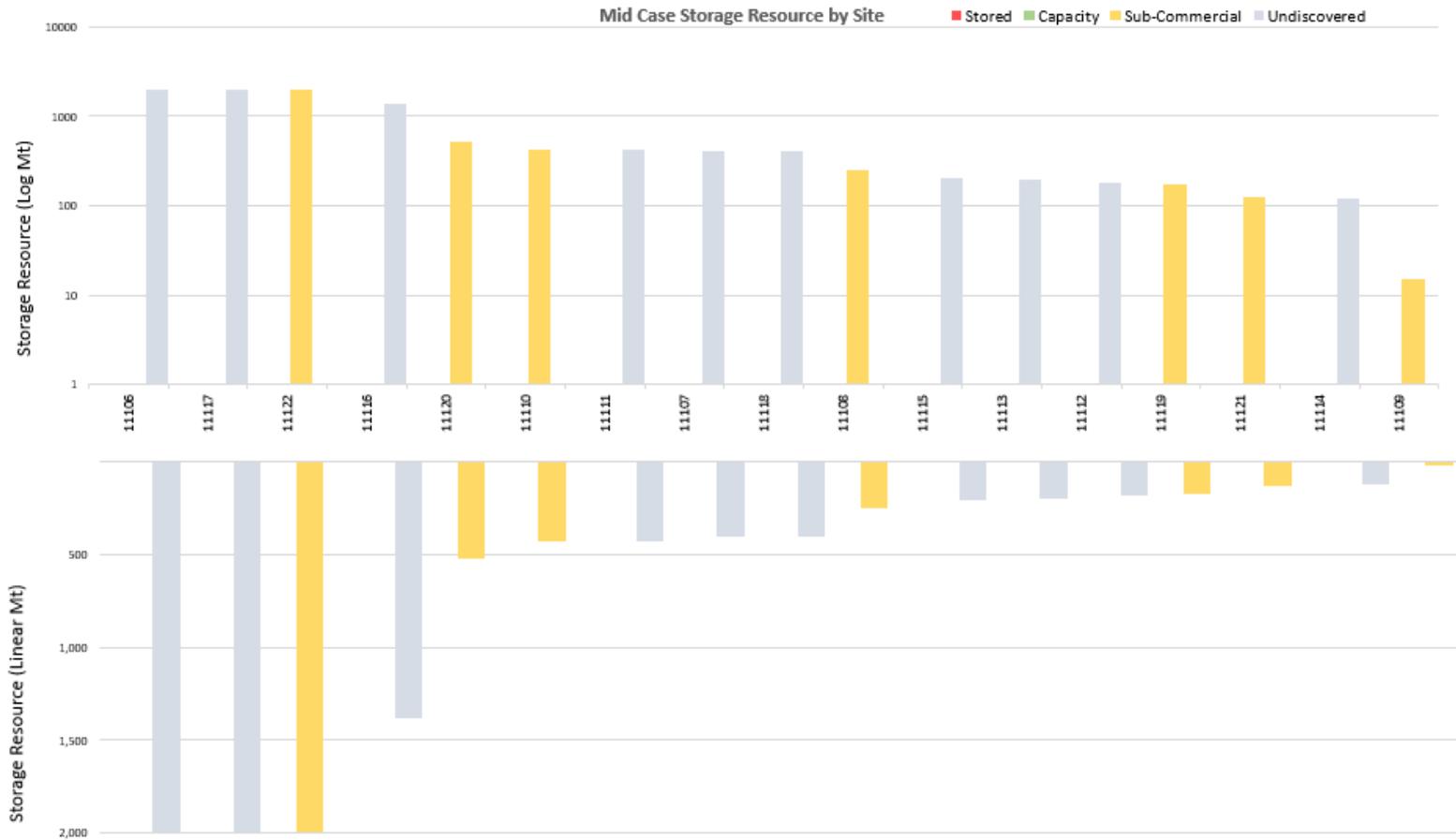


Figure 17-2: Storage resource summary for Hungary compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 17.3 Evaluation History

The first country-wide review paper was published in 2010 (P. Kubus, SPE, MOL Hungarian Oil and Gas) [1] which evaluated 180 hydrocarbon reservoirs for CCUS prospectivity. It highlighted a cumulative resource of 430 Mt, of which 155 Mt would be available within the following 10 years, with a further 16 Mt in the next 25 years. A key finding from this study was that, on average, a depleted hydrocarbon reservoir could store a maximum of 10 – 15 Mt of CO<sub>2</sub> and thus concluded that the MOL CCS task force couldn't see a viable EOR project in storing CO<sub>2</sub> within Hungarian depleted hydrocarbon reservoirs. Despite this, the paper does allude to significant potential prospective resources. The paper also references coal fields located across the North of the country and in the Southwest to have an estimated cumulative storage resource of 300 Mt. The paper studied deep saline aquifers, noting that the storage resource was an order of magnitude greater than hydrocarbon reservoirs, however, due to sparse data could not reliably produce volumetric estimates to support this. The paper reported that the Újfalu formation has a resource of 424 Mt, the Szolnok formation has a theoretical cumulative resource of 2090 Mt (183 Mt for Jászág Basin, 197 Mt for Makó Trough, 120 Mt for Pusztaföldvár Horst, 204 Mt for Békés Basin and 1380 Mt for Transdanubian area).

It is worth noting that the method used to calculate volumes in this study involved utilising an equation developed by Professor Dr József Pápay. This equation is based on the formation's compressibility and the highest applicable overpressure. The author highlights that this method is conservative among the available estimation methods.

The 2010 Kubus [1] paper cited a "Flagship" CCS project as a case study that sought to investigate the feasibility of utilising the Mátra Power Plant as a site for capturing CO<sub>2</sub> and transporting it to the potential storage sites located south of the power plant. Proposed sites utilised depleted hydrocarbon fields or deep saline aquifers (Szolnok Fm). Ultimately, the project appears to have concluded that depleted hydrocarbon reservoirs were not economically viable at this stage and that significant investment would be required to fund an exploration programme to quantify better the true volumetric potential of deep saline aquifers.

### 17.4 Resource Review

Hungary has no active or firm plans for CCS storage projects and has yet to establish a CCUS pilot project.

The majority of prospective formations within Hungary have been assessed as Undiscovered at either the Basin or Sequence level according to SRMS guidelines.

#### 17.4.1 Major Projects

Hungary did have a single historic proposed project that utilised the saline and hydrocarbon aquifers (namely the Szolnok & Algyo Formations) located close to the Matra power plant [1].

The saline constituent of the CCS site was suggested to have a storage potential of 250 Mt,

while the Hydrocarbon equivalent had a resource of 15 Mt.

Cycle 4 has evaluated this prospect as 'Discovered, not viable' because the authors published a technical plan for the full CCS lifecycle from capture to storage, including a pipeline linking the plant with the storage site. To the present day, no further research or information in the public domain has surfaced, suggesting that this project has been abandoned.

Though not necessarily definable as a single major project, Kubus et al. (2010) referenced and expanded on the work completed by the Hungarian National Oil Company (Mol Group), which stated volumes at a country level for hydrocarbon (not defined) reservoirs. The work volumetrically calculated a CCS storage resource of 430 Mt for 180 fields at the time of writing (2010). It went on to state that 155 Mt of this resource was available from 2010 through to 2020, and beyond that date, a further 16 Mt would be available in 2035.

#### **17.4.2 Depleted Oil & Gas Fields**

Azbek et al. (2011) [2] published a study on several oil and gas prospects in various Hungary basins, featuring the Szolnok and Eszak-Afold formations.

Their findings conclude that for the Northern Great Plains basin, the Eszak-Afold formations with the Eszak Afold field has a storage resource ranging from 150 – 200 Mt. Accordingly, the Szolnok formation with the Del-Afold field was assessed to have a resource ranging from 500 – 550 Mt within the South Great Plains basin, while in the Transdanubian basin, this same formation had a storage resource ranging from 1000 – 1500 Mt. Finally, within the Pannonian basin, the Szolnok formation was assessed for a resource of 1500 – 2500 Mt. This Cycle 4 has evaluated these prospects as being 'Discovered, Not viable' as storage is located within depleted fields. However, no evidence in the public domain suggests that any plans exist to appraise or evaluate these prospects for furthering a CCS project.

Berta et al. (2011) [3] evaluated the Szolnok and Algyo formations cumulatively within the Northern Great Plains basin as having a storage resource of 400 Mt. Due to the maturity of the information available and the regional nature of the assessment, this Cycle evaluated the Berta (2011) assessment as being 'Undiscovered at a Sequence play level'.

Fazekas et al. (2022) [4] have produced the most recent CCS publication involving Hungary, in which the authors stated a resource of 97 Mt for hydrocarbon reservoirs within the Pannonian basin. However, due to the scarcity of detail in Fazekas' (2022) publication on the location and origin of the reported resources, this Cycle preferred to use other more detailed sources to identify depleted oil and gas fields.

#### **17.4.3 Saline Aquifers**

Kubus et al. (2010) evaluated the Szolnok formation as it applies to the sub-basins of Hungary. These were classified at the 'Undiscovered, Sequence play' level and yielded storage estimates

as per the following:

Berta et al. (2011) [3] assessed the Szolnok & Algyo formations cumulatively within the Northern Great Plains basin to have a resource of 2000 Mt, which has been evaluated in this study as being 'Undiscovered at a Sequence play' level due to scarce information provided beyond formation name and regional location.

Kubus et al. (2010) [1] studied the Ujfalu formation within the Pannonian, stating a storage volume of 424 Mt. This assessment has been evaluated as meeting the threshold for Undiscovered, Sequence play level status according to SRMS.

Azbej et al. (2011) [2] produced a study evaluating the Upper and Lower Pannonian formations at a country level, producing a storage estimate of 400 and 2000 Mt depending on the formation's physical parameters. Due to the lack of information, the authors of this cycle deemed this evaluation immature and, therefore, evaluated it as 'Undiscovered, at basin play' level. The research also stated volumes of between 24 and 87 Mt for an unconventional prospect (coal seam).

## 17.5 Regulatory Framework

Hungary received a moderate definition when evaluated under the 2023 GCCSI CCS readiness index, with a score of 49.5.

The Mining Inspectorate and SZTFH (Supervisory Authority for Regulated Activities of Hungary) define and regulate detailed rules for geological structures suitable for storing carbon dioxide of energy and industrial origin to which decree no. 145/2012 and. 29/2022 are aligned toward.

The first known regulatory framework published by Hungary was under the Geological Storage Directive (May 2012) and states, "The potential sites should have adequate depth and should be sealed by impermeable strata. They should have porosity and permeability suitable for CO<sub>2</sub> injection".

Accordingly, in 2013, an assessment of the geological structures potentially suitable for the geological storage of carbon dioxide and their resource amounts was carried out, but it has not been updated since then. Under national legislation, storage capacities must be reassessed every five years [5].

## 17.6 Issues for the Assessment

The lack of public domain data and publications detailing methods for calculating storage volumes have limited the accuracy of the assessment for Hungary.

The most notable issue for storage resource assessment in Hungary is the large range of uncertainty in storage volume estimates for saline aquifers due to the lack of exploration work

carried out in the country.

Because of the issues raised, this catalogue is therefore unable to accurately represent the true volume of storage potential Hungary's geological resources can offer.

## **17.7 Future Updates**

### **17.7.1 Future CSRC cycles**

Should Hungary's storage systems develop further, this should be reviewed annually to ensure the Global Storage Catalogue is up to date.

# 18 Iceland

## 18.1 Summary

Iceland was assessed during Cycle 5. The CSRC has identified that Iceland has no published storage resource estimates, and so has zero sites to add to the CSRC database:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00	0.00
Capacity	0.00	0.00
Sub-Commercial	0.00	0.00
Undiscovered	0.00	0.00
Aggregated*	0.00	0.00

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Iceland.

Table 18-1: Storage resource classification summary for Iceland.

## 18.2 Evaluation History

Iceland was reviewed during Cycle 5. Iceland is not a hydrocarbon-producing country. No CO<sub>2</sub> storage evaluations for conventional CO<sub>2</sub> storage (saline aquifer/depleted fields) have been carried out at the federal level, nor are any available in the public domain. Iceland’s geology is unsuitable for conventional CO<sub>2</sub> storage being dominated by volcanic basalt rocks.

However, Iceland has an active and very developed industry for storing CO<sub>2</sub> through basalt mineralization. The country has developed significant infrastructure and conducted extensive research to build facilities for this method of CO<sub>2</sub> storage (Carbfix). Projects are now fully developed to an industrial scale. In addition, Iceland is a country that has housed pioneering CO<sub>2</sub> storage capture technology (Orca) such as direct air capture which has also been implemented to an industrial scale.

Carbfix leverages a CO<sub>2</sub> storage process which uses mineralisation as the primary trapping mechanism rather than pore space trapping (which is the initial trapping mechanism in saline aquifer and depleted fields). It involves imitating and accelerating a natural process through which dissolved CO<sub>2</sub> and reactive rock formations interact to form carbonate minerals. Carbfix started in 200 by four founding partners: Reykjavík Energy, the University of Iceland, CNRS in Toulouse, and the Earth Institute at Columbia University. In just seven years Carbfix became a fully operational industrial process to capture CO<sub>2</sub> and H<sub>2</sub>S from emission sources and permanently store it in the subsurface. The company's mission is to reach 1 Gt CO<sub>2</sub> of

permanently stored CO<sub>2</sub> as rapidly as possible.

Orca direct air capture was launched in 2021 and is the world's first and largest direct air capture and storage plant. The facility consists of eight collector containers, with an annual capture capacity of 500 tons each, capturing up to 4,000 tons of CO<sub>2</sub> per year. The heat and electricity required to run the process is supplied by the Hellisheidi Geothermal Power Plant.

### **18.3 Regulatory Framework**

Iceland's regulations for CO<sub>2</sub> storage are driven by the EU's Carbon Capture and Storage (CCS) Directive. The country has a developed set of regulations and legislation to permit industrial-scale CO<sub>2</sub> storage. The country is also exploring the potential of cross-border CO<sub>2</sub> transport and storage, aiming to import CO<sub>2</sub> from Europe.

### **18.4 Future Updates**

#### **18.4.1 Future Updates for Evaluators**

Given Iceland's unsuitable geology for conventional CO<sub>2</sub> storage, it is anticipated that no future research will be conducted here. However, if the CSRC starts to include alternative forms of storage such as basalt mineralization, then Iceland will be a prime candidate to review for storage potential, especially as there is a working example of a project such as this that has reached all stages of maturity through to commercialization.

#### **18.4.2 Future CRSC Cycles**

As above.

# 19 Ireland

## 19.1 Summary

Ireland was assessed for the first time in Cycle 4 of the CRSC. The CSRC has identified the CO<sub>2</sub> storage resource for Ireland in the table below.

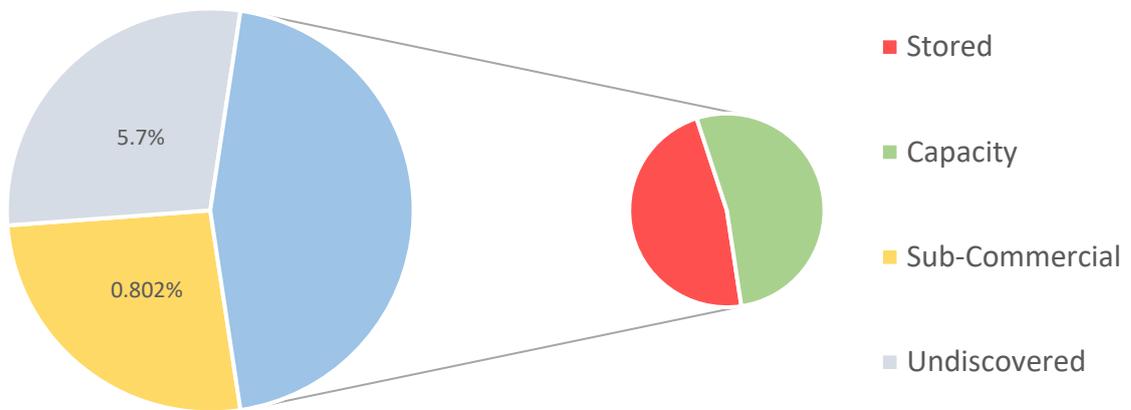
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	1.100	0.000
Undiscovered	89.534	0.000
Aggregated*	90.634	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Ireland.

Table 19-1: Storage resource classification summary for Ireland.

- Ireland has respectable potential for CO<sub>2</sub> storage offshore, with the most prospective opportunities located within the Peel Basin, Slyne Basin and East Irish Sea basins. The largest storage resource (at the sequence play level) is situated in the Sherwood Sandstone Group in the Peel basin at 68,000 Mt.
- Ireland’s onshore prospectivity may be lower. However, it has one sizeable prospect located in the Northwest Carboniferous basin with a resource of 730 Mt.
- Irish law does not currently support CO<sub>2</sub> storage.
- Ireland has a relatively low score of 25 within the 2023 CCS Chart of Legal and Regulatory Indicator system.

a) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

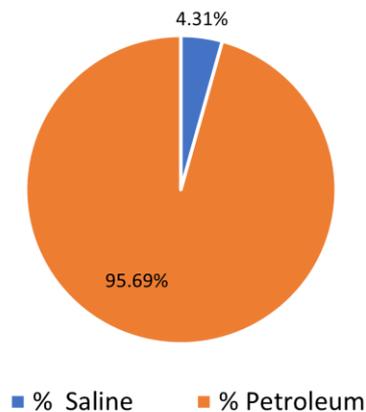


Figure 19-1: Ireland Spread of Storage Sites.

a) Spread of storage resource in all Irish sites across SRMS classifications; both project specified and not. b) Split of Irish storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 19.2 Resource Statement

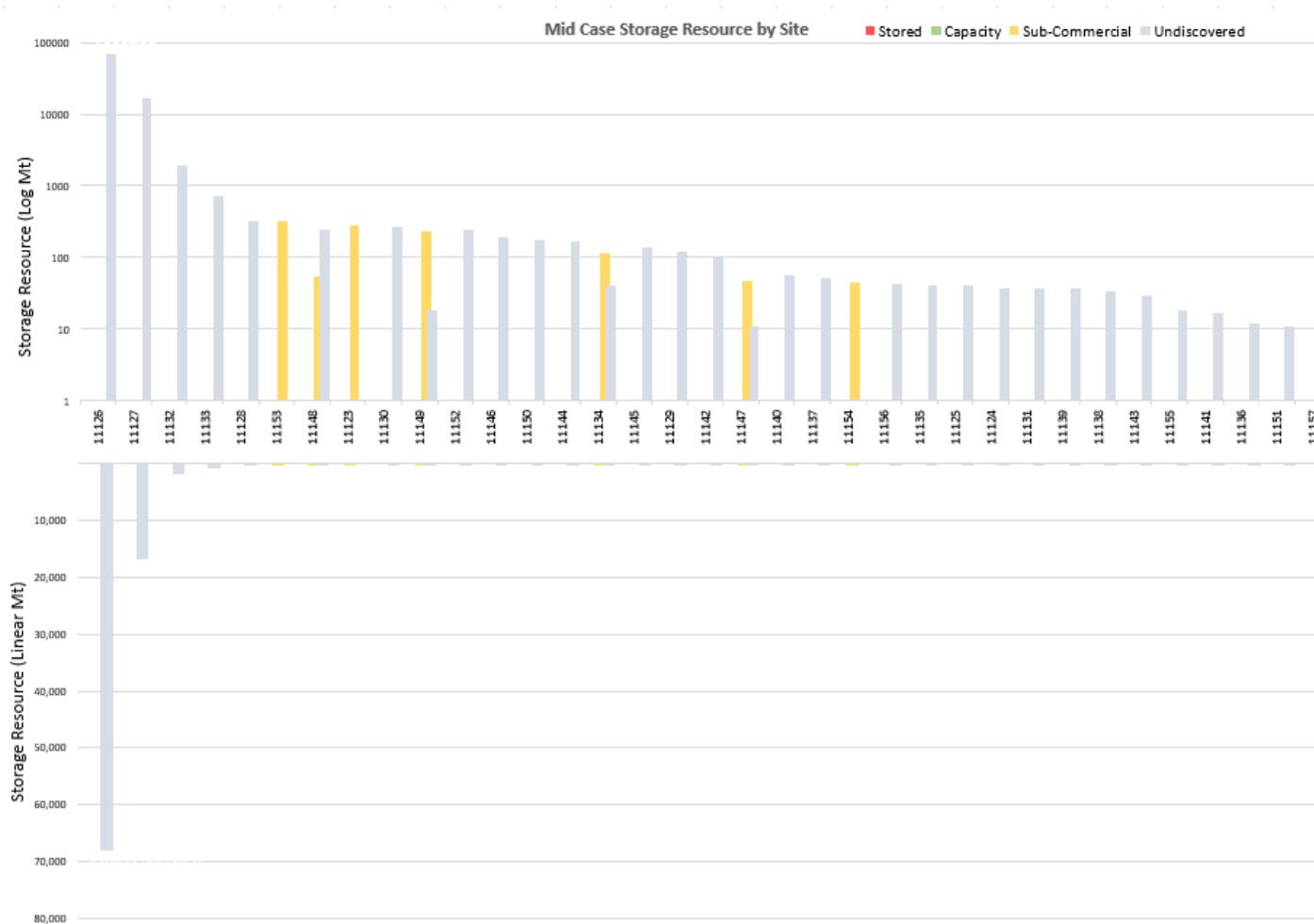


Figure 19-2: Storage resource summary for Ireland compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 19.3 Evaluation History

The first authors to study Ireland's CO<sub>2</sub> storage prospectivity were Bentham et al. (2008) [1], who took a "basin by basin" approach to produce this initial country-wide review. Bentham et al.'s study produced theoretical and effective volumetric estimates for some fields by supplementing oil and gas data wherever possible to support effective volumes. This is possibly the most complete assessment of Ireland's CO<sub>2</sub> storage resource, including many of the country's depleted hydrocarbon prospects.

Lewis et al. (2009) [2] followed on from this review, providing another independent set of volumes for much of the same fields, with both author's outputs in agreement.

In 2011, Farrelly et al. studied the onshore prospects within the onshore Clare basin.

The most recent studies were published in 2022 (English et al.) [3] and 2023 (O'Sullivan et al.) [4].

These former studies focused only on two assets, providing a reduced estimate for the Kinsale head field and a new appraisal of the Corrib gas field. The latter focused on underexplored assets, including the Corrib, Inishmore, and Inishbeg gas fields.

## 19.4 Resource Review

### 19.4.1 Major Projects

Ireland has been producing hydrocarbons from its offshore Atlantic basins since the early 1970s. However, despite having a number of prospective targets, both onshore and offshore, it has yet to establish a CCS pilot project due to the current ban on CO<sub>2</sub> storage by Irish law.

### 19.4.2 Depleted Oil & Gas Fields

There are 15 potential depleted oil and gas fields in Ireland's offshore waters. Quite significant resources could be found in the North Celtic Sea. Bentham et al. (2008) documented the earliest and possibly the complete assessment of Ireland's CCS resources, studying many of the country's depleted hydrocarbon prospects. They stated that the Kinsale Head Field, Southwest Kinsale and Spanish Point Field have storage estimates of 330 Mt, 5 Mt and 120 Mt, respectively.

Lewis et al. (2009) published a study on the same fields, concluding similar volumes. In 2023, O'Sullivan et al. published a study assessing the Corrib (East Irish Sea), Inishmore (North Celtic Sea) and Inishbeg fields (Donegal Basin). For Corrib, a range of 62 – 119 Mt was quoted for the full closure and a smaller volume of 15 – 199 Mt for the gas cap. English et al., (2022) also assessed the Corrib field arriving at a volume of 44 Mt. Inishmore had been assessed by O'Sullivan et al. to have a volume of 92-310 Mt within the Triassic formations and up to 29 Mt for the Carboniferous formations. Inishbeg was quoted to hold a volume of 60 – 566 Mt.

### 19.4.3 Saline Aquifers

In addition to studying depleted hydrocarbon prospects, Bentham et al (2008) also documented prospective resources within saline aquifers. The largest resource they defined was the Sherwood Sandstone Group within the Peel Basin which had a stated storage resource of 68,000 Mt. The next largest opportunity is the Sherwood Sandstone group, in the Central Irish Sea Basin with an assessed volume of stated 17,300 Mt. Significantly smaller in size, is the Sherwood Sandstone group within the Larne Portpatrick Basin which stated as having a storage resource of 2700 Mt. When considering closed structures, Bentham et al. highlighted a far smaller volume of 37 Mt per structure on average for this basin. These volumes for the Larne Portpatrick Basin are agreeable when compared with the assessment published in the Lewis et al. (2009) paper.

The final assessment completed by Bentham for the Sherwood Sandstone group was for the Central Irish Sea Basin, which was stated as 630 Mt.

Within the North Celtic Sea, Bentham et al. referred to prospective resources disclosed as "Greensand A", publishing a volume of 101 Mt and 40 Mt determined by assuming 100% porosity and 40% porosity, respectively.

In addition, Bentham et al. stated volumes for several closures. Five closures containing the Sherwood Sandstone are identified within the Central Irish Sea Basin, with volumes ranging from 28 – 190 Mt, while 7 closures also containing the Sherwood Sandstone were highlighted as having volumes ranging from 11 – 57 Mt within the Kish Bank basin. A singular site was identified within the Portpatrick Basin containing the Sherwood Sandstone, with a volume of 23 Mt.

For onshore resources, Bentham et al. published volumes of 1940 Mt and 730 Mt for the Enler Group within the Lough Neagh basin and Dowra Sandstone within the Northwest Carboniferous basin.

Farrelly et al., (2011) [5] completed an independent assessment of the onshore Clare basin concluding that for the Ross Sandstone. The entire aquifer had a volume of 18 Mt with a trap resource of just 4 Mt, while the Dinantian Limestone had a volume of 42 Mt with a trap volume of 11 Mt.

Several authors referenced in this report have published data on sites that fall below the threshold for SRMS assessment. However, they are listed below for completeness.

- Bentham et al. (2008) published data on the Bains field within the East Irish Sea. Details are sparse, but the volume was quoted as 5 Mt.
- Lewis et al (2009) published data on the Southwest Kinsale Head prospect within the Celtic Sea. This prospect has its reservoir within the Upper Wealden with the Gault

formation as a seal and was speculated to have a storage volume of 5 Mt.

- Farrelly et al. (2011) studied a trap within the onshore Clare basin, which has a reservoir within the Ross sandstone. The authors quoted the trap as having a storage volume of 4 Mt.
- O’Sullivan et al (2023) published data on two small sites. Corrib North is a prospect within the East Irish Sea with a reservoir in the Corrib sandstone of the Triassic age, which is then sealed by the Uilleann Halite Member. The authors stated a volumetric resource of between 2 – 14 Mt. The second was the Carboniferous aged Inishmore Carboniferous 1 prospect within the North Celtic Sea, which was quoted to have a resource of between 2 – 16 Mt.

## **19.5 Regulatory Framework**

Ireland has received a poor result following evaluation under the 2023 GCCSI CCS readiness index, scoring 25.

Irish law does not currently permit the storage of CO<sub>2</sub>. Progress for future CCS projects will need regulatory and policy advancement to permit CO<sub>2</sub> storage.

Ireland has a semi-state multi-utility company (Eirvia) that manages Ireland's energy network and is vested in decarbonising Ireland. Eirvia has conducted studies surrounding CCS feasibility; however, from a regulation standpoint, these primarily focus on the export of CO<sub>2</sub>.

## **19.6 Issues for the Assessment**

Ireland currently lacks dynamic and project-specific assessments. Hence, all assessments are mostly theoretical. Should Irish law permit CO<sub>2</sub> storage, then future research may refine many of the theoretical storage estimates and reveal the true volume of storage potential Ireland's geological resources can offer.

## **19.7 Future Updates**

### **19.7.1 Future CSRC cycles**

Should any further development in the Irish storage systems occur, this should be reviewed annually to ensure the Global Storage Catalogue is up to date.

## 20 Italy

### 20.1 Summary

Italy was assessed by the CSRC in Cycle 4. A summary of the CO<sub>2</sub> Storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	2.580	0.122
Undiscovered	5.623	0.000
Aggregated*	8.203	0.122

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Italy.

Table 20-1: Storage resource classification summary for Italy

Italy has a significant estimated CO<sub>2</sub> storage resource in saline aquifers and depleted hydrocarbon fields. Despite this, Italy's only CO<sub>2</sub> storage project plan is an Eni project utilising the Ravenna depleted hydrocarbon field. This might be explained by the low public acceptance of CO<sub>2</sub> storage and the fact that many depleted fields are converted to gas storage.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



C) Storage Resource by Type

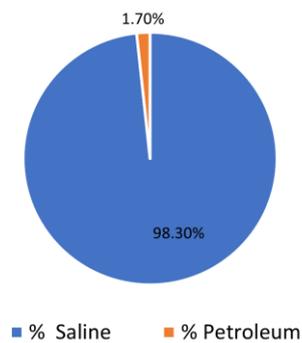


Figure 20-1: Italy Spread of Storage Sites.

A) Spread of storage resources in Italy sites across SRMS classifications; project specified. B) Spread of storage resources in Italy sites across SRMS classifications; both project specified and not. C) Split of Italy storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 20.2 Resource Statement

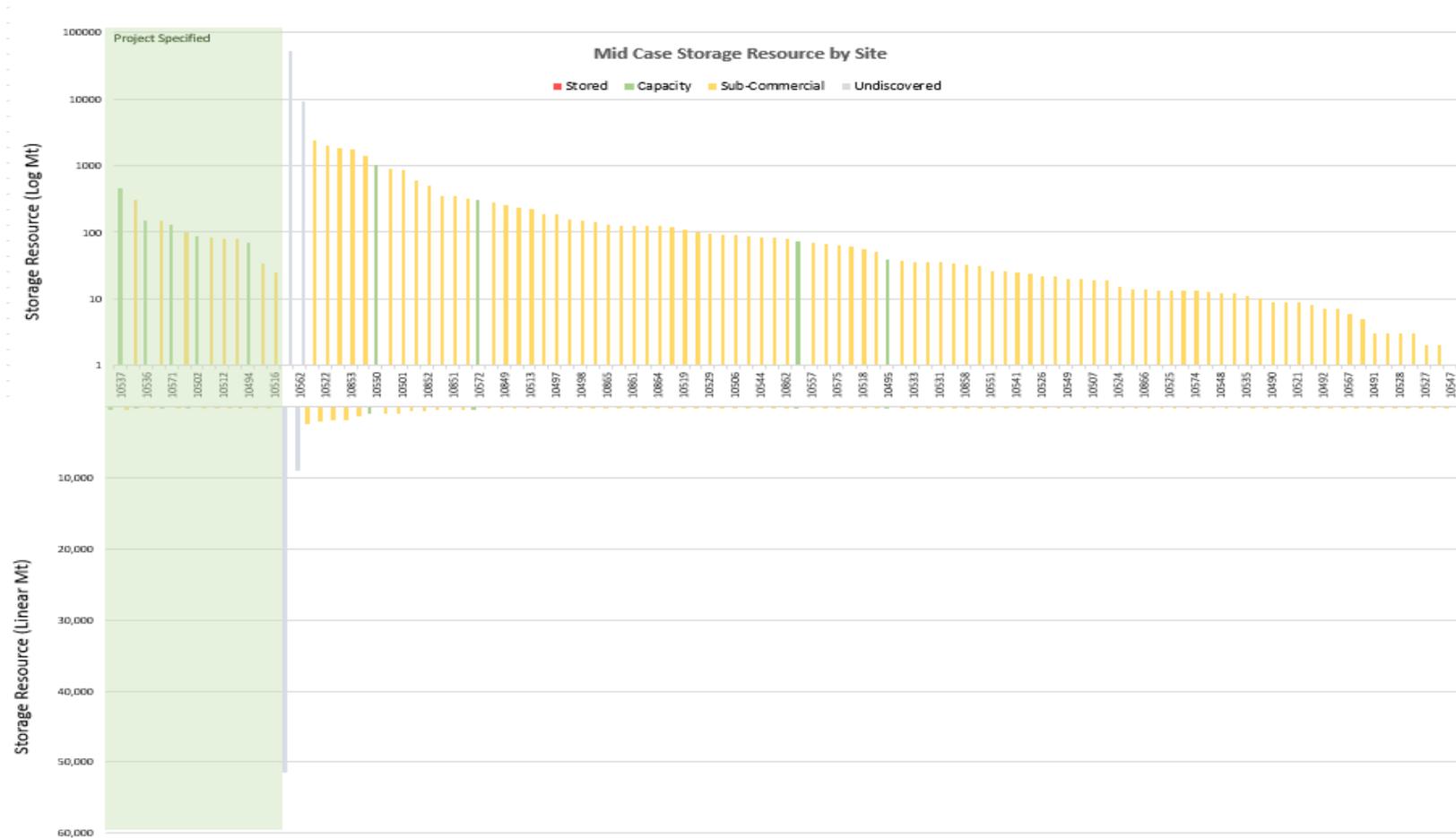


Figure 20-2: Storage resource summary for Italy compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 20.3 Evaluation History

In Italy, the evaluation of storage resources has been performed only in the context of research projects, as the role of CCS in the Italian energy strategy is still relatively marginal (CO<sub>2</sub>GeoNet-2021) [16]. Italy has the potential for CO<sub>2</sub> geological storage (CGS) in saline aquifers, both onshore and offshore, within both siliciclastic [1] and carbonate rocks [2]. These are supported by additional studies [3,4,5,6]. Italy's storage resources were evaluated by the GeoCapacity project (2009) [12] and CLEANER (2022). All the results are based mainly on public data from the Ministry of Economic Development via the "Visibility of Petroleum Exploration Data in Italy (VIDEPI)" project and from additional published databases. The ViDEPI dataset includes data from approximately 1650 wells and 55,000 km of 2D multichannel seismic profiles acquired since 1957 by several oil companies for hydrocarbon exploration. An ArcGIS project is available at: ([ArcGIS - WebGIS UNMIG](#)).

## 20.4 Resource Review

The geology of Italy is quite complex. It is characterised by a thrust belt area with the Alpine and Apennine chain in a compressional tectonic regime, foredeep and foreland areas in the East and south, and a back-arc basin in the west. The main Italian sedimentary basins, the Apennine foredeep and the Adriatic foreland, are characterised by thick siliciclastic sediments and carbonate accumulations and host the best potential storage sites. The potential reservoirs comprise deep saline aquifers hosted in both carbonate and sandstone formations. A theoretical storage resource ranging from 30 to more than 1,300 Mt CO<sub>2</sub> in the clastic formations has been estimated [1]. Additional potentially suitable areas have been identified by Civile et al. (2013) [2] in carbonate aquifer formations. Depleted oil and gas fields in the Malossa–San Bartolomeo area are considered to carry storage potential in the CO<sub>2</sub>.

Altogether, 34 saline aquifers are mapped with a total resource of just over 8 Gt. Information about specific storage reservoirs is limited, but the storage resource in hydrocarbon fields is estimated to be 139 Mt. Published detailed descriptions of the storage sites are limited. The most researched area is the Adriatic Sea by Proietti, G. et al. (2021) [7] and Proietti, G. et al. (2023) [8].

### 20.4.1 Major Projects

Sulcis site (Sardinia): National funding has been allocated for the construction of a 350 MWe coal-fired power plant / CCS demonstration plant in the Sulcis area of SW Sardinia. The recently approved EC-funded ENOS project (Enabling Onshore CO<sub>2</sub> Storage in Europe) will use the Sulcis site as one of its main field research laboratories. Site characterisation is ongoing, and work has begun to design gas injection experiments at 100-200 m depth in a fault [9,10].

In 2011, ENEL launched an innovative CO<sub>2</sub> capture plant at the Federico II coal power plant in Cerano, Municipality of Brindisi. It consisted of four units with a resource of 660 MWe each (a total resource of 2640 MWe). However, the capture plant was closed after two years due to

investment issues.

Within the CLEANER project, supported by the EC H2020 program, several cement industries, in collaboration with research centres in Italy and other European countries, are developing a calcium-looping technology to capture CO<sub>2</sub> in the cement production process. The study will also consider how to develop a full chain CCS project in Northern Italy. The Zero Emission Porto Tolle (ZEPT) Project covered the design, procurement, and construction of a demonstration CO<sub>2</sub> capture plant and the detailed site characterisation to verify the feasibility of the injection and storage of CO<sub>2</sub> safely and verifiably. The ZEPT Project (Porto Tolle) was suspended [11].

There was also an Eni feasibility study and pilot project of injection into a depleted hydrocarbon field in cooperation with Enel, which tested various chemical solutions to capture CO<sub>2</sub> at the Brindisi power plant. A CO<sub>2</sub> pipeline to the Stogit field for storage was planned to be in operation from 2012. After an initial testing period in March 2011, the project was expected to be operational by 2012. However, the project did not proceed to the operational phase.

Eni recently announced the new CCS "Ravenna hub". Depleted offshore gas fields in the middle Adriatic will be used for CO<sub>2</sub> storage utilising existing operational infrastructure. CO<sub>2</sub> will be supplied from new CO<sub>2</sub> capture systems at onshore Eni power plants and other nearby industrial plants. Ravenna CCS aims to become the pioneer hub for Italy and the Mediterranean. Led by Eni, the hub is in development. The plan was to launch Phase 1 in 2023, testing technologies in a full capture, transport and storage chain handling up to 100,000 tonnes per year [13].

#### **20.4.2 Depleted Oil & Gas Fields**

Hydrocarbon production in Italy is associated with the three main tectono-stratigraphic systems: 1. biogenic gas in the terrigenous Pliocene-Quaternary foredeep wedges; 2. thermogenic gas in the thrust terrigenous Tertiary foredeep wedges; and 3. oil and thermogenic gas in the carbonate Mesozoic substratum. The potential storage resource of 14 depleted fields, which represent only a small proportion of the total number of Italian hydrocarbon fields, has been estimated as gas reservoirs: 1.6 Gt - 3.2 Gt; oil reservoirs: 210 Mt - 226.5 Mt [12, 11]. The studied fields are, however, small; just three have estimated CO<sub>2</sub> storage resources above the CSRC threshold of 10Mt. Additional storage potential may exist in other depleted fields evaluated for natural gas storage and/or hydrogen storage, but not CO<sub>2</sub>.

#### **20.4.3 Saline Aquifers**

Most of the potential saline aquifer sites lie in the major Italian sedimentary basins, i.e., the Apennine foredeep and the Adriatic foreland, characterised by thick sediment accumulations. The potential reservoirs are represented mainly by permeable, terrigenous deep saline formations, whose resources range from 30 to more than 1300 Mt [12,1]. Offshore saline aquifers were estimated by Beretta (2012) [15], although very little information is found in the public domain. Additional storage potential may exist but has not yet been evaluated or

published in the public domain. For example, Barison et al. (2023) [15] present a list of deep saline aquifer sites, onshore and offshore, with hydrogen storage potential, but these have not been considered for use by CO<sub>2</sub> storage.

## **20.5 Regulatory Framework**

EU Directive no. 31 of 23 April 2009 was issued and implemented in Italy with Legislative Decree no. 162 of 14 September 2011. Another amendment stating that CO<sub>2</sub> storage is not permitted in seismically active areas was also implemented.

## **20.6 Issues for the Assessment**

The saline aquifers in Italy have been widely studied. They have been considered for gas storage, hydrogen storage and CO<sub>2</sub> storage. CO<sub>2</sub> storage in saline aquifers and depleted fields has not been a priority in Italy, although many depleted fields are used for gas storage. There has been limited maturation of CO<sub>2</sub> storage resource calculations since the 2009 GeoCapacity project, with the exception of the Adriatic Sea area. Further assessment of individual sites will be required to fully evaluate the country's storage potential.

### **20.6.1 Future evaluations**

Any new evaluations of storage potential should provide site or project-specific, pressure-limited storage resource estimates to allow the identification of high-potential resources.

### **20.6.2 Future CSRC cycles**

Any new storage resource estimates should be submitted by the author for assessment and inclusion in future updates of the CSRC.

# 21 Kosovo

## 21.1 Summary

Kosovo was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Kosovo.

Table 21-1: Storage resource classification summary for Kosovo.

## 21.2 Evaluation History

Kosovo has been sparsely investigated for storage resource and there is very limited literature in the public domain. A report by the World Bank [1], reviewed the potential of a CCS industry in developing countries, of which Kosovo was part of. There were no reported storage volumes. The report did however review the challenges facing Kosovo to developing a CCS industry based on regulatory barriers, power generation integration with CCS and financing.

