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Isaline Gravaud, Ane Elisabet Lothe, Alla Shogenova, Kazbulat Shogenov, Leandro Henrique Sousa, Adam Wojcicki, Caglar Sinayuc, Sevtac Bulbul, Betul Yildirim, Richard Stevenson, et al.

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Zero Emission Network to facilitate CCUS uptake in industrial clusters
(HORIZON-CL5-2021-D3-02-12)



Deliverable 1.2

**Identification of promising CCUS value chains in the two
ZEN regions for further analyses in WP3**

Release Status: Final

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(HORIZON-CL5-2021-D3-02-12)



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AUTHORISATION	Name	Signature	Date
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Executive summary

This document is Deliverable 1.2 of the CCUS ZEN project. The overall objective of the project is to explore the potential for enabling CCUS value chain deployment in the Baltic Sea region and the Mediterranean Sea region, as these two regions have lower maturity level for CCUS compared to the current development in the North Sea region.

This document makes the bridge between 2 objectives of the CCUS ZEN project: Objective 1: Technical mapping and Objective 3: Value chain scenarios. Deliverable 1.1 (Ringstad et al., 2023) summarised high-level regional mapping of emission sources, utilisation industry and infrastructure in the two CCUS ZEN regions. Based on this mapping, the current report aims at identifying promising clusters, hubs, and CCUS value chains in the studied regions.

A first screening of the mapped information, enabled to identify promising emissions clusters, as well as storage options for the captured emissions, and transport and intermediate storage solutions to connect the industrial cluster(s) with the potential storage site(s). This led to the definition of several promising value chains.

A list of 8 CCUS value chains is recommended for further analyses in WP3. These were selected based on the emissions clusters potential (including volume of emissions, distance between sites, capture projects), on the geological storage potential (including existing studies, storage capacities, potential for development), and on the ability to bring out new regions and potential PCI compared to those where projects are already on tracks. The potential for carbon utilisation is also tackled, looking at the existing projects around the value chains.

Four value chains are located in the Baltic region:

- The Baltic Lat-Lit-Onshore, located between Latvia and Lithuania;
- The Jutland network, linking Denmark, Germany and Sweden;
- The Copenhagen value chain, between Denmark and Sweden;
- The North Poland onshore value chain;

and four value chains are located in the Mediterranean region:

- The Soma - İzmir Aliğa – Prinos value chain, linking Türkiye and Greece;
- The Ebro offshore value chain, between Spain and France;
- The Beaucaire value chain in Southern France;
- The Southern Italy value chain.

In next step of the CCUS ZEN project, the identified value chains will be further analysed with integration of prospective CO₂ uses, development of CCUS value chain scenarios and technical modelling. Based on a SWOT analysis, the most promising CCUS value chain in each region will be selected for further development, including local business models.



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Acronyms	Full name
BECCS	Bio-Energy Carbon Capture and Storage
BECCU	Bio-Energy Carbon Capture and Utilization
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture Utilization and Storage
CO ₂	Carbon Dioxide
CSLF	Carbon Sequestration Leadership Forum
EC	European Commission
EHR	Enhanced hydrocarbon recovery
EOR	Enhanced oil recovery
EU	European Union
ETS	Emission trade system
FEED	Front End Engineering Design
FID	Final investment decision
GHG	Greenhouse gas
GIS	Geographical information system
ICCUS	Industrial Carbon Capture and Storage
NO _x	Nitrogen oxides
PP	Power plant
SRL	Storage Readiness Level
TRL	Technology Readiness Level
WtE	Waste to Energy



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1 Introduction

This document is Deliverable 1.2 of the CCUS ZEN project. The overall objective of the project is to explore the potential for enabling CCUS value chain deployment in two regions with lower maturity level for CCUS compared to the current development in the North Sea region. The two selected regions are the Baltic Sea region and the Mediterranean Sea region.

The CCUS ZEN mission is to contribute to the accelerated deployment of CCUS throughout Europe by enabling mutual, continuous learning between different stakeholder types and between European regions, drawing on learnings from ongoing and past projects, creating shared understanding of mission-critical implementation elements that need to work like clockwork, and building a coherent ecosystem of CCUS actors in Europe that are capable of delivering the requested contribution to European climate policy.

To achieve this, CCUS ZEN has five objectives:

1. **Technical mapping:** For each region, map and understand the nature and longevity of emission sources, identify transport corridors and modalities, assess cost-effective ('bankable') storage capacity in the selected regions, and define interactions between CCUS hubs-and-clusters, renewable-based integrated energy systems, and/or circular production modes.
2. **Non-technical mapping:** Identify and involve relevant end users, public authorities and social stakeholders and analyse their concerns and needs using appropriate techniques and methods from the social sciences and humanities.
3. **Value chain scenarios:** Elaborate detailed plans for the integration of CCUS in hubs and clusters linked to CO₂ storage sites via hubs, pipeline networks and shipping routes, with due attention to national and border-crossing permits and regulatory issues.
4. **Local business model:** Perform initial impact assessment and develop local business models for delivery of CO₂ capture, transport, utilisation and/or storage, including the separation of responsibilities across the CO₂ value chain.
5. **Knowledge sharing, dissemination, and communication:** Facilitate the exchange of knowledge and know how across CCUS projects, by continuing the activities of the existing European CCUS project network.

The five objectives are integrated in the project framework illustrated in Figure 1.1. Technical and non-technical mapping constitute a high-level regional screening of CCUS opportunities in the two CCUS ZEN regions. This is followed by a selection and analyses of four promising value chains in both regions. Based on the analyses, the most promising CCUS value chain in each region will be selected for further development, including local business models. Throughout the project, the work is supported by knowledge sharing, dissemination and communication with network partners and other relevant stakeholders.



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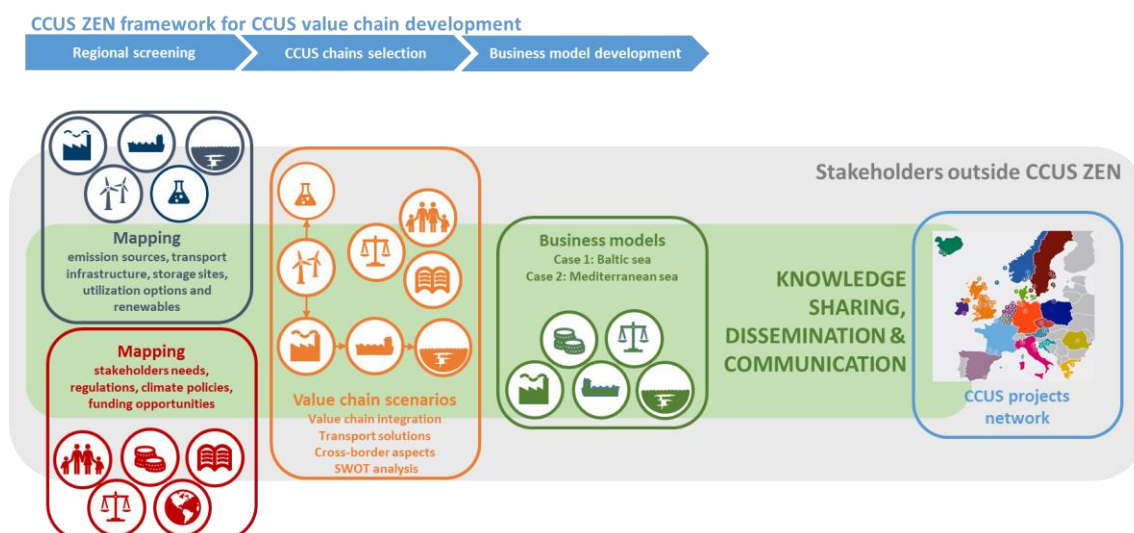


Figure 1.1 CCUS ZEN framework for CCUS value chain development

This document makes the bridge between **Objective 1: Technical mapping** and **Objective 3: Value chain scenarios**. Deliverable 1.1 of the CCUS ZEN project (Ringstad et al., 2023) summarised high-level regional mapping of emission sources, utilisation industry and infrastructure in the two CCUS ZEN regions. Based on this mapping, the current report aims at **identifying promising clusters, hubs, and CCUS value chains in the studied regions**.