## 21.3 Regulatory Framework

Kosovo does not have any regulations relating to geological carbon storage.

## 21.4 Issues for the Assessment

Due the limitations Kosovo has for long term CO<sub>2</sub> storage there is a limited amount of research.

## 21.5 Future Updates

### 21.5.1 Future CRSC Cycles

Future cycles could investigate if any project is planned on cross border agreements for capture-transport-sink projects with neighboring states.

## 22 Latvia

### 22.1 Summary

Latvia was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Latvia as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.440	0.053
Undiscovered	0.112	0.000
Aggregated*	0.552	0.053

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Latvia.

Table 22-1: Storage resource classification summary for Latvia.

- Latvia has been involved in two Pan-European studies; The GeoCapacity project [1] and CO<sub>2</sub>NET East. Several studies have investigated Latvian structures in more detail and derived improved resource estimates.
- 12 potential onshore CO<sub>2</sub> storage sites and five additional offshore sites are found in the Baltic Sea near the coastline of Latvia.
- There are no projects either active or in planning. However, Latvia does have interest and activity ongoing on other areas of the CCS value chain
- Geological storage and CCS are prohibited in Latvia. Arguments set in 2011 led to its prohibition. These were revised in 2012 but continued to support the prohibition of CCS in the country.
- Latvia has a value of 32.5 on the GCCSI CCS Regulatory Indicator system, 2023.

A1) Project  
Mid-Case Storage Resource



A2) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

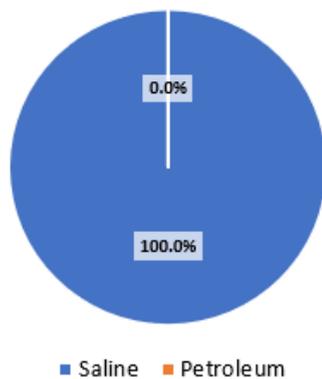


Figure 22-1: Latvian spread of Storage Sites.

A1&2) Spread of storage resource in all Latvian sites across SRMS classifications; both project specified and not. B) Split of Latvian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 22.2 Resource Statement



Figure 22-2: Storage resource summary for Latvia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 22.3 Evaluation History

Latvia has been involved in two Pan-European studies; The GeoCapacity project [1] and CO<sub>2</sub>NET East. The results identified 16 onshore traps with a theoretical resource estimate ranging from 5-74 Mt. Latvia was also involved in The BASTOR project (the Baltic Sea CO<sub>2</sub> Storage project) [1], which focuses on identifying and characterising potential sites for CO<sub>2</sub> storage in the southern Baltic Sea region and was conducted in 2014. It adopted the same methodology as the GeoCapacity project [2] for storage capacity estimates. The study did include dynamic modelling of the offshore Dalders monocline and Dalders structure. The study also identified two further offshore structures E6 and E7 as potential storage candidates.

Since then, further studies have been done in more detail on certain sites. The E6 and 7 structures were studied in more detail with respect to reservoir properties in 2013 and 2017 [3,4] but still concluded with a theoretical capacity assessment

The South Kandava and Luku-Duku [5] structures were assessed as part of an economic modelling study to investigate capture-transport and sink scenarios between Estonian and Latvian cross border projects.

The onshore Dobele structure was studied to a greater degree in 2021 [6]. Data that was derived from assessments conducted the 1987-1990 and some new additional data. The site was previously identified as potential storage for gas. This recent study found a much greater volume than previous studies done during the GeoCapacity projects due to consideration of a larger (and viable area) and a more optimistic storage efficiency (based on improved petrophysical data).

A study in 2018 [7] was also performed on the Blidine and North Blidine structures. This was part of a Masters thesis to create a conceptual model for storage and transport scenarios from Estonia to Latvia. The assessment created a static model and improved resource calculations on these structures

## 22.4 Resource Review

Of all the Baltic states that share the Baltic sedimentary basin (Estonia, Latvia & Lithuania), Latvia has been identified as having the most optimal geological conditions and suitable traps for CO<sub>2</sub> Storage. Only Lower-Middle Devonian and Cambrian stratigraphy meet the basic requirements for CO<sub>2</sub> storage. Any suitable structures or formation in Estonia are too shallow, and Lithuania has a lower number of prospective traps.

### 22.4.1 Major Projects

Since Latvia does not currently permit geological storage in its territories there are no projects either active or in planning. However, Latvia does have interest and activity ongoing on other areas of the CCS value chain.

Schwenk Latvia a cement plant, has implemented a CO<sub>2</sub> capture technology pilot project This company is also an industrial partner in the EU Horizon project GENESIS. The project aims to develop and upscale IPOSS (polyPOSSimide hybrid organic-inorganic) and MOF (Metal-organic

framework) membrane systems for CO<sub>2</sub> capture. Schwenk Latvia has also indicated that two other projects in the cement's group in Germany (a carbon capture and carbon utilisation project), if successful on an industrial scale, this may be implemented in Latvia also [7].

#### **22.4.2 Depleted Oil & Gas Fields**

Latvia undertook some research in the from 1958-1971 and 1986-1993 to investigate potential for oil and gas. From 1993 due to insufficient funds, any onshore and offshore drilling and seismic has been stopped. There are no reported resources for depleted oil and gas fields documented in the literature for Latvia.

#### **22.4.3 Saline Aquifers**

Latvia has a large part of the Baltic Syncline in its territory and includes the most promising extent of the two viable aquifers in this basin: the Lower Middle Devonian and Middle Cambrian. The lower Devonian only reaches depth suitable to storage in Lithuania. The Cambrian reservoir is composed of quartz sandstones with siltstones and shales. The thickness of the aquifer is in the range of 20–70 m. The porosity of sandstones does change significantly across the basin due variations in depth and temperature. The northern and eastern part have around 20–30% whilst this reduced to less than 5% in the central and western parts of the basin. The middle Cambrian has a thick regional seal of a 500–900 m thick Ordovician–Silurian shale.

As a consequence of the structural development of the Baltic sedimentary basin, a number of structures formed and have been identified for potential storage. These amount to 16 in total. Four have storage resources which are too low to be added to the CRSC; the Edole, Leipeja, Usam and Vergale structures.

One structure the Inčukalns, was established in 1968 for underground natural gas storage. This structure can store up to 2.3 billion m<sup>3</sup> of natural gas and is planned to be used in the future for the same purpose. This will likely complicate any consideration of this structure for CO<sub>2</sub> storage and is not entered as a resource in the CRSC due to its target use. The Dobele structure was also identified for gas storage but progression towards this has stalled [7].

Based on the seismological research and evaluation of the reservoir properties, 12 potential onshore CO<sub>2</sub> storage sites were established which are over 10 Mt: Aizpute, Dobele, Blidene, Northern Blidene, Snepelē, Southern Kandava, Degole, Luku-Duku, Kalvene, Viesatu, and Northern Kuldga. Two additional potential offshore sites were established in the Baltic Sea near the coastline of Latvia: E6 and E7. E7 has a resource too low to make the cut-off of 10 Mt. It is estimated to have a resource of 7 Mt.

Latvia also has a portion of the Baltic Sea Dalders structure and Dalders Monocline in its territory. Both have been cited as potential for offshore storage. Finally, there is likely a large area of the regional Cambrian region aquifer that could provide storage. However, both the Dalders Monocline, structure and regional Cambrian aquifer cover several states in the Baltic region. The workflow of the CRSC does not permit calculation of sites, so it is not possible to

delineate the portions of these aquifers by country and as such are not reported in Latvia as specific sites. Details of these sites are found in [2]. Regional estimates are cited as 16222 Mt for the Regional Cambrian Aquifer of which 1924 Mt are the Dalders Monocline. The Dalders structure is reported to have a storage resource of 128 Mt.

All structures carry uncertainty in terms of their properties and containment due to lack of data.

## 22.5 Regulatory Framework

Geological storage and CCS is prohibited in Latvia. Arguments set in 2011 led to its prohibition and were also revised in 2012 but continued to support the prohibition of CCS in Latvia. Arguments to support prohibition are [7]:

- Risk of leakage;
- Harm to nature and human health;
- Risk of drinking water contamination;
- A tonne of CO<sub>2</sub> leaked in the future may have a larger warming effect than now;
- Environmental costs and responsibilities in terms of time are similar to nuclear waste storage – it is undertaken by the whole society and the state, not by the private sector;
- Financial barriers;
- Technological barriers;
- CO<sub>2</sub> storage is currently prohibited in virtually all countries in the Baltic Sea region.

The issue of CCS/CCU is also briefly addressed in the National Climate and Energy Plan 2021-2030. It is worth noting, in terms of future progression towards permitting CCS in Latvia, that the National Climate and Energy Plan 2021-2030 does not envisage CCS solutions in Latvia until 2030. Latvia did amend existing legislation to implement Directive 2009/31/EC on the geological storage of carbon dioxide, although there is still a prohibition on the storage of CO<sub>2</sub> in onshore and offshore geological structures [7].

Some progress however, is a new law that is being developed called the 'Climate Law', which will also replace the current Law 'On Pollution'. The current draft plans to abolish the prohibition on the storage of CO<sub>2</sub> and encourage development of the regulatory framework. This law is still being developed and is subject to changes [7].

## 22.6 Issues for the Assessment

There is limited research in Latvia, however the research performed to date does help to define which structures may be most promising and some research has progressed to assess sites at a static and dynamic level. Any future projects in the country will help to refine assessments. Issues with assessment relate to storage efficiency – many use a high value of 40% which is likely to be overly optimistic. Additionally, there may be a vast opportunity for storage in

Cambrian aquifers which cross several Baltic states, however, estimates are not able to be calculated for these.

## **22.7 Future Updates**

### **22.7.1 Future CRSC Cycles**

Due to Latvia being identified as the most promising country in the Baltic states for storage, this country, once regulations permit storage, could be a focus for investment and an option for a regional storage hub. The lack of suitable storage sites in Lithuania and the absence of geological suitability in Estonia could mean more strategic cross-country agreements and development. Future updates should look at a change in country regulations and any corresponding updates to site investigations.

## 23 Liechtenstein

### 23.1 Summary

Liechtenstein was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Liechtenstein.

Table 23-1: Storage resource classification summary for Liechtenstein.

### 23.2 Evaluation History

There is an absence of any reported assessments on Liechtenstein for geological storage of CO<sub>2</sub>.

### 23.3 Regulatory Framework

Liechtenstein does not currently permit geological storage of CO<sub>2</sub>, neither does it have any current plans for cross border agreements for CO<sub>2</sub> transport or storage [1].

### 23.4 Issues for the Assessment

Due the prohibition Liechtenstein has for long term CO<sub>2</sub> storage there is an absence of research for any sites or other activities in the CCS value chain.

### 23.5 Future Updates

#### 23.5.1 Future CRSC Cycles

Future cycles could investigate any policy changes that may encourage any assessment.

## 24 Lithuania

### 24.1 Summary

Lithuania was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Lithuania as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.094	0.094
Undiscovered	0.147	0.147
Aggregated*	0.241	0.241

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Lithuania.

Table 24-1: Storage resource classification summary for Lithuania.

- Lithuania has been involved in two Pan-European studies; The GeoCapacity project and CO<sub>2</sub>NET East which assessed resources at a theoretical level. Recent academic studies assessed sites using dynamic simulations which significantly improved resource estimations.
- Lithuania has three saline aquifer sites with a total estimated resource of 147 Mt. There is also an oil zone that has been considered as whole rather than individual fields and this is estimated at 94 Mt. All sites have project-based evaluations.
- Geological storage of CO<sub>2</sub> prohibited in Lithuania. Although small scale projects of up to 10,000 tonnes are permitted. However, there is a policy roadmap prepared on how Lithuanian could develop CCS technologies and enable project deployment.
- Lithuania scores 36 on the GCCSI Legal and Regulatory Indicator system

A1) Project  
Mid-Case Storage Resource



A2) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

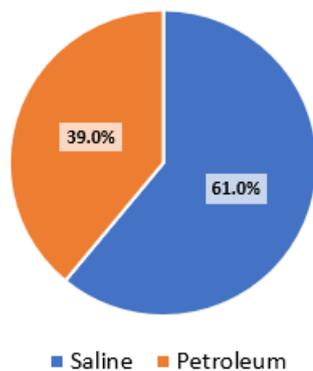


Figure 24-1: Lithuanian spread of Storage Sites.

A) Spread of storage resource in all Lithuanian sites across SRMS classifications; project specified B) Spread of storage resource in all Lithuanian sites across SRMS classifications; both project specified and not. C) Split of Lithuanian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 24.2 Resource Statement

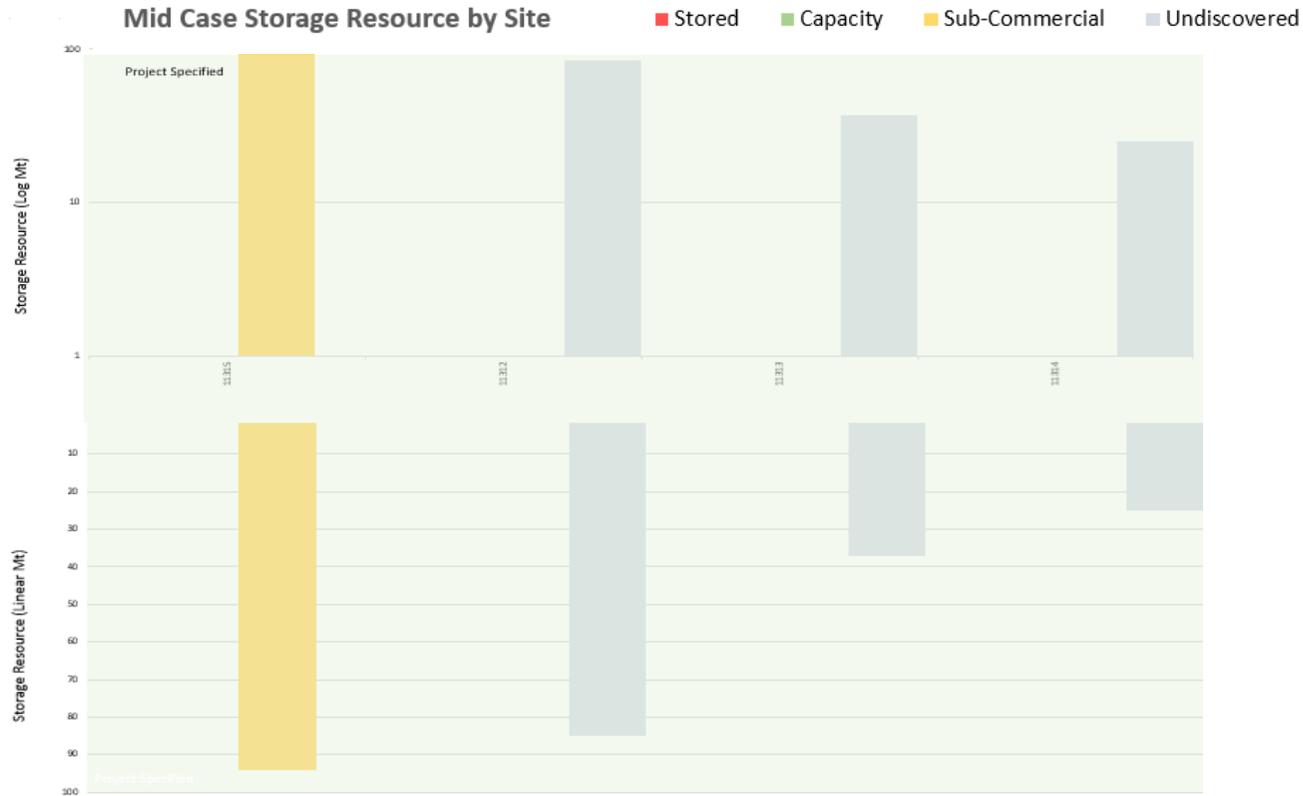


Figure 24-2: Storage resource summary for Lithuania compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 24.3 Evaluation History

Lithuania has been involved in two Pan-European studies; The GeoCapacity project [1] and CO<sub>2</sub>NET East. The results reviewed over 100 Cambrian structures, but most were deemed far too small to be economically viable for CO<sub>2</sub> storage. Only two onshore structures were identified as possible or storage; the Vaskai and Syderai and an offshore structure called D11. Oil fields were also reviewed but again all fields have little resource volume [1]. The country has been reviewed by various authors since then, with the studies and resource estimates being volumetric. Little change was made to either the number of identified structures or reported resources. Recent academic studies over the last five years have been more interrogative and focused on assessing identified structures using dynamic simulations and multi deterministic methods for both the saline aquifer aquifers and depleted oil fields [2]. This has resulted in quite significant changes to the results (See section 23.4.2 and 23.4.3).

## 24.4 Resource Review

Of the Baltic states that share the Baltic sedimentary basin (Estonia, Lithuania & Lithuania), Lithuania has been identified as having only moderate geological conditions and suitable traps for CO<sub>2</sub> storage. Only Lower-Middle Devonian and Cambrian stratigraphy meet the basic requirements for CO<sub>2</sub> storage. Lithuania is situated in the eastern part of the Baltic Sedimentary Basin. There are two main aquifers: The Cambrian saline aquifer and Middle–Lower Devonian saline aquifer. The deep saline Cambrian aquifer has basic requirements for CO<sub>2</sub> Storage and holds several structural traps. It is sealed by thick shale formations. Depth in this basin may be an issue depending on location; depths range from 0.3 km in Southeast Lithuania to more than 2 km in West Lithuania. The Middle–Lower Devonian saline aquifer is mainly located in Central and West Lithuania. However, depths exceeding 800 m and a temperature higher than 31 °C have been reported from only westernmost Lithuania and the adjacent Baltic Sea which limits this fairway for CO<sub>2</sub> storage [3].

### 24.4.1 Major Projects

Since Lithuania does not currently permit geological storage in its territories there are no projects either active or in planning. However, some companies (Klaipėdos nafta (KN), Larvik Shipping (LS), and Mitsui O.S.K. Lines (MOL) have shown interest in pre-feasibility evaluation such as a project which is involved in liquified CO<sub>2</sub> and hydrogen. The focus for CO<sub>2</sub> in this project is mainly to optimize export for storage in other parts of Europe [4].

### 24.4.2 Depleted Oil & Gas Fields

Lithuania has a hydrocarbon industry and potential for depleted oil field storage; however, all volumetric studies have revealed that the storage resource is very small. The research conducted by GeoCapacity showed that all fields have little resource volume, and in fact the total sum of all hydrocarbon fields only amounted to 7.6 Mt. However, the more recent numerical simulations performed in 2024 by Malik et al. [2], revised the Gargzdai oil zone and estimated it has a mid-range potential resource of 94 Mt based on injection over 30 years. The

oil zone as a whole was considered and assumed to be connected throughout. This approach may increase resource estimate significantly. In addition, the zone was considered to be fully sealing so caution needs to be applied to the full resource estimate in case structures have any fault or caprock weaknesses. Oil fields in this zone are likely very small and hence any project that considers using individual fields may have limited storage potential.

#### **24.4.3 Saline Aquifers**

Lithuania has two viable aquifers in the Baltic Basin: The Lower Middle Devonian and Middle Cambrian. The Cambrian reservoir is composed of quartz sandstones with siltstones and shales. The thickness of the aquifer is in the range of 40–60 m. The reservoir potential decreases towards the west due to cementation. Average porosity is around 22% in the central part of the basin which drops to around 10% in west Lithuania. The Devonian aquifer is located in Central and West Lithuanian and has an average porosity of 26% and permeability of 0.5-4D. As mentioned before, this aquifer is only at depths suitable for supercritical CO<sub>2</sub> in the westernmost area of Lithuania [3].

Three structures deemed suitable for storage have been identified. Two are onshore; the Syderiai and Vaskai structures and one offshore known as D11. They are all Lower to Middle Cambrian sandstone reservoirs. Volumetric assessments performed in the early assessment found a resource of around 21.5 Mt for Syderiai, 8.7 for Vaskai and 11.3 for D11. Syderiai is located in a favourable location close to two of the largest emitters in Lithuania: a refinery and cement factory. The most recent studies performed by [2] using numerical simulations revised the resource estimates. This assessment ignored any impact of fault fracturing and heterogeneity. Hence caution needs to be applied to considering these estimates since faulting can affect containment. After a 30-year injection simulation, mid-range values of 85 Mt for Syderiai, 25 for D11 and 37 Mt for Vaskai were found. This study has been used in the CRSC due to a greater degree of accuracy gained from dynamic simulations.

### **24.5 Regulatory Framework**

Geological storage of CO<sub>2</sub> prohibited in Lithuania. Although small scale projects of up to 10,000 tonnes are permitted. However, there is a policy roadmap prepared on how Lithuanian could develop CCS technologies and enable project deployment so future project may become legally viable [4].

### **24.6 Issues for the Assessment**

There is limited research in Lithuania, however the research done to date does help to define which structures may be most promising and some research has progressed to assess sites at a static and dynamic level. Any future projects in the country will help to refine assessments.

### **24.7 Future Updates**

#### **24.7.1 Future CRSC Cycles**

Future updates should look at a change in country regulations and any corresponding updates to site investigations.

# 25 Malta

## 25.1 Summary

Malta was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Malta.

Table 25-1: Storage resource classification summary for Malta.

## 25.2 Evaluation History

In 2021, a preliminary study was carried out to assess the potential for the geological storage of carbon dioxide in Malta (the details of which are not available in the public domain). The results highlighted geological risks and uncertainties associated with the offshore CO<sub>2</sub> storage and as such no sites were determined.

## 25.3 Resource Review

### 25.3.1 Major Projects

There are no major CO<sub>2</sub> Storage projects in Malta. However, the government's Continental Shelf Department is currently involved in assessing possible storage sites as part of an EU project (Geological Services for Europe) in response to the Net-Zero Industry Act adopted by the European Council in 2024. The aim is to provide an atlas of potential storage sites [2].

## 25.4 Regulatory Framework

The Directive 2009/31/EC on the geological storage of carbon dioxide was transposed into Maltese legislation in 2011 and then subsequently amended by Legal Notice 291 of 2015 (Geological Storage of Carbon Dioxide (Amendment) Regulations). [1]

## 25.5 Issues for the Assessment

Due the limitation Malta has for long term CO<sub>2</sub> storage there is a limited amount of research.

## **25.6 Future Updates**

### **25.6.1 Future CRSC Cycles**

Future cycles could investigate the results of any potential atlas research by the county's Continental Shelf Department.

## 26 Moldova

### 26.1 Summary

Moldova was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Moldova.

Table 26-1: Storage resource classification summary for Moldova.

### 26.2 Evaluation History

Moldova has been sparsely investigated for storage resource and there is very limited literature in the public domain. A report by the UN [1], assessed the potential of geological storage in Eastern Europe, the Caucasus and central Asia and concluded that there were not geological storage opportunities in Moldova.

### 26.3 Regulatory Framework

Moldova does not have any regulations relating to geological carbon storage.

### 26.4 Future Updates

#### 26.4.1 Future CRSC Cycles

Future cycles could investigate if any project is planned on cross border agreements for capture-transport-sink projects with neighboring states. Since Moldova has not reported that any carbon capture and storage activities will be part of its commitment to the Paris Agreement, then future domestic storage is unlikely should any sites be deemed viable for storage [2].

# 27 Montenegro

## 27.1 Summary

Montenegro was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Montenegro.

Table 27-1: Storage resource classification summary for Montenegro.

## 27.2 Evaluation History

Montenegro has been sparsely investigated for storage resource and there is very limited literature in the public domain. A report by the UN [1], assessed the potential of geological storage in Eastern Europe, the Caucasus and central Asia and concluded that there was no opportunity for this.

Furthermore, the National Inventory Document of Montenegro (2024) [2], clearly states that there are no activities in the country relating to carbon capture, transport or storage.

## 27.3 Regulatory Framework

Montenegro does not have any regulations relating to geological carbon storage.

## 27.4 Future Updates

### 27.4.1 Future CRSC Cycles

Future cycles could investigate if any project is planned on cross border agreements for capture-transport-sink projects with neighboring states.

## 28 North Macedonia

### 28.1 Summary

North Macedonia was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for North Macedonia as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.143	0.000
Aggregated*	0.143	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the North Macedonia.

Table 28-1: Storage resource classification summary for North Macedonia.

- CO<sub>2</sub> storage research in North Macedonia has been limited and driven mainly by international projects such as GeoCapacity and CO<sub>2</sub>StoP. There is no national atlas, and research has been primarily academic or part of EU-funded consortiums.
- Three saline aquifer sites in the Vardar Basin have been assessed (Ergelija, Sveti Nikole, and Veles), with a combined theoretical storage capacity of approximately 143 Mt. No depleted oil or gas fields have been considered viable.
- The main basin of interest is the Vardar Basin, while the Prilep-Bitola Basin was ruled out due to limited sedimentary thickness.
- No CO<sub>2</sub> storage projects have been initiated in North Macedonia, but the country has participated in EU-funded research and assessments.
- North Macedonia currently lacks a legal framework for CO<sub>2</sub> storage. While CCS is not explicitly permitted, the country is aligning its climate and energy policy with EU targets, signalling potential future regulatory development.
- Key challenges include moderate permeability of aquifers, lack of national research and funding, limited geological data, and no site-specific studies beyond volumetric assessments.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

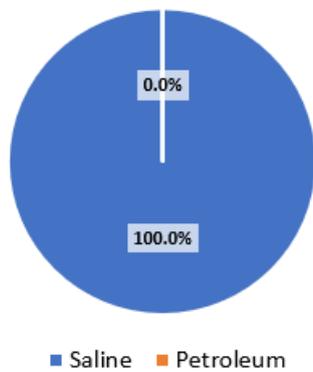


Figure 28-1: North Macedonian spread of Storage Sites.

A) Spread of storage resource in all North Macedonian sites across SRMS classifications; both project specified and not. B) Split of North Macedonian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 28.2 Resource Statement

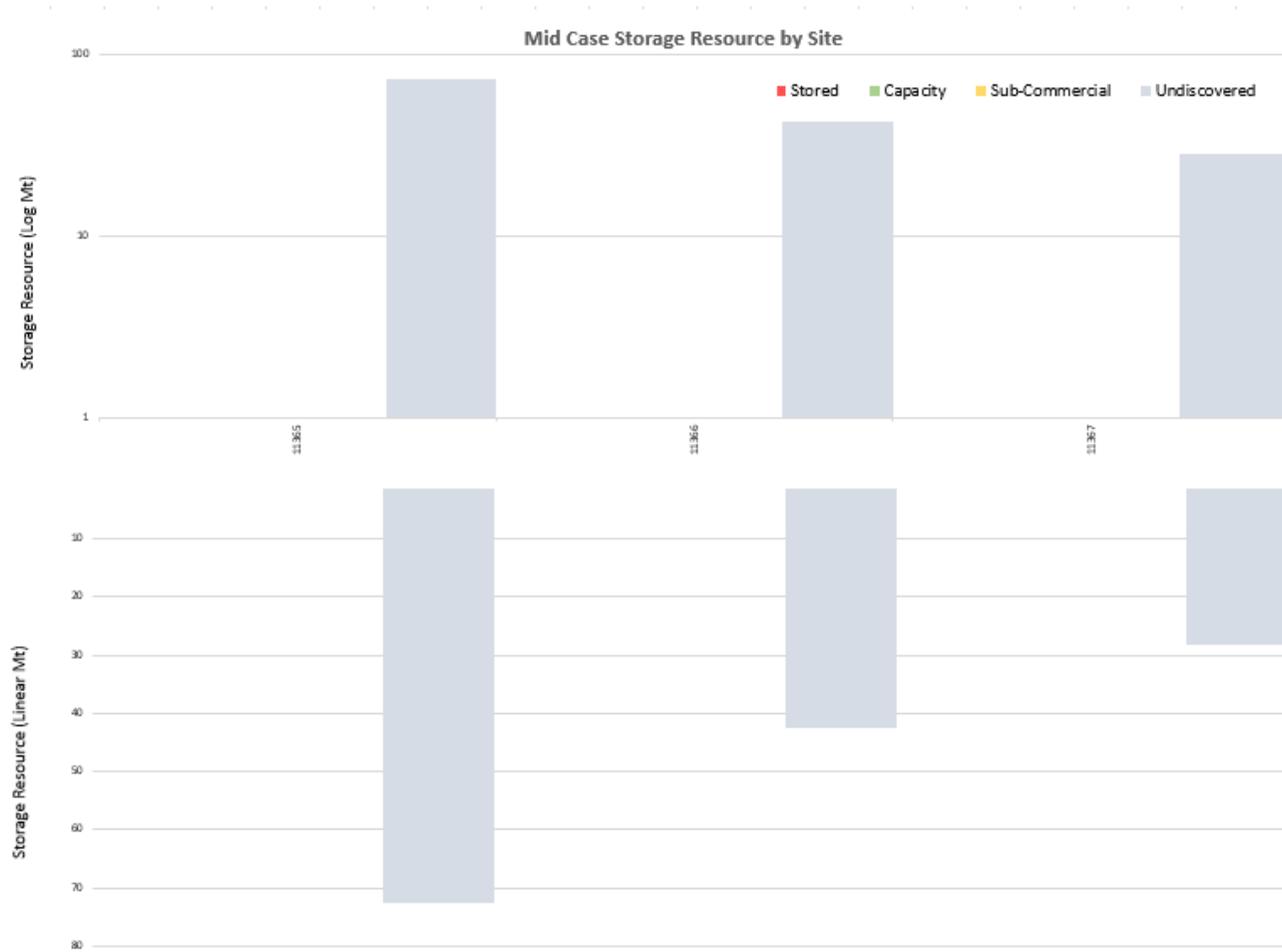


Figure 28-2: Storage resource summary for North Macedonia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 28.3 Evaluation History

Research into CO<sub>2</sub> storage in North Macedonia began in the late 2000s through international initiatives such as the GeoCapacity and CO<sub>2</sub>StoP projects. These assessments focused primarily on saline aquifers within the Vardar Basin, identifying three potential sites—Ergelija, Sveti Nikole, and Veles—with a combined theoretical storage capacity of over 140 Mt. The Prilep-Bitola Basin was also considered but found unsuitable due to limited sediment thickness. No hydrocarbon fields were assessed, as previous exploration revealed cemented and non-porous rocks. Overall, studies have been high-level and externally led, with limited national research, scarce data, and no dedicated funding. Geological complexity and the absence of a regulatory framework continue to constrain progress.

## 28.4 Resource Review

In North Macedonia, assessment of CO<sub>2</sub> storage capacities is very limited with an obvious lack of research for resource estimation. No hydrocarbon fields were assessed from the existing studies which resulted in the information that the possible reservoirs contain mostly very cemented rocks [1]. As for the aquifers, North Macedonia contains only two significant sedimentary basins. The first, the Prilep-Bitola Basin, is characterized by a limited sedimentary thickness, which significantly restricts its suitability for CO<sub>2</sub> storage. In contrast, the Vardar Basin presents more favorable conditions, with three potential aquifer sites identified for further evaluation [1].

### 28.4.1 Major Projects

There are no storage projects in North Macedonia due to the lack of regulations and a legislative framework for such activities. Major assessments of CO<sub>2</sub> storage potential in North Macedonia were carried out through internationally funded initiatives, beginning with the GeoCapacity project, completed in 2008 and supported by the European Commission [1]. North Macedonia was included in this assessment, which later served as a reference for the United Nations Economic Commission for Europe's Geologic CO<sub>2</sub> Storage Assessment [2]. Subsequently, the CO<sub>2</sub>StoP project further clarified the understanding of CO<sub>2</sub> storage potential in North Macedonia [3]. Within this framework, three aquifers located in the Vardar Basin were identified as potential sites.

### 28.4.2 Depleted Oil & Gas Fields

No depleted oil and gas fields have been identified or assessed for CO<sub>2</sub> storage in North Macedonia [2]. Geological and geophysical investigations, including deep drilling and well logging in areas such as Ovce Pole, Veles, and Tikves basins, confirmed the presence of saline water horizons and occasional gas shows but did not reveal any commercially viable hydrocarbon accumulations [1]. The reservoir rocks in these areas are predominantly cemented detrital and terrigenous deposits, further limiting their suitability for CO<sub>2</sub> storage. As a result, no sites related to depleted oil and gas fields are currently considered viable for storage.

applications.

### **28.4.3 Saline Aquifers**

North Macedonia's CO<sub>2</sub> storage potential is focused on saline aquifers within the Vardar Basin, where three specific sites (Ergelija, Sveti Nikole, and Veles) have been assessed in detail. These formations, located in Priabonian sandstones and sealed by Neogene clays, feature favorable geological characteristics including 12% porosity, 10 mD permeability, and brine salinity of 10,000 ppm [2]. The Ergelija site (200 km<sup>2</sup>) showed the highest potential with a mean storage estimate of 72.5 Mt, followed by Sveti Nikole (150 km<sup>2</sup>, 42.5 Mt) and Veles (100 km<sup>2</sup>, 28.3 Mt) [3]. All three were evaluated using a theoretical volumetric method with a 2% storage efficiency. Earlier assessments such as GeoCapacity and UNECE reported basin-wide estimates ranging from 390 Mt (1.5%) to 1,050 Mt (4%), but these lacked site-specific detail [1]. Due to the greater clarity, realistic parameters, and improved geological data provided by the CO<sub>2</sub>StoP project, the three specific sites were selected for inclusion in the database, rather than broader basin-level estimates. Although national geology is dominated by unsuitable crystalline rocks, these targeted aquifers offer promising conditions, with challenges primarily related to moderate permeability and rural surface settings.

## **28.5 Regulatory Framework**

At the time of completing Cycle 5, North Macedonia does not have a dedicated legal framework permitting CO<sub>2</sub> storage, and there are no specific regulations in place to govern CCS activities. However, the country is actively aligning its energy and climate policies with the European Union, signaling future potential for regulatory development. The Energy Development Strategy 2020–2040 outlines a complete coal phase-out by 2027 and aims for 45% of total energy production from renewables by 2040, indirectly supporting decarbonization efforts [4]. North Macedonia has also signed the Sofia Declaration on the Green Agenda, committing to a carbon-neutral continent by 2050 in line with EU objectives [4]. While CO<sub>2</sub> storage is not yet explicitly permitted, these legal and strategic developments suggest a growing readiness for future CCS implementation. To date, there are no known cross-border agreements for CO<sub>2</sub> transport or storage, but North Macedonia's engagement in EU-funded CCS projects indicates its interest in contributing to regional climate solutions.

## **28.6 Issues for the Assessment**

Assessment of CO<sub>2</sub> storage potential in North Macedonia faces significant uncertainties due to limited research activity, scarce data availability, and the absence of dedicated funding or ongoing national studies. Most evaluations to date stem from international projects, such as GeoCapacity and CO<sub>2</sub>StoP, and rely heavily on theoretical volumetric methods, and do not incorporate detailed geotechnical, regulatory, or socio-economic constraints, which could substantially reduce the practical storage capacity. Moreover, there is no established national regulatory framework for CO<sub>2</sub> storage, and site-specific studies remain minimal. Variations in reporting methodology and lack of consistent site data also affect the reliability and

comparability of estimates.

## **28.7 Future Updates**

### **28.7.1 Future CRSC Cycles**

Future CRSC cycles for North Macedonia should focus on updating assessments of the three saline aquifer sites in the Vardar Basin as more detailed geological data or national studies become available. Any future national or European study may also warrant reassessment, for potential assessment in other areas or basins that could reveal new storage opportunities. Updates will also be needed if legislative progress is made toward permitting CO<sub>2</sub> storage or if CCS-related projects are initiated under EU funding or regional cooperation.

## 29 Netherlands

### 29.1 Summary

The Netherlands was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

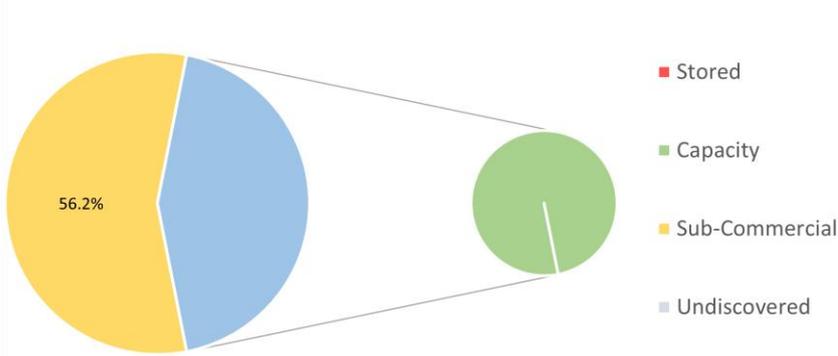
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
<b>Stored</b>	0.000	0.000
<b>Capacity</b>	0.400	0.400
<b>Sub-Commercial</b>	1.325	0.513
<b>Undiscovered</b>	1.485	0.000
<b>Aggregated*</b>	3.210	0.913

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of The Netherlands.

Table 29-1: Storage resource classification summary for The Netherlands.

- The Netherlands was an early adopter of CO<sub>2</sub> injection and storage, establishing a pilot project that injected 100,000t into the K-12B depleting gas field in 2014.
- Although there are currently no active CO<sub>2</sub> storage projects in the Netherlands, two CCS projects, Aramis and Porthos, are in the development phase.
- The Independent CO<sub>2</sub> Storage Assessment (ISA) project, commissioned in 2010, reviewed and evaluated the Dutch Continental Shelf's offshore storage potential.
- The Netherlands scored 58 in the 2023 CCS Chart of Legal and Regulatory Indicator system due to the country having specific CCS laws aligning with EU directives.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



C) Storage Resource by Type

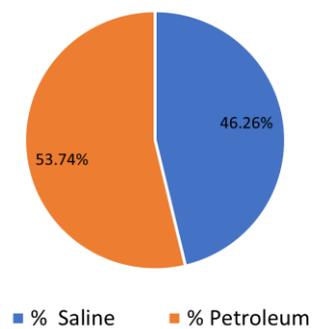


Figure 29-1: Netherlands Spread of Storage Sites.

A) Spread of storage resource in all the Netherlands sites across SRMS classifications; project specified. B) Spread of storage resource in all the Netherlands sites across SRMS classifications; both project specified and not. C) Split of the Netherlands storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 29.2 Resource Statement



Figure 29-2: Storage resource summary for the Netherlands compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 29.3 Evaluation History

While storage potential exists in both saline aquifers and depleted hydrocarbon fields, the evaluation history of the Netherlands has predominantly focused on depleted fields to utilise the offshore active hydrocarbon province in the Dutch sector of the Southern North Sea. A three-phase study – the Independent CO<sub>2</sub> Storage Assessment (ISA), was commissioned by the Rotterdam Climate Initiative in 2010 to evaluate the offshore storage potential of the Dutch North Sea. Phases 1 and 2 focused on near-shore (proximal to Rotterdam) opportunities and detailed characterisation of the highest ranked sites, including the P18 field which has been the focus of both the cancelled ROAD project and the current Porthos project. Phase 3 took a broader look at all potential geological structures in both saline aquifers and depleting hydrocarbon fields across the Dutch Continental Shelf. This study provides the widest review of the storage potential for offshore Netherlands.

## 29.4 Resource Review

### 29.4.1 Major Projects

The Netherlands has two CCS projects under development. Aramis has an estimated storage potential of 400Mt and is in joint development with Shell, Total Energies, EBN and Gasuine. The much smaller Porthos CCS project is estimated to have a storage resource of 37 Mt and is in joint development between Gasuine and EBN, which will seek to inject 2.5 Mt per annum for up to 15 years.

The Aramis project is spread across multiple offshore fields and will target storage within multiple geological intervals, namely the pre-salt Permian Rotliegendes, post-salt Triassic Buntsandstein and Cretaceous Holland Greensand. This project is an anchor project for other developments, including the Neptune Energy-led L10 CCS project, a carbon storage infrastructure project aiming to store up to 5 Mtpa, which entered FEED at the end of 2023. The Aramis project has progressed over a marked timeline. The initial phase of 2019 – 2021 saw the feasibility study and partnership formalisation signed off. Currently, the partners are progressing in phase 2, scheduled for 2022 – 2024, and will consider the design concept and CCS value chain parties' agreement. Phase 3, scheduled for 2025 – 2026, will be concerned with the FID across the value chain prior to project startup in Phase 4, which is targeted for 2028 – 2029. Beyond project start-up, the partners will then progress into phase 5, increasing resources from 7 Mtpa to 22 Mtpa. [1,2,3,4]

The Porthos project will target multiple depleted gas fields located approximately 20 Km offshore within the Dutch North Sea. The P18-2, P18-4 and P18-6 concessions are the fields of choice, with the P18-2 platform planned for CO<sub>2</sub> injection utilisation. The Porthos project has been underway since 2018, when the feasibility study was completed in April, after which the concept phase was signed off in January 2019. Early 2019 saw the FEED phase and technical development for transport and storage infrastructure being considered. Simultaneously, from

February and leading into March 2019, the expression interest companies were being negotiated and signed off. In June 2019, a memorandum on scope and detail was executed before July 2019 when the EU Commission awarded the project a 6.5 million Euros CEF subsidy for preparatory studies. From autumn 2019 to autumn 2020, joint development agreements were signed, and the EIA was completed. In February 2021, the project was awarded a 102 million Euros CEF subsidy by the EU Commission for construction works. Then, in autumn 2021, the transport and storage contracts were signed [5,6].

More recently, in September 2022, the CO<sub>2</sub> Storage permits for P18-2 and P18-4 fields were officially ratified, becoming irrevocable and thus enabling the FID to be completed in October 2023. Looking ahead, the Porthos project is scheduled to begin construction in the winter of 2023 and into 2024, with the ambition of the system going operational in 2026.

The ROAD CCS project [7] was a large integrated demonstration project to capture 1.1Mtpa CO<sub>2</sub> from a new coal-fired power station near Rotterdam. The CO<sub>2</sub> will be stored in offshore depleted gas fields attached to a single platform. Significant work was undertaken between 2009 and 2017 when the project was cancelled, including a FEED study and preparation for a final investment decision. The initial storage site was planned to be the P18-4 gas reservoir (total storage potential 8.1 Mt), and Europe's first storage permit was awarded (to TAQA) in 2013. To reduce project costs, the storage site was switched to the smaller Q16-Maas field (operated by ONE at the time; storage potential estimated at 1.9-2.3 Mt)

#### **29.4.2 Depleted Oil & Gas Fields**

Gas field storage potential (offshore sector) sits at approximately 1725 Mt. The ISA Phase 3 study [8] identified several gas field clusters as having the greatest storage potential in the offshore sector: K14/15 (165 Mt), K04/05 (140 Mt), K07/08/10 (195 Mt) and L10/K12 (175 Mt), and provided high-level indications of project risk associated with development, well integrity, and pore space availability, and an estimate of injection rates and project duration. The high potential P18 cluster of reservoirs was studied in Phase 1 but also has build-out storage potential in neighbouring fields, e.g., the P15 field at 40 Mt.

#### **29.4.3 Saline Aquifers**

Van der Meer et al. (2009) [9] studied three aquifers across the onshore and offshore Dutch North Sea. The study mapped out 41 aquifer traps (isolated or stacked with other formations) in the onshore sector and 32 traps in the offshore. A total of 438 Mt storage resource was estimated (not including gas fields in the onshore Roer Valley Graben within the Vlieland sandstone). This volume was broken down between individual aquifers as the Permian Slochteren Sandstone (337 Mt), the Triassic Bunter Sandstone (77 Mt) and the Jurassic/Lower Cretaceous Schieland Sandstone and Vlieland Sandstones (24 Mt).

Neele et al (2013) [1] also published evaluations of five sequences identified in Phase 3 of the ISA study as holding significant offshore storage potential at a combined ~1.5 Gt. The storage

resource estimates include the “Q1 - Lower Cretaceous” (110 – 225 Mt), PQ - Lower Cretaceous (360 Mt), F15 and F18 – Triassic (650 Mt), L10 and L13 – Upper Rotliegend (60 Mt), and the Step graben – Triassic (190 Mt). These values are favoured for the CRSC.

Data coverage and availability for saline aquifers are acknowledged as limiting factors for the maturation of this site type within the Netherlands. Vandeweijs et al. (2020) [10] published data on the K-12B demonstration project, where 0.09 Mt was injected and stored into the Upper Permian Slochteren Sandstone between 2004 and 2017.

## **29.5 Regulatory Framework**

The Netherlands has received a moderate evaluation under the 2023 GCCSI CCS readiness index, scoring 58.

The Ministry of Economic Affairs and Climate Policy is responsible for issuing storage permits for CO<sub>2</sub>. In 2011, the Dutch government announced it would not be engaged in any onshore storage of CO<sub>2</sub>, citing a lack of public support and instead suggesting it would target depleted gas fields offshore. This position was restated later in 2018.

The permit process for CCS storage within the Netherlands aligns with the EU strategy from which applicants can engage with the competent permitting authority. These Member States invite potential applicants to contact and engage with the authorities for information and advice. The requirements for a CO<sub>2</sub> storage permit application are set out in the Dutch Mining Act, amended in 2011 to include a transposition of the EU Storage Directive (EU Directive 2009/31/EC).

The Netherlands has issued storage permits (2021 and 2022) for the Porthos project. The Netherlands has also notified the European Commission of three storage applications for offshore areas: K14-FA from Shell International Exploration and Production B.V. and Shell Gas & Power Developments B.V., P18-6 from TAQA Offshore B.V. and EBN CCS B.V., and L04-A from TotalEnergies EP Nederland B.V.

The Netherlands is one of the only reporting countries (the other being Romania) where certain areas do not necessarily require an exploration permit to generate the information necessary for selecting storage sites. CO<sub>2</sub> storage in depleted oil or gas fields does not require new exploration activities because the existing data is considered sufficient.

## **29.6 Issues for the Assessment**

Given the generally limited static and dynamic data available for the sequences identified, storage values for saline aquifers should be considered preliminary resource estimates.

## **29.7 Future Updates**

### **29.7.1 Future evaluations**

Any updates or refinement of the ISA study should be used to improve the CSC content.

### **29.7.2 Future CSRC cycles**

As the projects are in the advanced stages of development and those recently awarded licenses publish additional data, the CSRC should be updated accordingly.

# 30 Norway

## 30.1 Summary

Norway was assessed during Cycle 1 and was updated in Cycle 2, 3, 4 and 5 to reflect continued injection of CO<sub>2</sub> in active projects. The CSRC has identified a CO<sub>2</sub> storage resource for Norway as follows:

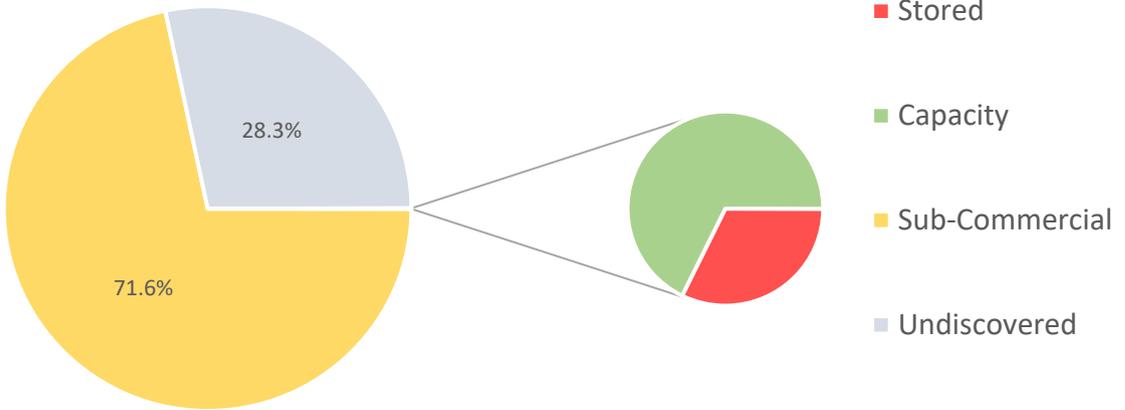
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.028	0.008
Capacity	0.084	0.017
Sub-Commercial	58.609	34.318
Undiscovered	42.197	13.561
Aggregated*	100.918	47.904

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Norway.

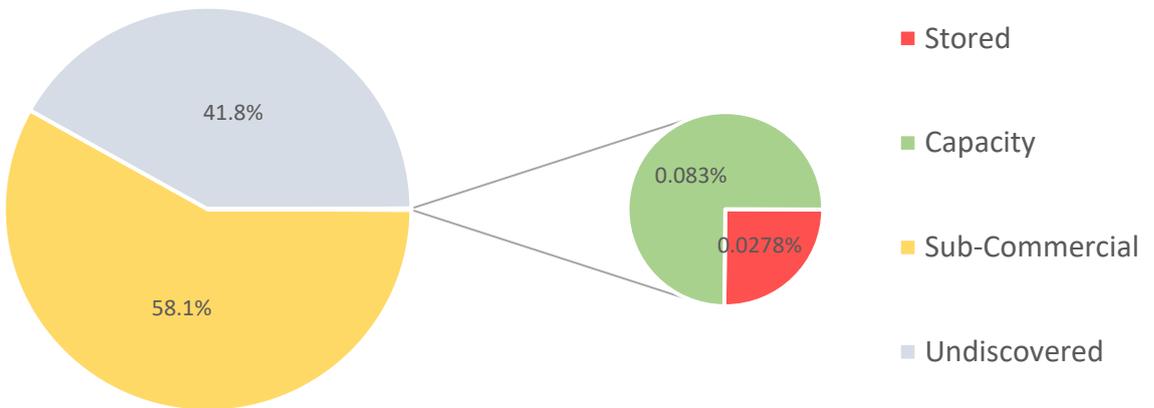
Table 30-1: Storage resource classification summary for Norway.

- There are currently a total of 51 sites at both local and regional scales located across five geological basins in the offshore sector. Most of the Norwegian storage resource is in the Norwegian North Sea.
- There is a total of 14 project-specified sites, the majority (13) of which also contain a simulation model.
- As of 2023, a total of 27 Mt of CO<sub>2</sub> has been injected into deep geological storage at Sleipner (19 Mt) and Snøhvit (8 Mt).
- Aside from Sleipner and Snovit, there are five current projects in the development stage, this being Havstjerne CCS (Wintershall DEA and Altera), the Northern Lights CCS project (Equinor, Shell, and Total Energies). Polaris CCS (Horisont, Equinor, Var Energi), Smeaheia CCS (Equinor), Trudvang CCS (Sval, Storegga and Neptune), Luna (Wintershall DEA, Total Energies and CapeOmega) and finally Poseidon (Aker BP and OMV).
- The Norwegian government has created solid foundations for a CCS market in Norway by introducing a high carbon tax for fossil fuel extraction and the GHG Emission Trading Scheme. However, gaps remain in CCS-specific legislation, according to the GCCSI Legal and Regulatory Indicator Report. Norway has a score of 61.5 within the 2023 GCCSI Chart of Legal and Regulatory Indicator [GCCSI 2023).

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



### C) Storage Resource by Type

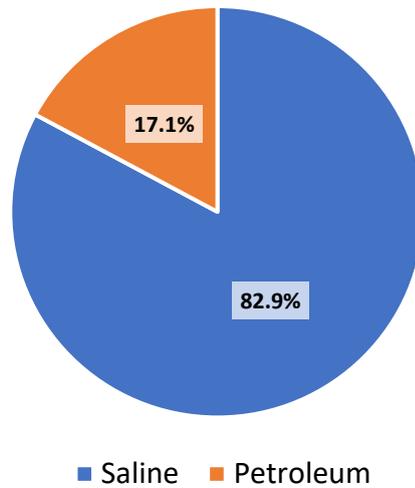


Figure 30-1: Norway Spread of Storage Sites.

A) Spread of storage resources in Norway sites across SRMS classifications; project specified.  
B) Spread of storage resources in Norway sites across SRMS classifications; both project specified and not.  
C) Split of Norway storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 30.2 Resource Statement

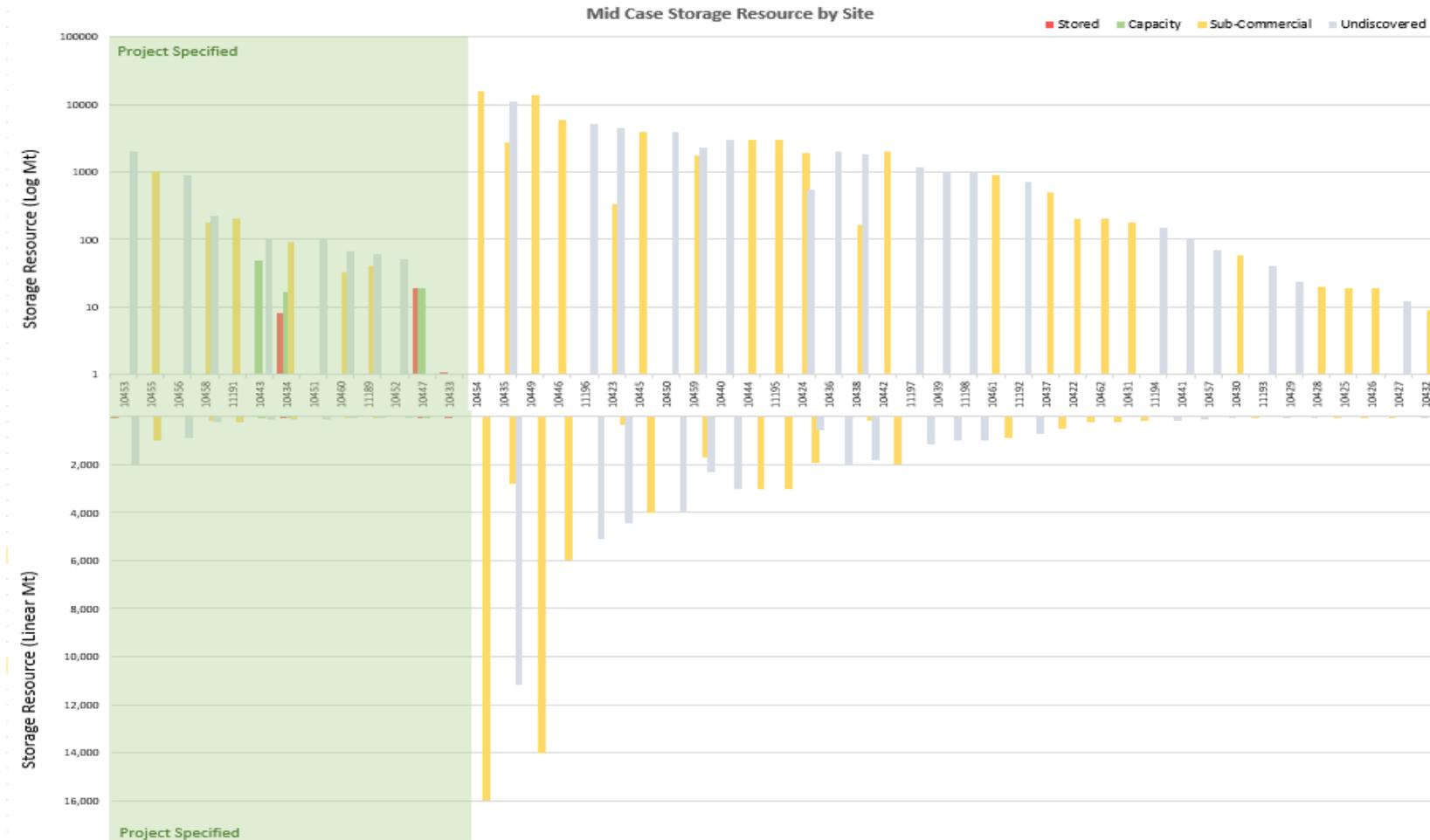


Figure 30-2: Storage resource summary for Italy compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 30.3 Evaluation History

The Norwegian CO<sub>2</sub> Storage Atlas is a key document for the evaluation of the storage resource in Norway [3]. It was prepared by the Norwegian Petroleum Directorate (NPD) at the request of the Ministry of Petroleum and Energy and formed the data source for the majority of the Norwegian sites within this assessment up to Cycle 4. The Atlas is compiled from both site-specific evaluations in published literature and regional evaluations by the NPD. It comprises three regional basin atlases: the Norwegian North Sea, the Norwegian Sea and the Barents Sea. Papers published following the release of the Atlas were included to supplement and update the Norwegian assessment.

Some additional sites were added to the database in 2024 as a result of the license rounds to award Polaris (2022), Trudvang (2023), and Smeaheia's consideration in the Northern Lights project. Additional sites are included as a result of more refined analysis from published papers by Lothe et al., 2019, and Anthonsen, 2014.

Norway has a similar overall resource character to the UK but enjoys larger areas of undrilled potential and storage resource prospectivity. It also has operational and developing CO<sub>2</sub> injection projects, which creates a spread of resources across the SPE SRMS classifications. Significant storage resources are recognised in the numerous supergiant petroleum fields within the Norwegian sector. However, as they have the potential to continue production beyond 2050, the storage resources in these petroleum provinces have been classified as discovered but inaccessible at this time. This is still the case in 2024 (Cycle 4).

In general, a volumetric method was adopted to estimate potential storage resources. A more detailed evaluation was made for a limited number of sites, sometimes including a simulation model. Where possible, the pore volume has been estimated using seismic and well data. Storage efficiency has been evaluated using a bespoke reservoir simulation model based on a reasonable development plan or sourced from a representative analogue. For hydrocarbon fields, a fluid replacement methodology was adopted.

Data availability dictates a site's maturity and the subsequent methodology to evaluate its storage potential in the Norwegian Atlas. This approach is described by the maturation pyramid, where the evaluation of a site only moves up the pyramid and becomes more mature when more data becomes available. When the site reaches a different maturity level, a different methodology will be deployed to estimate the site's storage resources.

In Norway, the vast amount of data and experience built through the petroleum industry allows some sites to be placed high up in the pyramid. The maturity pyramid methodology adopted in the Atlas is only weakly mappable to the SRMS, which uses an increase in chance of commerciality to mature a site. Furthermore, the storage resource nomenclature within the Norwegian Atlas contrasts with the SRMS. It defines "Prospectivity" as the potential to find a commercially viable CO<sub>2</sub> storage project rather than the potential to find "accessible pore

volume being suited to containment", as described in the SRMS. As a result, structures with reservoirs already proven by wells are held as "Prospects" rather than "Discoveries". Finally, in saline aquifers, the presence or absence of structures is not always clear. However, sites described as "Prospects" have been considered as structures in this assessment. No probabilistic work was reported within the Atlas.

## 30.4 Resource Review

### 30.4.1 Major Projects

In Norway, two commercial-scale CCS projects injecting CO<sub>2</sub> are Sleipner and Snøhvit. Operated by Equinor since 1996, Sleipner was the world's first offshore CCS facility. Natural gas produced at the site contains naturally occurring CO<sub>2</sub>, which is separated and stored within the Utsira Formation in the Norwegian North Sea. Sleipner has a stored CO<sub>2</sub> volume of 18.6 Mt (end-2019; P Ringrose, pers. comm; [4]) [5].

Snøhvit is an LNG facility similarly operated by Equinor but located in the Barents Sea. The natural gas produced from the Snøhvit, Albatross and Askeladd fields contains CO<sub>2</sub>, which is separated and injected into the Stø Formation. Both projects are referenced in the Atlas; however, evaluations focus primarily on additional storage potential within their respective saline aquifers. The Snøhvit project is evaluated in more detail in the Atlas; however, at the time of publication (2014), operations at Snøhvit had ceased due to an unexpected and rapid pressure build-up in the Tubaen Formation. It is reported that 1 Mt of CO<sub>2</sub> was stored during this time [3]. The asset has since been developed in the Stø Formation, which is believed to have greater hydraulic connectivity and should allow sufficient pressure dissipation.

Since Cycle 3, Norway has increased its major project list, namely due to the award of 7 licenses. Sites are added to the CRSC if injection rate and plan is published to allow calculation of anticipated full injection amount. If sites have only published injection rates then they are not included in the database since a full calculation of expected storage resource cannot be made:

1. The Aurora site (Johansen Formation) (EL001) is the storage site for the Northern Lights project. The project has been approved for Phase 1 with an injection of 1.5 Mt per year and is on target to start receiving CO<sub>2</sub> in 2024. Phase 2 anticipates expansion to 6-7 Mt/yr (<https://northernlightsccs.com>).

2. Trudvang CCS (EXL007) is in the pre-FEED stage and scheduled to start in 2029. It is anticipated to have storage of around 8-10 Mtpa and a total resource of around 200-300 Mt. The Trudvang project involves capturing CO<sub>2</sub> from several industrial emission sources in Europe and transporting it, either via ships or pipelines to the storage site (<https://trudvang-ccs.com/>).

3. The Polaris Project (EXL003) is a component of the planned Barents Blue Ammonia plant and will also provide a resource for third-party storage. German Energy Company E. ON intends

to store 1 Mt of CO<sub>2</sub> from European customers. Storage resource is currently projected at >3 Mtpa (<https://horisontenergi.no/projects/polaris/>).

4. The Smeaheia Project (EXL002) plans to provide storage for CO<sub>2</sub> transported from Northern Europe via pipelines and ships in the North Sea. Estimates project there is a resource for 30-50 Mt of storage and ~ 20Mtpa injection capacity. The license is 100% operated by Equinor.

5. Wintershall Dea has been awarded operatorship of the 'Havstjerne' CO<sub>2</sub> storage license (EXL006) and has a projected annual storage potential of up to 7 million tonnes of CO<sub>2</sub>. Transport is planned by ship from a cluster of emitters in the Baltics, Netherlands, Portugal and Spain.

6. The Luna site (EXL004) is the second license awarded to Wintershall Dea with participating interests from Total and CapeOmega Carbon Storage. Luna is estimated to have an injection capacity of 5 Mtpa. The partners plan to build a hub on the German North Sea for collection and transport up to Luna (<https://www.ogj.com/energy-transition/article/14298015/totalenergies-acquires-interest-in-luna-ccs-project>).

7. The final project to add to cycle 4 is the Poseidon Project (EXL005), awarded to Aker BP and OMV. The license is projected to potentially provide 5 Mtpa CO<sub>2</sub> storage. CO<sub>2</sub> is expected to be transported from Europe. The license holders collaborate with Hoegh LNG to transport CO<sub>2</sub> through marine CCS solutions. ([https://akerbp.com/en/borsmelding/aker-bp-and-omv-awarded-licence-for-CO<sub>2</sub>-storage-2/](https://akerbp.com/en/borsmelding/aker-bp-and-omv-awarded-licence-for-CO2-storage-2/)).

#### **30.4.2 Depleted Oil & Gas Fields**

The aggregated storage resource within hydrocarbon fields in the Norwegian sector is 17.3 Gt (1.1 Gt in the Norwegian Sea and 16 Gt in the North Sea. A smaller volume (0.2 Gt) lies in the Barents Sea; however, as no date for the cessation of production (CoP) was provided for these fields, the resource has been classified as "Discovered Inaccessible" in the CSRC Cycle 1. The fields within the Norwegian North Sea and the Norwegian Sea are either abandoned or are due to be abandoned by 2050. However, no sites in the published literature are reportedly undergoing active appraisal for CO<sub>2</sub> storage. They have been classified as "Discovered Development Not Viable". These data are all sourced from the Atlas, as no further publications were identified for depleted hydrocarbon fields in the CSRC.

#### **30.4.3 Saline Aquifers**

The storage resource for saline aquifers in Norway is spread across a range of the SRMS classifications, with aggregated storage resources: ~45.5 Gt Undiscovered, 41.5 Gt Sub-commercial, 0.083 Gt resource and 0.028 Gt Stored. The Undiscovered portion is primarily classified as "Sequence Play", with some sites classified as "Lead", where a nominal storage site was identified, or "Prospect", where a drill-ready target was present. The Capacity and Stored storage resources are from Sleipner and Snøhvit, where CO<sub>2</sub> has already been stored,

and further CO<sub>2</sub> is licensed for injection.

The storage resource is spread across a wide range of formations; however, the majority lies within the formations: Bryne and Sandnes, Utsira and Skade, and Sognefjord Delta.

Similar to the depleted hydrocarbon fields, little has been published assessing the storage resource of Norwegian aquifers since the Atlas was published. Recent work has focussed on the Utsira Formation and Garn Formation, where simulation modelling has identified optimal CO<sub>2</sub> injection locations across the regional aquifers. The additional sites entered in cycle 4 are from research that has better described and delineated specific structures in the Smeaheia area (Lothe et al. 2019). Some additional formation sites are added based on research that appears not to have been included in the NDP Atlas. These add around an extra 8000 Mt storage for saline aquifers. [1,6,7].

### **30.5 Regulatory Framework**

Norway has the highest CCS Policy-Indicator of the countries within the GCCSI Carbon Policy Indicator Report [8]. This is the result of the high level of carbon tax and the Greenhouse Gas Emission Trading Act implemented by the Norwegian government in 1991, which has facilitated the permanent storage of CO<sub>2</sub> at both Sleipner and Snøhvit [9]. The Norwegian government has also funded several R&D projects and facilities, including initiating Gassnova, a state-owned CCS enterprise, and the Technology Centre Møngstad, an R&D facility to test CCS technologies.

Norway is working to establish bilateral agreements to enable cross-border CO<sub>2</sub> transport, which it approved in 2010, to comply with the London Protocol (and amendment to Article 6 of the Protocol).

Norway scores 61.5 in the GCCSI Legal and Regulatory Indicator Report [2]. The rating shows that Norway has "CCS-specific laws or existing laws that are applicable across parts of the CCS cycle."

### **30.6 Issues for the Assessment**

There is a risk of double counting in the Utsira Formation between the regional, theoretical evaluation made in the NPD Atlas and a later study considering injection into optimal structures within the aquifer [6]. In accordance with the SRMS guidelines on aggregation of resources, double counting cannot be avoided due to the different maturity of the sites against the SRMS classification system [10]. In addition, it is difficult to establish the formations and structures in previous cycles that have become projects. There is limited information about the geology of sites in the literature and reports on projects. Future cycles must focus on sourcing more details to help define and clarify project formations and avoid double counting.

### **30.7 Future Updates**

### 30.7.1 Future CSRC cycles

It is recommended that future publications should focus on revisions and more detailed research on individual sites. If available, then dynamic simulations will make significant refinement to any theoretical estimates.

**Current stored volumes for Sleipner and Snøhvit.** The recent release of 4D seismic data and simulation models over the Sleipner field may help stimulate further research in this area.

**Published storage resource estimates for ongoing CCS projects.** Following the successful drilling of the Northern Lights injection well, updates on the storage resource of the site in the published literature would be welcome. Future updates to project progress should be included for Luna, Poseidon, Smeaheia, Polaris, Trudvang and Havstjerne.

# 31 Portugal

## 31.1 Summary

Portugal was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Portugal as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	2.506	0.011
Undiscovered	3.420	0.000
Aggregated*	5.926	0.011

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Portugal.

Table 31-1: Storage resource classification summary for Portugal.

- Portugal has been reviewed by several projects from a CCS value chain perspective: the EU FP7 Project COMET (2009-2013), Project KTEJO (2010-2011), *Roadmap for Portugal*, (2013-2015) and Horizon 2020 (2019-2022). In terms of resource evaluation Portugal has been reviewed in the CO<sub>2</sub>StoP project (2013) and by authors from the universities of Evora and Lisbon (2021 and 2024).
- There are 31 sites in Portugal with all except four in the Lusitanian basin, being offshore. There are nine in the Porto Basin, eight in the offshore Lusitanian basin and four in the onshore, four in the Alentejo and five in the Algarve. There are no depleted fields identified in Portugal.
- Portugal has transposed the EU Directive 2009/31/C for geological CO<sub>2</sub> storage under Decree-Law 60/2012, of 14th March (DL 60/2012) [7]. To date no permits for CCS activities have been given in Portugal and the country is still in an assessment phase.
- Portugal scores 40 on the GCCSI's Legal and Regulatory Indicator system.

A1) Project  
Mid-Case Storage Resource



A2) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

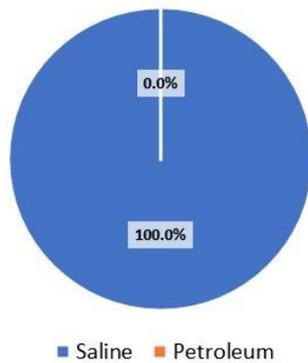


Figure 31-1: Portuguese spread of Storage Sites.

A1&2) Spread of storage resource in all Portuguese sites across SRMS classifications; both project specified and not. B) Split of Portuguese storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

### 31.2 Resource Statement



Figure 31-2: Storage resource summary for Portugal compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 31.3 Evaluation History

Portugal has been involved in several evaluations over the past decade.

The first research study on the CO<sub>2</sub> value chain in Portugal was relating to transport and storage. This study was the EU FP7 Project COMET and was conducted from 2009-2013. Its aim was to define an integrated transport and storage infrastructure for Portugal, Spain and Morocco. The project included most of the major CO<sub>2</sub> emitters in Portugal at the time of the study. It was the first integrated approach to cost-effectiveness for Portugal and in addition to considering the cost optimisation of pipelines for transport, also considered the viability of transport by ship [1]. The second project was Project KTEJO, conducted from 2010-2011. This project assessed the technical-economic viability of retrofitting the Pego coal power plant by evaluating potential geological onshore and offshore sites for CO<sub>2</sub> storage [2].

The third project was the *Roadmap for Portugal*, conducted between 2013-2015. This project was co-funded by the Global CCS Institute and investigated on the role that CCS could play in decarbonising the country's energy and industry sectors. In terms of storage, the study found that Portugal's onshore CO<sub>2</sub> storage offered the lowest cost solution, but that offshore capacity was larger and its utilisation politically more feasible [3].

The fourth project that Portugal was involved in was CO<sub>2</sub>StoP. The CO<sub>2</sub>StoP project (CO<sub>2</sub> Storage Potential in Europe - Project No. ENER/C1/154-2011-SI2.611598), made the first assessment of the European CO<sub>2</sub> storage capacity, both onshore and offshore. The project, which started in January 2012 and ended in December 2013, was funded by the European Commission. The CO<sub>2</sub>Stop project included 26 countries and 27 Partners [4].

The last project Portugal was involved in was the Horizon 2020 Coordination and Support Action STRATEGY-CCUS project which ran from 2019-2022. This project aimed to develop strategic plans for CCUS development in eight regions of Southern and Eastern Europe. One of the regions that was studied in more detail, was the Lusitanian Basin which includes about 42% of the major fixed CO<sub>2</sub> emission sources of the country. This project revisited the Horizon 2020 PilotSTRATEGY Project 7 – "CO<sub>2</sub> Geological Pilots in Strategic Territories." The PilotSTRATEGY project was a follow-up project to STRATEGY-CCUS. Its aim was to improve the characterization of potential sites for a CO<sub>2</sub> injection pilot that brings together compatible storage and transport options identified by STRATEGY-CCUS [5].

Finally, to date the most recent research is academic (from researchers at the University of Evora and Lisbon) and has focused on refining the storage sites, their volume and geological risks. These studies have provided the most comprehensive and insightful reviews on potential storage volumes and are used in the CRSC [6]. One of which started to assess some selected sites in the Lusitanian basin with more rigorous scenario analysis and numerical simulations. [8].

## 31.4 Resource Review

Portugal has both onshore and offshore CO<sub>2</sub> storage options in saline aquifers. Whilst the research has mainly been academic, there is a good insight of research on the potential sites within all Portugal's geological basin areas.

### 31.4.1 Major Projects

There are no major storage projects to date in Portugal. Portugal according to the EU directive update in 2023 [7] is still in the assessment phase regarding CCS activities and storage.

### 31.4.2 Depleted Oil & Gas Fields

There are no depleted oil and gas field option in Portugal due to an absence of a domestic hydrocarbon industry.

### 31.4.3 Saline Aquifers

Saline Aquifer options exist both onshore and offshore.

Lusitanian basin: Both onshore and offshore reservoirs are mainly characterized by siliciclastic deposits (sands and sandy-conglomeratic sediments) and capped by evaporitic intercalations. The offshore basin has eight potential storage structures. The main formation is Torres Vedras Group with porosities ranging between 15 and 40%. Overlying this formation is the Cacém Formation with values of porosities of the order of 15%. Three sites in this offshore sector have been reviewed as part of the PilotSTRATEGY project [5,8] and were taken forward for volumetric stochastic modelling by a research group in 2023 [8]. Two sites (Q6-TV2 and Q3-TV5) were previously assessed by a similar study group in 2021 [6] and proven to have ample resource (768 and 119 Mt respectively). The 2023 study downgraded these sites to significantly lower resource using the volumetric stochastic approach to 2 and 4.5 Mt respectively [8]. Those two sites now no longer make the 10Mt cut off for the CSRC. Site Q4-TVI was also downgraded in terms of resources from the 2021 studies (239 Mt) [6] and just made the CRSC cut-off with 11 Mt. The 11 Mt was a calculation solely for structurally trapped CO<sub>2</sub>. The study continued to with a numerical model for structural, dissolution and mineral trapping and calculated the Q4-TVI prospect may be over 30 Mt when considering long term trapping mechanisms. It is not clear in literature if the same areas in both studies were used for these sites. Caution should therefore be considered when reviewing this resource.

In the onshore setting of this basin, the Torres Vedras Group is a confined freshwater aquifer. This onshore sector of the formation has either been eroded or is too shallow (i.e. <800 m) for CO<sub>2</sub> storage. The second onshore formation is the Triassic Silves Group with porosities of up to 15–25% and is sealed by low-porosity sediments of the Dagorda Formation. Four sites were identified: São Mamede, Alcobça, São Pedro de Moel and Alvorninha. The sites have been identified as being potentially highly compartmentalized.

In the Porto basin there are eight sites identified in both the Torres and Silves group. The

Torres Vedras Group has porosities ranging from 20 to 40% and thickness varying from 160 m to almost 1000 m. It is sealed by the Cacém Formation which is generally less than 100 m thick and has porosities of around 10%. The Silves Group has porosities of up to 20% and thicknesses greater than 800 m. It is sealed by low-porosity sediments of the Dagorda Formation.

The Alentejo Basin has four storage sites. The most favourable locations for CO<sub>2</sub> storage are in the shallow offshore. Reservoir characteristics are described as fair to good and the thin evaporite coverage of the Dagorda units may provide a suitable seal. In addition, the overlying argillaceous sections of the Silves Group could provide an additional seal.

Finally, in the Algarve basin five sites were identified in Cretaceous and Miocene plays. There are possible reservoirs in both Early and Late Cretaceous sequences with porosities ranging from 15 to 30%. The containment of these sands could be compromised due to the overlying Paleogene formations having variable porosities and may render them a risk for containment. In addition, the Cretaceous resource may be restricted by lateral continuity. In terms of the Miocene play, these sand layers have porosities ranging from 20 to 33%, are around 250-400 thick and are overlain by extensive shale deposits from the Miocene-Pliocene.

All sites identified are over the threshold of 10 Mt, except five in the Lusitanian basin (having 2, 4, 4.5, 7, and 8 Mt) [6,8].

### **31.5 Regulatory Framework**

Portugal has transposed the EU Directive 2009/31/C for geological CO<sub>2</sub> storage under Decree-Law 60/2012, of 14th March (DL 60/2012) [7]. To date no permits for CCS activities have been given in Portugal and the country is still in an assessment phase of characterizing potential sites. The significant involvement that Portugal has had in many European CCS projects has helped to establish a good foundation for potential CCS project strategies in the country.

### **31.6 Issues for the Assessment**

The assessments used provide only theoretical resource volumes (except one site in the Lusitanian Basin). At present, despite being involved in several evaluation studies there is a lack of dynamic assessments for Portuguese storage sites, and this will affect the accuracy of resource calculations.

### **31.7 Future Updates**

#### **31.7.1 Future CRSC Cycles**

Future updates would look for any projects or site updates that may have evolved from the investigation from Strategy CCUS. Any further assessment using dynamic simulations will also be beneficial to refine the site resources in Portugal.

## 32 Poland

### 32.1 Summary

Poland assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	CO <sub>2</sub> storage resource (Gt)
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	3.696	0.000
Undiscovered	79.175	0.000
Aggregated*	82.870	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Poland.

Table 32-1: Storage resource classification summary for Poland.

- Poland has undertaken an evaluation of prospective sites for carbon storage. Most of this work has been conducted by the Polish Geological Institute and the Polish Academy of Sciences.
- The country was assessed as part of the CCS4CEE project funded by EEA and Norway grants. Poland was identified as being a potential cluster for CCS. This project ultimately led to a CCS roadmap for building momentum for long-term CCS deployment in Poland.
- CCS in Poland is limited by regulatory barriers. The key barrier is that onshore CO<sub>2</sub> Storage is not yet permitted.
- Poland has developed small-scale pilot projects and is in the process of developing larger scale projects.
- Storage potential exists in depleted oil and gas fields, saline aquifers, and coal seams. By far, the most significant storage resource is found in aquifer structures.
- The CCS4CEE project identified Poland as a potential storage hub for adjacent countries. If regulations are developed to allow onshore CCS development, Poland has significant aquifer storage potential, a strong research and development knowledge base, and few industrial and natural barriers to both storage and transportation network development.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

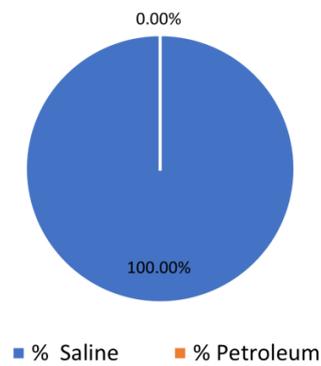


Figure 32-1: Poland Spread of Storage Sites.

A) Spread of storage resource in all Polish sites across SRMS classifications; both project specified and not. B) Split of Polish storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 32.2 Resource Statement

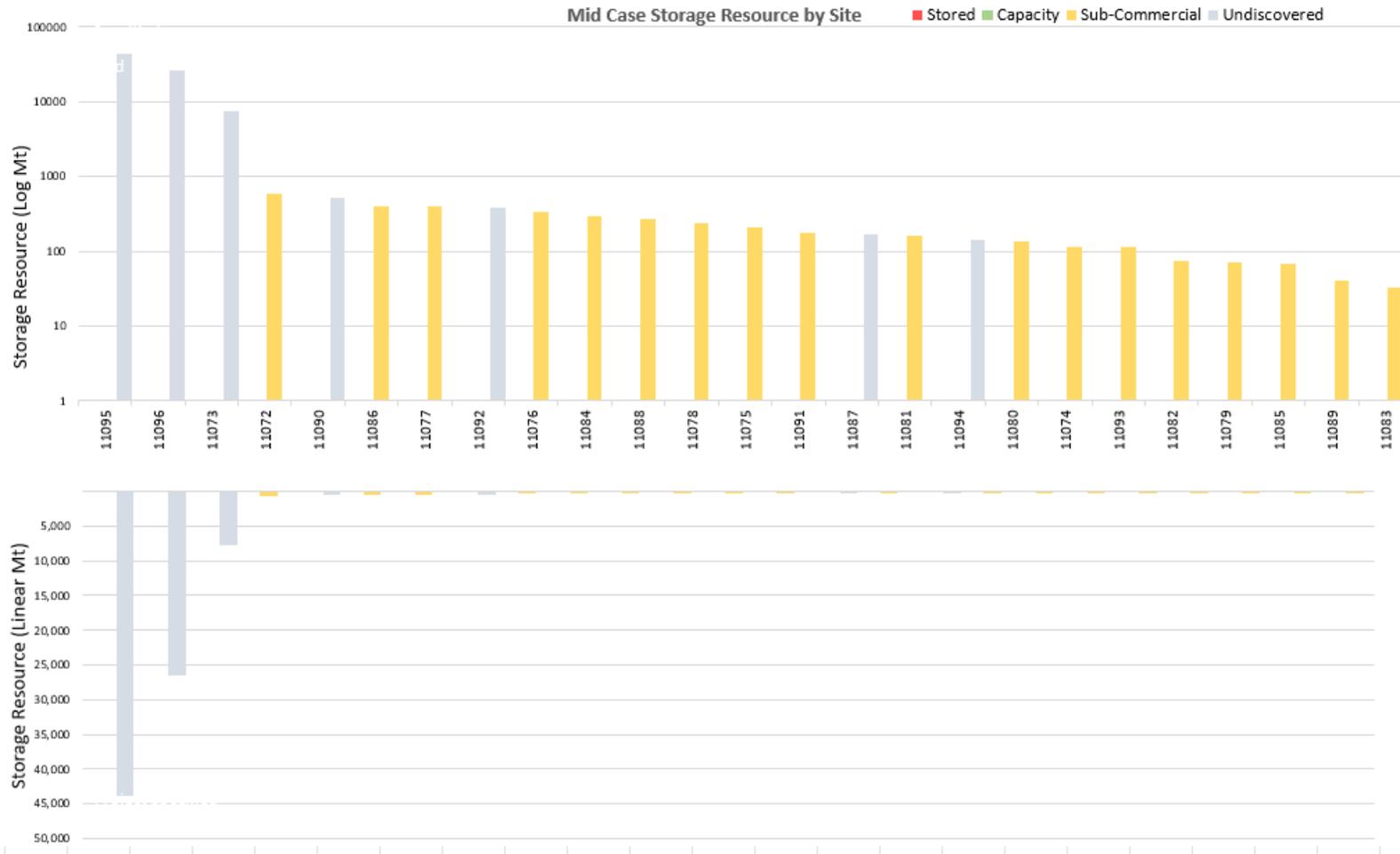


Figure 32-2: Storage resource summary for Poland compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 32.3 Evaluation History

### Polish Geological Society

From 2008 to 2012, the Ministry of the Environment launched a national program, "Identification of Formations and Structures for Safe Geological Storage of CO<sub>2</sub>, together with their Monitoring Program", conducted by the Polish Geological Institute [1]. The aim was to identify storage opportunities that meet the feasibility, safety and environmental impact requirements specified in the draft "EU Directive on the geological storage of carbon dioxide". This detailed and comprehensive project covered detailed geological characterisation of potential sites, simulation modelling for CO<sub>2</sub> injections, risk assessment and development of monitoring programs. The study's outcome was the creation of an interactive atlas and database for potential CO<sub>2</sub> storage sites. A total of 45 aquifer structures with storage potential were identified across 8 regions. Four detailed case studies were also performed on selected aquifers. Numerous wells penetrate the formations where the aquifers reside and were used to provide insight into aquifer quality in the study. Both volumetric and dissolved storage potential were reported in the study. The study also identified 38 oil and gas fields for potential storage, although only 14 exceed the CSRC minimum threshold of 10Mt of storage resource. Unfortunately, permission to use this data in the CSRC was not provided during Cycle 4. Therefore, the values reported in the CRSC are from other sources in the public domain. The report is, however, accessible in the public domain, and references are provided so interested parties can access the additional information.