The two regions to be explored by CCUS ZEN are the Baltic Sea region and the Mediterranean Sea region:

Baltic Sea region

The Baltic Sea region defined in CCUS ZEN covers Denmark including its inland waters and the easternmost of Northern Sea, Sweden, Finland, Germany, Estonia, Latvia, Lithuania, Poland and the Baltic Sea (Figure 1.2)

Mediterranean Sea region

The Mediterranean Sea region defined in CCUS ZEN covers France, Spain, Italy, Greece, Türkiye and the Mediterranean Sea (Figure 1.3)

This report will present in the two first sections the methodology followed in the project for the identification of CCUS value chains in the studied regions, then the mapping of existing projects. Then, Section 4 and Section 5 will describe the analyses carried out in the Baltic region and in the Mediterranean region, respectively.



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Figure 1.2 The CCUS ZEN Baltic Sea region: Denmark including its inland waters and the easternmost of Northern Sea, Sweden, Finland, Germany, Estonia, Latvia, Lithuania, Poland and the Baltic Sea.



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Figure 1.3 The CCUS ZEN Mediterranean Sea region: France, Spain, Italy, Greece, Türkiye and the Mediterranean Sea.



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2 Methodology

2.1 Important features for CCUS value chains

Brownsort (2020) proposed a list of features that can be used to describe potential industrial CCUS clusters, based on general knowledge of existing and proposed ICCUS clusters. The list was suggested as a structure for considering the strengths and weaknesses of different clusters. This approach describes potential clusters in terms of six groups of features: i) emissions; ii) the area; iii) the industries; iv) relationships, v) infrastructure and vi) CO₂ storage. However, that the group “Relationships” relates to social aspects, rather than technical conditions, and therefore will not be addressed in this report. Table 2-1 describes the features included in each of the other five groups.

A methodology for definition of clusters and transport systems is described in Brownsort (2020) and is based on three questions, defining:

- WHAT CO₂ will be captured?
- HOW will this CO₂ be captured, collected, transported?
- WHERE will this CO₂ be stored?

This methodology is shown schematically in Figure 2.1 and described in detail in Brownsort (2020).

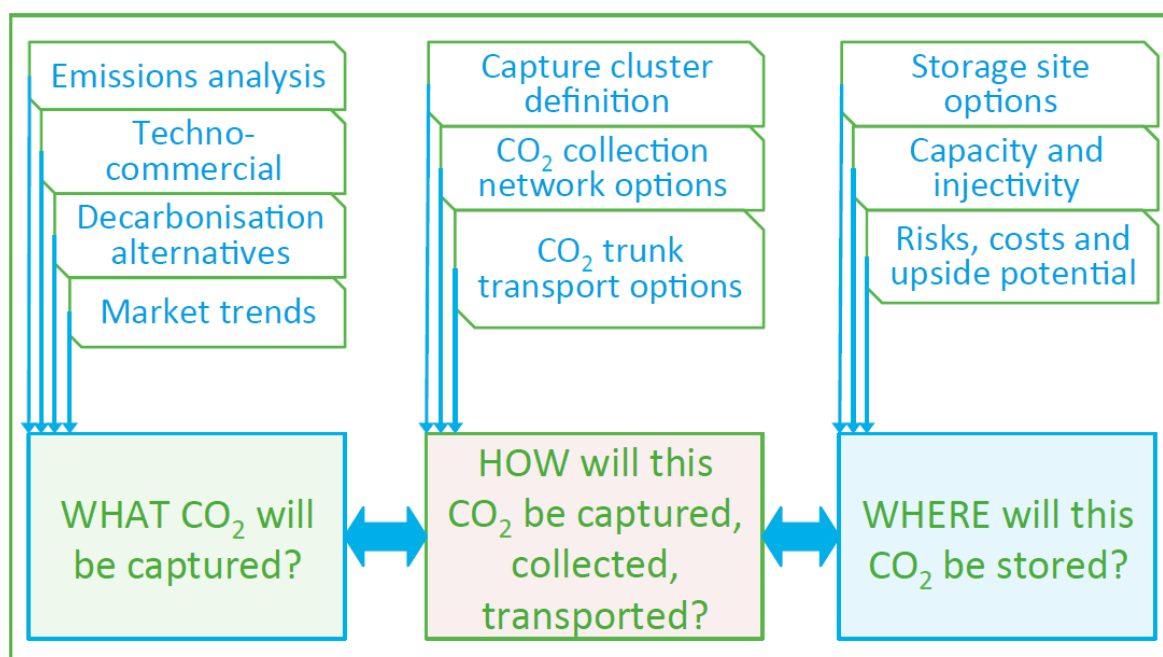


Figure 2.1 Cluster definition methodology – schematic outline, from Brownsort (2020)



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Table 2-1 Features to describe potential industrial CCUS clusters, from Carneiro and Mesquita (2020)

GROUP	Feature/ factor	Comment for cluster
EMISSIONS	Emission location distribution	How closely “clustered” is the area, are there few or many vents at facilities?
	Emission volume distribution	Are there “anchor” emitters, several large emitters, many small emitters?
	Emission volume profile	Are facilities at risk/closing, or is investment occurring, is there seasonal variation?
	Emissions type and quality	Are there significant process emissions, are there high-concentration emissions, are there problematic contaminants?
AREA	Industrial area character	Is it urban or remote, large or small, spread out or dense?
	Importance of industry	Is the area predominantly industrial, is industry main employer in area?
	Cluster recognition	Is there an existing cluster mentality, history of cluster focus, existing study results?
INDUSTRIES	Integration of industry	Is there a common culture, cross-industry bodies, service interdependence, sharable resources etc?
	Decarbonisation alternatives	What scope/feasibility for energy efficiency, electrification or biomass, hydrogen?
	CCU	What potential for CCU, is it “defining” e.g. EOR demand or syngas availability?
	Motivation for decarbonisation	Will industry prioritise decarbonisation?
INFRASTRUCTURE	Motivation for CCS	Can industry gain from CCS?
	CO ₂ collection options	Are there existing pipeline corridors, rail links, liquid-CO ₂ (L-CO ₂) terminals, are there geographic or other constraints on routes for collection?
	CO ₂ consolidation options	Are sites for consolidation hubs available, e.g. For buffer storage, central processing, compression or liquefaction?
	Existing CO ₂ infrastructure	Are there any existing capture, transport or utilisation operations or experience?
STORAGE	Infrastructure reuse options	Are there relevant existing pipelines, ports, terminals?
	Storage accessibility	Is area close to known potential CO ₂ storage sites?
	Storage capacity	Is accessible storage of suitable capacity, injectivity, security?
	Storage flexibility	Are there alternatives to primary storage site?
	Storage development integration	Is there an organisation interested/capable of developing storage?



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2.2 CCUS ZEN approach

As a starting point, information collected during technical mapping about CO₂ emission sources, transport options and storage sites (Ringstad et al. 2023), has been gathered into a common GIS-project to facilitate visualization and analysis.