### CCS4CEE

Poland was part of the CCS4CEE [2] project funded by the EEA and Norway grants. The project aimed to renew the discussions on the long-term deployment of CCS in the CEE (Central and Eastern Europe) countries and assess the potential for CCS in terms of transport, geological storage, regulations, knowledge, and government support. Poland was identified as a potential CO<sub>2</sub> Storage hub for neighbouring countries due to its significant storage potential, estimated between 10.1 and 15.5Gt and comparatively much lower annual emission levels, which allows it to have spare resources.

Poland was also part of CO<sub>2</sub>StoP [3], GeoCapacity [4], and GESTCO. GeoCapacity provided resource estimates in Mesozoic aquifers at the regional scale (Lower Cretaceous – 7,647 Mt, Lower Jurassic – 43,826 Mt, Lower Triassic – 26,494 Mt) and for selected 18 geological structures (3,522Mt). Storage resources were calculated for Polish hydrocarbon fields using a 1:1 volumetric replacement of hydrocarbons with supercritical CO<sub>2</sub>, estimated at 764.32 Mt.

## 32.4 Resource Review

### 32.4.1 Major Projects

No major storage projects exist in Poland. However, despite regulatory challenges, Poland has continued to conduct research and develop projects along the full CCS value chain, thereby

developing technological expertise. Finished projects include research and development projects by Polish research institutes, two much larger scale CCS projects that were abandoned in 2011 and 2013, and a pilot project conducted for carbon capture from coal-fired plants and CO<sub>2</sub> Methanation by Tauron Polska Energia S.A. Ongoing projects included a capture and storage project in the Borzeccin gas reservoir managed by the Polish Oil Mining and Gas Extraction and a capture and utilisation project designed by IchPW for CIECH Soda Polska. Planned projects include CCS applied to the CHOP station in Przemyśl and the Poland EU CCS interconnector project [5].

#### **32.4.2 Depleted Oil & Gas Fields**

The Polish Geological Survey assessed 38 depleted hydrocarbon fields. Due to permissions restrictions on the use of the publications that these fields are reported in it has not been possible to include each individual field in the CRSC. There they are summarized below. These fields are situated in two major petroleum provinces: the Carpathian overthrust and the Carpathian Foredeep, with target storage formations in Neogene, Miocene, and Cretaceous formations, and Western Poland, where the predominant fields are Permian Zechstein—Rotliegend fields. Storage potential has been assessed to be in the range of 784-1021 Mt.

Storage resource was calculated using the approach of the FP5 GESTCO project, which was based on the assumption of 1:1 volumetric replacement of extracted hydrocarbons with supercritical CO<sub>2</sub>. Such an approach refers to effective resources, albeit a very preliminary one.

In the southeastern part of the Carpathians and Carpathians Foredeep, 12 gas fields were considered, resulting in storage resources ranging from 4.1Mt (Uszkowce Field) to 244.57Mt (Przemyśl Field). The GeoCapacity project refers to the total storage in this region of 421Mt, which is mainly found in Paleocene and Miocene formations.

In Western Poland (in the basement of the Polish Lowland), 13 Permian gas fields were estimated to carry a total storage resource of 240Mt, ranging from 2.41Mt (Gorzyslaw) to 92Mt (Zuchlow).

The offshore region in the Baltic Depression has only minor potential.

#### **32.4.3 Saline Aquifers**

The Polish Geological Study applied methodology used by the FP6 EU GeoCapacity Project combined with the parameters outlined in the CO<sub>2</sub> STORE Project (Chadwick et al., 2008). They provide a volumetric and dissolved storage resource that can be accessed in the publication. Sites were assessed in Mesozoic, Miocene, Carboniferous, Permian saline aquifers, and the Carpathian Front (Basement). Four sites were selected for more detailed injection simulations: Budziszewice-Zaosie (Bełchatów), Skórczow-Czechowice (USB), Choszczno-Suliszewo (NW Poland), Poznań trough (Greater Poland).

---

The German-Polish Lowlands basin (Permo-Mesozoic European Platform) has the following

saline aquifer sites:

- Lower Cretaceous Barremian-Albian sandstones and carbonate sandstones are intercalated with low permeable siltstone and mudstone. The formation outcrops at the surface and then descends to depths of over 2800 m in the basin centre. At the basin's centre, sediment thickness can reach 500m.
- Lower Jurassic resources include Toarcian and Upper Pleinesbachian aquifers. The upper Toarcian (Borucice beds of the lower Aalenian Sandstone present one of the better aquifers and are sealed by Upper Aalenian claystone-mudstone. The second, deeper aquifer is related to Upper Pliensbachian (Slawecin Serie) and is sealed by Lower Toarcian claystone-mudstone. This aquifer is found at the surface through to depths of 3900m at the basin centre.
- Lower Triassic resources are found in the middle Buntersandstein sediments, which are sealed by the Roethian clastic-carbonate-evaporitic sequences. Suitable units for storage are found at depths of 1500 - 5300m in the basin centre to several hundred meters at the basin margins.

Within the Polish Lowland area, several anticlines have been identified as sites for potential CO<sub>2</sub> storage. The largest structure (Bodzanov) has an estimated resource of 575.5Mt, while the smallest structure (Chabowo-T) has an estimated resource of 69.3Mt. These structures have Lower Cretaceous, Lower Jurassic, and Lower-Upper Triassic formations. Significant potential may be found in some of these structures.

To summarize, 25 structures have been identified in the Polish Lowlands and all have been drilled to some extent.

### **Coal Fields**

Although the CSRC does not include non-conventional storage estimates, Poland does have significant potential in its coal beds. In addition to saline aquifers and depleted hydrocarbon fields, there is also theoretical storage of methane in the Upper Silesian Coal Basin. A total storage of 1254 Mt is estimated. A further 27 coal fields were selected for assessment, mainly in the southern part of the basin. These are 1-2 km deep and demonstrate a good seal in the overburden. For these fields, a total CO<sub>2</sub> storage resource of 414.6Mt is estimated.

## **32.5 Regulatory Framework**

Poland has been identified as having a CCS readiness index of 45 by the GCCSI. As part of the EU, Poland has a committed NDC (Nationally Determined Contributions) to remove 3,278 Kt of CO<sub>2</sub> equivalent from 2026-2029 and reduce emissions by 17.7% by 2030. The most significant regulatory barrier for Poland's potential CCS industry is that onshore CO<sub>2</sub> storage is prohibited. There is hope that future amendments will address these issues. However, other limitations

are high financial security, a state that does not provide any support scheme for CCS or having CCS and climate strategies high up the agenda. These factors will restrict the development of CO<sub>2</sub> storage sites to only the largest corporate organisations. Poland is considering export options for CO<sub>2</sub> to the North Sea and being part of the EU CC Interconnector project, ECO<sub>2</sub>CEE, to transport CO<sub>2</sub> to Lithuania. The CCS4CEE project identified limited natural and infrastructure barriers to CO<sub>2</sub> storage and CCS technology development.

Several changes to CCS technology in Poland happened during 2021/2022, including law amendments, future project announcements, research, and the creation of the Minister of Climate and Environment. The reports from the CCS4CEE project detail these changes, comprehensive road maps, and recommendations for enabling future deployment of CCS projects in Poland [2].

## **32.6 Issues for the Assessment**

Although the detailed Polish Geological Society report thoroughly evaluates the storage potential in saline aquifers and depleted hydrocarbon fields, only a few project-based flow models exist. Permission to include this data was requested during Cycle 4, but no response was received. The historic lack of government momentum for CCS has limited further research. Most sites are assessed at volumetric storage resources.

## **32.7 Future Updates**

### **32.7.1 Future evaluations**

Published evaluations for the sites currently active in Poland would be welcome for future updates to the CSRC. If Poland's regulations change, more projects may commence, allowing better insight into the potential future of the CCS industry in the country.

### **32.7.2 Future CSRC cycles**

Future update cycles will need to focus on any projects being developed and the associated storage sites that include them. Any changes in CCS regulations will need to be reviewed to assess how they may change the face of Poland's CCS industry.

## 33 Romania

### 33.1 Summary

Romania was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
<b>Stored</b>	0.000	0.000
<b>Capacity</b>	0.000	0.000
<b>Sub-Commercial</b>	0.425	0.000
<b>Undiscovered</b>	18.000	0.000
<b>Aggregated*</b>	18.425	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Romania.

Table 33-1: Storage resource classification summary for Romania.

- Published databases of CO<sub>2</sub> storage potential in Romania indicate significant storage resources are present in saline aquifers and depleted hydrocarbon fields.
- Storage in saline aquifers is predominantly in onshore formations, with limited storage identified in the offshore sector.
- Both depleted oil (seven fields) and gas (seven fields) fields have been identified as having storage potential. Some of these, for example, the Copsa Mica depleted gas field, are significant storage resources at 100Mt.
- The Getica CCS project, a demonstration project planned to decarbonise a lignite coal-fired power station with storage in local saline aquifers, was proposed in 2011 to capture and store 1.5Mtpa CO<sub>2</sub>. The project was put on hold due to a lack of funding for capture FEED and storage appraisal studies and has not been re-started.
- CO<sub>2</sub> storage follows the EU approach to CO<sub>2</sub> storage, having transposed the EU CCS Directive; however, the national legislation for CCS in Romania remains somewhat fragmented.

A) Project and Non-Project Mid-Case Storage Resource



B) Storage Resource by Type

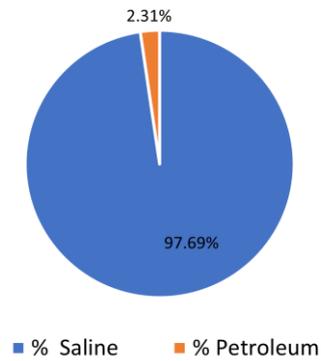


Figure 33-1: Romania Spread of Storage Sites.

A) Spread of storage resource in all Romania sites across SRMS classifications; both project specified and not. B) Split of Polish storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

### 33.2 Resource Statement

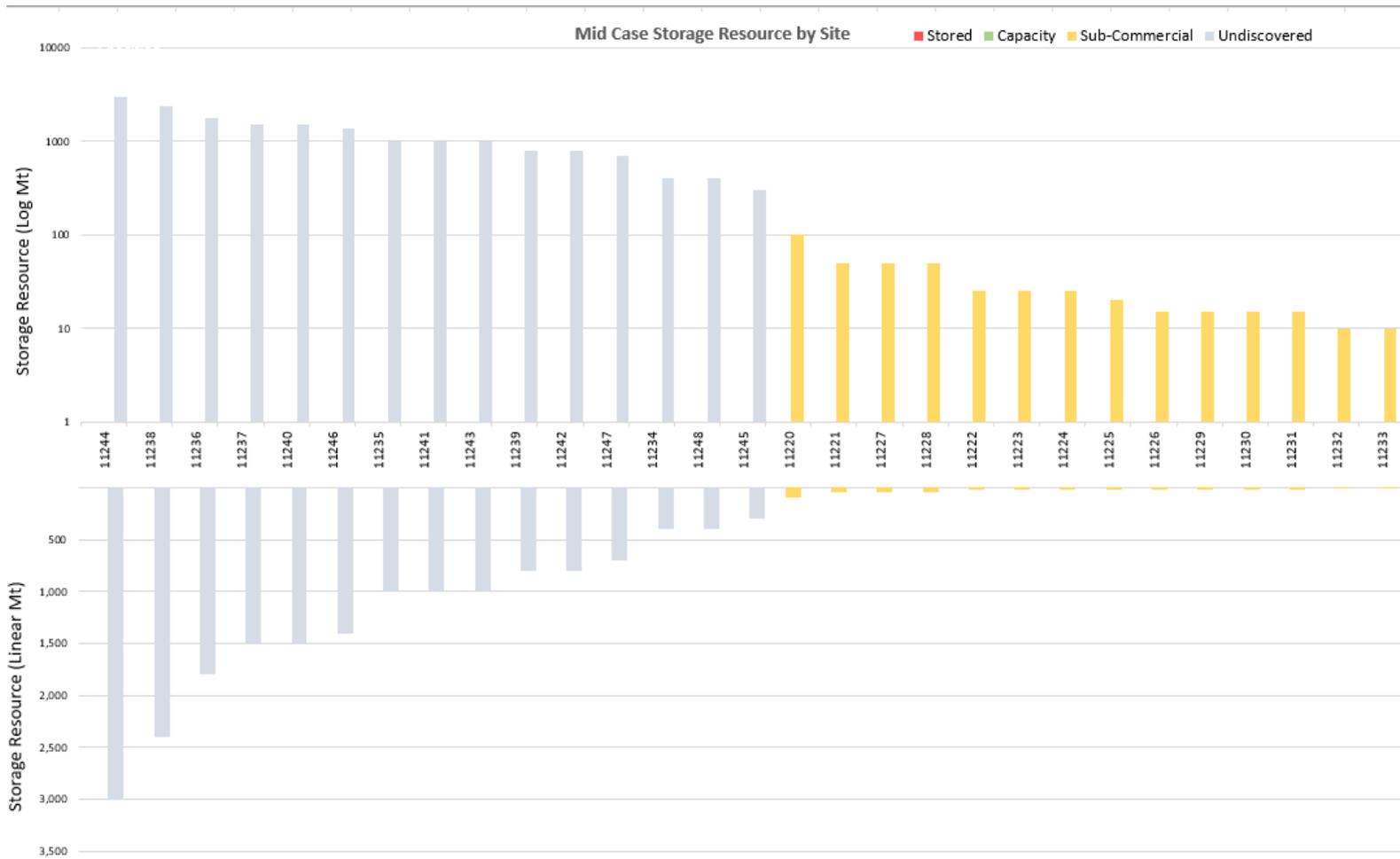


Figure 33-2: Storage resource summary for Romania compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 33.3 Evaluation History

CO<sub>2</sub> storage potential in Romania was evaluated by the EU GeoCapacity project (2009) [1], and this remained the dominant source of storage estimates until a second EU Commission-funded project, 'Assessment of CO<sub>2</sub> storage potential in Europe' [2], was published. This project covered storage potential in 27 countries, including Romania. Project products include a detailed report and accompanying storage resource database. However, the data from EU GeoCapacity was re-used for sites in Romania in all but a single case due to a lack of available subsurface data to refine the storage estimates. The data presented by CO<sub>2</sub>SToP have been utilised for the CSRC in preference to the EU GeoCapacity project reports as a more detailed report on the technical approach is provided and storage resource estimates for individual storage sites are reported.

The EU GeoCapacity project identified Romania as having high storage potential in saline aquifers (up to 1900 Gt) and high (up to 4 Gt) potential in depleted hydrocarbon fields. The CO<sub>2</sub>SToP database downgraded these storage estimates, with the storage resource within hydrocarbon fields decreasing to 514 Mt, with an even split between depleted oil and gas fields.

Mapping of emitters and storage opportunities for the Federatia Patronala Petrol si Gaze (FFPG; 2022) identified six main areas of interest: Gorj, Dolj, Galati-Buzau, Prahova, Mures, and Valcea but also utilised EU GeoCapacity storage resource figures with no additional refinement.

The EU-funded 'Strategy CC(U)S' project (2019-2022) evaluated Romania as part of the effort to develop low-carbon energy and industry in Southern and Eastern Europe. The Galati region in eastern Romania was selected as a potential CCS cluster development, matching one of the largest industrial emitter clusters (emissions over 121.5Mtpa from 42 major industrial installations) with unnamed depleted hydrocarbon fields (offshore and onshore) and saline aquifers.

The Rex-CO<sub>2</sub> [3] consortium project also focused on the Salonta, Oltenia, depleted gas field as an example of a 'typical' depleted field in the region. No CCS project has been associated with the Salonta field, but it provides a case study for potential well re-use.

### 33.4 Resource Review

The reported storage resources are located within saline aquifers and depleted hydrocarbon fields.

The CO<sub>2</sub>SToP project applied a methodology in which storage units were mapped at the reservoir formation level. To qualify as a storage unit, the formation had to be part of a formation present at depths >800m and have an effective caprock. At the sequence level, storage units are saline aquifers considered to have potential for CO<sub>2</sub> storage but may also contain one or more 'daughter units', which are defined as structural or stratigraphic traps or

oil and gas fields.

Note: different volumetric storage estimation methods were used for each storage type (unit, daughter structural/stratigraphic unit, depleted field):

- Storage units: A pore volume-based approach using CO<sub>2</sub> density at anticipated reservoir conditions and a selected storage efficiency factor. The daughter unit pore volume is subtracted before the mass of CO<sub>2</sub> is calculated.
- Structural and stratigraphic traps: A probabilistic estimate of storage in all daughter units was calculated using either the volumetric (with storage efficiency) approach or a pressure capacity approach (where data are available), whereby the maximum allowable pressure increase and rock/fluid compressibility are applied.
- Depleted fields: storage potential is based on a reserves replacement approach using the Ultimately Recoverable Reserves (URR). The URR is divided by either the oil or gas formation factor and translated to CO<sub>2</sub> mass using the anticipated CO<sub>2</sub> density at reservoir conditions.

#### **33.4.1 Major Projects**

Since the failure of the Getica CCS Demonstration project (see below), there have been no further developments in the country. As such, no publicly announced major projects are currently under development, but this should be reviewed in the future.

#### **33.4.2 Depleted Oil & Gas Fields**

Romania has had an active hydrocarbon industry for over a century (FPPG, 2022), resulting in existing infrastructure (pipelines, wells) and expertise in developing large-scale surface-subsurface projects. The total storage resource in depleted fields is estimated to be 514 Mt, with an even split of 246.78 Mt in oil fields and 267.56 Mt in gas fields (EU CO<sub>2</sub> Storage Potential database) [2]. However, not all fields included in this estimate meet the 10Mt threshold for the CSRC. The CSRC database's data are derived from the original EU GeoCapacity study, as no follow-up studies (e.g., CO<sub>2</sub>StoP) were able to access sufficient data to update the storage resource estimates.

Seven gas fields (out of nine named fields) have been identified as carrying greater or equal to the threshold 10 Mt storage resource estimate, the largest being the Copsa Mica field (100 Mt), the Ghergheasa field (50 Mt) and the Targu Mures Dome, Sangeorgiu de Padure, the Stramba-Rogojelu fields (all at 25 Mt). Seven (7) oilfields (out of 22 named fields) also qualify for inclusion in the CSRS, although these are slightly smaller. The largest are the Baeni and Bibesti-Bulbuceni oil fields, with a 50 Mt estimated storage resource.

#### **33.4.3 Saline Aquifers**

Most of Romania's storage resources are in onshore saline aquifers, with Gigatonne-scale storage predicted. Published figures for offshore resources suggest limited opportunity, with

three Albian-age clastic aquifers identified (Strategy CCUS, 2020) estimated to hold a combined 17Mt storage resource, but individually, none exceed 7Mt.

At the time of Cycle 4, only data at the sequence level (utilising the CO<sub>2</sub>StoP storage unit resources) were available for saline aquifers. No individual structural or stratigraphic traps (daughter units) were identified.

#### **33.4.4 Demonstration and Pilot Projects**

The Getica CCS Demonstration project, decarbonising a lignite coal-fired power station with storage in local saline aquifers, was proposed in 2011 and was able to align public and private support while also encouraging the development of a legislative framework for CCS in Romania. This was due to be the first integrated CCS project in the country. The project was due to be operational by 2015/16 with a project lifespan of 14 years. Up to 1.5Mtpa CO<sub>2</sub> was to be captured from the Turceni plant Unit 6 through retrofit of a capture unit. The project was eventually put on hold due to a lack of funding for capture FEED and storage appraisal studies and, to date, has not been re-started.

### **33.5 Regulatory Framework**

Romania has transposed the EU CCS Directive via Government Emergency Ordinance (GEO) 64/2011, Art.22. This gave CCS Regulation implementation authority to the National Regulatory Authority for Energy (ANRE) and the National Agency for Mineral Resources (ANRAM). However, according to a recent study for FFPG by PwC and EPG Consulting in 2022 (FFPG, 2022) [4], the national legislation for CCS in Romania remains rather fragmented.

### **33.6 Issues for the Assessment**

A key issue for the assessment of storage potential in Romania was the limited information in the public domain. While the potential resources have been reviewed over the past 15 years, the published estimates have not been updated since 2009. Given the basin and sequence level scale and volumetric storage resource methodology, they are almost certainly an overestimation.

### **33.7 Future Updates**

#### **33.7.1 Future evaluations**

Future storage evaluations should focus on accessing and utilising subsurface data to enable identification and delineation of storage sites. Storage resource estimates must be based on site-specific geo-models and flow modelling using a pressure-limited approach to derive a more realistic range of values.

#### **33.7.2 Future CSRC cycles**

If additional site evaluations are performed, these should be submitted to the OGCI CSRC for inclusion in the database. All future submissions should provide storage estimates derived from appropriate dynamic approaches.

# 34 San Marino

## 34.1 Summary

San Marino was assessed during Cycle 5. This country is reported as having no geological storage potential.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.000	0.000
Aggregated*	0.000	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of San Marino.

Table 34-1: Storage resource classification summary for San Marino.

## 34.2 Evaluation History

There are no published reports that San Marino has areas suitable for geological storage of CO<sub>2</sub>. Neither are there any reports of any future intention for San Marino to investigate geological CO<sub>2</sub> storage. San Marino is a small (61km Sq), landlocked country in the Apennine Mountain range and therefore unlikely to have significant potential for domestic geological storage

## 34.3 Regulatory Framework

There is no reported regulatory framework for geological storage of CO<sub>2</sub> in San Marino.

## 34.4 Future Updates

### 34.4.1 Future CRSC Cycles

Due to the countries size, lack of industry absence of suitable geology San Marino will not need updates in the future.

# 35 Serbia

## 35.1 Summary

Serbia was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Serbia as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.110	0.000
Undiscovered	0.250	0.000
Aggregated*	0.360	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Serbia.

Table 35-1: Storage resource classification summary for Serbia.

- Serbia was reviewed for CO<sub>2</sub> storage resources in the pan-European study, CO<sub>2</sub>STOP and the by a small number of researchers. There is limited literature in the public domain and any resource reported is a theoretical volumetric estimate.
- There is an active hydrocarbon industry in Serbia and its depleted oil and gas fields have been identified as potential candidates for CO<sub>2</sub> storage. Very little information is available on saline aquifers, although they are acknowledged as a potential storage option and one resource value for the whole country is provided.
- All reported depleted oil and gas storage options are in the Pannonian Basin in the north of the country. Saline aquifers may also exist in this basin and in the Dinarides and Vardar Zone although no resources are published for these areas.
- Although there is no dedicated operational storage project in Serbia, the country does have projects being undertaken relating to CO<sub>2</sub> capture and preliminary investigations into a capture and storage project to produce blue hydrogen.
- The main principles and priorities identified in the Directive 2009/31/EC are partially transposed through the Law on Mining and Geological Research.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

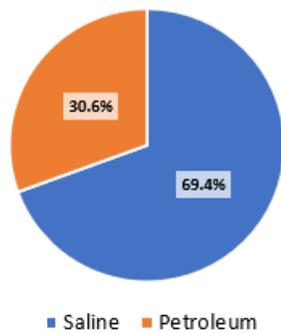


Figure 35-1: Serbian spread of Storage Sites.

A) Spread of storage resource in all Serbian sites across SRMS classifications; both project specified and not. B) Split of Serbian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 35.2 Resource Statement

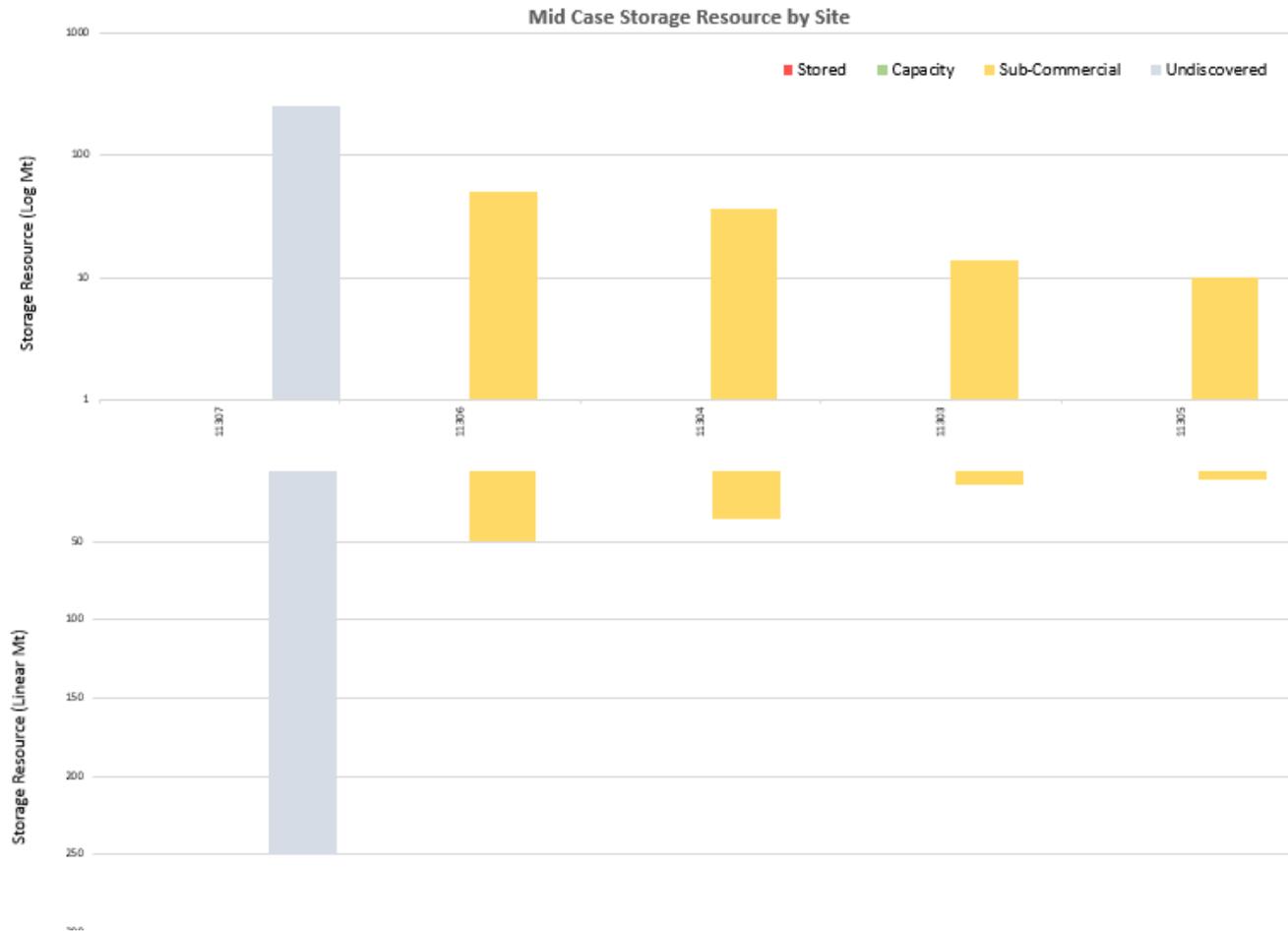


Figure 35-2: Storage resource summary for Serbia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 35.3 Evaluation History

There is very little research on CO<sub>2</sub> storage in Serbia. The country did participate in CO<sub>2</sub>STOP but did not provide any data on storage sites or resource estimates. The Scientific and Technological Centre NIS-Naftgas (NIS = Naftna Industrija Srbije), has been assessing the potential for long term storage in Serbia and primality looking at oil and gas fields in the Pannonian Basin. This research has been published in a handful of papers [1,2,3].

The research on Serbian oil and gas fields was performed pre-2019 and the detail of the assessments are uncertain but did provide theoretical capacity estimates [1]. Despite limited research in the public domain Serbia has plans for a CO<sub>2</sub> storage project relating to blue hydrogen production at the Panchevo oil refinery. In addition, Serbia does have projects dealing with CO<sub>2</sub> EOR (see Major Projects section 34.4.1) [1,2]. There may well be some more extensive research being performed within the country, but this is not yet available in the public domain.

Research on saline aquifers is very limited, and the presentation results of a study performed in 2007 from the Geophysical Institute, NIS-Naftgas is found to show localities of potential saline aquifer storage. No resource volume is reported, however [4]. The oil and gas fields in Serbia have a high natural CO<sub>2</sub> content.

### 35.4 Resource Review

Based on the available literature, Serbia's main CO<sub>2</sub> storage potential is in its depleted oil and gas fields located in the north of the country. This is also where the most data is available for assessing any storage site potential. Very limited research and studies exist for saline basins.

#### 35.4.1 Major Projects

Although there is no dedicated operational storage project in Serbia, the country does have projects being undertaken relating to CO<sub>2</sub> capture and preliminary investigations into a capture and storage project to produce blue hydrogen.

The Rusanda oil field is Serbia's first CO<sub>2</sub> EOR project. Serbia's oil and gas company Naftna Industrija Srbije (NIS) invested in a High Pressure Acid-gas capture technology (HiPACT) amine plant which removes the CO<sub>2</sub> from natural gas. The removed CO<sub>2</sub> is then used for enhanced recovery back into the Rusanda field. The plant currently injects 12000 cu m/d of CO<sub>2</sub> from an Elemir gas refinery to capture natural CO<sub>2</sub> and use for EOR [2]. The CO<sub>2</sub>-EOR project in the oil field Rusanda uses a total of 150 000 cubic meters of CO<sub>2</sub> per day that is separated from natural gas mixtures [1]. The second CCS project is related to blue hydrogen production at the Panchevo oil refinery. The project is currently at a benchmarking analysis stage for the latest technologies for CO<sub>2</sub> capture, transport, utilization and storage. The project started in 2022 and is undertaken by the Scientific-Technological Center, a subsidiary of parent company NIS. Some research investigated the analysis of several scenarios relating to various hydrogen

production volumes and found CO<sub>2</sub> emissions savings could equate to 350,000–530,000 tCO<sub>2</sub>/year for capture and storage. The proposed project involves transporting CO<sub>2</sub> via pipelines to a depleted gas field located 40 km from the refinery [5].

#### **35.4.2 Depleted Oil & Gas Fields**

Serbia has an established hydrocarbon industry with a network of pipelines to support it. There are 80 discovered oil and gas fields, with more than 300 reservoirs in the country and hence provides a proven working system of trap and seal. 53 of those fields are in production. The region is drilled extensively with over 400 exploration wells and 1400 appraisal wells. The oil and gas fields sit in four groups in the northern area of the country in the Pannonian basin [1]. The research performed by [1] grouped the fields into four CO<sub>2</sub> storage clusters. It is likely that individual fields have very small resource amounts. Any future projects, therefore, could possibly investigate potential interconnected storage between fields.

The structures identified as most prospective are close to the II and IV cluster of oil and gas fields (see [1] for location) and close to the HiPACT unit at Elemir. The infrastructure here used to transport hydrocarbons may help facilitate the provision of pipelines for CO<sub>2</sub> transport.

#### **35.4.3 Saline Aquifers**

There is an absence of any literature in the public domain that reports on Serbia's saline aquifer storage. Although a value (250 Mt) is reported in one reference [3], it is not indicated where or how this was calculated. Some research done in 2007 [4] indicated specific zones within Serbia that may have more suitable geology for CO<sub>2</sub> storage. The study identified 17 sites (although no resources were reported), through the country in the Pannonian Basin, Dinarides, Vardar Zone, Serbo-Macedonian massif and Carpatho-Balkan arc. Eight sites in the Vardar zone are suggested as being optimum. The Vardar zone is in the southern part of the Serbo-Macedonian massif with the general reservoir characteristics being described as impermeable to low permeable, with some fracture porosity. However, there is a high potential for earthquakes, with around 70% of the 117 seismogenic faults in the Dinarides and Vardar zones.

### **35.5 Regulatory Framework**

In Serbia, the main principles and priorities identified in the Directive 2009/31/EC are partially transposed through the Law on Mining and Geological Research. This law will help adoption of secondary legislation relating to identification of storage sites. The Serbian Government aims to define the conditions, criteria, procedures and issuing of approvals for storage in both saline aquifer and depleted fields [6].

The recently adopted Climate Change Act has provided some motivation for potential implementation of carbon capture and storage projects in the oil and gas industry. The Act provides a mechanism named Clean Development Mechanism (CDM). The CDM could motivate major emitters (e.g. Naftna Industrija Srbije j.s.c. (NIS)), to focus on carbon capture and storage projects aiming to benefit from the reduction of CO<sub>2</sub> emissions and contribute to the

overall sustainable development of Serbia. Although not currently enabled at the time of writing, there are plans to enable this Act in the near future [7].

## **35.6 Issues for the Assessment**

There are very limited studies done in Serbia to assess the resource for CO<sub>2</sub> storage. Those that have been done do not detail methodology, site breakdown or any properties associated with the geology.

## **35.7 Future Updates**

### **35.7.1 Future CRSC Cycles**

Since Serbia has shown progress investigating a carbon capture value chain, future assessments should look for more refined storage assessments or any sites that have become of interest for a project.

## 36 Slovakia

### 36.1 Summary

Slovakia was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

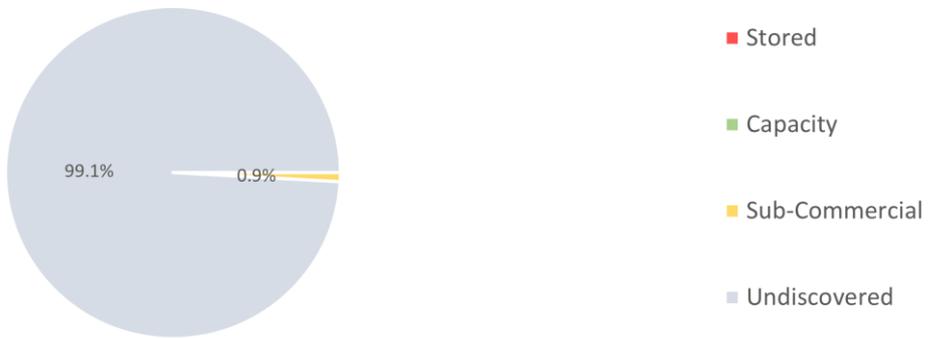
Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.100	0.000
Undiscovered	11.218	0.000
Aggregated*	11.318	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Slovakia.

Table 36-1: Storage resource classification summary for Slovakia.

- Storage resources are reported in saline aquifers and oil and gas fields. The greatest potential exists within deep saline aquifers.
- The Slovakian government passed acts into local Slovak law in 2009 so the country may align with the CCS European Parliament and Council Directives. Slovakian law, therefore, permits CO<sub>2</sub> storage, but federal financial support may be difficult.
- Data mapping and a country-wide assessment were available in the public domain in 2023. The Slovak State Geological Institute and the University of Košice have published findings from 2009 to 2016 in research databases. Slovakia was part of the CCS4CEE project (2021). CO<sub>2</sub>.
- The most prospective areas for CCUS storage are located within the onshore basins: the Danube Basin in the west and the Transcarpathian Basin in the east. However, the Slovak State Geological Institute has licensed areas for CCUS exploration outside of these basins in the country's central region.
- Ten individual sites with assessed storage potential have been identified in Cycle 4. However, these ten sites don't provide a comprehensive picture of the total storage potential within Slovakia, as some papers discuss storage potential at a country-wide level for saline aquifers or depleted oil and gas fields.
- Slovakia has a score of 48.5 within the 2023 CCS Chart of Legal and Regulatory Indicator system due to the country having specific CCS laws aligning with EU directives.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

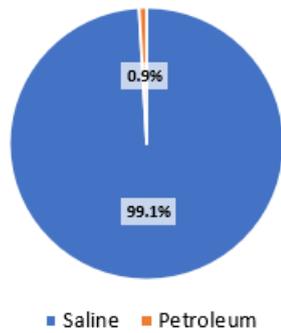


Figure 36-1: Slovakia Spread of Storage Sites.

A) Spread of storage resource in all Slovakian sites across SRMS classifications; both project specified and not. B) Split of Slovakian storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 36.2 Resource Statement

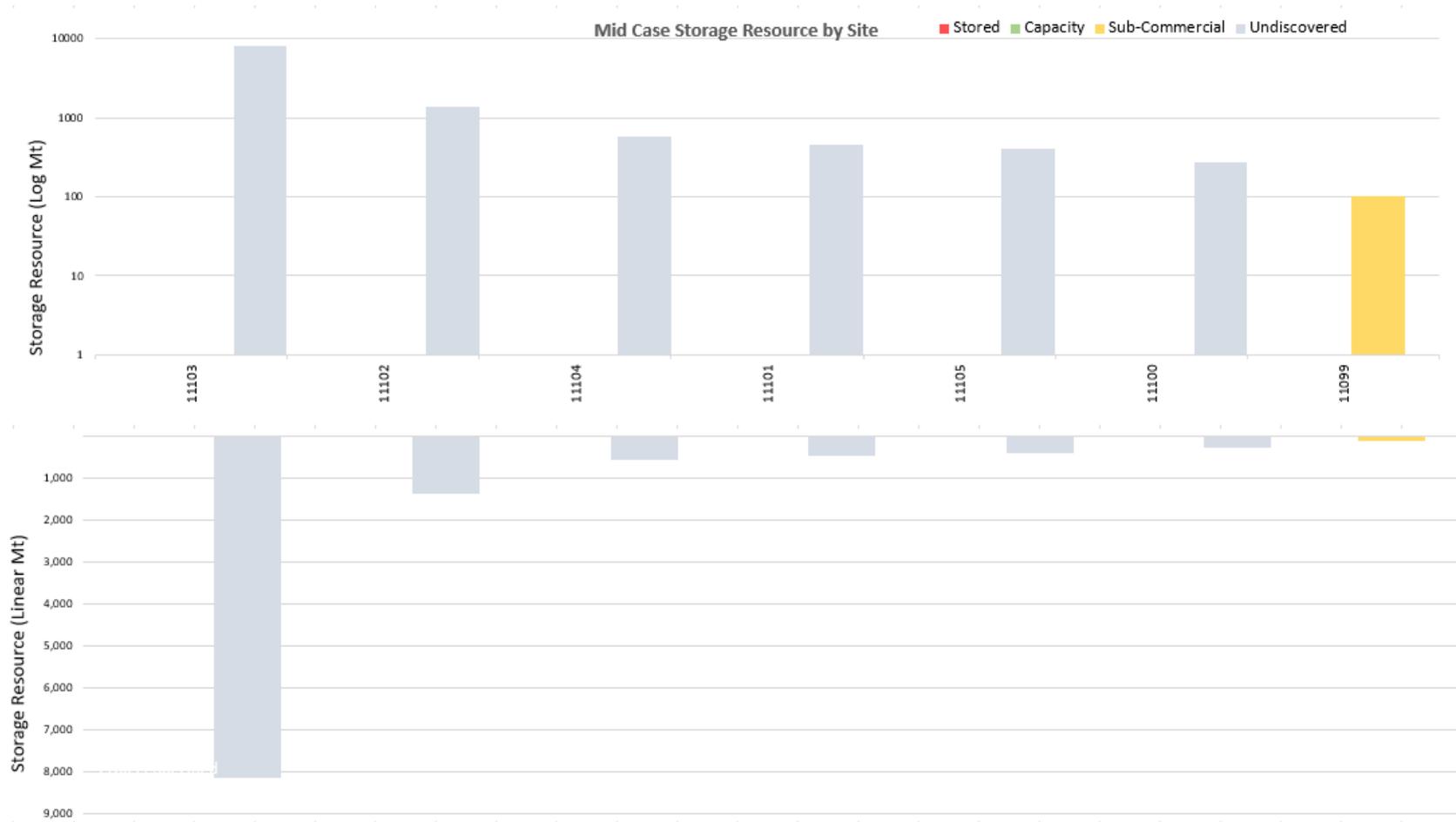


Figure 36-2: Storage resource summary for Slovakia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 36.3 Evaluation History

The first countrywide review for potential CCS storage sites within Slovakia was published in 2009 (Kucharič et al.) [1] as part of the EU Geocapacity Project. Within the East Slovak Basin, the Sarmatian Sandstone and Pannonian Sandstone are quoted as having volumes of 273 Mt and 446 Mt, respectively. Triassic Dolomites within the Bzovik Basin was quoted to have the potential for a volume of 567 Mt. Within the Danube basin; the Pannonian and Pontian aquifers represent potential storage volumes of 1361 Mt and 8165 Mt. 134 Mt were reported resource estimates for oil and gas fields.

In 2011, the preliminary results of a Slovakian national project undertaken by Kucharič et al [2] were published. The paper highlights a range of storage potential between 5 – 15 Mt for the Borovské complex, a conglomerate aquifer located in the Central Carpathians and 100 Mt for the Vysoká-Zwendorf Gas field located in the Vienna Basin and operated by OMV.

In 2016, Pinka et al. [3] published findings for volumes at a country-wide level that dwarf the earlier findings of Kotulová et al. (2009). This latest evaluation by Pinka et al. proposes volumes of 400 – 10,000 Gt for Saline Aquifers and 134 Mt Oil and Gas fields.

The most recent CCUS storage volumes for Slovakia were published in 2021 (Bartovic et al.) [4] by the CCS4CEE project. The paper discusses volumes at a country-wide level, highlighting the potential for 1716 – 13,708 Mt of storage volume in regional saline aquifers and 134 Mt in Oil and Gas fields.

### 36.4 Resource Review

Within Slovakia, the most identified storage potential is situated within saline aquifers, with only a small contribution from oil and gas fields.

All Cycle 4 entries to the CSRC are classified as undiscovered at the basin and sequence play levels.

#### 36.4.1 Major Projects

At Cycle 4, Slovakia has yet to initiate a pilot CCUS project.

#### 36.4.2 Depleted Oil & Gas Fields

Researchers have only published data specifying storage volumes in the Vysoká – Zwendorf gas field, which is quoted as having 100 Mt of potential storage resource. Beyond this, gross figures for storage volumes associated with oil and gas fields within Slovakia range from 100 Mt – 930 Gt.

#### 36.4.3 Saline Aquifers

Within the East Slovakian basin, the Sarmatian and Pannonian sandstone formations were assessed to have storage estimates of 273 Mt and 446 Mt, respectively. In the Danube basin,

published estimates of 1361 Mt and 8165 Mt are cited for the Pannonian and Pontian aquifers. The Bzovik prospect, in the South Slovakian basin, is reported at 567 Mt [1,5].

In 2011, Kucharic et al [3] published storage resource estimates for the Borovské complex located near Aaiun – Tarfaya, which ranged from 5 – 15 Mt. The authors also assessed a volume ranging from 30 – 60 Mt for the Zlata Bana stratovolcano, which is an unconventional prospect within the Trans Carpathian Basin.

## **36.5 Regulatory Framework**

Slovakia has been evaluated as moderate under the 2023 GCCSI CCS with a score of 48.5, which relates to the country's specific CCS laws aligning with EU directives. However, supporting a pilot project will be economically challenging for Slovakia and could hinder future CO<sub>2</sub> storage development.

## **36.6 Issues for the Assessment**

Public domain data and publications detailing methods for calculating storage volumes are limited. This impacts the accuracy of any storage estimates and evaluations underassessment for Slovakia. Due to these limitations, the assessed storage potential for Slovakia in Cycle 4 is considered an inaccurate representation of the available resources.

## **36.7 Future Updates**

### **36.7.1 Future CSRC cycles**

Should any further development in the Slovakia storage systems occur, this should be reviewed annually to ensure the Global Storage Catalogue is current.

# 37 Slovenia

## 37.1 Summary

Slovenia was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Slovenia as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	0.076	0.000
Aggregated*	0.076	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Slovenia.

Table 37-1: Storage resource classification summary for Slovenia.

- Slovenia has been part of three pan-European CO<sub>2</sub> storage assessment projects. The reported values for storage from these projects are inconsistent.
- Slovenia has four sites in the CRSC database for saline aquifers. There are 33 other sites identified but they do not make the CRSC cut-off of 10 Mt.
- There is a very small resource reported in depleted hydrocarbon reservoirs, but a more significant 157 Mt in saline basins distributed through the country.
- There are no geological storage projects in the country, but some industries are investigating other parts of the CCS value chain.
- The Directive 2009/31/EC on the geological storage of carbon dioxide, has been transposed into the legal order of the Republic of Slovenia, however, the country does not currently permit geological storage of CO<sub>2</sub>.
- Slovenia has a value of 36 on the GCCSI CCS Regulatory Indicator system, 2023.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

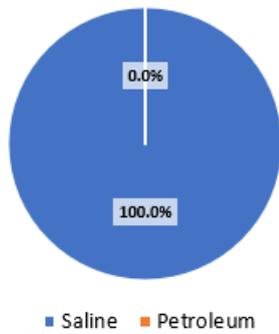


Figure 37-1: Slovenian spread of Storage Sites.

A) Spread of storage resource in all Slovenian sites across SRMS classifications; both project specified and not. B) Split of Slovenian storage resources between saline aquifers and hydrocarbon fields, Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 37.2 Resource Statement

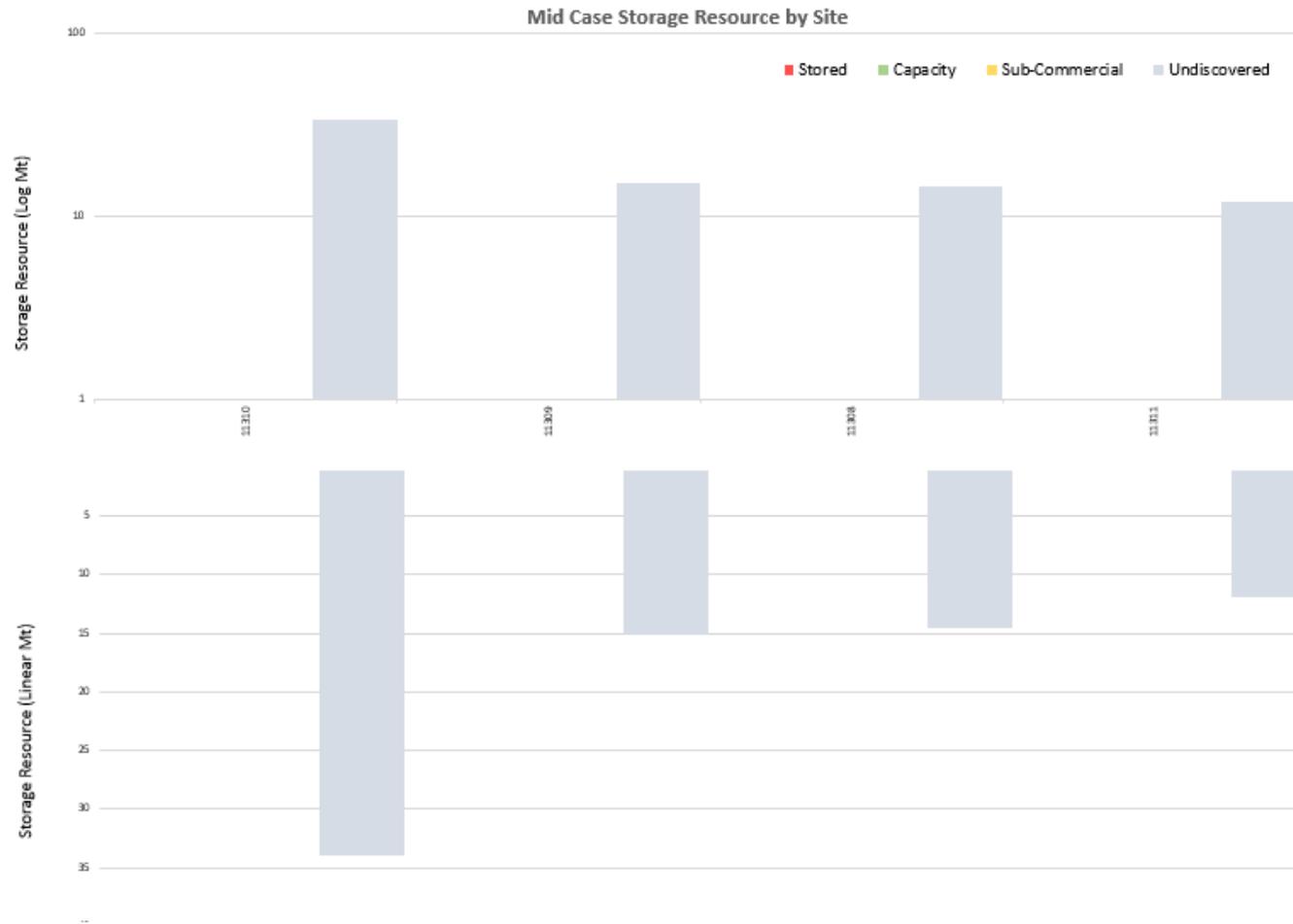


Figure 37-2: Storage resource summary for Slovenia compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 37.3 Evaluation History

Slovenia has been part of three pan European CO<sub>2</sub> storage studies:

- Slovenia was part of the CASTOR project in 2006 [1]: The Castor project (CO<sub>2</sub> from Capture to Storage) mapped saline aquifers, storage reservoirs (geological structures), gas fields, oil fields, coal beds and emission sources from eight eastern European countries.
- Slovenia was also part of the GeoCapacity project: The EU GeoCapacity (EU GeoCapacity – Assessing European Capacity for Geological Storage of Carbon Dioxide) updated previous storage projects (GESTCO) and included reviews of regional saline aquifers, storage reservoirs, potential storage in oil and gas fields and un-mineable coal beds for 25 European countries and two provinces in China [2].
- Lastly Slovenia was part of CO<sub>2</sub>Stop; The CO<sub>2</sub>Stop project (CO<sub>2</sub> Storage Potential in Europe - Project No. ENER/C1/154-2011-SI2.611598), made the first assessment of the European CO<sub>2</sub> storage capacity, both onshore and offshore. The project, which started in January 2012 and ended in December 2013, was funded by the European Commission. The CO<sub>2</sub>Stop project included 26 countries and 27 Partners [9].

However, since then there have been no further country storage site specific assessments. The brief assessments to date report resources on both saline aquifer and depleted oil and gas fields. The resources in depleted oil and gas fields are too low to be reported in the CRSC. [3]

The reported figures for Slovenian resources amongst literature highly inconsistent:

- GeoCapacity reported a conservative 92 Mt and an optimistic 500 Mt. Limited information is available on how this figure was calculated.
- CO<sub>2</sub>STOP assessed 37 sites in Slovenia and all but three made the cut off for the CRSC. The total amount of all aquifers amounted to 154 Mt. Three sites made the CRSC cut-off of 10 Mt: VIP-4 = 15.12 Mt, VIP-5 = 34.02 Mt and ILB-1 = 11.95 Mt. The total amounting to 61Mt
- Slovenia was recently included in the CCS4CEE project in 2023 and has benefited from this analysis in terms of assessing its readiness for CCS relating to existing infrastructure for transport, current legislation, social acceptance and current projects in the CCS/CCU value chain. This report listed three sites (Pečarovci, Dankovci and Besnica) with a total resource of 63Mt. This report also stated a full country resource of 92 Mt. CO<sub>2</sub>Stop however, reports the Pečarovci, Dankovci and Besnica sites as having a cumulative assessment of 7.76 Mt making them too low for the CRSC.

The absence of data to support any resource calculations for Slovenia has made entries for the CRSC uncertain. CO<sub>2</sub>Stop resource estimates are used in the CRSC since the methodology used to calculate the resource is consistent and comprehensive, and therefore comparable with other European countries.

## 37.4 Resource Review

There have been indications of storage onshore in both saline aquifer and small depleted oil and gas fields.

### 37.4.1 Major Projects

There are no major projects for geological storage in Slovenia. However, there are several projects/research relating to capture of CO<sub>2</sub>.

The Salonit Anhovo Cement manufacturer is currently one of the largest CO<sub>2</sub> emitters in Slovenia and in an effort to achieve their goal to be carbon neutral they plan to have a pilot capture project starting from 2025-2030 with the view to a full-scale project by 2035 [4].

The Kemijski Institut (National Institute of Chemistry) has been involved in past and current international projects related to CCU/CCS; The first is ORACLE, where the institute was a partner in this project. The project was funded by Horizon 2020 and studied carbon-free production of ammonia. The second project was MEFCO<sub>22</sub> which investigated producing green methanol from captured CO<sub>2</sub>. The institute was the project concept originator and the largest public partner. Finally, the institute also provided research for the FREsmE project which looked at synthesis of methanol from CO<sub>2</sub> extracted from iron furnaces for marine fuels. The project completed in June of 2021 [4].

Energetika Maribor who are a heat and electricity producer and distributor, are currently investigating CO<sub>2</sub> capture and storage at their proposed waste-to-energy plant in Maribor. The aim is to capture up to 16.049 tonnes of CO<sub>2</sub> per year from the energy produced [4].

Premogovnik Velenje, who are Slovenia's largest coal mine and Eurofins Erico were involved in project MOVECB. This project aimed to investigate better understanding of the process of CO<sub>2</sub> storage in coal. A small-scale injection was performed at the Velenje coal mine to investigate adsorption, desorption and migration processes for local coal conditions [6].

### 37.4.2 Depleted Oil & Gas Fields

Storage opportunities in depleted oil and gas fields are very limited. To date, any studies (GeoCapacity) have found a nominal resource. The CCS4CEE [4] review cited that the Dolina and Petišovci in the NE part of Slovenia, had a resource between 1.8 and 5.3 Mt although the research underpinning this has not been available.

### 37.4.3 Saline Aquifers

Saline Aquifer studies are also limited in terms of their research and remain at a basin level. The recent report by the Geological Survey of Denmark and Greenland for Clean Air Task Force reported 37 aquifer sites distributed through the country that amount to around 154 Mt of potential storage. The report only summarized CO<sub>2</sub>Stop data that originated from 2012. However, the more recent CCS4CEE reports repeat estimates performed by GeoCapacity which

is 92 Mt. This report does subdivide the resources into three locations (Pečarovci, Dankovci and Besnica structures). Those aquifer locations are found in the CO<sub>2</sub>Stop database but their reported resource is very small.

As mentioned before CO<sub>2</sub>Stop identified 37 aquifers. Four made the cut-off for the CRSC. The remaining sites have very nominal storage with a storage capacity of 93Mt Mt in total. According to CO<sub>2</sub>Stop these aquifers are distributed through the country and their location are specified in the database.

## **37.5 Regulatory Framework**

Directive 2009/31/EC on the geological storage of carbon dioxide, has been transposed into the legal order of the Republic of Slovenia via the Energy Act 32. However, geological storage of carbon dioxide is still prohibited in the country and its continental shelf under Article 258 of the Environmental Protection Act. 1. In terms of regulations however, the legal and regulatory framework for CCU/CCS in Slovenia is viewed to be sufficient. With regards to the future policy on geological storage in the country, there are not any plans in place for the country to determine additional review of storage opportunities. In terms of cross-border CO<sub>2</sub> transport and storage, Slovenia, does not yet have an experience at reviewing or implementing this [4,7]. Carbon capture and utilisation (not storage) is likely to be more appealing for Slovenia if it is to start venturing in developing a CCU/CCS value chain.

Slovenia is a landlocked country and therefore this may continue to be a long terms factor that prevents onshore CO<sub>2</sub> storage from being legislated in the country [4].

## **37.6 Issues for the Assessment**

The main issues with assessment have been the lack of research in the public domain to assess where research has been done and how. This has led to highly inconsistent reporting of resources. As such, caution needs to be taken when using any resource estimates for this country.

## **37.7 Future Updates**

### **37.7.1 Future CRSC Cycles**

It may be unlikely that there will be much movement on policy to permit storage in Slovenia, However, future updates could review any developments with projects that involved cross border transport and storage of CO<sub>2</sub>. Future updates would also greatly benefit from gaining more fact-based assessments to gain more accurate storage resource estimates.

# 38 Spain

## 38.1 Summary

Spain was assessed for the CSRC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	6.931	0.000
Undiscovered	13.840	0.000
Aggregated*	20.771	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Spain.

Table 38-1: Storage resource classification summary for Spain.

- Spain has been extensively reviewed in early pan-European CO<sub>2</sub> storage projects such as GeoCapacity, ALGECO<sub>2</sub> and COMET. Much of these results have been incorporated into a comprehensive CO<sub>2</sub> Atlas published in 2010 by IGME.
- Three pilot projects for CO<sub>2</sub> capture and one for CO<sub>2</sub> storage were developed between 2006 and 2014. However, this trend did not continue. The economic crisis and uncertainty about the role of CCS in the energy transition slowed that momentum and no commercial or demonstration projects are planned in Spain in the near future.
- A total of 91 sites in Spain have been added to the CRSC database In Cycle 4, with the majority located in aquifers. Only one onshore oil field has been considered. Most offshore fields have been designated for gas storage.
- The main aquifers are all onshore in Spain.
- CCS in Spain is currently challenged by its legislation. Although the EU Directive 2009/31/CE was transposed to Spanish legislation, it has not been accepted at a regional level, which prevents projects from being permitted.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

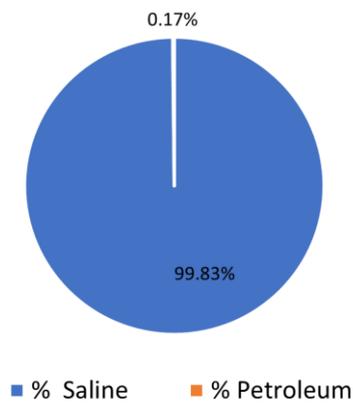


Figure 38-1: Spain Spread of Storage Sites.

A) Spread of storage resources in Spain, all Spanish sites across SRMS classifications; both project specified and not. B) Split of Spanish storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 38.2 Resource Statement

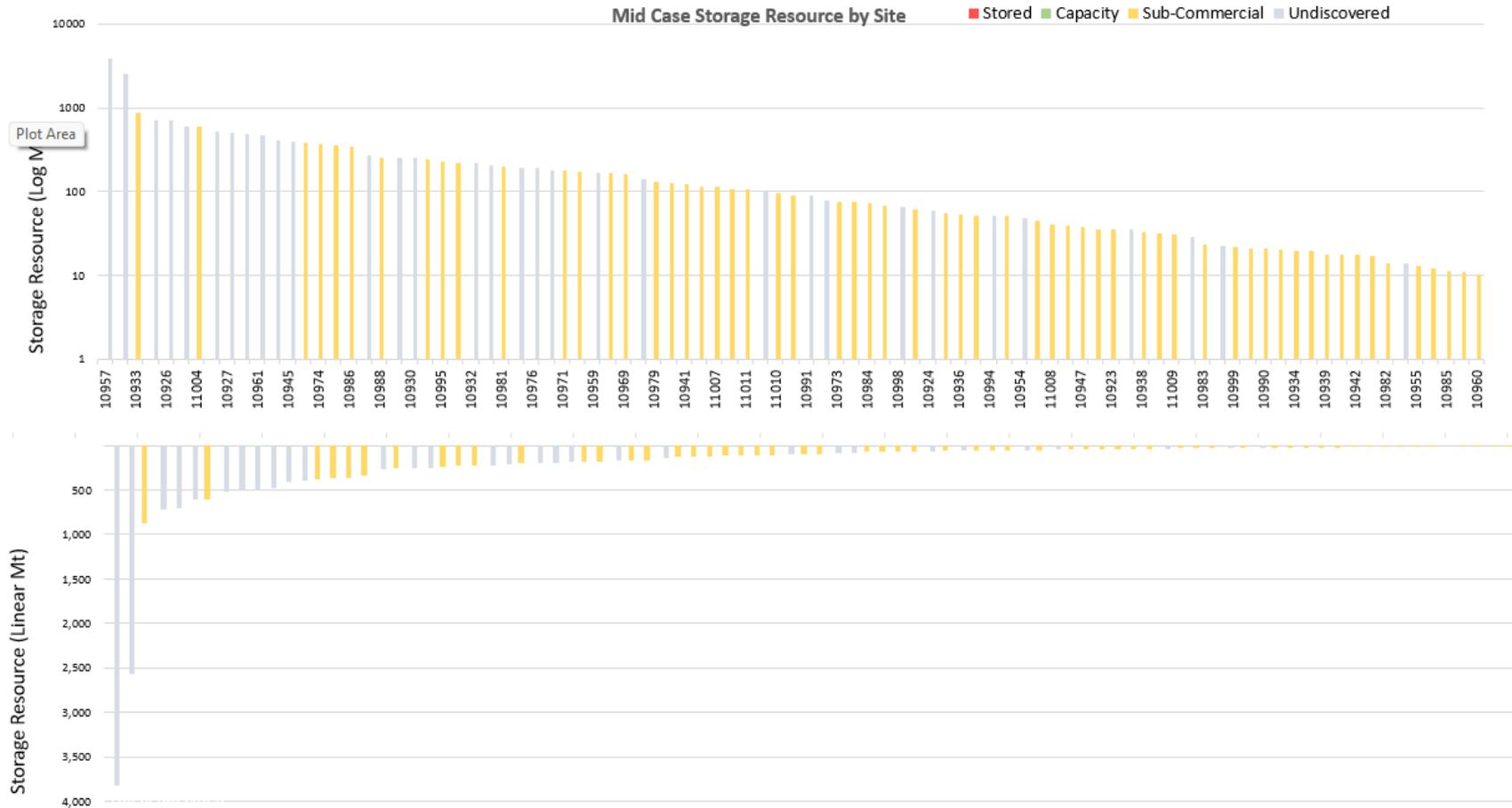


Figure 38-2: Storage resource summary for Spain compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 38.3 Evaluation History

The evaluation of CCS potential in Spain started with the GeoCapacity project (2006-2009), which reviewed CO<sub>2</sub> storage in deep saline aquifers and hydrocarbon reservoirs. The assessment revealed a total storage resource of 14 Gt, almost entirely in deep saline aquifers.

Subsequently, the Spanish Geological and Mining Survey (IGME) conducted the ALGECO<sub>2</sub> project (2009–2010) to mature the characterisation of potential storage structures in Spain and create a CO<sub>2</sub> storage atlas, IGME (2009). Martínez del Olmo (2019) [1] revisited the characteristics of these favourable structures and improved the results by complementing the inventory for all of Spain with the offshore saline aquifers. These have all been included in the CSRC catalogue.

From 2010 to 2013, the COMET project aimed to identify and assess the most cost-effective CO<sub>2</sub> transport and storage infrastructure available to serve the West Mediterranean area, including Portugal, Spain, and Morocco [2]. The overall strategy of COMET comprised four fundamental tasks, including the complete inventory of present and future CO<sub>2</sub> sources and sinks in the region, cost modelling of national and regional energy systems, the in-depth assessment of selected transport networks, and the dissemination of the information. Based on the results of the COMET project, a further study conducted an injection rate and cost assessment for CCS development in the West Mediterranean area. It concluded that about 11–15 clusters of 43 storage prospects defined in the study area are cost-effective, depending on the emission mitigation scenario [3].

A recent study presented a novel source-to-sink assessment methodology based on a hubs and clusters approach to identify favourable regions for CCS deployment and attract renewed public and political interest in viable deployment pathways [4].

All evaluations are based on a volumetric approach as defined by the EU GeoCapacity study. Many sites are classified as Discovered due to the presence of wells as detailed by the ALGECO<sub>2</sub> project. However, whilst the EU Directive 2009/31/CE was transposed to Spanish Legislation, it has not been accepted at a regional level which prevent projects being permitted and as such all sites are classified as inaccessible.

### 38.4 Resource Review

Different subdivisions of the Spanish sedimentary basins for the CO<sub>2</sub> storage resource estimation have been applied in different studies. CO<sub>2</sub>

The GeoCapacity project gave an overall resource estimation of 35Mt in depleted hydrocarbon fields and 14.3Gt (14,300 Mt) in regional aquifers. Spain also carries some storage potential in non-conventional storage with an estimated 200Mt held in coal beds. The storage resource was based on a volumetric approach using the methodology of Brook et al., 2003 and Bachu et al., 2007 [11]. All subsequent studies have also used and validated the storage resource values published by both this study and ALGECO<sub>2</sub> projects.

Due to the current legislation status in Spain, CO<sub>2</sub> storage is not permitted; hence, all sites are classified

as Inaccessible.

### 38.4.1 Major Projects

There are a total of four carbon capture projects in Spain, with only one being a pilot CO<sub>2</sub> storage project and another a research project. No CCUS projects are running or planned for the near future in Spain.

The Compostilla project [5] was a proposed circulating fluidized-bed (CFB) oxyfuel CCS demonstration project. Captured CO<sub>2</sub> was to be stored in nearby onshore saline formations in the Duero basin. The injection trial site of this project was at the Hontomin storage site. Phase I of the project received EU EEPR funding of up to EUR 180 million (Dec 2009), and partners Endesa, CIUDEN and Foster Wheeler signed contracts with the EU Commission in May 2010. Phase I delivered a 30MW pilot, transport and storage pilot trials and a FEED Study. The FEED Study was completed and published in 2013. FID was expected before the end of 2013, but the partners decided not to proceed with the demonstration project. The injection pilot project at Hontomín was put on hold in 2018 due to political and administrative reasons [6].

The Elcogas project, run by ELCOGAS S.A., developed a precombustion CO<sub>2</sub> capture and H<sub>2</sub> production pilot plant with a 335 MW Integrated Gasification Combined Cycle (IGCC). It was built in Puertollano, an old industry centre for hydrocarbon refinery and processing in Central-SW Spain [7]. The power plant, along with the CO<sub>2</sub> capture and H<sub>2</sub> production plant, was shut down in 2016 due to accumulated debt.

The La Pereda pilot, located in NW Spain on the site of the coal-fired La Pereda power plant, was developed by a consortium of national and international partners, including Endesa Generacion, Hunosa, Foster Wheeler, and CSIC (the Spanish National Research Council) and commenced in 2009. This project received EU funding through three projects: CaOling (2009–2013), ReCaL (2012–2015), and CaO2 (2014–2017). The operating company, Hunosa, is converting the La Pereda power plant to be biomass-fueled, but there is no update about the reuse of the capture pilot facility [4].

The CARBOLAB project was an RFCS 4-year project aimed at gathering and analysing the effects of CO<sub>2</sub> injection in coal at a panel scale in an existing underground coal mine in the north of Spain.

### 38.4.2 Depleted Oil & Gas Fields

In Spain, the possibility of storing CO<sub>2</sub> in depleted fields or in depleting oil and gas is of little relevance due to the scarcity of hydrocarbon resources. Added to this is that the few hydrocarbon fields exploited are being used for natural gas storage [8]. Hence, the estimated 35 Mt storage resource of CO<sub>2</sub> [1] is entered in the database as a single entry and not field-specific since CO<sub>2</sub> storage potential has been refined across individual fields.

### 38.4.3 Saline Aquifers

A total of 12 basins with 103 traps within saline aquifers are considered suitable for CO<sub>2</sub> storage. Most are located in the Mesozoic – Cenozoic basin onshore and 5 offshore. For the GeoCapacity project, Spain storage structures were divided into 4 geologic onshore domains:

1. Cadena Ibérica & Submeseta Meridional.
2. Cadenas Béticas & cuenca del Guadalquivir
3. Pyrenees and Ebro Basin
4. Cadena Cantábrica & Duero Basin

According to the IGME Atlas, most, if not all, designated saline resources were tested by mostly unsuccessful hydrocarbon exploration drilling campaigns between the 1950s and 1980s.

### 38.5 Regulatory Framework

The EU Directive 2009/31/CE was transposed to Spanish Legislation as Law 40/2010 on 29 December 2010 on the geological storage of carbon dioxide, but the development of specific regulations to tackle each project case has not been carried out to date [9]. Due to control of regional jurisdiction in Spain, whilst accepted on a national level, the directive was not incorporated into regional law. Hence the permitting of injection of CO<sub>2</sub> for storage is not yet possible at the regional level. In the case of Hontomín, this was passed for research purposes as the study was considered a pilot at under 10Mt and is regulated by Mining Law 22/1973 (Spanish Law 22/1973, 1973) [9]. The absolute laws relating to CO<sub>2</sub> storage in Spain are unclear and fluid; hence, prospective storage development would need clarity on the legal status, depending on the region in question. Spain scores 43.5 on the CCS readiness scale as defined by the GCCSI [10].

### 38.6 Issues for the Assessment

No offshore reservoir characteristics and CO<sub>2</sub> storage specific papers have been found. The papers of Martínez del Olmo (2019) and Sun et al. (2021) mention the potential for offshore hubs for CO<sub>2</sub> storage but provide only limited information. Most structures require new data acquisition since the data is limited to old seismic data and wells drilled for hydrocarbon exploration.

### 38.7 Future Updates

#### 38.7.1 Future evaluations

Future evaluations should seek to address any updates to legislation and, if this has changed, to encourage any projects or research.

#### 38.7.2 Future CSRC cycles

Should any further development in Spanish legislation occur, key onshore and offshore sites should be reviewed to establish if any have progressed to a project level.

## 39 Sweden

### 39.1 Summary

Sweden was assessed for the CRSC in Cycle 4. A summary of the CO<sub>2</sub> storage resource is shown in the Table below.

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
<b>Stored</b>	0.000	0.000
<b>Capacity</b>	0.000	0.000
<b>Sub-Commercial</b>	1.583	0.200
<b>Undiscovered</b>	1.786	0.700
<b>Aggregated*</b>	3.369	0.900

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Sweden.

Table 39-1: Storage Resource Classification Summary for Sweden.

- A storage resource is reported to be present in saline aquifers. Sweden has a limited history of hydrocarbon exploration and production; however, no depleted fields have been identified as having storage potential.
- Evaluation of potential storage sites began in 2011 by the Swedish Geological Survey. SLR Consulting assessed Sweden as part of the BASTOR project in 2013 [1] and evaluated storage estimates based on the GeoCapacity method. Sweden was also part of the Mustang project (2009-2014) (EU, ID: 227286) [2] run by the EU grant project Coordinated by Uppala University and also SwedeSTORECO<sub>2</sub> [3], a pre-feasibility study to store CO<sub>2</sub> in Sweden (2012-2013). Further assessments in 2014 applying the EU GeoCapacity methods were used to compile the NORDICCS Nordic CO<sub>2</sub> Storage Atlas (2011-2015 [4]) (Anthonsen et al., 2014) [5]. Studies have also been undertaken to assess selected storage sites using probabilistic and dynamic modelling methods [1, 6].
- A total of 12 potential storage units have been identified in Sweden in the south-east Baltic Sea and south-west Scania. Both areas underwent drilling and seismic surveys in the 1970s-80s for hydrocarbon exploration. The Middle Cambrian Faludden aquifer (South East Baltic Sea) and the Early Albian-Cenomanian Arnager Greensand aquifer, and the Jurassic Höganäs-Rya aquifer (South West Scania) are the most promising units. Additional units in the Baltic include early Palaeozoic aquifers, and in the Scania area, aquifers in formations from the Triassic, Jurassic, and Early Cretaceous have been identified.
- Sweden has no active CCS projects within its borders. Sweden is involved in carbon capture projects through BECCS but favours storage options in adjacent Nordic countries with more CO<sub>2</sub>

storage and hydrocarbon production expertise. Since March 2014, geological storage of CO<sub>2</sub> has been permitted in Sweden [7].

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

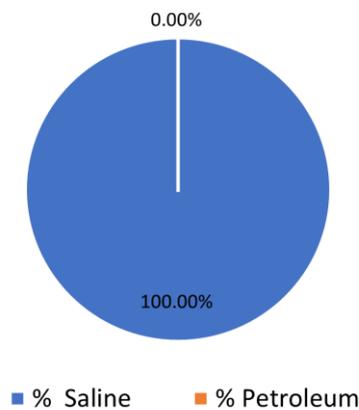


Figure 39-1: Spread of Swedish Storage Sites

A) Spread of storage resources in Sweden Sites across SRMS classifications; both project specified and not. B) Split of Swedish storage resources between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 39.2 Resource State

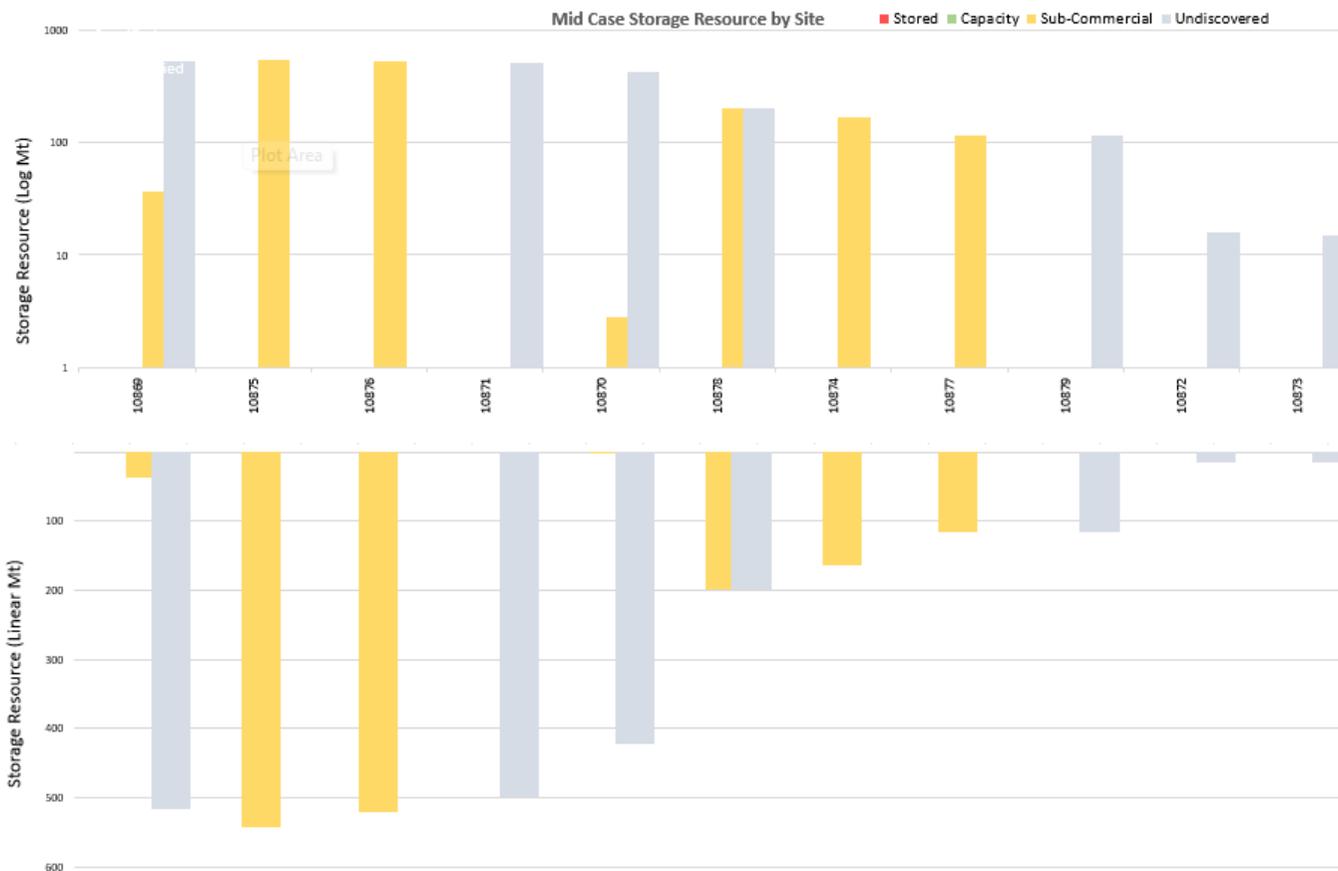


Figure 39-2: Storage resource summary for Sweden compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 39.3 Evaluation History

The first evaluation of potential storage resources in Sweden began in 2011 and was performed by the Swedish Geological Survey (SGU), Anthonsen et al., (2013) [8] and Erlström et al. (2011) [9]. This research identified three suitable areas (deep saline aquifers), all situated in the offshore southernmost area of the Sweden Baltic Sea. They used the USDOE assessment methods to evaluate Cambrian aquifers, which included the Viklau, När and Faludden sandstones. The study estimated the effective CO<sub>2</sub> storage potential in structural closures to be approximately 100 Mt and the effective storage resource for the Faludden stratigraphic trap between 0.4 Gt and 4.5 Gt [1].

Further assessment in the offshore area of the Southwest Skåne revealed suitable aquifer seal pairs. No structural traps were identified; however, 3 potential aquifer units were identified: the Lower Triassic Bunter and Ljunghusen, the Uppermost Triassic to Hettangian Höganäs Formation and the Lower Cretaceous Arnager Greensand. The estimated CO<sub>2</sub> storage resource in the Triassic aquifer is 750Mt, the Jurassic sandstone 4.5Gt and the Cretaceous sandstone 5Gt. However, there was great uncertainty about these estimates. The last area identified was in the southeast part of the Kattegat Sea, with an estimated 80-150Mt [8].

A regional assessment of the CO<sub>2</sub> storage potential in the Baltic Basin was published as part of the BASTOR project in 2013. Similarly to the SGU project, this study assessed CO<sub>2</sub> storage resources across the Baltic Basin and identified favourable sites for CO<sub>2</sub> storage. However, the study authors (SLR) could use a considerable quantity of proprietary data such as interpretations, maps, seismic and well data. Using the GeoCapacity methodology, this data was used to calculate storage estimates. It identified that the combined storage resource of eight large structural closures in Cambrian saline aquifers was estimated at 761.37 Mt. The study also assessed the total effective storage resource in the Faludden stratigraphic trap to be 1923 Mt [1].

The NORDICCS CCS Competence Centre is a joint task force of the five Nordic countries. A significant project undertaken was the creation of a Nordic CO<sub>2</sub> Storage Atlas, published in 2015. The Swedish component was based on screening and analysing existing wells and seismic data in deep saline aquifers in the Swedish Baltic Sea and Southwest Scania area. The resulting CO<sub>2</sub> storage resource estimates were calculated using volumetric methods based on lithology, volume, net/gross, porosity, permeability, injectivity, reservoir type, salinity, CO<sub>2</sub> density at reservoir conditions, efficiency factor, and cap rocks [5]. The study outcome identified eight deep saline aquifers and one structural trap with a preliminary estimate of total storage resources in Sweden over 3400 Mt. Each formation aquifer was also assessed for its resource and storage efficiency based on the approaches published by the U.S. DOE. Future work from these studies anticipated dynamic modelling and ranking to refine resource estimates.

Mortensen et al., 2014 and 2016 [12,6] continued the NORDICCS review work to rank the most prospective formation and perform static and dynamic modelling on selected sites.

The 2014 study, which used a set of variables with defined optimal ranges for both reservoir (e.g., porosity, permeability, thickness, facies) and seal (e.g., lithology, lateral extent, fault intensity) and additional safety issues, found the Cretaceous Arnager Greensand, Cambrian Faludden and Jurassic Höganäs-Rya formations to be most prospective. Estimated storage resources from the NORDICCS study were used.