Based on a first screening of the mapped information, promising emissions clusters have been identified, as well as storage options for the captured emissions. Transport and intermediate storage solutions have then been suggested to connect the industrial cluster(s) with the potential storage site(s). This led to the definition of several promising CCS value chains.

Although it was not a criterion in the identification of the value chains, existing CO₂ utilisation in the identified clusters were also looked at. However, integrating the potential for CO₂ use in the CCS value chains will be performed in depth in next step of the project (WP3 CCUS value chain scenarios).

For the purpose of the analysis, both Baltic and Mediterranean region were subdivided into geographical sectors where the following approach was carried out. An Excel template was set up to be filled for each geographical sector to enable the analysis and the description of suggested value chains. These Excel sheets contains all relevant technical information about the identified value chains to be forwarded to WP3 for further analysis.

2.2.1 Emission sources

First, a screening of the emission sources in each geographical sectors leads to the identification of promising sites for CO₂ capture. The focus is put on identifying clusters of emitters, where CO₂ could be captured from different industrial sites and gathered at a hub before common transport to storage. Yet, standalone emitters can also be identified as promising for CCUS value chains, depending on their amount of emissions, location, type of industry, etc.

For each emission source, information about the facility is collected from previous mapping (facility name, company, location, coordinates WGS84, and industrial sector), along with information about the facility's emissions (annual amount of CO₂ emitted, emissions trend, share of biomass and of waste-to-energy). The reported CO₂ emissions are in general from 2021, except for some facilities where only older data are available. Clusters are defined, with the total amount of emissions, the number of facilities in the cluster, and the share of each industrial sector in the total emissions.

2.2.2 Storage potential

In parallel, a screening of potential storage sites in the geographical sector is carried out, based on public and available data. For each mapped storage site, information is gathered about the storage name, the type of reservoir (deep saline aquifer or depleted hydrocarbon field), the onshore or offshore location, the capacity of the reservoir (mean value), and the SRL level indicating the maturity of the capacity evaluation (see Ringstad et al. 2023).



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2.2.3 Value chains

In a second step, one or more value chains are suggested, linking one or more emission clusters to one or more storage sites. The amount of total emissions of the clusters and the storage capacities are taken into account. However, it is recognised that, at this stage of the study, numbers should be treated with caution. On the one side, the maturity level of the storage sites are often low, inferring potential smaller capacities when the resource is further assessed. On the other side, total amount of the clusters' emission does not exactly represent the amount of captured CO₂, but rather a maximum, as not 100% of the emissions would be eventually captured. Besides, level of emissions in 2021 do not foresee of future emissions of the cluster, as by 2050 other low carbon levers would be set up. These aspects will be detailed in following steps of the project (WP3 and WP4).

In this report, high-level CCUS value chains are suggested. Transport options and intermediate storage solutions are proposed, based on estimated distances, to connect the promising industrial clusters or emitters with the potential storage sites. Different scenario can be foreseen, depending on the storage site selected or on the transport option. Both national and trans-national transport infrastructures are considered.



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3 Mapping of existing projects

This section presents a summary of the major existing CCUS projects from the Baltic and Mediterranean Sea regions. The purpose of this mapping exercise was to create a resource that could be used to help identify obvious cluster groupings across these regions. In doing so, this also helps to build a better understanding of which sectors, organisations, areas, countries and regions that are particularly conducive to CCUS developments.

With the current fast pace of CCUS developments, the list is necessarily non-exhaustive, but is deemed to cover the most prominent project plans to date. The list was compiled based on information gleaned from a range of publicly available sources, including project websites, EU-level communications, industry and grey literature sources, as well as targeted internet searches.

Projects with a status ranging from speculative to operational were included. Projects that have been cancelled or have finished at report writing were not included. The different status categories are summarised in Table 3-1.

Table 3-1 CCUS project status classifications

Status	Notes
Operational	Once a project is clearly operational, following the stages below or is publicly announced as being so. This can be some time following a FID and construction stage.
Pilot	Once a project is operational following the stages below and before full-scale operations have started.
In Build	Once FID has been announced and construction has started.
In Design	Pre-FEED or FEED study stage.
In Planning	Feasibility study stage.
Speculative	Project plan/potential announced but with no firm details.

3.1 CCUS projects in the Baltic Sea region

3.1.1 Denmark

A total of 14 projects were identified for Denmark (see



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Table 8-1 in Appendix): 5 in planning, 4 in design, 4 in build and 1 at the pilot operational stage. At least 5 projects are on industry and at least 3 on power generation. At least are 6 dedicated storage projects: 3 each for offshore and onshore.

3.1.2 Sweden

A total of 12 projects were identified for Sweden (see

Table 8-2): 4 in planning, 6 in design and 2 in build. At least 9 projects are on industry and at least 2 on power generation. At least 7 are dedicated storage projects, at least 4 of which are offshore.

3.1.3 Finland

Three projects were identified for Finland (see Table 8-3): 2 in planning and 1 in full-scale operation. All three projects are on industry, none of which are known to include dedicated geological storage.

3.1.4 Germany

25 projects were identified for Germany (see

Table 8-4): 11 in planning, 5 in design, 3 in build, 4 at the pilot operational stage and 2 fully operational facilities. At least 15 projects are on industry and at least 4 on power generation, with 1 research project. At least 5 are dedicated storage projects, at least 4 of which are offshore.

3.1.5 Estonia

Two projects were identified for Estonia (see Table 8-5): both are in planning and both are CCU projects on industry.

3.1.6 Latvia

Three projects were identified for Latvia (see Table 8-6): all in planning, CCS project on power and cement industry with dedicated onshore and/or offshore storage.

3.1.7 Lithuania

A total of 2 projects were identified for Lithuania (see both in planning and both CCS projects on industry with dedicated offshore storage.

3.1.8 Poland

A total of 9 projects were identified for Poland (see

Table 8-8): 5 speculative, 1 in planning, 2 in build, and 1 fully operational facility. At least 3 projects are on industry and at least 5 on power generation, with 1 upstream project on gas



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production. At least 5 are dedicated storage projects, at least 3 of which are offshore and 2 onshore.

3.2 CCUS projects in the Mediterranean Sea region

3.2.1 France

A total of 9 projects were identified for France (see

Table 8-9): 2 in planning, 4 in design, 1 in build, 1 at the pilot operational stage and 1 fully operational facility. Eight projects are on industry and one project is upstream on gas production (H₂). At least 7 are dedicated storage projects, 5 of which are offshore and 2 onshore.

3.2.2 Spain

A total of 6 projects were identified for Spain (see Table 8-10): 3 in planning, 1 in build, 1 at the pilot operational stage and 1 fully operational facility. At least 4 projects are on industry and at least 2 on power generation. At least 1 is a dedicated storage project - onshore.

3.2.3 Italy

A total of 7 projects were identified for Italy (see Table 8-11): 2 in planning, 2 in design, 1 in build, 1 at the pilot operational stage and 1 fully operational facility. At least 5 projects are on industry and at least 2 on power generation. At least 3 are dedicated storage projects – all offshore.

3.2.4 Greece

One project was identified for Greece (see

Table 8-12): in planning, Prinos CCS project on industry with dedicated offshore storage.

3.2.5 Türkiye

No planned or active projects were identified for Türkiye. However, Ministry of Energy and Natural Resources in cooperation with Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) have started the “National Carbon dioxide Capture and Utilisation Technologies Road Map” studies in 2022.



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4 Analysis in the Baltic Sea region

4.1 Eastern Baltic Sea: Estonia, Latvia and Lithuania

4.1.1 Presentation of the geographical region

For Estonia, Latvia and Lithuania several CCUS clusters have been recognised, evaluating large CO₂ fossil emitters, Bio-CO₂ emitters and waste to energy plants, as presented in Figure 4.1. The largest total CO₂ emissions (8.2 Mt, Table 4-1 and 11.5 t per capita) are produced in Estonia, and the lowest in Latvia (1.8 Mt, Table 4-2 and 3.85 t per capita) (EU ETS, 2022, Crippa et al, 2022).



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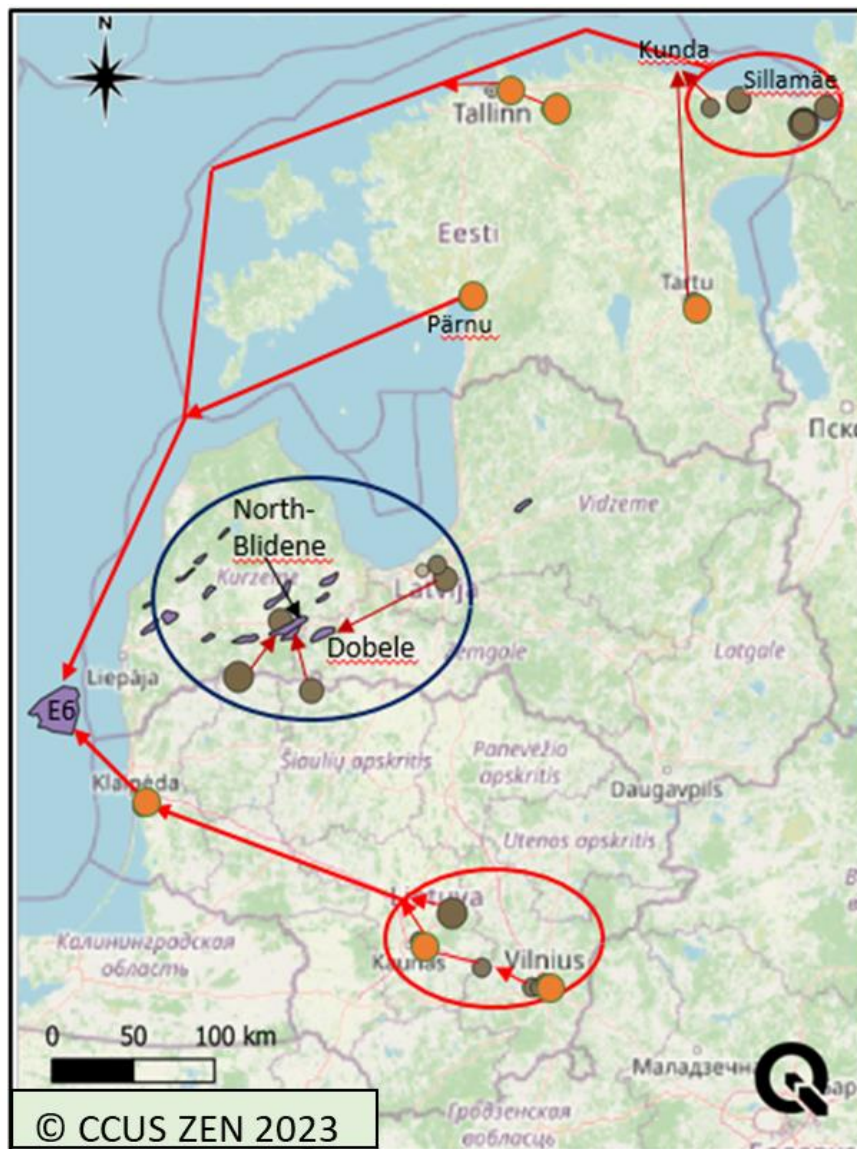


Figure 4.1 Estonian-Latvian-Lithuanian CCUS clusters. Large fossil CO₂ emissions reported in EU ETS are shown by brown circles. Bio-CO₂ emissions and waste to energy plants (not reported in EU ETS) are shown in orange points. The onshore cluster is shown by the large blue oval, while the offshore CCUS cluster is shown by red circles and arrows (updated after the CCUS ZEN project Q-GIS database).

Estonia, Latvia and Lithuania are located in the common Baltic Sedimentary Basin, while the best CO₂ storage capacity and geological conditions for gas storage are available in Latvia. In Estonia sedimentary basin is too shallow and there are no suitable structures found. In Lithuania, the depth of the prospective Cambrian Deimena Formation sandstone is increasing for more than 2 km and reservoir properties became less favourable for CO₂ gas storage (less porosity and higher temperature).

At the present time, CO₂ geological storage is forbidden in all three countries. In Estonia, such regulations were implemented based on the lack of suitable CO₂ geological storage



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sites, while in Lithuania CO₂ storage was permitted before 2019 when the new government banned it. CO₂ injection for research purposes is permitted in Latvia and Estonia. The process of changing climate strategy, policy and CCS regulations is ongoing in Latvia initiated by the largest CO₂ producers (Latvenergo and Schwenk Latvia). Among the Baltic States, only Estonia is a member of the London Protocol and implemented an amendment to Article 6 permitting the export of CO₂ for offshore storage under the seabed in deep geological structures. In this situation, Estonia, Latvia, and Lithuania can share their efforts and available resources to compose common CCUS clusters.

4.1.2 Emission sources

The largest fossil CO₂ emission sources in Estonia are represented by four power plants (PP) and three plants producing shale oil (SOP) (Table 4-1). All these plants are located in the North-East of Estonia, and they are using Estonian oil shales for energy and oil production. Among them, Eesti Energia (Enefit) PPs are producing also bio-emissions during the combustion of wood waste together with oil shale. Additionally, several Estonian plants are producing bio-emissions, including paper and pulp production (Horizon Paper Factory), energy cogeneration plants (Fortum plant in Pärnu and Anne plant in Tartu) and one waste-to-energy plant (WtE) located in Iru near Tallinn. In total about 8.2 Mt CO₂ was produced in 2021, including 6.4 Mt from fossil fuels and 1.76 Mt bio-emissions.

Table 4-1 Large CO₂ emissions produced in Estonia and Lithuania included in offshore cluster

Cluster name	Emitter ID	Facility name	Company name	City	Industry sector	CO ₂ reported (ETS) (t/y)	CO ₂ from biomass (t/y)	CO ₂ from Waste-to-energy (t/y)	Total CO ₂ emissions (t/y)
		ESTONIA							
Baltic-Est-Lat-Lit-Offshore	E_EE_1	Eesti Power Plant	Enefit Power As	Auvere	Power	2607958	16000		2623958
Baltic Est-Lat-Lit-Offshore	E_EE_3	Auvere Power Plant	Enefit Power As	Auvere	Power	885666	409944		1295610
Baltic Est-Lat-Lit-Offshore	E_EE_4	Auvere Shale Oil Plant	Enefit Power As	Auvere	Shale Oil Plant	788760			788760
Baltic Est-Lat-Lit-Offshore	E_EE_5	Balti Power Plant	Enefit Power As	Narva	Power	645847	187767		833614
Baltic Est-Lat-Lit-Offshore	E_EE_6	VKG Shale Oil Plant	VKG Oil As	Kohtla-Järve	Shale Oil Plant	697209			697209