The dynamic and static modelling by [6] took the Faludden and Arnager formations into both a static basin modelling assessment and a dynamic simulation approach. Both gave quite differing results, with the static model approach presenting more unfavourable estimates due to the lack of structural trapping in the region. The dynamic approach accounted for more residual trapping. The outcome of these studies continued to support the viability of these storage units for CO<sub>2</sub>. However, there are large differences between these studies and the earlier estimates from NORDICCS and SLR. The dependency of a modelling approach on spatial data is a contributing factor here – the areal extent in Mortensen 2016 is limited compared to the volumetric estimates from NORDICCS, SLR, etc.

Sopher et al., 2014 [1] reviewed the main storage units in Sweden – the Faludden, Nar and Viklau sandstones using methods given by the U.S. DOE and U.S. Geological Survey to calculate CO<sub>2</sub> storage resources probabilistically. The Dalders structure, in the southeastern part of the Swedish sector of the Basaltic Sea, has estimated low, mid and high storage resources of 85 Mt, 145 Mt and 224 Mt, respectively, however the majority of storage potential resides in the adjacent Estonian waters. The regional Faludden stratigraphic unit was estimated to have low, mid and high effective storage estimates of 4330 Mt, 5579 Mt and 6962 Mt, respectively.

### **39.4 Resource Review**

#### **39.4.1 Major Projects**

There are no major storage projects in Sweden as defined by the CSRC. However, Sweden does have a BECCS project underway in Stockholm, which will export CO<sub>2</sub> to the North Sea for storage [13].

#### **39.4.2 Depleted Oil & Gas Fields**

No detailed reviews of storage potential in depleted oil and gas fields are available in the public domain, and no specific calculations have been made yet for the depleted oil and gas fields in Sweden.

#### **39.4.3 Saline Aquifers**

Work undertaken evaluating storage potential in Sweden has focused on saline aquifers.

Most of the storage resources for saline aquifers in Sweden are classified as discovered and undiscovered. There are a few wells present in some sites and three sites have simulation studies (Faludden and Arnager sands). Eleven sites with storage estimates exceeding 10 Mt were logged in the CSRC. These sites are located in the Swedish sector of the Baltic basin and the Swedish sector of the South West Scania area. The majority of these estimates are “sequence play”. There are no resources onshore.

The Cambrian Faludden formation in the Baltic Sea and Jurassic Höganäs-Rya Cretaceous and Arnager formation in South West Scania are considered to have the greatest promise for storing CO<sub>2</sub>. The Faludden is a large homogenous, gently dipping sand unit, an open/semi-closed aquifer covering around 33000km<sup>2</sup>. The area of this formation in Sweden is at a suitable depth under 800 m and is 11000 km<sup>2</sup>. This is mainly a stratigraphic trap except for Faludden sands in the Dalders Structure. It is capped by a thick multi-sequence set of seals comprising Ordovician – Silurian carbonates, shale, and marlstones [4&6].

The Albian-Cenomanian Arnager Greensands, which cover 5200 km<sup>2</sup>, are gently dipping but fault bound northeast by the Romeleåsen Fault Zone and partly fault confined through the remaining distribution. The quality of the sands starts to diminish further North. The Arnager sands are capped by a thick seal of clayey limestone, chalk, and interbedded sands and silts. [4&6]. The quality of these seals is uncertain due to the lack of physical properties [8]. There are limited structural opportunities in this aquifer.

The Jurassic Höganäs-Rya aquifer includes a CO<sub>2</sub> storage potential of around 2100 km<sup>2</sup>. It is a very gently dipping semi-closed aquifer, bound in the North by the Romeleåsen Fault Zone. Stratigraphic trap opportunities may exist in lens-shaped sand bodies. The Höganäs-Rya aquifer unit is capped by a regional dense shale layer and further capped with a thick sequence of clay-rich limestone and chalk. (Anthonsen et al., 2014). Regarding fault-related issues (compartmentalisation and reactivation), the southwest Scania area is tectonically more complex than the Baltic Basin.

The Dalders structure, partially located in the southwestern part of the Swedish sector of the Baltic Sea, is the only large structural trap. Despite being a large structural closer with an estimated mid-range resource of 145 Mt, it can only store 1-2 years of Swedish emissions [1]. Due to its location and size, it is unlikely to be feasible to develop CO<sub>2</sub> Storage.

### 39.5 Regulatory Framework

Sweden is not planning any injection of captured CO<sub>2</sub> into aquifers within its jurisdiction. However, to meet its commitment to carbon neutrality by 2045, Sweden is investing in bioenergy with carbon capture (BECCS) and considering the export of captured CO<sub>2</sub> to permanent storage in Norway. This is due to more favourable geology and greater expertise in CCS operations in Norway than in Sweden [9].

There are no regulatory barriers to exporting CO<sub>2</sub> after the IMO allowed for the application to the amendment of Article 6 of the London Protocol in 2019. Sweden has ratified the 2009 amendment and drawn up proposals with Norway. With respect to storing CO<sub>2</sub> in the future, some regulatory challenges for storing CO<sub>2</sub> in the Baltic Sea could occur, namely from The Baltic Marine Environment Protection Commission Helsinki Commission (HELCOM) and Natura 2000 [10]. Sweden scores 56 in the 2023 CCS Legal and Regulatory indicator (the highest being Australia at 70) [12].

### **39.6 Issues for the Assessment**

Whilst there are several assessments in Sweden with increasing granularity for selected sites, the main issues with further assessment of CO<sub>2</sub> storage in Sweden are the lack of data and the age of the existing data. Most datasets are derived from oil and gas exploration in the 1970-80s, which limits the insight that can be gained through interpretation and modelling. There is also great uncertainty over the physical properties of the aquifers. In addition, Sweden does not view CO<sub>2</sub> storage as a solution to use within its country boundaries, at least for the foreseeable future; therefore, it is unlikely to gather new data.

### **39.7 Future Updates**

#### **39.7.1 Future Evaluations**

If Sweden decides to investigate its country storage further or consider developing sites rather than pursuing the export strategy it currently has, then this should be reviewed to update the CSRC.

## 40 Switzerland

### 40.1 Summary

Switzerland was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Switzerland as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	0.000	0.000
Undiscovered	2.080	0.110
Aggregated*	2.080	0.110

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of Switzerland.

Table 40-1: Storage resource classification summary for Switzerland.

- Assessments in Switzerland have mostly been at a sequence level where the country has been included as part of Pan-European studies (CO<sub>2</sub>Stop).
- Sites are classified at a sequence level and include four formations in the Swiss Molasse Basin. Studies have not progressed beyond sequence level, except a dynamic study on a small test area.
- There is a small pilot project underway, called the Trüllikon project ("CITru"). The CO<sub>2</sub> injection target is the Middle Triassic Schinznach Formation.
- Switzerland has no dedicated national legislation in place for geological storage of CO<sub>2</sub>, although plans exist to update this in the near future.
- Overall lack of research, and any that has been performed is at a sequence level, has made resource estimates for Switzerland carry some uncertainty.
- Switzerland scores 19 on the GCCSI CCS readiness scale.

A1) Project  
Mid-Case Storage Resource



A2) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

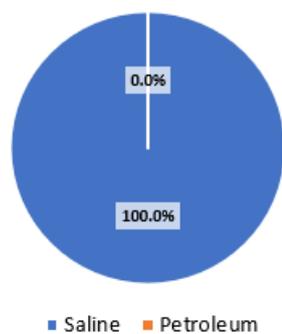


Figure 40-1: Switzerland spread of Storage Sites.

A) Spread of storage resource in all Swiss sites across SRMS classifications; project specified.  
 B) Spread of storage resource in all Swiss sites across SRMS classifications; both project specified and not.  
 C) Split of Swiss storage resources between saline aquifers and hydrocarbon fields, (include both projects specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 40.2 Resource Statement

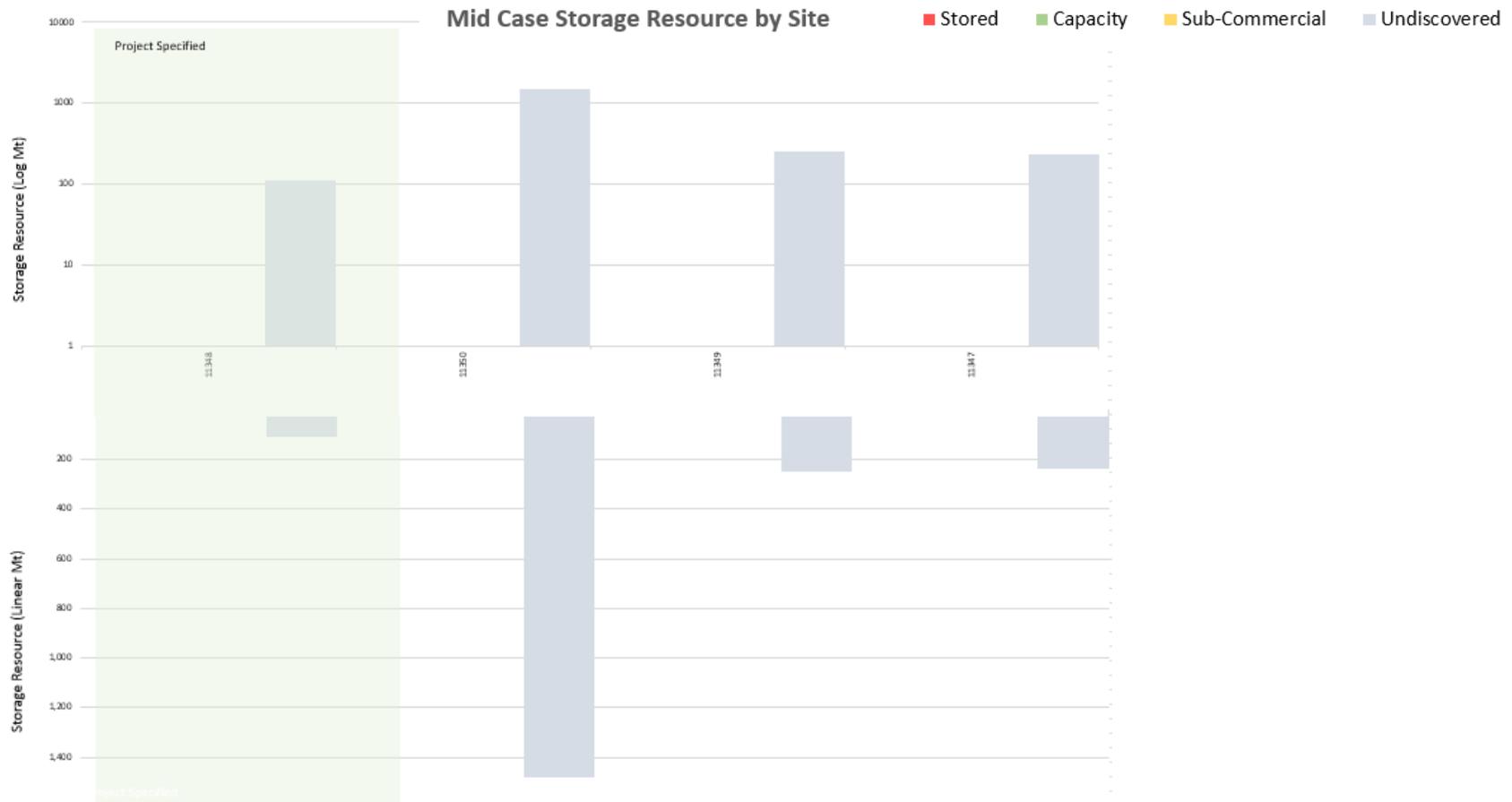


Figure 40-2: Storage resource summary for Switzerland compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

### 40.3 Evaluation History

Switzerland to date, has not been assessed to a maturity level beyond formation level. The Country, whilst active in research projects (see Major Projects below) has not until recently gathered momentum to take CCS seriously as part of its NetZero strategies.

Switzerland was reviewed by Chevalier et al., 2010 [1] and identified four stratigraphic zones. They followed the methodology after Bachu 2003 and performed a comprehensive screening process for the formations in the Swiss Molasse Basin which resulted in the calculation of theoretical resource. CO<sub>2</sub>STOP [2] also identified the same four stratigraphic zones in the basin and reported the same resource as Chevalier 2010.

CO<sub>2</sub>Stop resource estimates have been used in the CRSC for three sites since the methodology used to calculate the resources is consistent and therefore comparable with other European countries.

A recent study in 2024 performed a project-based assessment on an area in the Molasse basin to assess potential storage in a small site at Triemli in the Trigondus Dolomite. The dynamic pressure-limited assessment tested several scenarios and then scaled up the results to assess full potential of the Trigondus Dolomite in the Swiss Molasse Basin and Jura area. A notional development plan for the site was also provided. [3].

### 40.4 Resource Review

Thea aquifer sites are situated in the Swiss Molasse basin. Four stratigraphic intervals have been identified

#### 40.4.1 Major Projects

There are no major storage projects in Switzerland to date, but there is a small pilot project underway. The project is called the Trüllikon project ("CITru"). Initially the Trüllikon site was investigated in detail as part of the Swiss radioactive waste management program. Hydraulic tests carried out in the TRU1-1 well and gathered properties from the Upper Muschelkalk formation and low-permeability cap rock (Bänkerjoch Formation). Once the well was no longer needed for investigations into radioactive waste, it was decided to repurpose it and use it as a candidate for a CO<sub>2</sub> injection pilot. The CO<sub>2</sub> injection target is the Middle Triassic Schinznach Formation (1084 m top). This is a 70 m thick dolostone reservoir and the upper member of the Muschelkalk Group. There is no intention to use Trüllikon for future CO<sub>2</sub> storage [4,5,6].

There are two further projects also underway in the CCS value chain:

- Limeco Waste-to-Energy Dietikon; The Limeco Waste-to-Energy Dietikon is a joint effort between Aker Carbon Capture and Limeco. Aker Carbon Capture has been awarded a feasibility study by Limeco for a new waste-to-energy plant in Dietikon, Aker's modularized CCS units, known as Just Catch, will be utilized to capture CO<sub>2</sub>, with

the liquefied CO<sub>2</sub> transported via truck or train [7].

- KVA Linth CCS is a feasibility study on implementing iCapsolEoP carbon capture technology at a waste-to-energy (WTE) plant in Switzerland. This initiative aims to capture over 100,000 tonnes of carbon dioxide annually and will be operational in 2025 [7].

#### 40.4.2 Depleted Oil & Gas Fields

Switzerland does not have an active hydrocarbon industry. However, whilst Switzerland has no depleted oil/gas fields there are hydrocarbon accumulations. Some 75 million m<sup>3</sup> of natural gas have been produced from the Finsterwald gas field during the 1980s. In terms of potential storage capacity for this field, there are no published estimates of the gas initially in place (GIIP) and hence no estimates of CO<sub>2</sub> storage capacity [7].

#### 40.4.3 Saline Aquifers

Switzerland has three large-scale geological zones, the Jura Alps, the Swiss Molasse basin and the Alps. The Swiss Molasse basin has been identified as holding the most promise for CO<sub>2</sub> storage. The sedimentary fill of the Swiss Molasse Basin is spatially extensive and up to 6,000 m deep. The Jura zone is not a sedimentary basin but has been cited as having potential for storage since it includes most of the formations found in the Swiss Molasse Basin.

The Swiss Molasse Basin is relatively undeveloped for resources and knowledge is limited. However, over the past decade or so there has been an increase in knowledge gain of the geology due to several projects investigating the resources of the basin for radioactive waste repositories, geothermal energy, water supply and underground civil engineering.

There are four formations reported to have potential for storing CO<sub>2</sub> in Switzerland; Mesozoic sandstones, sealed by the Anhydrite Group; the Upper Muschelkalk sealed by the Gipskeuper; the Hauptrogenstein Formation sealed by the Effinger Member, and the Upper Malm plus Lower Cretaceous which are sealed by the Lower Freshwater Molasse [1].

The central part of the basin, particularly the Fribourg-Olten-Luzern area, is reported as having moderate to high potential for CO<sub>2</sub> storage due to favourable sealed aquifers. In western Switzerland, the Jura, and southern Swiss Molasse Basin have lower potential. A theoretical storage capacity of 2,680 Mt of CO<sub>2</sub> was estimated by Chevelier et al., 2010 [1]. Estimates remain theoretical for most of the formations.

A dynamic simulation was performed on the Trigondus Dolomite (layer in the upper Muschelkalk), at Triemli in Canton Zurich. The Trigondus Dolomite which is 20-30 m thick is reported as especially favourable for storage. Due to the broad depth range of the formation (<100 m in the north to >5000 m in the south) only a feasible area to 300-640 km<sup>2</sup> (using a

depth of 800-1130 m) is suitable for CO<sub>2</sub> storage.

The numerical simulations estimate a storage capacity of 1.57 Mt of CO<sub>2</sub> over 30 years with a single vertical well at 40 MPa injection pressure, with estimated capacities ranging from 0.17 Mt to 21.2 Mt. By scaling this up the study indicates that 300-640 km<sup>2</sup> of suitable aquifer conditions in the Swiss Molasse Basin and Jura area could equate to a 70-150 Mt resource for storage. A notional storage plan for the scaled-up site was also provided and would need approximately 60 wells, similar to those used in the Triemli case study. This number could be reduced to 35 wells if 500 m horizontal wells are utilized [3].

### **40.5 Regulatory Framework**

Switzerland has no dedicated national legislation in place for geological storage of CO<sub>2</sub>. In Switzerland, the 26 Cantons have sole sovereignty over the subsurface and are responsible for defining the regulatory framework for geological CO<sub>2</sub> storage if deemed necessary. As of May 2025 [8,9] the Council of States Environment, Spatial Planning and Energy Committee (ESPEC-S) has begun instructions to the Federal Council to draw up legislation for the capture, transport and storage of CO<sub>2</sub>.

### **40.6 Issues for the Assessment**

Switzerland has an absence of research for CO<sub>2</sub> storage site beyond the formation classification. The upscaled Triemli assessment still places the Swiss Molasse Basin at a formation level. All reported values are theoretical and will likely be overestimated.

### **40.7 Future Updates**

#### **40.7.1 Future CRSC Cycles**

Future updates will benefit from any research that enables progression of sites up the SRSM maturity classification. Recent renewed interest in getting regulations in place for CO<sub>2</sub> storage may encourage further assessments and studies.

## 41 Ukraine

### 41.1 Summary

Ukraine was assessed during Cycle 5. The CSRC has identified a CO<sub>2</sub> storage resource for Ukraine as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.000	0.000
Capacity	0.000	0.000
Sub-Commercial	4.486	0.000
Undiscovered	60.000	0.000
Aggregated*	64.486	0.000

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the Ukraine.

Table 41-1: Storage resource classification summary for Ukraine:

- Research in Ukraine has been primarily academic and international in nature, with no national CO<sub>2</sub> storage atlas. Key studies include those by Bellona (2014), the World Bank (2022), and the EU-funded LCOIR-UA and CTS projects.
- No CO<sub>2</sub> storage projects have been implemented. Several studies have assessed potential, but the lack of regulations has prevented project development.
- A total of 12 depleted fields and two major saline aquifer basins have been assessed.
- Main storage locations are in the Dnieper–Donetsk and North Carpathian Basins, along with limited offshore potential in the Black Sea.
- CCS is not yet permitted in Ukraine. While some EU-aligned energy directives exist, there is no dedicated legal framework for CCS.
- Key issues include limited geological data, conceptual-only assessments, and regulatory absence. All estimates are theoretical and carry high uncertainty.

A) Project and Non-Project  
Mid-Case Storage Resource



B) Storage Resource by Type

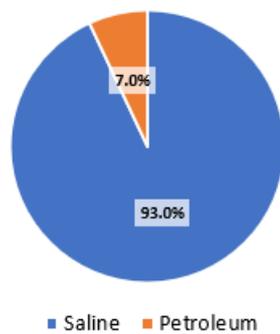


Figure 41-1: Ukrainian spread of Storage Sites.

A) Spread of storage resource in all Ukrainian sites across SRMS classifications; both project specified and not. B) Split of Ukrainian storage resources between saline aquifers and hydrocarbon fields, (include both project specified and not specified). Note: due to the large variance in the size of values, numbers in pie plots do not add up to 100.

## 41.2 Resource Statement

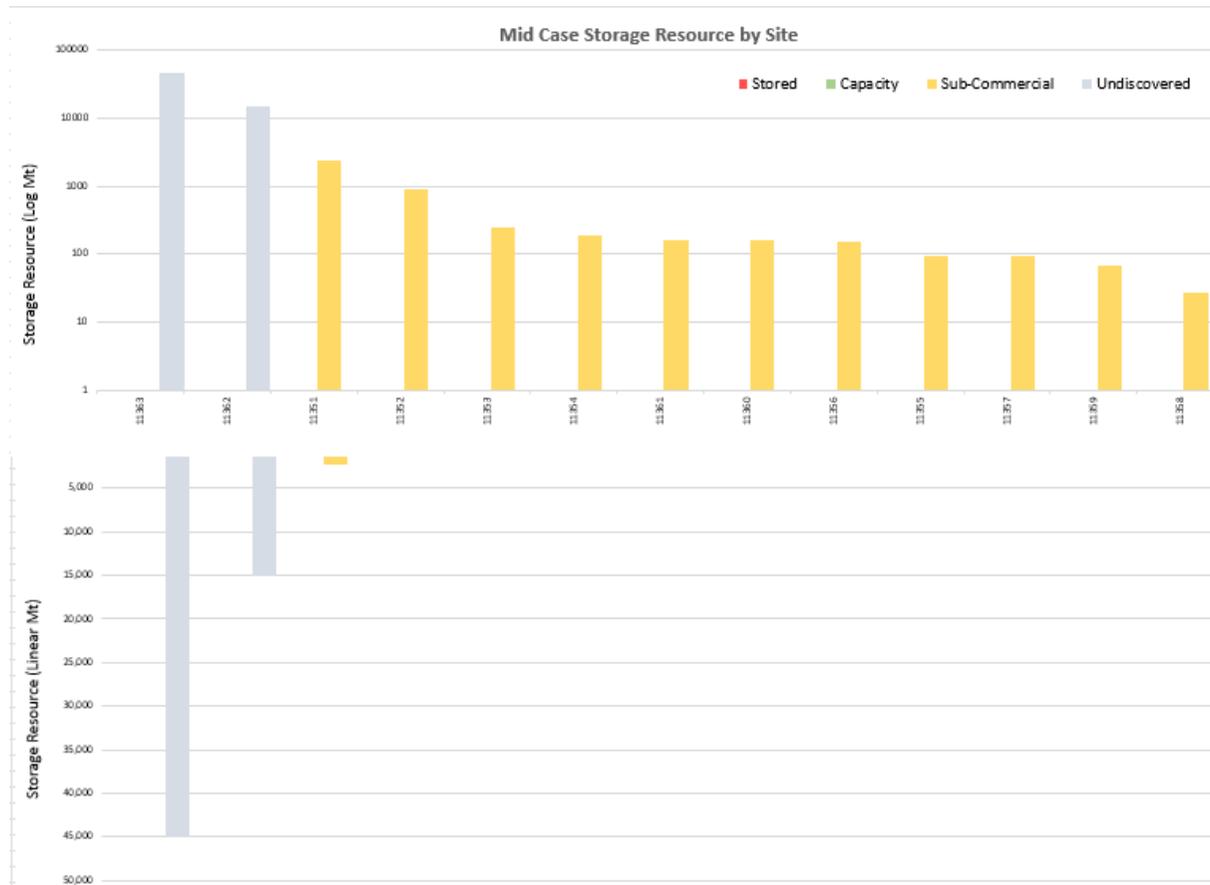


Figure 41-2: Storage resource summary for Ukraine compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 41.3 Evaluation History

Research into CO<sub>2</sub> storage in Ukraine began in the early 2010s, mainly through academic studies and international collaborations. While Ukraine does not yet have a national storage atlas, several high-level assessments have been conducted, including the Bellona study in 2014 [1], the EU-funded Low-Carbon Opportunities Industrial Regions of Ukraine project [2], and the World Bank's research on "Blue H<sub>2</sub> and CCUS in Ukraine" [3]. These studies primarily focused on the Dnieper–Donetsk Basin and the North Carpathian Basin, as well as selected offshore fields in the Black Sea. Overall, the findings suggest Ukraine has substantial theoretical CO<sub>2</sub> storage potential, especially in saline aquifers, although depleted hydrocarbon fields could also offer viable options. However, most evaluations have remained conceptual, using volumetric estimates with limited geological data. The absence of a regulatory framework and limited access to field data continue to pose challenges, leaving considerable uncertainty around the true storage capacity.

## 41.4 Resource Review

To date, only geophysical research methods are used to search for and assess promising CO<sub>2</sub> storage sites in Ukraine. These studies suggest that although the storage capacity in depleted fields can be limited in Ukraine, saline formations are extensive in the country and have the potential to permanently store large volumes of CO<sub>2</sub>.

### 41.4.1 Major Projects

There are no storage projects in Ukraine due to the lack of regulations and a legislative framework for such activities. However, some studies looking into the use of CCUS technologies in Ukraine include a Bellona study from 2014 (Ukraine CCS: Ukrainian perspectives on industry and energy security) [1], the EU-funded "Low-Carbon Opportunities Industrial Regions of Ukraine" (LCOIR-UA) [2], the World Bank project section "Blue H<sub>2</sub> and CCUS in Ukraine" [3], lastly the "CTS Project: CO<sub>2</sub> transport and storage solutions in the Black Sea" [4].

### 41.4.2 Depleted Oil & Gas Fields

Soon to be depleted oil and gas fields in Ukraine deemed suitable for CO<sub>2</sub> Storage are found in the Dnieper - Donets Basin and the Norther Carpathians Basin. The most significant storage potential is in the Dnieper - Donets Basin. The study published in 'Blue H<sub>2</sub> and CCUS in Ukraine' [3] assessed 11 soon to be depleted major hydrocarbon fields. The storage capacities were calculated using the theoretical volumetric approach, based on available volumes of all produced fluids from the field and removing the volume of any injected fluids.

In the Dnieper - Donets Basin in Eastern Ukraine, the main future depleted fields and their capacities are as follows: Shebelynske gas field (2,391 Mt), Zakhidno-Khrestyshynske gas field (907 Mt), Yefremivske gas field (242 Mt), Melekhivske gas field (185 Mt), Rozpashnivske oil field (94 Mt), Medvedivske gas field (157 Mt), Mashivske gas field (93 Mt), Solokhivske gas field (28 Mt), Opishnyanske oil field (67 Mt), and Yablunivske oil field (159 Mt).

In the Northern Carpathians Basin in Western Ukraine, only one soon to be depleted oil and gas field was assessed, the Bytkiv-Babchynske field, which has the potential to store 163 Mt of CO<sub>2</sub>.

In addition, the "CTS Project: CO<sub>2</sub> transport and storage solutions in the Black Sea" [4] assessed storage capacities in the Black Sea in Ukraine. The reservoirs have been identified in depleted gas and gas condensate fields (Holitsyna, Arkhangelske, Shtormove) confined to Karkinite-North Crimean depression. Gas and gas condensate reservoirs, which are considered as potential CO<sub>2</sub> storages, primarily referred to Oligocene-Lower Miocene (Maykop series) and Lower Paleocene formations. The preliminary theoretical CO<sub>2</sub> storage capacity was estimated using a simple formula from the EUGeoCapacity project [5]. However, the resulting values were below the minimum capacity threshold for database entry with a total estimation of 9.39 Mt for all 3 sites: Holitsyna field (3.33 Mt), Arkhangelske (1.95 Mt), and Shtormove (4.11 Mt).

### 41.4.3 Saline Aquifers

Ukraine has two well-known sedimentary basins with readily available data on formation thickness: the Dnieper–Donetsk Basin and the North Carpathian Basin, with maximum formation thicknesses of approximately 20 km and 12 km, respectively [3]. A high-level estimate of CO<sub>2</sub> storage capacity was calculated for both basins using the theoretical volumetric approach based on volume replacement methodology published by Kearns et al in 2017 [6]. The results of the basin-wide capacity of Dnieper–Donetsk was 45,000 Mt, and the basin-wide capacity for North Carpathian was 15,000 Mt [3].

## 41.5 Regulatory Framework

At present, Ukraine lacks a dedicated legislative framework for carbon capture and storage (CCS). Nonetheless, it has adopted certain EU regulations that are indirectly connected to CCS, such as the Directive on energy end-use efficiency and energy services. While these regulations do not explicitly define the legal status of CCS stakeholders or the structure of the CCS market, they provide a foundational conceptual basis that can support the future development of specific legislation. [7]

To meet its international commitments under paragraph 19 of Article 4 of the Paris Agreement and paragraph 35 of Decision 1/CP.21 of the UNFCCC Conference of the Parties, as well as to comply with the Cabinet of Ministers of Ukraine's directives from December 7, 2016 (№ 932-r, approving the Concept for implementing state climate policy until 2030) and March 28, 2018 (№ 244-r, approving the Government's priority action plan for 2018), Ukraine developed the Strategy for Low Carbon Development until 2050. This strategy outlines the adoption of innovative technologies for carbon capture, storage, and reuse. These technologies, alongside energy efficiency and renewable energy initiatives, are expected to reduce greenhouse gas emissions by 1,064 Mt CO<sub>2</sub> equivalent between 2012 and 2050 [8].

## 41.6 Issues for the Assessment

Limited research and very limited data availability for most of the CO<sub>2</sub> storage resources in Ukraine will affect the accuracy of storage estimates. All estimates before future depleted hydrocarbon sites are based on hydrocarbon replacement volumes, with lack of documentation on formation properties and storage efficiency factors used. In addition, the saline aquifer estimates are both basin-wide high level volumetric estimates and therefore present a lot of generalization and uncertainty. Should Ukrainian law permit CO<sub>2</sub> storage, then future research may refine many of the theoretical storage estimates and reveal the true volume of storage potential Ukraine's geological resources can offer.

### **41.7 Future Updates**

#### **41.7.1 Future CRSC Cycles**

Future evaluations should address any legislation updates and if this has helped encourage any projects or research. CSRC updates will be strongly dependent on Ukraine's regulations. Should CCS be permitted, any sites undergoing evaluation to transition to storage will need to be reviewed with more clarity and robust data assessment.

## 42 United Kingdom

### 42.1 Summary

The United Kingdom was assessed during Cycle 1 and updated in Cycle 2 to reflect changes in licensing and UK Government funding announcements. The Cycle 4 updates reflect the recent license awards, progress with major storage and CCS value chain projects, revised storage estimates based on current research and the addition of several new sites to reflect site characterisation and identification in the literature. The CSRC has identified a CO<sub>2</sub> storage resource for the United Kingdom as follows:

Classification	CO <sub>2</sub> storage resource (Gt)	
	Project and no project	Project specified only
Stored	0.00000	0.00000
Capacity	0.960	0.539
Sub-Commercial	19.816	2.180
Undiscovered	60.565	0.000
Aggregated*	81.341	2.719

\* The aggregated resource represents the summed storage resource across all maturity classes and as such should not be viewed as representative of the potential of the UK.

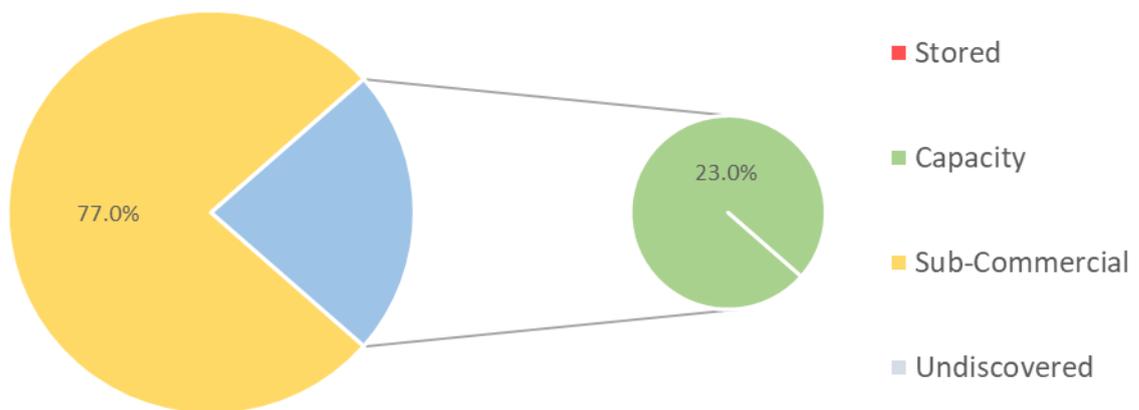
Table 42-1: Storage Resource Classification Summary for the UK.

- 110 sites are identified in the UK, although only 107 are entered in the database. Three fields, despite being in a CCS license block, do not have reported volumes yet (these are the Sean Fields). Twenty new sites have been added, and 86 sites have been updated from Cycles 1-3.
- 12 of the new sites are core storage units for major CO<sub>2</sub> storage projects in the UK, either as the primary storage site or as part of an expansion plan for the projects.
- Several CCS projects are under planning or development in the UK. Two have been approved for Track 1 funding from the UK Government – HyNet in the East Irish Sea and the East Coast Cluster (utilising the Northern Endurance storage site) in the southern North Sea. Track 2 approved funding includes the Acorn project in the Northern North Sea and the Viking CCS project in the Southern North Sea. Ten more projects relating to the CCS value chain (not storage focused) are also in operation in the UK today. Many of these are part of cluster projects associated with the major storage projects with Track 1 and Track 2 funding. Other projects associated with the first UK CO<sub>2</sub> Storage licensing round acquisitions are beginning to be publicised.
- The success of the NSTA CO<sub>2</sub> Storage licensing round in 2023 led to the award of 21 licenses. One is in the Eastern Irish Sea, 2 are in the Central North Sea, 4 in the

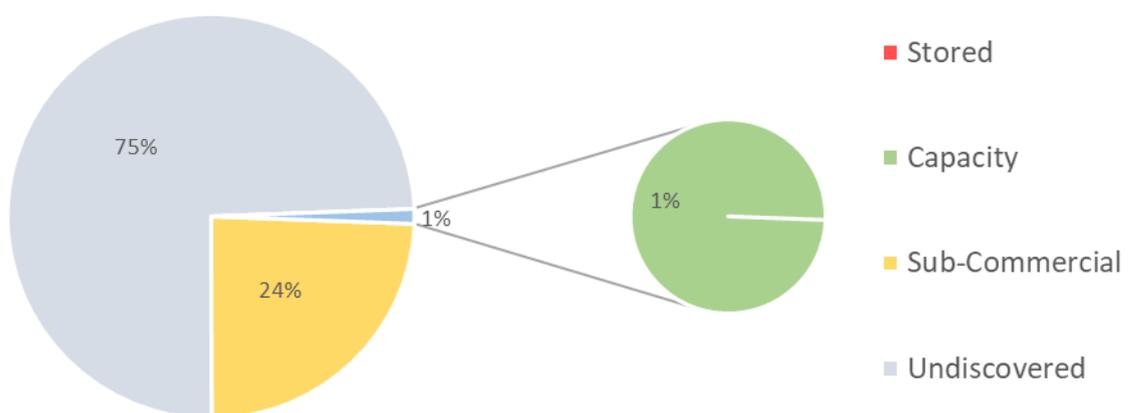
## CO<sub>2</sub> Storage Resource Catalogue - Appendix C: Europe

Northern North Sea and 14 are in the Southern North Sea. This brings the total license awards for storage and appraisal to 27. More details can be accessed on the NSTA website.

A) Project  
Mid-Case Storage Resource



B) Project and Non-Project  
Mid-Case Storage Resource



## c) Storage Resource by Type

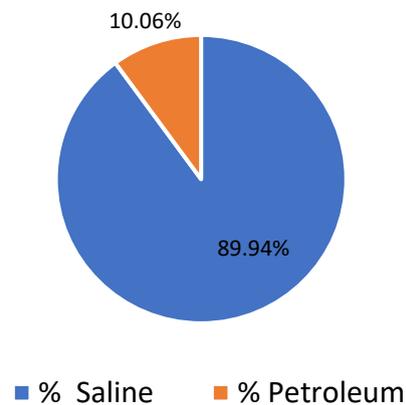


Figure 42-1: UK Spread of Storage Sites.

A) Spread of storage resources in the UK (110) across SRMS classifications where a project has been specified. B) Spread of storage resources in all UK sites across SRMS classifications; both project specified and not. C) Split of UK storage resource between saline aquifers and hydrocarbon fields, both project specified and not. Note: due to the large variance in size of values, numbers in pie plots do not add up to 100.

## 42.2 Resource Statement

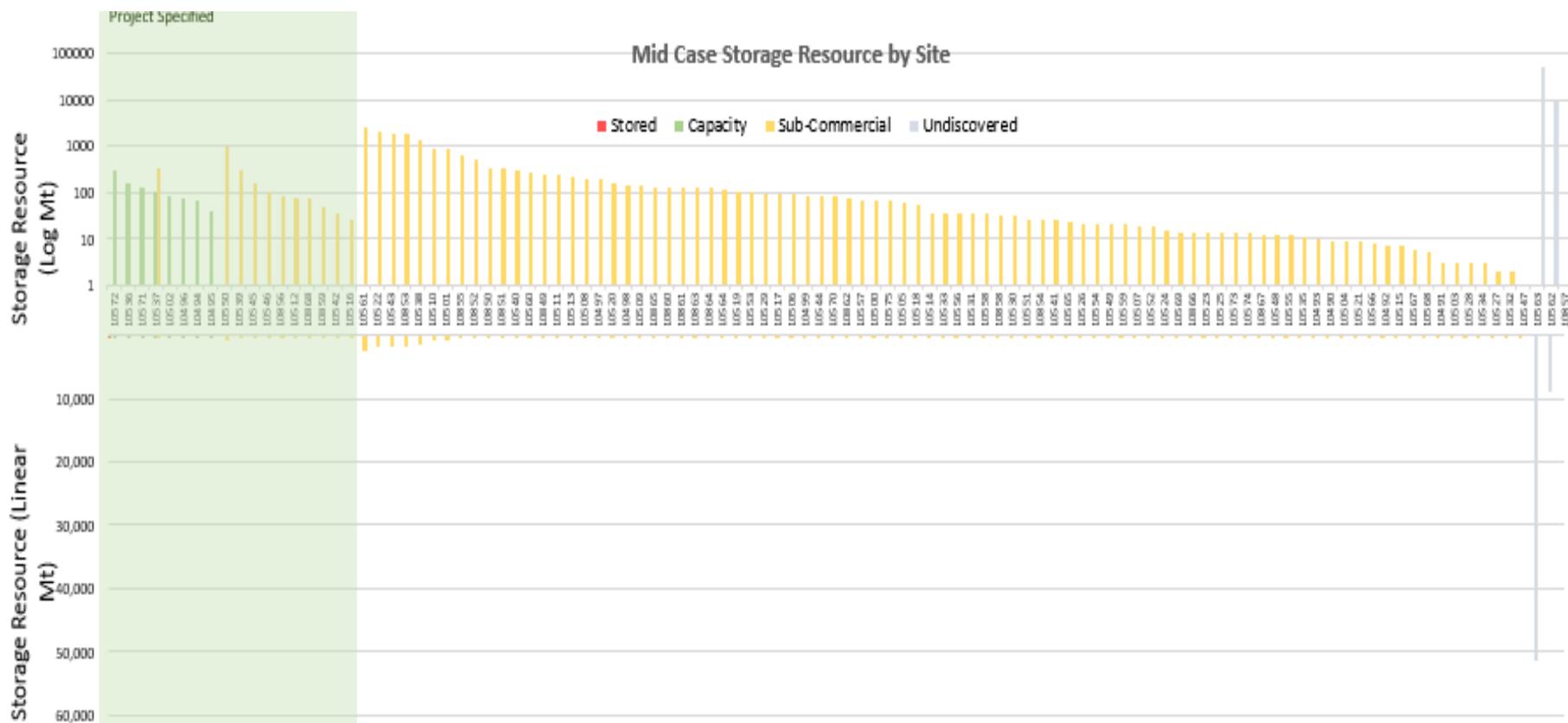


Figure 42-2 : Storage resource summary for the UK region compiled in the CSRC.

Graph above is log scale and graph below is linear. Green box highlights sites where a project has been specified.

## 42.3 Evaluation History

The most widespread source for the estimation of CO<sub>2</sub> storage resources within the UK is still *CO<sub>2</sub>Stored*, the UK CO<sub>2</sub> Storage Evaluation Database, hosted and under development by the British Geological Survey and The Crown Estate and under license from the Energy Technologies Institute (ETI) [8]. Unfortunately, due to the restriction of the CO<sub>2</sub>Stored license for non-commercial use only, it has not been used directly in previous CSRC Cycles. Cycle 1 was heavily reliant on literature that references the values from CO<sub>2</sub>Stored. The main source in cycle 1 was summary sheets created by the Energy Technologies Institute (ETI) [1]. Additional sites included in Cycle 4 that were not previously included in Cycle 1 & 2 are from the same publication. Additional updates in Cycle 4 include resources delineated in the UK CO<sub>2</sub> storage license round. These sites storage volumes and associated data are taken from the operator's summary reports, some limited academic papers and government reports. Some simulations for various sites exist in public literature, e.g. Pickerill, and have been used to update storage estimates where applicable. A paper by Karvounis and Blunt 2021 [2] calculated volumes based on pressure dissipations/limitation modelling and derived a more refined range of storage of resource estimates for some fields across the UK. These have not been used in Cycle 4 due to the results being presented in a non-tabular range, which limits the accuracy with which a range can be defined for the criteria used by the CRSC.

## 42.4 Resource Review

### 42.4.1 Major Projects

The UK has four major projects underway (from Track 1 and Track 2 UK government funding) and others in the early stages of assessment.

1. Track 1 Cluster funding includes HyNet North West and the Northern Endurance Partnership. HyNet North West is a project with several components that include the production, transport, and storage of low-carbon hydrogen in several fields in the North West and North Wales [3]. There is also a CO<sub>2</sub> storage element to help decarbonise heavy industry and hydrogen production, which will transport CO<sub>2</sub> to the Hamilton and Lennox depleted gas fields. The project aims to reach FID in mid-2024.
2. The Northern Endurance partnership will enable the Net Zero Teeside and East Coast Cluster projects to store and transport CO<sub>2</sub>. It is hoped to reach FID in September 2024 [4,5]. It is expected that volumes of 100 Mt will be captured and stored during Phase 1. These volumes are therefore placed in the SRMS class as Justified for Development. According to the Northern Endurance Partnership, Endurance has the capacity to store 450 Mt. If additional sites are included surrounding Endurance then the capacity can increase to 1 billion tonnes. The remaining resources (450Mt - 100Mt = 300Mt) in cycle 4 are placed in the contingent classes.

3. Track 2 Cluster funding is now confirmed for the Acorn Project. Acorn has received licenses from the NSTA for Acorn and East Mey, which will expand the total storage to around 240MT. Acorn is expected to store at least 5Mt/yr by 2030 from several emitters in Scotland, the UK and Europe. There is potential for non-pipeline transport via shipping [6,7].
4. Viking CCS has also been approved for Track 2 funding and is expected to start operating in 2027. It is projected to store 10Mt/yr by 2030 from major emitters in the Humber regions and up to 15Mt by 2035. FID is expected in 2024. Viking CCS plans to use decommissioned pipelines to transport CO<sub>2</sub>. Storage will be in the depleted Viking gas fields, with up to eight reservoirs available [8].

Early development projects are underway in some recently acquired license blocks. Two projects from Perenco, Orion (Amethyst and West Sole fields) and Poseidon (Leman field and others), aim to deliver CO<sub>2</sub> capture and storage.

The Poseidon project plans to come online in 2029. Injection rates of 1.5 million tonnes per annum (Mtpa), increasing to ~10Mtpa by 2034 and peaking at ~40Mtpa, over 40 years, are cited. It will serve the decarbonisation of East Anglia, Greater London, and Southeast England. The combined storage resource for this project includes the Leman field, a mixture of saline aquifers (including the Bunter Closure 9) and depleted gas fields surrounding Leman. Combined resources are estimated at having a resource capacity of 935Mt [14]. It is not stated in the literature which fields and aquifers will potentially be used. 1.5 Mt is cited as the initial injection volumes. Only 37.5 Mt (1.5 Mt x 25yrs) can be classed as development pending at present under the current project phase which is still in FEED. It is expected to be ramped up to 40Mtpa when at full operating scale– the exact timeline of which is not stated. As yet it is not possible to clearly define how much will be injected into the full complex and when. The remaining 897.5 Mt is classed as development unclarified until further details emerge on the development plans. Double counting may be an issue here but as yet due to limited information; it is not possible to define which sites will provide the expected portion of the full resources quoted. Future cycles will need to focus on monitoring up to date literature on this project to provide more refined SRMS estimates.

Orion aims to inject 1 Mtpa, rising to 6 Mtpa with injection commencing in 2031. Orion will serve the Humber area and have a maximum capacity of 126 Mt of CO<sub>2</sub> [9,10, 14]. Orion is aimed to provide additional capacity for decarbonization of the Humber area over a planned 30 year period. Orion will use both the Amythyst and West Sole fields with pipeline transport from the Dimlington CO<sub>2</sub> processing terminal. At present at an initial injection rate of 1Mtpa over 30 years, provides a resource of 30Mt for development pending as the project is still in FEED stage.

#### 42.4.2 Depleted Oil & Gas Fields

The status of the UK's depleted oil and gas field storage potential has changed very little since Cycle 3 with respect to all remaining discoveries, with some awaiting a detailed study.

Regarding SRMS classification, many sites have now been classified as 'Justified for Development' based on the advancement of the cluster projects over the last few years. Some adjustments to volumes have been made based on research over the past two years and the advancement of project studies. All projects have yet to reach FID. This is anticipated to happen for some projects in 2024. Several sites have also been targeted by recent license awards and have therefore moved up the classification system to 'Development on Hold'. The Hewett field has also received a submission for a Carbon Storage License (by ENI) and is under appraisal as the storage element of the Bacton Thames Net Zero Initiative [13].

Several new sites have been added based on the license awards. Four fields offshore Shetland (Magnus, Tern, Eider and Thistle) were awarded to Enquest [11,12], two depleted fields in the SNS were awarded to Perenco (Amethyst and West Sole) [9,10] with two additional fields (Indefatigable and Sean) were awarded to Shell. Volumes and data for these sites are very limited (Sean fields are omitted from the database due to no publicly reported volumes). Most information is found in company reports and investor presentations. Future cycles will benefit from updates if the license holders publish in-depth studies.

#### **42.4.3 Saline Aquifers**

The status of the UK's saline aquifers remains unchanged since Cycle 3 with respect to all remaining discovered (with very few as undiscovered) due to the region's wealth of oil and gas wells. Several of the Bunter sites (36,38,39,40) have been included in the development plans for Endurance and are awaiting a more detailed assessment. These have been reclassified as 'On Hold' due to being situated in an awarded license block.

### **42.5 Regulatory Framework**

The UK is the second most highly rated country in the GCCSI Policy Indicator Report (score of 68) due to the ambitions for CCUS deployment outlined in the Clean Growth Strategy in 2017. In 2020 and 2021, the UK Government released their Energy White Paper detailing how the UK energy supply will meet Net Zero ambitions and pledged £1 billion towards the development of a series of clusters and hubs across the UK, further demonstrating its commitment to the UK CCS industry. The UK is one of five countries that have ratified the Article 6 amendment to the London Protocol. It is working with countries through the North Sea Basin Taskforce and others to advance ratification further. The UK also participates in ERA-NET to accelerate CCS technologies with 8 other European countries and funds many ventures for the low-carbon industry. On an international front, the UK is committed to convening and leading a new international working group to drive down costs and accelerate CCUS deployment. It has achieved this with several investment and collaboration initiatives.

### **42.6 Issues for the Assessment**

The restrictions on commercial access to CO<sub>2</sub>Stored still hinder the wealth of data that could be added to the CSRC for the UK. As a result, storage volumes rely on access to publications

referencing the CO<sub>2</sub>Stored database or other publications showing more detailed studies on individual sites that exhibit good storage potential. As with Cycle 3, this may lead to an underrepresentation of storage volumes. With respect to the UK projects cited by storage license holders, access to the source of the research for the volumes they publish on websites and presentations is not available. Hence, the volumes they cite are taken at face value on their company publications. Any future published works on these sites and projects will need to be reviewed for a more in-depth analysis of potential storage volumes.

### **42.7 Future Updates**

#### **42.7.1 Future CSRC cycles**

Published evaluations for the sites currently active in the UK would enable future updates to the CSRC. This would better represent the maturity of the storage resources associated with these projects.

## 43 Bibliography

### 43.1 ALL

Global CCS Institute, "CCS Policy Indicator (CCS-PI)," 2023

### 43.2 Albania

1. Vangkilde-Pedersen, T. (ed.) (2009): Storage capacity. — EU GeoCapacity Report D16, 166 pages
2. Hatziyannis, G. 2009. Review of CO<sub>2</sub> Storage capacity of Greece, Albania and FYROM. EU GeoCapacity open final conference. 21-22 October, 2009, Copenhagen, Denmark.
3. Trans Adriatic Pipeline (TAP). <https://wbif.eu/project/PRJ-ALB-ENE-014>. Accessed 18/06/2025
4. REC Albania 2021. Monitoring of The Strategy for Climate Change and Action Plan, 2020-2030, REC EN\_ Monitoring of the Climate Change Strategy in Albania.pdf

### 43.3 Austria

1. Scharf, C. and T. Clemens, 2006, CO<sub>2</sub> Sequestration Potential in Austrian Oil and Gas Fields, SPE 100176
2. Welkenhuysen, K., Brüstle, A-K., Bottig, M., Andrea Ramírez, A., Swennen, R., 2 & Piessens, K., (2016), A techno-economic approach for capacity assessment and ranking of potential options for geological storage of CO<sub>2</sub> in Austria, *Geologica Belgica*, 19/3-4: 237-249
3. Tom Mikunda, T., Franců, J., Pereszlényi, M., Hladík, V., Vladimír. K., Kulich, J., Götzl, G., Kollbotn, L., Jankulár, M., (2020), ENOS D6.7 Report: Towards a strategic development plan for CO<sub>2</sub>-EOR in the Vienna Basin
4. CO<sub>2</sub>GeoNet (2021): State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update, CO<sub>2</sub>GeoNet Report, 325 p.; DOI: 10.25928/CO<sub>2</sub>geonet\_eu32-o21u.
5. Federal Ministry republic of Austria Sustainability and Tourism, (2019), Long-Term Strategy 2050 – Austria Period through to 2050, pursuant to Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action as per Decision 1/CP.21, paragraph 35 in accordance with Article 4, paragraph 19 of the Paris Agreement.

### 43.4 Belarus

1. United Nations 2021. Geologic CO<sub>2</sub> storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy, United Nations, Geneva , [https://unece.org/sites/default/files/2021-04/Geologic%20CO<sub>2</sub>%20storage%20report\\_final\\_EN.pdf](https://unece.org/sites/default/files/2021-04/Geologic%20CO2%20storage%20report_final_EN.pdf)
2. IEA (International Energy Agency), (2015). Storing CO<sub>2</sub> through Enhanced Oil Recovery. Paris.

3. Government of the Republic of Belarus, Updated Nationally Determined Contribution of the Republic of Belarus, [https://unfccc.int/sites/default/files/NDC/2022-06/MD\\_Updated\\_NDC\\_final\\_version\\_EN.pdf](https://unfccc.int/sites/default/files/NDC/2022-06/MD_Updated_NDC_final_version_EN.pdf)

## 43.5 Belgium

1. Poulsen, N., Holloway, S., Neele, F., Smith, N.A. and Kirk, K. 2014. Assessment of CO<sub>2</sub> storage potential in Europe. European Commission Contract No ENER/C1/154-2011-SI2.611598. GEUS, CO<sub>2</sub>StoP Final Report, 56, The Geological Survey of Denmark and Greenland (GEUS), <https://repository.europe-geology.eu/egdidocs/egdi/56-2014+final+report.pdf>
2. European Commission, 2020. European CO<sub>2</sub> Storage Database. [https://setis.ec.europa.eu/european-CO2-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en). Accessed 23/04/2025
3. Christensen, NP., Holloway, S. 2004. Assessing European potential for geological storage of CO<sub>2</sub> from fossil fuel combustion. Project no. ENK6-CT-1999-00010. European Commission. [https://www.bgr.bund.de/EN/Themen/Nutzung\\_tieferer\\_Untergrund\\_CO2Speicherung/Projekt/CO2Speicherung/Abgeschlossen/Nur-Deutsch/Gestco/GESTCO\\_summary\\_report\\_2004.pdf?\\_\\_blob=publicationFile&v=2#:~:text=The%20case%2Dstudy%20of%20the,of%20less%20than%201500%20m.](https://www.bgr.bund.de/EN/Themen/Nutzung_tieferer_Untergrund_CO2Speicherung/Projekt/CO2Speicherung/Abgeschlossen/Nur-Deutsch/Gestco/GESTCO_summary_report_2004.pdf?__blob=publicationFile&v=2#:~:text=The%20case%2Dstudy%20of%20the,of%20less%20than%201500%20m.)
4. Holloway, S. 1996. The underground disposal of carbon dioxide, Contract No JOU2 CT92-003 1. [nora.nerc.ac.uk/id/eprint/502763/1/Joule%20II%20final%20report.pdf](http://nora.nerc.ac.uk/id/eprint/502763/1/Joule%20II%20final%20report.pdf)
5. Piessens, K., Laenen, B., Mathieu, P., Baele, J.M., Hendriks, C., Vandeginste, V., Welkenhuysen, K., Dreesen, R., Bierkens, J., Broothaers, M., Hildenbrand, S., Lagrou, D., Nijs, W., Bertrand, E., De Visser, E. and Brandsma, R. 2008. Policy Support System for Carbon Capture and Storage. Final Report Phase 1, Research Programme Science for a Sustainable Development, [https://www.belspo.be/belspo/ssd/science/finalreports/reports/pss-ccs\\_finrep\\_2008.def.pdf](https://www.belspo.be/belspo/ssd/science/finalreports/reports/pss-ccs_finrep_2008.def.pdf)
6. Piessens, K. 2011. Quantifying the CO<sub>2</sub> storage potential in Belgium: Working with theoretical capacities, Energy Procedia, GHGT-10, 4, 4905–4912, <https://doi.org/10.1016/j.egypro.2011.02.459>, <https://www.sciencedirect.com/science/article/pii/S1876610211007387>
7. Welkenhuysen, K., Piessens, K., Baele, J.-M., Laenen, B. and Dusar, M. 2011. CO<sub>2</sub> storage opportunities in Belgium, Energy Procedia, GHGT-10, 4, 4913–4920, <https://doi.org/10.1016/j.egypro.2011.02.460>, <https://www.sciencedirect.com/science/article/pii/S1876610211007399>
8. The CCS Hub. 'Antwerp@C.'. <https://ccushub.ogci.com/wp-content/uploads/2022/07/CCUS-Hub-Antwerp@C-Kairos@C.pdf>. Accessed 16/04/2025
9. Fluxys. 'Ghent Carbon Hub'. <https://www.fluxys.com/en/projects/ghent-carbon-hub>. Accessed 16/04/2025

10. Wallonia.be. 'Carbon capture: The Walloon Industry soon to be connected to the North Sea.'  
<https://www.wallonia.be/en/news/carbon-capture-walloon-industry-soon-be-connected-north-sea>. Accessed 16/04/2025.
11. European Commission 2023. Belgium: Member States report on Implementation of Directive 2009/31/EC on the geological storage of carbon dioxide ("CCS Directive"),
12. GCCSI, 2023, CCS Legal and Regulatory Indicator 2023.  
<https://www.globalccsinstitute.com/wp-content/uploads/2023/10/CCS-Legal-and-Regulatory-Indicator-Report-Global-CCS-Institute-.pdf>

### 43.6 Bosnia and Herzegovina

1. European Commission. (2013). WP2 Report – Storage capacity: EU GeoCapacity project – Assessing European capacity for geological storage of carbon dioxide. European Commission.  
[https://www.researchgate.net/publication/262688927\\_WP2\\_Report\\_-\\_Storage\\_capacity\\_EU\\_GeoCapacity\\_project\\_-\\_Assessing\\_European\\_Capacity\\_for\\_Geological\\_Storage\\_of\\_Carbon\\_Dioxide](https://www.researchgate.net/publication/262688927_WP2_Report_-_Storage_capacity_EU_GeoCapacity_project_-_Assessing_European_Capacity_for_Geological_Storage_of_Carbon_Dioxide)
2. United Nations Economic Commission for Europe (UNECE). (2021). Geologic CO<sub>2</sub> storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy.  
[https://unece.org/sites/default/files/2021-04/Geologic%20CO<sub>2</sub>%20storage%20report\\_final\\_EN.pdf](https://unece.org/sites/default/files/2021-04/Geologic%20CO2%20storage%20report_final_EN.pdf)
3. CO<sub>2</sub>GeoNet. (2021). State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update. CO<sub>2</sub>GeoNet Association. [https://doi.org/10.25928/CO<sub>2</sub>geonet\\_eu32-o21u](https://doi.org/10.25928/CO2geonet_eu32-o21u)

### 43.7 Bulgaria

1. Georgiev, G., 2007, CO<sub>2</sub> emissions and geological storage opportunities in Bulgaria, International Congress "Environmental and Energy Principles of the Sustainable Development", 27 May 2007, Sofia.
2. Hatziyannis, G., Falus, G., Georgiev, G., Sava, C., (2009), Assessing capacity for geological storage of carbon dioxide in central – east group of countries (EU GeoCapacity project), Energy Procedia 1,3691–3697
3. Martinez, R., Suárez, I., Carneiro, J., Le Nindre, Y.M. & Boevida, D., 2013, Storage capacity evaluation for development of CO<sub>2</sub> infrastructure in the west Mediterranean, Energy Procedia, 37, 5209, 5219
4. Levesley, G. (2018), New Gas Storage Capacity in Galata – To enhance Regional Energy Security and facilitate Gas Market Liberalization. Petroceltic June 2018  
[https://bulenergyforum.org/sites/default/files/3-3\\_galata\\_gas\\_storage\\_june\\_18.pdf](https://bulenergyforum.org/sites/default/files/3-3_galata_gas_storage_june_18.pdf)
5. Georgiev, G., 2009, Bulgaria country Review, EU GeoCapacity project conference October 2009 oral presentation.

6. Bulgaria: new carbon capture and storage laws, <https://cms-lawnow.com/en/ealerts/2011/10/bulgaria-new-carbon-capture-and-storage-laws> (accessed 26/2/24)

### 43.8 Croatia

1. Veloso, F. M. L. 2021. Maturity level and confidence of storage capacities estimates in the promising regions. EU H2020 STRATEGY CCUS Project 837754, Report, pp 125. Tom Mikunda, T., Franců, J., Pereszlényi, M., Hladík, V., Vladimír. K., Kulich, J., Götzl, G., Kollbotn, L., Jankulár, M., (2020), ENOS D6.7 Report: Towards a strategic development plan for CO<sub>2</sub>-EOR in the Vienna Basin
2. Vulin, D., Vodopić, F., Arnaut, M., Saftić, B., Kolenković Močilac, I., Karasalihović Sedlar, D. and Marko Cvetković, M.;(2021). Assessment of current state, past experiences and potential for CCS deployment in the CEE region: Croatia. BUILDING MOMENTUM FOR THE LONG-TERM CCS DEPLOYMENT IN THE CEE REGION project. <https://ccs4cee.eu/assessment-of-current-state-ccs-4-cee/>
3. Saftic, B., I.K. Mocilac, M. Cvetkovic, D. Vulin, J. Velic and B. Tomljenovic, 2019, Potential for the geological storage of CO<sub>2</sub> in the Croatian part of the Adriatic offshore, Minerals, 9, 10.
4. IOGP, Interactive map of CCS projects in Europe. <https://iogpeurope.org/european-ccs-projects-map/> (Accessed 17/06/24)
5. HOLCIM. KODECONET ZERO PROJECT. <https://www.holcim.com/what-we-do/green-operations/ccus/kodeco> (Accessed 17/06/24)

### 43.9 Czechia

1. Bartovic V., Hruby M., Visnerova A. Assessment of current state, past experiences and potential for CCS deployment in the CEE region Building momentum for the long-term CCS deployment in the CEE region, 2023, Prague Document Title Lorem ipsum doloris sunt est quidam. (ccs4cee.eu)
2. ENOS. Enabling onshore storage in Europe. <http://www.enos-project.eu/>. (Accessed 17/06/24)
3. Saulius Sliupa, Richard Lojka, Zuzana Tasáryová, Vladimír Kolejka, Vít Hladík, Julia Kotulova, Ludovit Kucharic, Vlado Fejdi, Adam Wójcicki, Radosław Tarkowski, Barbara Uliasz-Misiak, Rasa Slaupiene, Inara Nulle, Raisa Pomeranceva, Olga Ivanova, Alla Shogenova, Kazbulat Shogenov (2013). CO<sub>2</sub> storage potential of sedimentary basins of Slovakia, Czechia, Poland and the Baltic States Geological Quarterly Vol 57(No 2)
4. Tom Mikunda, Juraj Franců, Miroslav Pereszlényi, Vít Hladík, Vladimír Kolejka, Jakob Kulich, Gregor Götzl, Lars Kollbotn, Michal Jankulár, 2020, D6.7 Report: Towards a strategic development plan for CO<sub>2</sub>-EOR in the Vienna Basin, ENOS

5. MND, Geological Storage of CO<sub>2</sub>, <https://www.mnd.eu/en/project/CO2-storage-in-rock-structures/>. (accessed 18/06/24)
6. Carbon Gap Policy Tracker. Czechia. <https://tracker.carbongap.org/region/czech-republic/> . (Accessed 18/06/24)
7. CO<sub>2</sub>StoP - a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe, [https://setis.ec.europa.eu/european-CO2-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en) (accessed 07/03/24)

### 43.10 Denmark

1. Anthonen, K., Bernstone, C., & Feldrappe, H. (2014). Screening for CO<sub>2</sub> storage sites in Southeast North Sea and Southwest Baltic Sea. *Energy Procedia*, 5083-5092.
2. Hjelm, L., K.L. Anthonen, K. Dideriksen, C.M. Nielsen, L.H. Nielsen and A. Mathiesen, 2022, Capture, Storage and Use of CO<sub>2</sub> (CCUS). Evaluation of the CO<sub>2</sub> storage potential in Denmark, 2021
3. Greensand. Project Greensand. <https://www.projectgreensand.com/en>. (Accessed 18/06/24)
4. Anthonen, K. L., Aagaard, P., Bergmo, P. E. S., Gislason, S. R., Lothe, A. E., Mortensen, G. M., & Snæbjörnsdóttir, S. Ó., 2014, Characterisation and selection of the most prospective CO<sub>2</sub> storage sites in the Nordic region, *Energy Procedia*, 63, 4884, 4896
5. Bonto, M., Welch, M. J., Lüthje, M., Andersen, S. I., Veshareh, M. J., Amour, F., Afrough, A., Mokhtari, R., Hajiabadi, M. R., Alizadeh, M. R., Larsen, C. N., & Nick, H. M. , 2021, Challenges and enablers for large-scale CO<sub>2</sub> storage in Chalk Formations., *Earth Science Reviews*, 222
6. Larsen, M., N. Bech, T. Bidstrup, N.P. Christensen, O. Biede and T.G. Vangkilde-Pedersen, 2007, Kalundborg case study, a feasibility study of CO<sub>2</sub> storage in onshore saline aquifers, *Danmarks og Grønlands Geologiske Undersøgelse Rapport*, 2007, 3, 1, 81
7. Member State report on Implementation of Directive 2009/31/EC on the geological storage of carbon dioxide ("CCS Directive"), 2023, ([https://ec.europa.eu/assets/clima/ccs/2023/policy\\_ccs\\_country\\_report\\_2023\\_denmark\\_en.pdf](https://ec.europa.eu/assets/clima/ccs/2023/policy_ccs_country_report_2023_denmark_en.pdf)) Accessed 01/03/2024.

### 43.11 Estonia

1. Vangkilde-Pedersen T, Kirk K, Smith N, Maurand N, Wojcicki A, Neele F, et al. FP6 EU GeoCapacity Project, Assessing European Capacity for Geological Storage of Carbon Dioxide, Storage Capacity, D42, GeoCapacity Final Report 2009; p. 1-63, <http://www.geology.cz/geocapacity/publications>.
2. Christensen NP, Halloway S, et al. Geological Storage of CO<sub>2</sub> from Combustion of Fossil Fuel, EU FP5, Summary Report, The GESTCO project; 2004
3. Baltac, S., Pusceddu, E., O'Sullivan, C., Galbraith-Olive, H. and Henderson, C. 2023. Unlocking Europe's CO<sub>2</sub> Storage Potential. CATF European CO<sub>2</sub> Storage Report, Clean Air Task Force, [https://cdn.catf.us/wp-content/uploads/2023/07/21155827/CATF\\_European-CO2-Storage-Report\\_July-23](https://cdn.catf.us/wp-content/uploads/2023/07/21155827/CATF_European-CO2-Storage-Report_July-23).

4. Ploom, H., Oeselg, V. and Sau, M. 2021. Assessment of current state, past experiences and potential for CCS deployment in the CEE region - Estonia, The Building momentum for the long-term CCS deployment in the CEE region, <https://ccs4cee.eu/news-articles>
5. Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO<sub>2</sub> emissions: the Estonian–Latvian cross-border case study, *Energy Procedia*, GHGT-10, 4, 2385–2392, <https://doi.org/10.1016/j.egypro.2011.02.131>, Economic modelling of the capture–transport–sink scenario of industrial CO<sub>2</sub> emissions: The Estonian–Latvian cross-border case study – ScienceDirect
6. Simmer, K. 2018. Estonian-Latvian Transboundary Carbon Dioxide Capture, Transport and Storage (CCS) Scenario for the Cement Industry, Masters Thesis, Tallinn Univeristy of Technology, [https://www.bing.com/ck/a?!&&p=e5576b07089f6d3386c7fe6da75f458db3df83a111765d2c060af6bda2fd32beJmltdHM9MTczNjcyNjQwMA&ptn=3&ver=2&hsh=4&fclid=0ac464da-e8cf-6f2f-2869-772ce9f76e5c&psq=Estonian-Latvian+Transboundary+Carbon+Dioxide+Capture%2c+Transport+and+Storage+\(CCS\)+Scenario+for+the+Cement+Industry&u=a1aHR0cHM6Ly9kaWdpa29ndS50YWx0ZWNoLmVIL2V0L0Rvd25sb2FkL2ZmNGI5ODNhLTQ2NjMtNDU4MCMWlWLTlWmZlLOWY2MDRmYw&ntb=1](https://www.bing.com/ck/a?!&&p=e5576b07089f6d3386c7fe6da75f458db3df83a111765d2c060af6bda2fd32beJmltdHM9MTczNjcyNjQwMA&ptn=3&ver=2&hsh=4&fclid=0ac464da-e8cf-6f2f-2869-772ce9f76e5c&psq=Estonian-Latvian+Transboundary+Carbon+Dioxide+Capture%2c+Transport+and+Storage+(CCS)+Scenario+for+the+Cement+Industry&u=a1aHR0cHM6Ly9kaWdpa29ndS50YWx0ZWNoLmVIL2V0L0Rvd25sb2FkL2ZmNGI5ODNhLTQ2NjMtNDU4MCMWlWLTlWmZlLOWY2MDRmYw&ntb=1)
7. Estonia, C. 2023. CCS National Roadmap - Estonia, The Building momentum for the long-term CCS deployment in the CEE region, <https://ccs4cee.eu/building-momentum-for-the-long-term-ccs-deployment-in-the-cee-region-ccs-national-roadmaps/>
8. Estonia's Communication to the European Commission under Article 3(1) of Regulation (EU) No 2012/2018

### 43.12 France

1. Poulsen, N., Holloway, S., Kirk, K, Neele, F. and Smith, N.A; CO<sub>2</sub>StoP – a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe.
2. Veloso FML. 2021, Maturity level and confidence of storage capacities estimates in the promising regions. EU H2020 STRATEGY CCUS Project 837754, Report, 2021;125.
3. Carneiro, J. and de Mesquita Lobo, F.; (2021). Maturity level and confidence of storage capacities estimates in the promising regions. D2.3\_StorageResources. January 2021 Project ID NUMBER 837754. STRATEGY CCUS (H2020-LC-SC3-2018-2019-2020/H2020-LC-SC3-2018-NZE-CC) <http://www.strategyccus.eu/project-outputs/methods-outputs/>
4. Cavanagh, AJ, Wilkinson, M and Haszeldine, RS. 2020. Bridging the Gap, Storage Resource Assessment Methodologies, EU H2020 STRATEGY CCUS Project 837754, Report, pp 67.
5. Czernichowski-Lauriol , I., Czop, V., Delprat-Jannaud , F., El Khamlichi, A., ,L., Lafortune, S., Nevicato, D. and Savary, D.; (2021): The Gradual Integration of CCUS into National and Regional Strategies for Climate Change Mitigation, Energy Transition, Ecological Transition,

Research and Innovation: An Overview for France. 15th International Conference on Greenhouse Gas Control Technologies, GHGT-15.

6. Duscha, Vicki, 2022: Regulatory framework for CCUS in the EU and its Member States. An analysis for the EU, six Member States and the UK. Deliverable within the project PilotSTRATEGY, supported under grant agreement No. 101022664
7. Thibeau, S., Chiquet, P., Prinet, C. and Lescanne, M.; (2013): Lacq-Rousse CO<sub>2</sub> Capture and Storage Demonstration Pilot: Lessons Learnt from Reservoir Modelling Studies. *Energy Procedia*, Volume 37, 2013, Pages 6306-6316, ISSN 1876-6102, <https://doi.org/10.1016/j.egypro.2013.06.559>.
8. CARBON CAPTURE AND STORAGE The Lacq pilot -Project and injection period 2006 – 2013. <https://www.globalccsinstitute.com/archive/hub/publications/194253/carbon-capture-storage-lacq-pilot.pdf>
9. O. Gassara, A. Estublier, B. Garcia, S. Noirez, A. Cerepi, C. Loisy, O. Le Roux, A. Petit, L. Rossi, S. Kennedy, T. Brichart, P. Chiquet, L. Luu Van Lang, F. André Duboin, J. Gance, B. Texier, B. Lavielle, B. Thomas, (2021). The Aquifer-CO<sub>2</sub>Leak project: Numerical modeling for the design of a CO<sub>2</sub> injection experiment in the saturated zone of the Saint-Emilion (France) site, *International Journal of Greenhouse Gas Control*, Volume 104, 2021, 103196, ISSN 1750-5836, <https://doi.org/10.1016/j.ijggc.2020.103196>.  
(<https://www.sciencedirect.com/science/article/pii/S1750583620306216>)
10. Gravaud, Isaline and M. L. Veloso, Fernanda and Prézélus, Flavie and Bidel, Alexandre and Diallo, Tidjan and Zrida, Mohamed and Malanda, Noémie and Chauzeix, Benoit and Laurent, Faustine and Villeneuve, Jacques and Doucet, Muriel and Lambert, Marie-Odile and Lalizel, Benoit and Combe, Michel, Biomass-Origin Carbon Capture, Storage and Utilization in Greenhouses: The CO<sub>2</sub>serre Project in Centre-Val De Loire (France) (March 25, 2021). *Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021*, Available at SSRN: <https://ssrn.com/abstract=3812275> or <http://dx.doi.org/10.2139/ssrn.3812275>
11. Blaizot, M., Giannangeli, F. and Ait Ettajer, T.; (2022): The PYCASSO territories Project: a Large Onshore CCUS Hub for Southern Europe. *EAGE GET 2022*, Nov 2022, Volume 2022, p.1 – 4 DOI: <https://doi.org/10.3997/2214-4609.202221114>

### 43.13 Germany

1. Project Ketzin, <https://www.CO2ketzin.de/en/home> (accessed 05/03/2024)
2. Holler, S. and P. Viebahn, 2011, Assessment of CO<sub>2</sub> storage capacity in geological formations of Germany and Northern Europe, *Energy Procedia*, 4, 4897, 4904
3. Anthonsen, K.L., and Christensen, N.P., (2021), EU Geological CO<sub>2</sub> storage summary, DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2021/34
4. Bense, F.A. and F. Jahne-Klingberg, 2017, Storage Potentials in the Deeper Subsurface of the

Central German North Sea, Energy Procedia, 114, 4595, 4622

5. Knopf, S. and F. May, 2017, Comparing Methods for the Estimation of CO<sub>2</sub> Storage Capacity in Saline Aquifers in Germany: Regional Aquifer Based vs. Structural Trap Based Assessments, Energy Procedia, 114, 4710, 4721
6. Müller C, Reinhold K, editors. Informationssystem Speichergesteine für den Standort Deutschland - eine Grundlage zur klimafreundlichen, geotechnischen und energetischen Nutzung des tieferen Untergrundes (Speicher-Kataster Deutschland). Report, Berlin/Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe; 2011.
7. Jähne-Klingberg F, Wolf M, Steuer S, Bense F, Kaufmann D, Weitkamp A. Speicherpotenziale im zentralen deutschen Nordsee-Sektor. Report, Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe; 2014.

#### **43.14 Greece**

1. Christensen, N.P., and Holloway, S., (eds), 2004, The GETSCO project, Summary Report, European Union Fifth Framework Programme for research and Development project Nio. ENK6-CT-1999-00010.
2. EU GeoCapacity, Assessing European Capacity for Geological Storage of Carbon Dioxide (2009) Project no. SES6-518318
3. Tasianas, A. and Koukouzias, N., (2016), CO<sub>2</sub> Storage Capacity Estimate in the Lithology of the Mesohellenic Trough, Greece. Energy Procedia, Volume 86, 2016, 334-341.
4. Koukouzias, N., Tyrologou, P., Karapanos, D., Carneiro, J., Pereira, P., de Mesquita Lobo Veloso, F., Koutsovitis, P., Karkalis, C., Manoukian, E., Karametou, R., (2021), Carbon Capture, Utilisation and Storage As a Defence Tool Against Climate Change: Current Developments in West Macedonia (Greece). Energies, 14, 3321.
5. Cavanagh, A.J, Wilkinson, M and Haszeldine, RS. 2020. Bridging the Gap, Storage Resource Assessment Methodologies, EU H2020 STRATEGY CCUS Project 837754, Report
6. Corless, V., Fjøsna, E., Havlik, J., Hoff, E., Taylor, D., Tjetland, G., and Vazaios, I., (2010) A bridge to a greener Greece A realistic assessment of CCS potential, The Bellona Foundation, Athens, Greece.
7. Arvanitis, A., Koutsovitis, P., Koukouzias, N., Tyrologou, P., Karapanos, D., Karkalis, C., and Pomonis P., (2020), Potential Sites for Underground Energy and CO<sub>2</sub> Storage in Greece: A Geological and Petrological Approach, Energies, 13, 2707

#### **43.15 Hungary**

1. Kubus, P., 2010, CCS and CO<sub>2</sub>-Storage Possibilities in Hungary, SPE International Conference on CO<sub>2</sub> Capture, Storage, and Utilization, New Orleans, Louisiana, USA, November 2010. Paper Number: SPE-139555-MS
2. Azbej, T., V. Corless, J. Helseth, G. Falus, E. Fjona, J. Havlik, E. Hoff, G. Tjetland, 2011, The

Power of Choice - A CCS Roadmap for Hungary, Bellona Environmental CCS Team (BEST)

3. Berta, M., C. Király, G. Falus, J. Gy and C. Szabó, 2011, Preliminary physical and geochemical study on a sedimentary rock series of the Pannonian Basin for CCS (Hungary), 4, 4719, 4723
4. Fazekas, D., Á. Hartvig and J. Hidi, 2022, CCS National Roadmap – Hungary
5. Carbon Gap Policy Tracker, Hungary. <https://tracker.carbongap.org/region/hungary/>. Accessed 18/06/24

### 43.16 Italy

1. Donda, F., Volpi, V., Persoglia, S. and Parushev, D.; (2011): CO<sub>2</sub> storage potential of deep saline aquifers: the case of Italy International Journal of Greenhouse Gas Control, Volume 5, Issue 2, March 2011, Pages 327-335.
2. Civile, D., Zecchin, M., Forlin, E., Donda, F., Volpi, V., Merson, B. & Persoglia, S. (2013): CO<sub>2</sub> geological storage in the Italian carbonate succession. — International Journal of Greenhouse Gas Control, 19: 101-116
3. Buttinelli, M., Procesi, M., Cantucci, B, Quattrocchi, F. and Boschi, E.; (2011)The geo-database of caprock quality and deep saline aquifers distribution for geological storage of CO<sub>2</sub> in Italy. Energy, Volume 36, Issue 5, May 2011, Pages 2968-2983
4. Amorino, C. (2005) 'CO<sub>2</sub> geological storage by ECBM techniques in the Sulcis area (SW Sardinia Region, Italy)', Paper presented at Second International Conference on Clean Coal Technologies for our Future, Sardinia, Italy.
5. Castelletto, N., P. Teatini, G. Cambolati, D. Bossie-Codreanu, O. Vincké, J. Daniel, A. Battistelli, M. Marcolini, F. Donda and V. Volpi (2013) Multiphysics modeling of CO<sub>2</sub> sequestration in a faulted saline formation in Italy, Advances in Water Resources, Volume 62, Part C, 2013, Pages 570-587,
6. Colucci, F., Guandalini, R., Macini, P., Moia, F., Savoca, D. et al. (2016): A feasibility study for CO<sub>2</sub> geological storage in Northern Italy 2016. International Journal of Greenhouse Gas, Control Volume 55, December 2016, Pages 1-14.
7. Proietti, G., Cvetković, M., Saftić, B., Conti, A., Romano, V. and Bigi, S. (2021): 3D modelling and capacity estimation of potential targets for CO<sub>2</sub> storage in the Adriatic Sea, Italy. Petroleum Geoscience 2021;
8. Proietti, G., Conti, A., Beaubien, S. E. and Bigi, S. (2023): Screening, classification, capacity estimation and reservoir modelling of potential CO<sub>2</sub> geological storage sites in the NW Adriatic Sea, Italy 2023, International Journal of Greenhouse Gas Control Volume 126, 2023, 103882, ISSN 1750-5836,
9. Bigi, S., M. C. Tartarello, L. Ruggiero, S. Graziani, S. E. Beaubien and S. Lombardi; (2017). Ongoing and Future Research at the Sulcis Site in Sardinia, Italy – Characterization and Experimentation at a Possible Future CCS Pilot, Energy Procedia, Volume 114, 2017, Pages 2742-2747, ISSN 1876-6102,

10. Tartarello, M. C., Plaisant, A., Bigi, S., Beaubien, S. E., Graziani, S., Lombardi, S., Ruggiero, L., De Angelis, D., Sacco, P. and Maggio, E.;(2017): Preliminary results of geological characterization and geochemical monitoring of Sulcis Basin (Sardinia), as a potential CCS site.
11. CO<sub>2</sub>Geonet. <https://CO2geonet.com/home/> . (Accessed 16/06/24)
12. Vangkilde-Pedersen, T. (ed.) (2009): Storage capacity. — EU GeoCapacity Report D16, 166 pages
13. The CCUS Hub. <https://ccushub.ogci.com/hubs-in-action>. (Accessed 18/06/24)
14. Beretta, S. et al. (2012): Geological characterization of Italian reservoirs and numerical 3D modelling of CO<sub>2</sub> storage scenarios into saline aquifers. Geophysical Research Abstracts Vol. 14, EGU2012-10115, 2012 EGU General Assembly
15. Barison, E.; Donda, F.; Merson, B.; Le Gallo, Y.; Réveillère, A. (2023). An Insight into Underground Hydrogen Storage in Italy. Sustainability 2023, 15, 6886.
16. CO<sub>2</sub>GeoNet. State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update. CO<sub>2</sub>GeoNet Report. 2021. [www.CO2geonet.com/state-of-play/](http://www.CO2geonet.com/state-of-play/).[https://CO2geonet.com/media/73750/CO2geonet\\_state-of-play-in-europe\\_2021.pdf](https://CO2geonet.com/media/73750/CO2geonet_state-of-play-in-europe_2021.pdf)

### **43.17 Ireland**

1. Bentham, M.S., Kirk, K.L. & Williams, J. 2008, Basin-by-Basin analysis of CO<sub>2</sub> storage potential of all-island Ireland, British Geological Survey Internal Report CR/08/040
2. Lewis, D., Bentham, M., Cleary, T., Vernon, R., O'Neill, N., Kirk, K., Chadwick, A., Hilditch, D., Michael, K., Allinson, G., Neal, P. & Ho, M. , 2009, Assessment of the potential for geological storage of carbon dioxide in Ireland and Northern Ireland, Energy Procedia, 1, 1, 2655, 2668
3. English, J.M. and English K.L., 2022, Carbon Capture and Storage Potential in Ireland — Returning Carbon Whence It Came, First Break, 40, 5, 35, 44
4. O'Sullivan, C., P. Rodriguez-Salgado, C. Childs and P. Shannon, 2023, Subsurface storage capacity in underexplored sedimentary basins: Hydrogen and carbon dioxide storage on the Irish Atlantic margin
5. Farrelly, I., Loske, B., Neele, F. & Holdstock, M., 2011, Assessment of the potential for geological storage of CO<sub>2</sub> in the vicinity of Moneypoint, Co. Clare, Ireland, Energy Procedia, 4, 4754, 4763

### **43.18 Kosovo**

1. Kulichenko, N and Ereira, El. 2012. Carbon capture and storage in developing countries: a perspective on barriers to deployment. World Bank. ISBN 978-0-8213-9609-4; 978-0-8213-9610-0 1.