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Baltic Est-Lat-Lit-Offshore	E_EE_7	VKG Energia North Thermal Power Plant	VKG Energia Oü	Kohtla-Järve	Power	593857			593857
Baltic Est-Lat-Lit-Offshore	E_EE_18	Kiviõli Chemical Plant	Kiviõli Keemia-tööstuse OÜ	Kiviõli	Shale Oil Plant	159357			159357
Baltic Est-Lat-Lit-Offshore	E_EE_9	Horizon Paper Factory	Horizon Tselluloosi ja Paberi AS	Kehra	Paper and pulp	12888	239481		252369
Baltic Est-Lat-Lit-Offshore	E_EE_10	Utilitas Tallinn Power Plant	Utilitas Tallinna Elektri jaam Oü	Tallinn	Power	9796	259000		268796
Baltic Est-Lat-Lit-Offshore	E_EE_12	Fortum Cogeneration Plant	Fortum Eesti As	Pärnu	Power		268000		268000
Baltic Est-Lat-Lit-Offshore	E_EE_13	Anne Cogeneration Plant	Anne Soojus As	Tartu	Power		244450		244450
Baltic Est-Lat-Lit-Offshore	E_EE_14	Iru Waste to Energy Plant	Enefit Power As	Iru	WtE			138483	138483
						Total for Estonia:			8164463
		LITHUANIA							
Baltic Est-Lat-Lit-Offshore	E_LT_1	Achema	Ab "Achema"	Kaunas	Chemical	2208916			2208916
Baltic Est-Lat-Lit-Offshore	E_LT_4	Lietuvos Energijos Gamyba, PP	Ab "Lietuvos Energijos Gamyba"	Vilnius	Power	304646			304646
Baltic Est-Lat-Lit-Offshore	E_LT_7	Vilniaus Šilumos Tinklai PP N2	Ab "Vilniaus Šilumos Tinklai"	Vilnius	Power	293090			293090
Baltic Est-Lat-Lit-Offshore	E_LT_5	Kaunas WtEP		Kaunas	WtE			198000	198000
Baltic Est-Lat-Lit-Offshore	E_LT_6	Vilnius WtEP		Vilnius	WtE			169000	169000



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Baltic Est-Lat-Lit-Offshore	E_LT_8	Fortum Klaipeda WtEP	Uab „Fortum Klaipėda“	Klaipeda	WtE			126007	126007
Baltic Est-Lat-Lit-Offshore	E_LT_9	UAB "Toksika" hazardous WtEP	UAB "Toksika"	Šiauliai	Hazardous WtE			79000	79000
Baltic Est-Lat-Lit-Offshore	E_LT_11	UAB Kauno WtEP	UAB Kauno kogeracine jėgaine	Vilnius	WtE	112704		112704	112704
								Total for Lithuania	3491363
								Total for offshore cluster	11655826

The largest CO₂ emissions in Latvia are produced by four plants including the Schwenk Latvia cement plant in Broceni and three PPs located near Riga, including two Latvenergo PPs and one Rigas Siltums thermal plant. Altogether they produced 1.75 Mt CO₂ in 2021 (Table 4-2). Bio-emissions were not reported by emitters to national authorities in Latvia.

Table 4-2 Large CO₂ emissions produced in Latvia and Lithuania included in onshore cluster

Cluster name	Emitter ID	Facility name	Company name	City	Industry sector	CO2 reported (ETS) (t/y)	Total CO2 emissions (t/y)
Baltic Lat-Lit-Onshore 1	E_LV_1	Schwenk Latvija	Sia "Schwenk Latvija"	Broceni	Cement	752118	752118
Baltic Lat-Lit-Onshore 1	E_LT_2	Orlen Lietuva	Ab "Orlen Lietuva"	Telšiai	Refineries	1501524	1501524
Baltic Lat-Lit-Onshore 1	E_LT_3	Akmenės Cement	Ab "Akmenės Cementas"	Šiauliai	Cement	997056	997056
Baltic Lat-Lit-Onshore 2	E_LV_2	Latvenergo Tec-2	As "Latvenergo"	Riga	Power	675287	675287
Baltic Lat-Lit-Onshore 2	E_LV_3	Latvenergo Tec-1	As "Latvenergo"	Riga	Power	227341	227341
Baltic Lat-Lit-Onshore 2	E_LV_4	Rigas Siltums TP	As "Rīgas Siltums"	Riga	Power	99743	99743



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Baltic Lat-Lit-Onshore							Total for onshore cluster	4253069
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The largest CO₂ emissions in Lithuania are produced by five plants including Achema, Orlen refineries, Akmenes Cement and two power plants in Vilnius. Together with two WtE cogeneration plants 5.54 Mt CO₂ were produced in Lithuania and reported in EU ETS in 2021. Another three waste-to-energy plants produced together 0.45 Mt bio-CO₂. About 6 Mt of CO₂ emissions were produced in Lithuania by large emitters in 2021 (Table 4-1 and Table 4-2).

4.1.3 Storage potential

The most prospective CO₂ storage reservoir in the Baltic States is related to Deimena Regional stage sandstones of the Cambrian Wuliuan Stage. Estimated earlier storage capacity is about 400 Mt onshore and 300 Mt CO₂ offshore (Šliaupa, 2013). Since 2013, CO₂ storage capacity of the largest structures has been re-estimated and static structural geological models were constructed for four west Latvian onshore structures (Dobele, South-Kandava, Blidene, and North Blidene) and offshore structure E6 (Shogenov et al. 2013a, 2013b; Simmer 2018). The largest storage capacity onshore is available in the North-Blidene and Dobele structures and the largest storage site offshore is E6 structure (Table 4-3).

The North Blidene and Blidene structures located in western Latvia were recently applied in the Estonian-Latvian onshore CCUS scenario (Shogenova et al, 2021). Their optimistic and conservative CO₂ storage capacity was estimated by Simmer (2018), (Table 4-3). The North Blidene is an anticlinal uplift cut by west-east striking fault. The Blidene uplift is located in the down-dip block confined by the paralleling fault to the south and verging SW-NE of, the throw of the fault is about 400 m. These two structures are studied by five wells (Figure 4.2).

The estimated area of the Dobele structure considering closing contour of 1075 m is 70 km² and amplitude is up to 110 m. The tectonic structure is located on the hanging-wall of the west-east oriented fault. These three structures are confined to the common Saldus-Inčukalna elevated fault zone. The Dobele uplift was drilled by 17 deep wells penetrating the Cambrian Deimena Formation and 5 wells were drilled in the hanging wall of the controlling fault (Figure 4.3). The Cambrian reservoir is represented by quartz sandstones interbedded by thin layers of sandy siltstone and mudstones. Deimena Formation sandstones were defined at 965–1013 m depth in the Db91 well, and 1346–1390 m depth in the Db92 well (Shogenov 2013a, Janson and Zeltins, 2015).

The E6 offshore structure (Figure 4.3, right) was discovered by seismic exploration and drilled in 1984 by well E6-1 (1068 m depth) located 37 km from the coast of Latvia. The structure coincides with the zone of Liepaja-Saldus uplifts and was estimated as prospective for oil exploration in the 10.5 m thick Upper Ordovician Saldus Formation reservoir. The structure is an anticline bounded on three sides by faults. The E6 structure consists of two different compartments (E6-A and E6-B) divided by the inner fault. The total area of the



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structure is 600 km² considering the closing contour of the reservoir top located at a depth of 1350 m (BSL). The area of the larger E6-A part is 553 km². Prospective for CO₂ storage Cambrian Deimena Formation reservoir in the E6 structure was assessed as the largest storage site in the region. The Deimena Formation consists of quartz oil-stained sandstones with subordinate shale layers deposited in a shallow marine basin. The major Deimena reservoir overlies the shales of the Kybartai Regional stage (40 m thick). The Cambrian reservoir is sealed by large thick Silurian-Ordovician shale cap rock of 268 m thick in well E6-1. Offshore E6 structure has a smaller depth compared to onshore structures.