### **43.19 Latvia**

1. Shogenova, A., Silaupa, S. and Shogenov, K. 2009. The Baltic Basin: Structure, properties of reservoir rocks, and capacity for geological storage of CO<sub>2</sub>, Estonian Journal of Earth Sciences,

- 58, 4, 259– 267, doi: 10.3176/earth.2009.4.04
2. Nilson, P.A. 2014. CCS in the Baltic Sea region – Bastor 2, Elforsk report 14:50, Elforsk, 14\_48\_rapport.pdf
  3. Shogenov, K., Shogenova, A. and Olga. V. 2013. Potential structures for CO<sub>2</sub> geological storage in the Baltic Sea: Case study offshore Latvia, Bulletin of the Geological Society of Finland, 85, 65-81, 10.17741/bgsf/85.1.005.
  4. Shogenov, K., Forlin, E. and Shogenova, A. 2017. 3D geological and petrophysical numerical models of E6 structure for CO<sub>2</sub> storage in the Baltic Sea, Energy Procedia, 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13,, Lausanne, Switzerland, 114, 3564 – 3571, <https://doi.org/10.1016/j.egypro.2017.03.1486>, 3D Geological and Petrophysical Numerical Models of E6 Structure for CO<sub>2</sub> Storage in the Baltic Sea - ScienceDirect
  5. Shogenova, A., Shogenov, K., Pomeranceva, R., Nulle, I., Neele, F. and Hendriks, C. 2011. Economic modelling of the capture–transport–sink scenario of industrial CO<sub>2</sub> emissions: the Estonian–Latvian cross-border case study, Energy Procedia, GHGT-10, 4, 2385–2392, <https://doi.org/10.1016/j.egypro.2011.02.131>, Economic modelling of the capture–transport–sink scenario of industrial CO<sub>2</sub> emissions: The Estonian–Latvian cross-border case study - ScienceDirect
  6. Krumin, Š, J., Klavin, Š, M., Delin, A., Damkevics, R. and Seglin, Š, V. 2021. Potential of the Middle Cambrian Aquifer for Carbon Dioxide Storage in the Baltic States, Energies, 14, 3681, <https://doi.org/10.3390/en14123681>, Potential of the Middle Cambrian Aquifer for Carbon Dioxide Storage in the Baltic States.
  7. Simmer, K. 2018. Estonian-Latvian Transboundary Carbon Dioxide Capture, Transport and Storage (CCS) Scenario for the Cement Industry, Masters Thesis, Tallinn Univeristy of Technology
  8. CCS4CEE 2023. Summary of CCS4CEE project - Latvia, The Building momentum for the long-term CCS deployment in the CEE region, <https://ccs4cee.eu/news-articles/>
  9. GCCSI, 2023, CCS Legal and Regulatory Indicator 2023. <https://www.globalccsinstitute.com/wp-content/uploads/2023/10/CCS-Legal-and-Regulatory-Indicator-Report-Global-CCS-Institute-.pdf>

### **43.20 Liechtenstein**

1. EFTA Surveillance Authority. 2023. Report on the Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide

### **43.21 Lithuania**

1. Shogenova, A., Silaupa, S. and Shogenov, K. 2009. The Baltic Basin: Structure, properties of reservoir rocks, and capacity for geological storage of CO<sub>2</sub>, Estonian Journal of Earth Sciences, 58, 4, 259-267, doi: 10.3176/earth.2009.4.04
2. Malik, S., Makuškas, P., Karaliūtė, V., Pal, M. and Sharma, R. 2023. Assessing the Geological Storage Potential of CO<sub>2</sub> In Baltic Basin: A Case Study of Lithuanian Hydrocarbon and Deep

Saline Reservoirs, <https://www.mdpi.com/2075-163X/14/11/1112>

3. Sliapiene, R and Sliapa, S, 2011, Prospects for CO<sub>2</sub> geological storage in deep saline aquifers of Lithuania and adjacent territories *Geologija*, 53, 3, pp. 121-133.
4. Škikūnas, E. and Krulikovskis, D. 2021. Assessment of current state, past experiences and potential for CCS deployment in the CEE region - Lithuania, *The Building momentum for the long-term CCS deployment in the CEE region*, <https://ccs4cee.eu/news-articles/>
5. Malik, S., Makauskas, P., Sharma, R. and Pal, M. 2024. Evaluating Petrophysical Properties Using Digital Rock Physics Analysis: A CO<sub>2</sub> Storage Feasibility Study of Lithuanian Reservoirs, *Applied Sciences*, 14, 23, 10826, <https://doi.org/10.3390/app142310826>, <https://www.mdpi.com/2076-3417/14/23/10826>
6. Šliaupa, S., Michelevičius, D., Šliaupienė, R. and Liugas. J. 2024. Assessment of the Potential for CO<sub>2</sub> Storage and Utilization in the Fractured and Porous Reservoir of the Cambrian Sandstones in West Lithuania's Baltic Basin, *Minerals*, 14, 11, 1112, <https://doi.org/10.3390/min14111112>

#### 43.22 Malta

1. European Commission, 2021. Malta - Changes, reviews and updates of national implementation legislation. [https://ec.europa.eu/assets/clima/ccs/2023/policy\\_ccs\\_country\\_report\\_2023\\_malta\\_en.pdf](https://ec.europa.eu/assets/clima/ccs/2023/policy_ccs_country_report_2023_malta_en.pdf)
2. Contentalshef.gov.mt. Geological Storage of Carbon Dioxide. Accessed 13/5/2025. <https://continentalshelf.gov.mt/geological-survey/geological-storage-of-carbon-dioxide/>

#### 43.23 Moldova

1. United Nations 2021. Geologic CO<sub>2</sub> storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy, United Nations, Geneva, [https://unece.org/sites/default/files/2021-04/Geologic%20CO<sub>2</sub>%20storage%20report\\_final\\_EN.pdf](https://unece.org/sites/default/files/2021-04/Geologic%20CO2%20storage%20report_final_EN.pdf)
2. Government of the Republic of Moldova, Updated Nationally Determined Contribution of the Republic of Moldova, [https://unfccc.int/sites/default/files/NDC/2022-06/MD\\_Updated\\_NDC\\_final\\_version\\_EN.pdf](https://unfccc.int/sites/default/files/NDC/2022-06/MD_Updated_NDC_final_version_EN.pdf)

#### 43.24 Montenegro

1. United Nations 2021. Geologic CO<sub>2</sub> storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy, United Nations, Geneva, [https://unece.org/sites/default/files/2021-04/Geologic%20CO<sub>2</sub>%20storage%20report\\_final\\_EN.pdf](https://unece.org/sites/default/files/2021-04/Geologic%20CO2%20storage%20report_final_EN.pdf)
2. National Inventory Document 2024 of Montenegro submission under the United Nations Framework Convention on Climate Change (UNFCCC), [https://unfccc.int/sites/default/files/resource/2.%20NID\\_2024\\_MNE.pdf](https://unfccc.int/sites/default/files/resource/2.%20NID_2024_MNE.pdf)

### 43.25 North Macedonia

1. European Commission. (2013). WP2 Report – Storage capacity: EU GeoCapacity project – Assessing European capacity for geological storage of carbon dioxide. European Commission. [https://www.researchgate.net/publication/262688927\\_WP2\\_Report\\_-\\_Storage\\_capacity\\_EU\\_GeoCapacity\\_project\\_-\\_Assessing\\_European\\_Capacity\\_for\\_Geological\\_Storage\\_of\\_Carbon\\_Dioxide](https://www.researchgate.net/publication/262688927_WP2_Report_-_Storage_capacity_EU_GeoCapacity_project_-_Assessing_European_Capacity_for_Geological_Storage_of_Carbon_Dioxide)
2. United Nations Economic Commission for Europe (UNECE). (2021). Geologic CO<sub>2</sub> storage in Eastern Europe, Caucasus and Central Asia: An initial analysis of potential and policy. [https://unece.org/sites/default/files/2021-04/Geologic%20CO<sub>2</sub>%20storage%20report\\_final\\_EN.pdf](https://unece.org/sites/default/files/2021-04/Geologic%20CO2%20storage%20report_final_EN.pdf)
3. CO<sub>2</sub>Stop (2013). European CO<sub>2</sub> Storage Database (CO<sub>2</sub>Stop project, FP7-ENERGY-2010-1-265847). Brussels: European Commission. Retrieved from [https://setis.ec.europa.eu/european-CO<sub>2</sub>-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en)
4. CMS. (2024, February 22). Renewable energy in North Macedonia. Retrieved from <https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/north-macedonia>

### 43.26 Netherlands

1. Aramis CCS. (n.d.). <https://www.aramis-ccs.com/project>
2. Aramis. The CCUS Hub. (2022, August 2). [https://ccushub.ogci.com/focus\\_hubs/aramis/](https://ccushub.ogci.com/focus_hubs/aramis/)
3. Aramis. Gasunie. (n.d.). <https://www.gasunie.nl/projecten/aramis>
4. The Dutch Aramis Project - sharp-storage. SHARP. (2021, November 14). [https://sharp-storage-act.eu/case\\_study/the-dutch-aramis-project/](https://sharp-storage-act.eu/case_study/the-dutch-aramis-project/)
5. Project. Porthos. (2023, February 22). [https://www.porthosCO<sub>2</sub>.nl/en/project/](https://www.porthosCO2.nl/en/project/)
6. Porthos. The CCUS Hub. (2022b, March 2). [https://ccushub.ogci.com/focus\\_hubs/rotterdam-porthos/](https://ccushub.ogci.com/focus_hubs/rotterdam-porthos/)
7. Andy Read and Marc Kombrink (2018). ROAD, Public Close-Out Report Overview. <https://www.globalccsinstitute.com/wp-content/uploads/2019/09/ROAD-Close-Out-Report-Overview-final.pdf>
8. Neele, F., Hofstee, C., Arts, R., Vandeweyer, V., Nepveu, M., ten Veen, J., & Wilschut, F. (2013). Offshore Storage Options for CO<sub>2</sub> in the Netherlands. *Energy Procedia*, 37, 5220–5229. <https://doi.org/10.1016/j.egypro.2013.06.438>
9. van der Meer, L. G. H., & Yavuz, F. (2009). CO<sub>2</sub> storage capacity calculations for the Dutch subsurface. *Energy Procedia*, 1(1), 2615–2622. <https://doi.org/10.1016/j.egypro.2009.02.028>
10. Vandeweyer, V., Hofstee, C., Pelt, van, W., & Graven, H. , 2020, CO<sub>2</sub> injection at K12-B, the final story, Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021.

### 43.27 Norway

1. K. Anthonsen, C. Bernstone and H. Feldrappe, "Screening for CO<sub>2</sub> storage sites in Southeast

- North Sea and Southwest Baltic Sea," Energy Procedia, pp. 5083-509 2, 2014.
2. Global CCS Institute, "CCS Legal and Regulatory Indicator (CCS-LRI)," 2018.
  3. Norwegian Petroleum Directorate, "CO<sub>2</sub> Storage Atlas - Norwegian Continental Shelf," NPD, 2014.
  4. Equinor, "Climate data," [Online]. Available: <https://sustainability.equinor.com/climate-tables>. [Accessed 24 February 2021].
  5. S. Thibeau, L. Seldon, F. Masserano, J. Canal Vila and P. Ringrose, "Revisiting the Utsira Saline Aquifer CO<sub>2</sub> Storage Resources using the SRMS Classification Framework," in 14th Greenhouse Gas Control Technologies Conference, Melbourne, 2018
  6. H. M. Nilsen, K.-A. Lie and O. Andersen, "Analysis of CO<sub>2</sub> trapping capacities and long-term migration for geological formations in the Norwegian North Sea using MRST-CO<sub>2</sub>lab," Computers & Geosciences pp. 15-26, 2015.
  7. A. E. Lothe, B. Emmel, A. Grøver and P. E. Bergmo, "CO<sub>2</sub> storage and modelling and capacity estimation for the Trøndelag Platform, offshore Norway - using a basin modelling approach," Energy Procedia, pp. 3648-3657, 2014.
  8. Global CCS Institute, "CCS Policy Indicator (CCS-PI)," 2018.
  9. Norwegian Petroleum, "Emissions to Air," 2020. [Online]. Available:<https://www.norskpetroleum.no/en/environment-and-technology/emissions-to-air/>.
  10. Society of Petroleum Engineers (SPE), "CO<sub>2</sub> Storage Resources Management System," SPE, 2017.

### 43.28 Portugal

1. Boavida, D., Carneiro, J., Tosaco, G., Martinez, R., Van den Broek, M. and Gastine, M. 2012. COMET Final Report - Integrated infrastructure for CO<sub>2</sub> transport and storage in the west Mediterranean, <https://cordis.europa.eu/project/id/241400/reporting>
2. Tejo Energia (2011) Estudo de viabilidade da captura e armazenamento de CO<sub>2</sub> na central termoeléctrica do Pego. Relatório final técnico-científico. Tejo Energia. Lisboa. 130 pp.
3. Seixas, J., Fortes, P., Dias, L., Carneiro, J., Mesquita, P., Boavida, D., Aguiar, R., Marques, F., Fernandes, V., Helseth, J., Ciesielska, J. and Whiriskey, K. 2015. CO<sub>2</sub> capture and storage in Portugal, a bridge to a low carbon economy, 1-22, Bellona, [https://dspace.uevora.pt/rdpc/bitstream/10174/17077/1/CCS\\_roadmap%20Portugal%20P1%20ENG.pdf](https://dspace.uevora.pt/rdpc/bitstream/10174/17077/1/CCS_roadmap%20Portugal%20P1%20ENG.pdf)
4. European Commission, 2020. European CO<sub>2</sub> Storage Database. [https://setis.ec.europa.eu/european-co2-storage-database\\_en](https://setis.ec.europa.eu/european-co2-storage-database_en). Accessed 23/04/2025
5. European Union, 2025. Strategy CCUS. <https://www.strategyccus.eu/>. Accessed 23/04/2025
6. Pereira, P., Ribeiro, C. and Carneiro, J. 2021. Identification and characterization of geological formations with CO<sub>2</sub> storage potential in Portugal, Petroleum Geoscience, 27, 3, Petgeo2020-123, <https://doi.org/10.1144/petgeo2020-123>, Identification and characterization of geological formations with CO<sub>2</sub> storage potential in Portugal | Petroleum Geoscience | GeoScienceWorld

7. European Commission 2023. Portugal: Member States report on Implementation of Directive 2009/31/EC on the geological storage of carbon dioxide ("CCS Directive"), [https://ec.europa.eu/assets/clima/ccs/2023/policy\\_ccs\\_country\\_report\\_2023\\_portugal\\_en.pdf](https://ec.europa.eu/assets/clima/ccs/2023/policy_ccs_country_report_2023_portugal_en.pdf)
8. Pereira, P., Caeiro, M.H., Carneiro, J., Ribeiro, C., Casacão, J, Pina, B., Revaux, C., Findlay, R. Plougoule, A. and Msika, C. 2023. Assessing Offshore Prospects for CO<sub>2</sub> Storage in Portugal: From Pilot-Scale to Commercial Site, The Fourth EAGE Global Energy Transition Conference and Exhibition, , Novmeber, 45778, [tps://doi.org/10.3997/2214-4609.202321027](https://doi.org/10.3997/2214-4609.202321027)

### 43.29 Poland

1. Wójcicki, A, Nagy, S., Lubaś, J., JChećko, J., Radosław Tarkowski, R., 2014, Assessment of Formations and Structures suitable for the safe CO<sub>2</sub> Geological Storage (InPoland) including the Monitoring of Plans, Warsaw, Polish Ministry of Environment
2. Fabiszewska-Solares, J., Kobyłka, K., Laskowski, K., Marszał,K., 2023, CCS National Roadmap (Poland) in The Building momentum for the long-term CCS deployment in the CEE region, Available on: <https://ccs4cee.eu/news-articles/> (Accessed 17/01/2023)
3. CO<sub>2</sub>StoP - a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe, [https://setis.ec.europa.eu/european-CO2-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en) (accessed 07/03/24)
4. Tarkowski, R., Uliasz-Misiak , B. and Wójcicki A. , 2009, CO<sub>2</sub> storage capacity of deep aquifers and hydrocarbon fields in Poland–EU GeoCapacity Project results, Energy Procedia, 1, 2671, 2677
5. Poland – EU CCS Interconnector, [https://ec.europa.eu/energy/maps/pci\\_fiches/PciFiche\\_12.9.pdf](https://ec.europa.eu/energy/maps/pci_fiches/PciFiche_12.9.pdf) (accessed 07/03/24)

### 43.30 Romania

1. Dudu, A. (2009). WP 2 Romanian Report: Romanian Storage Capacity. EU GeoCapacity Final Conference, Copenhagen, 21-22 October 2009. Published by: GeoCapacity. Accessed from: <http://www.geology.cz/geocapacity/events/copenhagen-presentations>
2. CO<sub>2</sub>StoP - a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe, [https://setis.ec.europa.eu/european-CO2-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en) (accessed 07/03/24)
3. Dudu, A., Morosanu, I., Sava, C.S., Iordache, G., Avram, C. & Sorin, A. (2017). CO<sub>2</sub> geological storage possibilities in Histria Depression – Black Sea (Romania). Geo-Eco-Marina, 23, pp. 171-176. Published by: GeoEcoMar. Accessed from: <https://journal.geoecomar.ro/geo-eco-marina/issue/view/vol.23>
4. PWC and EPG. Carbon Capture Storage Potential in Romania. June 2022. [https://ccs.fppg.ro/wp-content/uploads/2022/07/PwC\\_EPG\\_CCS-Study\\_EN\\_FINAL.pdf](https://ccs.fppg.ro/wp-content/uploads/2022/07/PwC_EPG_CCS-Study_EN_FINAL.pdf)

### 43.31 Serbia

1. Nešić. S. and Kara, S. 2019. CO<sub>2</sub> Sources, Transportation and Storage Possibilities in Serbian Oil and Gas Fields, 10th "Trondheim Conference on CO<sub>2</sub> Capture, Transport and Storage, Trondheim, Norway, 17-19 June,
2. Nešić, S., Mitrovic, V. and Dabetic Ex Filipovic, M. 2017. Serbia evaluates its CO<sub>2</sub> storage potential, Oil and Gas Journal, 115, 12, 50-52, (PDF) Serbia evaluates its CO<sub>2</sub> storage potential.
3. Nešić. S., Kara, S. and Fominykh, S. 2023. CCUS in Serbia - Ongoing projects and future trends, The 12th Trondheim Conference on CO<sub>2</sub> Capture, Transport and Storage, Trondheim, Norway, 21 June, [https://www.researchgate.net/publication/372156784\\_CCUS\\_in\\_Serbia\\_-\\_Ongoing\\_projects\\_and\\_future\\_trends](https://www.researchgate.net/publication/372156784_CCUS_in_Serbia_-_Ongoing_projects_and_future_trends)
4. Komatina-Petrovic, S. 2007. Geology of Serbia and potential localities for geological storage of CO<sub>2</sub>, Workshop on CCS, Zagreb, Croatia, 27-28 February, [https://www.geology.sk/CO2neteast/documents/workshop\\_zagreb/Snezana\\_Komatina-Petrovic-Geology\\_of\\_Serbia\\_and\\_potential\\_localities\\_for\\_geological\\_storage\\_of\\_CO2.pdf](https://www.geology.sk/CO2neteast/documents/workshop_zagreb/Snezana_Komatina-Petrovic-Geology_of_Serbia_and_potential_localities_for_geological_storage_of_CO2.pdf)
5. S. Nešić, S. Fominykh, A. Vertlyugina, A. Sizykh, and U. Božovic, 2024, Decarbonization Challenges in Oil Refining: A Perspective on Blue Hydrogen Production at Panchevo Oil Refinery, SPE-220018-MS, <https://doi.org/10.2118/220018-MS>
6. Republic of Serbia. Transposition of Directive on geological storage of carbon dioxide. May 2022. <https://euinfo.rs/plac3/en/news/transposition-of-directive-on-geological-storage-of-carbon-dioxide/>. Accessed 19/06/2025
7. Fominykh, S. 2022. The Decarbonisation Perspectives: The Implementation of Carbon Capture and Storage Projects in the Oil and Gas Industry Under the Serbian Climate Change Act, 2022 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe), Novi Sad, Serbia, 1-5, IEEE, doi: 10.1109/ISGT-Europe54678.2022.9960626.)

### 43.32 Slovakia

1. Kucharic, L., 2009, GEOCAPACITY project WP 2 country review slovakia - geology, Geocapacity Results and the Future for Geological Storage of CO<sub>2</sub>, Copenhagen, 21-22 October 2010
2. Kucharič, L., M. Radvanec, L. Tuček, Z. Németh, D. Bodiš, K. Čechovská, J. Derco, J. Michalko, J. Wallner, P. Liška and B. Antal, 2011, Preliminary results of the Slovakian national project regarding carbon dioxide storage in underground spaces, Energy Procedia, 4, 4921, 4930
3. Pinka, J. (2014). Options and prospects of underground storage of carbon dioxide in the Slovak Republic. SGEM International Multidisciplinary Scientific GeoConference EXPO Proceedings.
4. Vladimír Bartovic, Michal Hrubý, Alexandra Visnerová, (2021), Assessment of current state, past experiences and potential for CCS deployment in the CEE region, IN: BUILDING MOMENTUM FOR THE LONG-TERM CCS DEPLOYMENT IN THE CEE REGION.

5. Kucharic, L., 2008, Case for CO<sub>2</sub> geological storage - site Bzovik Central Slovakia Volcanic Area, Slovak Geological Magazine, 73, 80

### 43.33 Slovenia

1. European Commission, 2008. CO<sub>2</sub>, from Capture to Storage (CASTOR), <https://cordis.europa.eu/project/id/502586>. Accessed 24/04/2025
2. Vangkilde-Pedersen, T. (ed.) (2009): Storage capacity. — EU GeoCapacity Report D16, 166 pages. [https://climate.ec.europa.eu/system/files/2016-11/geocapacity\\_en.pdf](https://climate.ec.europa.eu/system/files/2016-11/geocapacity_en.pdf)
3. Marijan, K. 2012. Possibility of geological CO<sub>2</sub> Storage in depleted/partially depleted layers of hydrocarbons in Northeast Slovenia, Underground mining Engineering, 21, 161-168, <https://ume.rgf.bg.ac.rs/index.php/ume/article/view/75>
4. Maver, M. 2021. Assessment of current state, past experiences and potential for CCS deployment in the CEE region - Slovenia, The Building momentum for the long-term CCS deployment in the CEE region, <https://ccs4cee.eu/news-articles/>
5. Anthonsen, K.L., and Christensen, N.P., (2021), EU Geological CO<sub>2</sub> storage summary, DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2021/34
6. Orežnik, K., Kozinc, J., Lpeh, N., Justin, B. and Van Wageningen, N. 2007. CO<sub>2</sub> Storage and ECBM Case Study in Velenje Coalmine (Slovenia), Geophysical Research Abstracts, 9, 11089, SRef-ID: 1607-7962/gra/EGU2007-A-11089
7. Republic of Slovenia, 2023. Report by the Republic of Slovenia on the implementation of the Directive 2009/31/EC on the geological storage of carbon dioxide pursuant to the Article 27(1) thereof
8. GCCSI, 2023, CCS Legal and Regulatory Indicator 2023. <https://www.globalccsinstitute.com/wp-content/uploads/2023/10/CCS-Legal-and-Regulatory-Indicator-Report-Global-CCS-Institute-.pdf>
9. European Commission, 2020. European CO<sub>2</sub> Storage Database. [https://setis.ec.europa.eu/european-co2-storage-database\\_en](https://setis.ec.europa.eu/european-co2-storage-database_en). Accessed 23/04/2025

### 43.34 Spain

1. Martínez del Olmo, W. , 2019, Cambio climático, acuerdos de París y trampas geológicas donde secuestrar el CO<sub>2</sub> en España, Revista de la Sociedad Geológica de España, 32, 2, 87, 106
2. Boavida, D., Carneiro, J., Martinez, R., van den Broek, M., Ramirez, A., Rimi, A., Tosato, G., & Gastine, M. , 2013, Planning CCS Development in the West Mediterranean, Energy Procedia, 37, 3212, 3220
3. Carneiro, J., R. Martinez, I. Suarez, Y. Zarhloule and A. Rimi, 2015, Injection rates and cost estimates for CO<sub>2</sub> storage in the west Mediterranean region, Environmental Earth Sciences, 73, 2951, 2962

4. Sun, X., J. Alcalde, M. Bakhtbidar, J. Elío, V. Vilarrasa, J. Canal, J. Ballesteros, N. Heinemann, S. Haszeldine, A. Cavanagh, D. Vega-Maza, F. Rubiera, R. Martínez-Orio, G. Johnson, R. Carbonell, I. Marzan, A. Travé, and E. Gomez-Rivas, 2021, Hubs and clusters approach to unlock the development of carbon capture and storage – Case study in Spain, *Applied Energy*, 300
5. Compostilla Phase II Project Details, <https://www.geos.ed.ac.uk/sccs/project-info/13> (accessed 26/02/2024)
6. CO<sub>2</sub>GeoNet (2021): State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update, CO<sub>2</sub>GeoNet Report, 325 p.; DOI: 10.25928/CO<sub>2</sub>geonet\_eu32-o21u
7. Casero, P. Coca, P., García-Peña, F. & Hervás, N. (2017)- Case Study: ELCOGAS Puertollano IGCC power plant, Spain, Editor(s): Ting Wang, Gary Stiegel, *Integrated Gasification Combined Cycle (IGCC) Technologies*, Woodhead Publishing, 2017, Pages 753-775, ISBN 9780081001677, <https://doi.org/10.1016/B978-0-08-100167-7.00019-6>.
8. Zapatero, M. A., Suarez, I., Arenillas, A., Marina, M., Nita, R.C. and Martinez, R.; (2009) Assessing European Capacity for geological storage of Carbon Dioxide. Grupo de Almacenamiento Geologico De CO<sub>2</sub> (IGME).
9. de Dios, J.C. & Martínez, R.; (2019): The permitting procedure for CO<sub>2</sub> geological storage for research purposes in a deep saline aquifer in Spain. *Int J Greenh Gas Control*, 91 (2019), Article 102822, 10.1016/j.ijggc.2019.102822
10. Global CCS Institute, "CCS Policy Indicator (CCS-PI)," 2023
11. Bachu, S., Bonijoly, D., Bradshaw, J., Burruss, R., Holloway, S., Peter Christensen, N. & Magne Mathiassen, O.; (2007). CO<sub>2</sub> storage capacity estimation: Methodology and gaps. *International Journal of Greenhouse Gas Control*, Volume 1, Issue 4, 2007, Pages 430-443,

### 43.35 Sweden

1. Sopher, D., Juhlin, C., & Erlström, M. , 2014, A probabilistic assessment of the effective CO<sub>2</sub> storage capacity within the Swedish sector of the Baltic Basin, *International Journal of Greenhouse Gas Control*, 30, 148, 170
2. EU MUSTANG Project, 2014, A multiple space and time scale approach for the quantification of deep saline formations for CO<sub>2</sub> storage, <https://cordis.europa.eu/project/id/227286#:~:text=The%20objectives%20of%20MUSTANG%20are%20to%20develop%20and,public%20confidence%20and%20acceptance%20and%20promoting%20its%20deployment.> (Accessed 08/03/24)
3. Juhlin, C., *SwedSTORECO<sub>2</sub>: Plans for a Swedish onshore test site for CO<sub>2</sub> storage via seismic surveying and drilling on Gotland, Sweden*. Uppsala University, <http://basrec.net/wp-content/uploads/2015/04/C3-Juhlin.pdf> (accessed 08/03/24)

4. Anthonsen, K.L., P. Aagaard, P.E.S. Bergmo, S.R. Gislason, A.E. Lothe, G.M. Mortensen and S.O. Snæbjörnsdóttir, 2014, Characterisation and Selection of the Most Prospective CO<sub>2</sub> Storage Sites in the Nordic Region, 63, 4884, 4896
5. Anthonsen, K.L., Frykman, P., Nielsen, C.M., von Platen-Hallermund, F., Gausby, M., Sundal, A., Aagaard, P., Gao, Y., Lothe, A., Bergmo, P., Emmel, B.U., Mortensen, G.M., Erlström, M., Snæbjörnsdóttir, S. Ó., Gislason, S.R., The Nordic CO<sub>2</sub> Storage Atlas, 2015, Nordic CCS Competence Centre, Geological Survey of Denmark and Greenland (GEUS), <https://data.geus.dk/nordicccs/about.xhtml> (accessed 8/3/24)
6. Mortensen, G.M., P.E.S. Bergmo and B.U. Emmel, 2016, Characterization and Estimation of CO<sub>2</sub> Storage Capacity for the Most Prospective Aquifers in Sweden, 86, 352, 360 Geological Survey of Sweden, <https://www.sgu.se/en/physical-planning/carbon-capture-and-storage-ccs/> (accessed 08/03/24)
7. Anthonsen, K.L., P. Aagaard, P.E.S. Bergmo, M. Erlstrom, J.I. Fareide, S.R. Gislason, G.M. Mortensen and S.O. Snæbjörnsdóttir, 2013, CO<sub>2</sub> Storage Potential in the Nordic Region, Energy Procedia, 37, 5080, 5092
8. M. Erlström, D. Fredriksson, N. Juhojuntti, U. Sivhed, L. Wickström, Lagring av koldioxid i berggrunden – krav, förutsättningar och möjligheter, vol. 131, Sveriges geologiska undersökning Rapporter och meddelanden (2011), pp. 7-94
9. Swedish Energy Agency, 2022, Carbon Capture and Storage, <https://www.energimyndigheten.se/en/sustainability/carbon-capture-and-storage> (accessed 08/03/24)
10. Kjärstad, Jan and Johnsson, Filip, Conditions for CCS and Bio-CCS in Sweden (April 6, 2021). Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021, Available a SSRN: <https://ssrn.com/abstract=3820820> or <http://dx.doi.org/10.2139/ssrn.3820820>
11. Global CCS Institute, "CCS Policy Indicator (CCS-PI)," 2023
12. Mortensen, G.M., 2014, CO<sub>2</sub> storage atlas for Sweden - a contribution to the Nordic Competence Centre for CCS, NORDICCS, 1, 5
13. BECCS Stockholm, <https://beccs.se/> (accessed 08/3/24)

### 43.36 Switzerland

1. Chevalier, G., Diamond, L.W. and Leu, W. 2010. Potential for deep geological sequestration of CO<sub>2</sub> in Switzerland: a first appraisal, Swiss Journal of Geosciences, 103, 427-455, 10.1007/s00015-010-0030-4, [https://www.researchgate.net/publication/225470506\\_Potential\\_for\\_deep\\_geological\\_sequestration\\_of\\_CO2\\_in\\_Switzerland\\_A\\_first\\_appraisal](https://www.researchgate.net/publication/225470506_Potential_for_deep_geological_sequestration_of_CO2_in_Switzerland_A_first_appraisal)
2. CO<sub>2</sub>StoP - a project mapping both reserves and resources for CO<sub>2</sub> storage in Europe, [https://setis.ec.europa.eu/european-CO2-storage-database\\_en](https://setis.ec.europa.eu/european-CO2-storage-database_en)

3. Gunatilake, T., Zappone, A., Zhang, y., Zbinden, D., Mazzotti, M. and Wiemer, S.; (2025): Quantitative Modeling and Assessment of CO<sub>2</sub> Storage in Saline. Aquifers: A Case Study in Switzerland, Carbon Capture Science & Technology (2024), <https://www.sciencedirect.com/science/article/pii/S2772656824001714>
4. Zbinden, D., Rinaldi, A.P., Schultz, R., Alt-Epping, P., Diamond, L.W., and Wiemer, S. 2025. The pilot CO<sub>2</sub> test injection project in Trüllikon, Switzerland: project outline and first simulation results. EGU25-16614, <https://doi.org/10.5194/egusphere-egu25-16614>
5. Schultz, R., Rinaldi, A.P., Roth, P., Herfried Madritsch, H., Gunatilake, T., and Wiemer, S., 2024. Pre-screening of induced seismicity risks for CO<sub>2</sub> injection at Trüllikon, Switzerland, International Journal of Greenhouse Gas Control, Volume 138, October 2024, 104239
6. Diamond, L.W., Alt-Epping, P., Brett, A.C., Aschwanden, L., and Wanner, C., 2024. Geochemical–hydrogeological feasibility study of a CO<sub>2</sub> injection test into a saline aquifer in Switzerland 22nd Swiss Geoscience Meeting, Basel 2024. [https://geoscience-meeting.ch/sgm2024/wp-content/uploads/abstracts/Diamond\\_Larryn\\_09-02-24-09-21-52.pdf](https://geoscience-meeting.ch/sgm2024/wp-content/uploads/abstracts/Diamond_Larryn_09-02-24-09-21-52.pdf)
7. GCCSI, 2025, CO<sub>2</sub>RE database. Accessed 25 June 2025. <https://co2re.co/>
8. CO<sub>2</sub>GeoNet 2021. State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update, CO<sub>2</sub>GeoNet Report, 10.25928/co2geonet\_eu32-o21u, [https://co2geonet.com/media/73750/co2geonet\\_state-of-play-in-europe\\_2021.pdf](https://co2geonet.com/media/73750/co2geonet_state-of-play-in-europe_2021.pdf)
9. Federal Department of the Environment, Transport, Energy and Communications DETEC, 2025. CO<sub>2</sub> capture, removal and storage: overview of the legal framework. [file:///C:/Users/H159921/Downloads/Faktenblatt%20CCS\\_NET%20Ubersicht%20rechtlicher%20Rahmen%20\\_EN.pdf](file:///C:/Users/H159921/Downloads/Faktenblatt%20CCS_NET%20Ubersicht%20rechtlicher%20Rahmen%20_EN.pdf)

### 43.37 Ukraine

1. Bezsonov, B., Marusyk, Y., Romanyuk, Y., & Myroniuk, V. (2014). CO<sub>2</sub> capture and storage: Ukrainian perspectives on industry and energy security. Bellona Foundation. Retrieved from [https://www.researchgate.net/publication/334204173\\_CO2\\_Capture\\_and\\_Storage\\_Ukrainian\\_Perspectives\\_on\\_Industry\\_and\\_Energy\\_Security](https://www.researchgate.net/publication/334204173_CO2_Capture_and_Storage_Ukrainian_Perspectives_on_Industry_and_Energy_Security)
2. Donetsk National University, Report: Guidelines for the Implementation of CCT and CCS technologies in the Eastern Regions of Ukraine, Retrieved from: <https://eurogrant.ucoz.ru/about/about4.html>
3. Cauchois, G., Venugopal, M., Gassan-zade, O., Kornienko, H., & Beck, B. (2022). Blue H<sub>2</sub> and CCUS in Ukraine. Proceedings of the 16th Greenhouse Gas Control Technologies Conference (GHGT-16), 23–24 Oct 2022. SSRN. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=4276183](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4276183)
4. Dudu, A.-C., Demchuk, Y., Virshylo, I., Kurylo, M., Berenblyum, R., Nermoen, A., Iordache, G., Dragoş, A.-G., Sava, C.-Ş., Avram, C., Stelea, L., Anghel, S., Bratakh, M., & Melnyk, L.

- (2025). CTS Project: CO<sub>2</sub> transport and storage solutions in the Black Sea. *Advances in Carbon Capture Utilization and Storage*, 3, 1–15. <https://www.extrica.com/article/24736>
5. European Commission. (2013). WP2 Report – Storage capacity: EU GeoCapacity project – Assessing European capacity for geological storage of carbon dioxide. European Commission. [https://www.researchgate.net/publication/262688927\\_WP2\\_Report\\_-\\_Storage\\_capacity\\_EU\\_GeoCapacity\\_project\\_-\\_Assessing\\_European\\_Capacity\\_for\\_Geological\\_Storage\\_of\\_Carbon\\_Dioxide](https://www.researchgate.net/publication/262688927_WP2_Report_-_Storage_capacity_EU_GeoCapacity_project_-_Assessing_European_Capacity_for_Geological_Storage_of_Carbon_Dioxide)
  6. Kearns, J., Teletzke, G., Palmer, J., Thomann, H., Kheshgi, H., Chen, Y.-H. H., Paltsev, S., & Herzog, H. (2017). Developing a Consistent Database for Regional Geologic CO<sub>2</sub> Storage Capacity Worldwide. *Energy Procedia*, 114, 4697–4709. <https://doi.org/10.1016/j.egypro.2017.03.1603>
  7. Postoiu, C., Nazare, D., Miu, L., Cătuți, M., & Dudău, R. (2021). Assessment of current state, past experiences and potential for CCS deployment in the CEE region. Energy Policy Group. <https://www.enpg.ro/assessment-of-current-state-past-experiences-and-potential-for-ccs-deployment-in-the-cee-region/>
  8. CO<sub>2</sub>GeoNet. (2021). State-of-play on CO<sub>2</sub> geological storage in 32 European countries — an update. CO<sub>2</sub>GeoNet Association. [https://doi.org/10.25928/CO2geonet\\_eu32-o21u](https://doi.org/10.25928/CO2geonet_eu32-o21u)

### 43.38 UK

1. Energy Technologies Institute (ETI). 2015. "DECC Storage Appraisal: Strategic UK CO<sub>2</sub> Storage Appraisal - Project - Addendum."
2. Karvounis, P. and Blunt, M. J., 2021, Assessment of CO<sub>2</sub> geological storage capacity of saline aquifers under the North Sea, *International Journal of Greenhouse Gas Control*, 111
3. HyNet North West, 2020, HyNet CCUS Pre-Feed Key Knowledge Deliverable, WP1: Full Chain Basis of Design
4. BP Exploration Operating Company Limited, 2022, Endurance Storage Development Plan, Key Knowledge Document, NS051-SS-REP-000-00010
5. BP, 2021, Net Zero Teesside & Northern Endurance Partnership Technology Plan, NS051-EN-PLN-000-00007
6. Pale Blue Dot, 2021, Acorn CCS Project D08 Operations and Maintenance Philosophy ACCS-X-00-PB-PM-KK-000P
7. Energy Technologies Institute (ETI). 2016. "D04: Initial Screening & Down-Select, 10113ETIS-Rep-03-2.0ACT Acorn, 2019, D20 Final Report, 10196ACTC-Rep-35-01
8. The Viking Project, <https://www.vikingccs.co.uk/about>
9. Perenco. Orion. <https://perenco-ccs.com/the-orion-project/> Accessed: 18/06/24)
10. Perenco. Poseidon. <https://perenco-ccs.com/the-poseidon-project/> Accessed: 18/06/24)

11. EnQuest Retail shareholder presentation September 2023,  
[https://www.enquest.com/fileadmin/content/Presentations/HY\\_2023\\_EnQuest\\_-\\_IMC\\_Retail\\_Presentation.pdf](https://www.enquest.com/fileadmin/content/Presentations/HY_2023_EnQuest_-_IMC_Retail_Presentation.pdf) (accessed 18/01/23)
12. EnQuest, EnQuest Annual Report 2023,  
[https://www.enquest.com/fileadmin/content/Annual\\_Reports/Annual\\_Reports\\_2023/41076\\_EnQuest\\_AR22\\_SR\\_spreads.pdf](https://www.enquest.com/fileadmin/content/Annual_Reports/Annual_Reports_2023/41076_EnQuest_AR22_SR_spreads.pdf) (accessed 18/01/23)
13. Bacton Thames Net Zero. <https://www.eni.com/static/bactonthamesnetzero/>. Accessed 18/06/24
14. Perenco outlines plans for new UK CCS projects Poseidon and Orion.  
<https://www.energyvoice.com/renewables-energy-transition/ccs/552064/perenco-poseidon-orion-ccs/> Accessed 12/07/24