Both onshore and offshore structures have good reservoir properties, while the temperature is higher offshore (36°C) compared to 18–23°C onshore. Because the lower temperature is more suitable for CO₂ storage, the density of CO₂ stored will be higher onshore than in offshore structure (Table 4-3). All structures discussed in the paper were drilled by one (E6) to 23 (Dobele) wells that can be rated as an Optimistic scenario, rather than Conservative scenario, considering of seismic exploration, drill cores, logging, hydrogeological, geothermal and other data available.

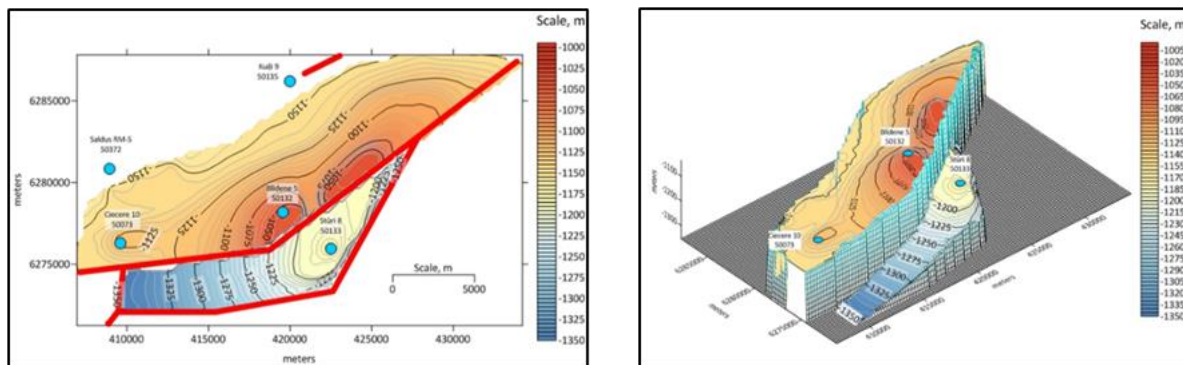


Figure 4.2 Left - Contour maps of the Deimena Formation in the North Blidene (above) and the Blidene (below) structures. A fault line is indicated with a red polyline; Right - 3D structure maps of the Deimena Formation in the North Blidene and the Blidene structures (Simmer, 2018)

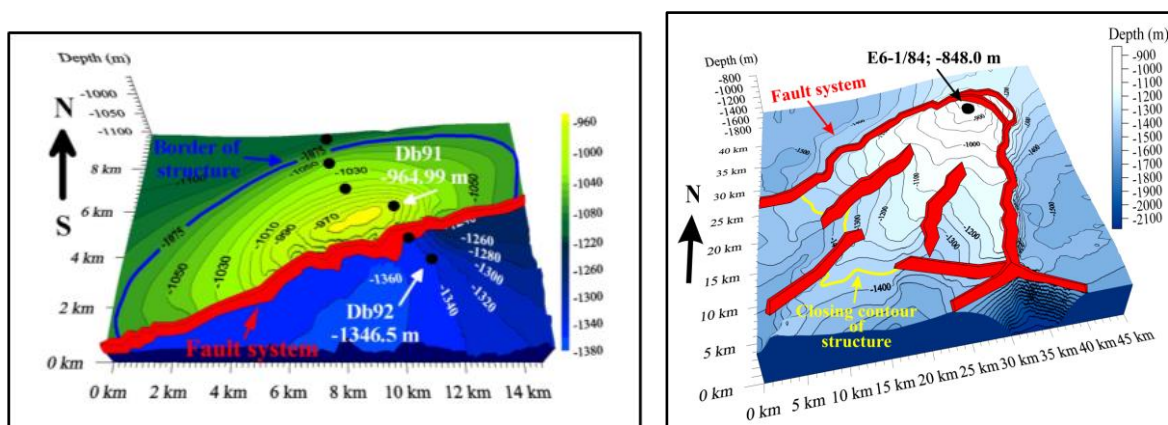


Figure 4.3 Left - Static model of the Dobele onshore storage site in Latvia. Right – E6 storage site offshore Latvia (Shogenov, 2013a, b)



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Table 4-3 Parameters of CO₂ storage sites selected for the Baltic scenarios

Parameters	North Blidene	Blidene	Dobele	E6-A
Storage ID	S_LV10	S_LV2	S_LV4	S_LV5
Depth of reservoir top, m	1035-1150	1168-1357	965-1013	848-901
Reservoir thickness, m	48	66	52	53
Trap area, km ²	141	62	70	553
CO ₂ density, kg/m ³	881	866	900	658
Net to gross ratio, %	75	80	85	90
Salinity, g/l	100-114	100-114	114	99
Permeability, mD	370-850	370-850	0.1-670/360	10-440(170)
T, °C	18	22.9	18	36
Storage eff. factor (Seff) Optimistic/Conservative (%)	30/4	5/3	20/4	10/4
Porosity (min-max/avg), %	12.5-25.6/20	13.5-26.6/21	10-26/19	14-33/21
Optimistic CO ₂ storage capacity (min-max/avg), Mt	167-342/267	19-37.5/29.6	56-145/106	243-582/365
Conservative CO ₂ storage capacity (min-max/avg), Mt	22.2- 45.5/35.6	11.4- 2.5/17.8	11-29/21	97-233/146

4.1.4 The Latvia/Lithuania onshore value chain (selected for WP3)

The Baltic onshore value chain includes four of the largest Latvian CO₂ emitters and two Lithuanian plants located close to the Latvian-Lithuanian border (Orlen refinery – E_LT_2 and Akmenes cement plant – E_LT_3, owned by Schwenk). This cluster will store annually 3.1 Mt CO₂ from three plants:

- Latvian and Lithuanian Schwenk-owned cement plants (E_LV_1 and E_LT_3) and
- Orlen Refinery(E_LT_2) in the onshore North Blidene structure (S_LV10).

Latvian two Latvenergo PP (E_LV_2 and E_LV_3) and one Rigas Siltums TP (E_LV_4) located in the Riga region will store about 0.95 Mt CO₂ in the Dobele structure site (S_LV4) in western Latvia using up to 150 km CO₂ pipelines.



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The most relevant CO₂ use option for Estonia is to use CO₂ for mineral carbonation of Estonian burned oil shale (BOS) (Shogenova et al, 2021). Another possible CO₂ use option is to CO₂ use for geothermal energy recovery. This could be applied in the region of central Latvian geothermal anomaly, reaching 62°C in Pape 23 well at the west-south coast of Latvia and 55°C in Vircava-5 well, located about 35-40 km from the Dobeles structure by road. All countries are planning to produce hydrogen. They can store it in the Blidene structure onshore (Figure 4.1).

4.1.5 The Estonia/Latvia/Lithuania offshore value chain

The Baltic offshore cluster includes all large Estonian and Lithuanian fossil and bio-emission sources – one of which Klaipeda Waste-to-energy Plant and other sources located in central and south-eastern Lithuania. These emitters will transport their emissions by pipelines and ship them to the E6 storage site located 80 km from Klaipeda Port. Estonian north-east cluster, composed of seven emission sources (four plants produced only fossil emissions and three power plants using both oil shales and biomass for energy production) will use CO₂ pipeline or truck/train transport to Sillamäe and Kunda ports and then ship CO₂ to the E6 storage site in Latvia (615 km by ship from Sillamäe). This cluster will be able to capture and store annually 11.1 Mt CO₂, including 9 Mt of fossil and 2.1 Mt of bio-CO₂ (95% of the produced emissions).

The most relevant CO₂ use option for this cluster is the use of CO₂ for geothermal energy recovery in the E6 structure. All countries are planning to produce hydrogen. They can store it in the smaller E6-B compartment of the E6 structure offshore (Figure 4.2 and Figure 4.3).



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Table 4-4 Description of the Eastern Baltics value chains

Value chain name	Emission cluster	Total CO ₂ emissions, t/y	Storage sites	Capacity, Mt	Distance emission to storage, km	Transport option(s)
Baltic Est-Lat-Lit-Offshore	Baltic Est-Lit-Offshore	11,655,826	E6-A	396	80 km (Klaipeda), 645 km (Sillamäe)	pipelines and ship
Baltic Lat-Lit-Onshore (a)	Baltic Lat-Lit-onshore	3,250,698	North Blidene & Blidene	297	9-70 km	pipeline
Baltic Lat-Lit-Onshore (b)	Baltic Lat-Lit-onshore	1,002,371	Dobele	106	150 km for Latvenergo Tec+2	Pipeline
Baltic Lat-Lit-Onshore (a+b)	Baltic Lat-Lit-onshore	4,253,069	North Blidene, Blidene and Dobele	403	9-150 km	pipeline

4.1.6 Conclusions

- The two largest onshore and one offshore storage sites in Latvia have the capacity to store all large Estonian, Latvian, and Lithuanian fossil and bio-CO₂ emissions.
- A total 15.1 Mt of fossil and bio- CO₂ could be captured, transported, used and stored, while only 13.7 Mt of fossil CO₂ produced annually. The negative balance is about 1.4 Mt CO₂.
- Additional revenues will come from geothermal energy recovery in Latvia for local heating and cooling needs, CO₂ mineral carbonation of BOS in Estonia and hydrogen production and storage in the Baltic CCUS clusters.
- The average optimistic storage capacity of the studied structures will be enough for more than 50 years, while conservative for 14.5 years. The CCUS cluster scenario represents the substantial volume to store the emitted CO₂ for the long transitional period. Additional structures in the wester Latvia located near the largest ones could be also developed for CO₂ and H₂ storage.



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4.2 Finland

4.2.1 Presentation of the geographical region

The selected value chain (Figure 4.4) presents a CCUS opportunity for the selected Helsinki emitter cluster in Finland, connecting it to the Danish potential storage site of Rødby. It consists, therefore, of a cross-border CCUS value chain.



Figure 4.4: Selected value chain for the Finland region.

Finland aims to become carbon neutral by 2035. The largest emission sources are the pulp and paper industry and thermal power and heat plants. Biogenic CCS has, therefore, a high potential. Nonetheless, there is no CCUS specified target defined in Finland and no national support systems are in place for CCS deployment. Finland does not have suitable geologic formations for CO₂ storage and heavily relies on natural carbon sinks such as forests and soils to reach their 2035 targets. In respect to BECCS, being Finland Europe's largest pulp and paper producer, CO₂ storage locations are very relevant.

4.2.2 Emission sources

The selected emitters of the Helsinki cluster are presented in Table 4-5 and Figure 4.5. The cluster sums approximately 6.5 millions tonnes of CO₂. Its emissions are originated mainly from Refineries, Power and Chemicals industries. The cluster selection decision is supported not only by its geographical arrangement and the high CO₂ volumes, but also the possibility that the location provides in shipping the CO₂ to storage sites in other countries.



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Table 4-5: Helsinki emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ total [t/yr]
E_FI_4	Neste Oyj, Porvoon Jalostamo	Uusimaa	Refineries	2,360,000
E_FI_10	Helen Oy, Salmisaaren Voimalaitokset	Uusimaa	Power	1,136,000
E_FI_17	Helen Oy, Hanasaari B - Voimalaitos	Uusimaa	Power	818,000
E_FI_18	Helen Oy, Vuosaaren Voimalaitokset	Uusimaa	Power	771,000
E_FI_24	Fortum Power And Heat Oy, Suomenojan Voimalaitos	Uusimaa	Power	562,000
E_FI_26	Borealis Polymers Oy, Petrokemian Laitokset	Uusimaa	Chemicals (other)	537,000
E_FI_62	Linde Gas Oy Ab, Kilpilahden Vedyntuotantolaitos	Uusimaa	Chemicals (other)	150,000
E_FI_64	Fortum Power And Heat Oy, Kivenlahden Lämpökeskus	Uusimaa	Power	143,000
Total Helsinki cluster				6,477,000



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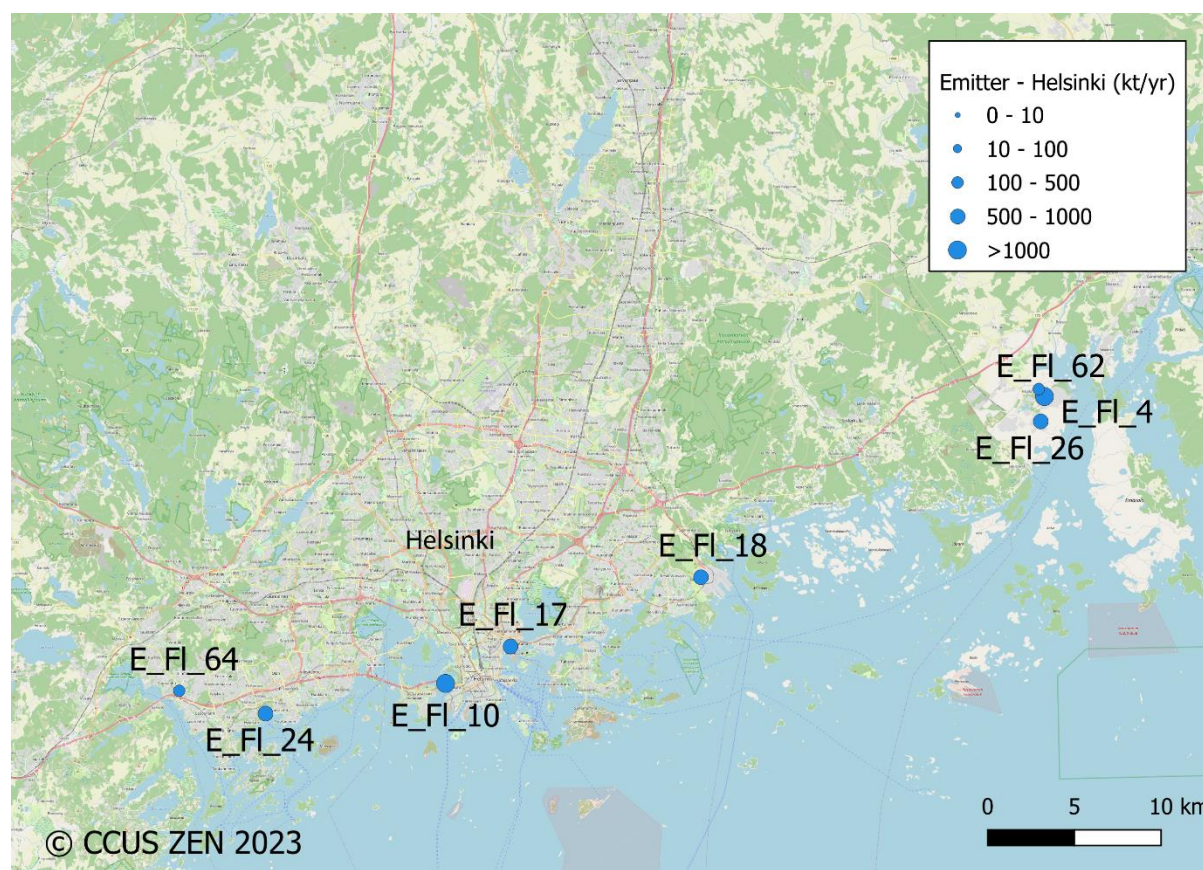


Figure 4.5: Helsinki emission cluster with eight emitters marked, see Table 4-5 for more details.

4.2.3 Storage potential

The most prominent storage sites mapped for Finish CO₂ injection are located in Denmark or the Baltic states (Lithuania, Latvia, Estonia). For this value chain, the Danish Rødby storage site was selected due to its storage capacity and the possibility of a shipping line connecting it to the emission cluster.

Hjelm et al. (2020) provides reported data on the Rødby storage site reproduced in Table 4-6:

Table 4-6: Rødby storage site data

Structure	Area		Gross Thickness (m)		Net/Gross		Porosity		CO ₂ density (kg/m ³)		Depth (m)	Permeability (mD)	
	min	max	min	max	min	max	min	max	min	max		min	max
Rødby BF	69	179	205	307	0.19	0.31	0.17	0.29	630	770	-1300	81	856



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Rødby storage capacity and storage readiness level is presented in Table 4-7.

Table 4-7: Storage capacity of Rødby

Storage type	Storage name	On/offshore	Capacity mean (million tonnes)		Storage Readiness Level
			P90	P10	
Deep Saline Aquifer	Rødby	Onshore	242	449	3.1

4.2.4 Helsinki value chain

The emission clusters included in this value chain are presented in Table 4-8.

Table 4-8: Summary of emission clusters for the Helsinki value chain

Country	Cluster	Total CO ₂ emissions [ton/yr]	Number of emitters
Finland	Helsinki Cluster	6,477,000	8

The Rødby total storage capacity varies approximately from 242 to 449 million tonnes of CO₂.

For CO₂ transportation, the value chain envisages a shipping connection from Helsinki to Rødby, reproducing existing shipping lanes already in use.

The selected value chain can be used as an initial perspective on the export of CO₂ from Finland. The Helsinki cluster has the capability of developing to a CO₂ export hub and the Danish storage sites have the best potential to perform as carbon sinks.

The Helsinki value chain hosts also some interesting potential for CCU projects - listed in the CO₂ Value Europe's database on CCU¹ - like the concepts of BECCU project and its FOREST CUMP suite for the production of olefins from CO₂; or the Power-to-Gas plant prepared in VANTAA and the St1 CCU methanol project in Lappeenranta with the support of NextGeneration EU. Additionally, the Carbon2x concept further north (Riihimäki) for the production of chemicals from CO₂ can be well connected to the Helsinki cluster. The CCU value chain can be supported by hydrogen infrastructure prepared and financed through IPCEI in Porvoo.

¹ <https://database.co2value.eu/>



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4.3 Poland

4.3.1 Northern Poland

4.3.1.1 Presentation of the geographical region

The selected region (Figure 4.6 **Error! Reference source not found.**) includes northern part of Poland, within historical regions of Kuyavia and Masovia (south) and Gdańsk Pomerania together with part of Warmia-Masuria (north). Within the region, refinery, chemical, paper and pulp, cement and lime as well as energy industry installations are present.

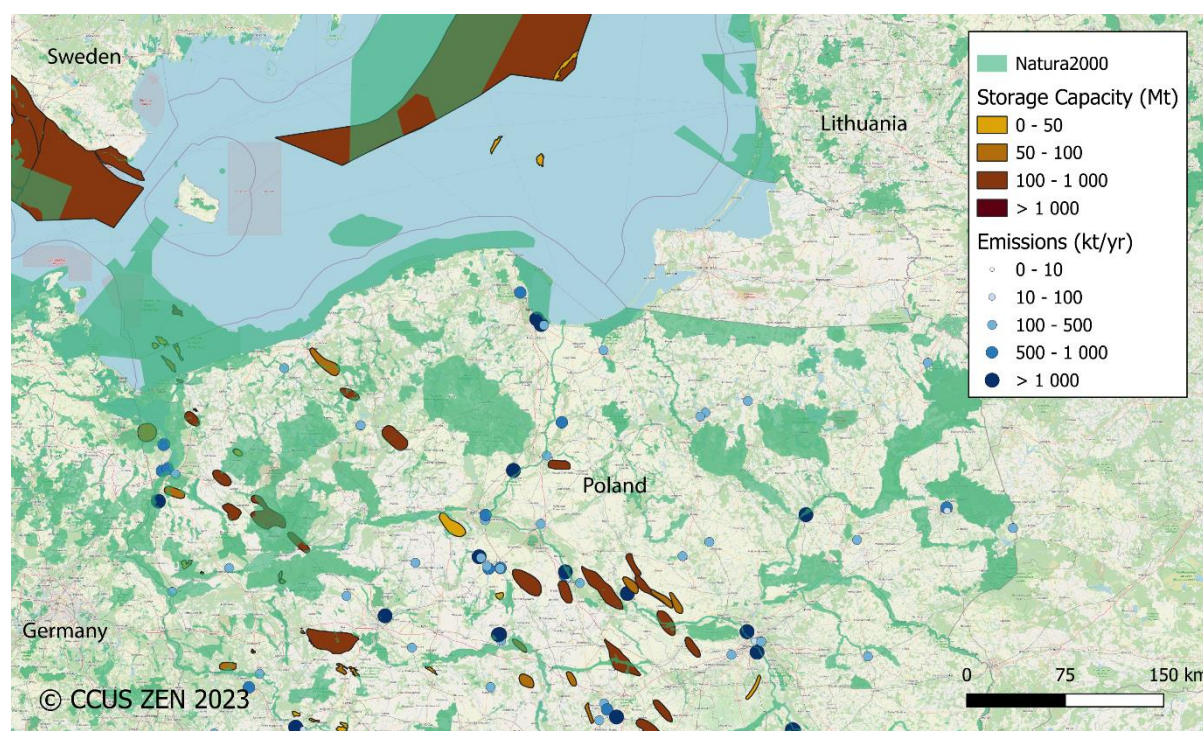


Figure 4.6: Geographical extent of the Northern Poland region (the region is outlined in red in the map on top left corner). Coloured polygons indicate identified potential storage sites and blue dots represent the emissions sites.

At this moment no official government backed strategy/roadmap on implementation of CCUS in that region (and in entire country as well) is published yet. CCUS is vaguely mentioned in national strategy on energy transformation (MCE, 2021a). However, in 2021, Polish Minister of Climate and Environment appointed an advisory board - the Team on Development of CCUS technologies where representatives of government, industry and research organizations were invited in order to facilitate implementation of CCUS technologies in Poland (MCE, 2021b) and the Team is working on relevant strategies and roadmaps. Regulations relevant to CCUS – Polish geological and mining law and some other laws (RCL, 2021) have just been amended by the Parliament and adopted in order to facilitate implementation of commercial CCUS projects in Poland. Previous law and the competent authority (Ministry of Climate and Environment) regulations (to be amended) allowed CO₂



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storage in case of a demo project within offshore area in NE part of Polish Baltic sector but the new law is not so restrictive. In the fifth PCI list adopted by EC in November 2021 the project “Poland – EU CCS Interconnector” (emitters from the industrial cluster in the wider area around Gdańsk, Poland using the terminal in port of Gdańsk then ship transport and storage under North Sea) has been included. The project has been proposed by consortium of Air Liquide Polska, PKN Orlen S.A., Port of Gdańsk, Lafarge Cement S.A. and Sogestran Shipping, and is on early stage of development, its first phase is to be completed by year 2026 (EC, 2023). Part of this cluster is awarded by EU Innovation Fund Lafarge CCS project of Kujawy cement plant (Global Cement, 2022), located about 200 km south of Gdańsk, in which railway transport option to port of Gdańsk is scheduled. The project “Poland – EU CCS Interconnector” has recently changed name to “ECO2CEE” because Lithuanian assets of PKN Orlen have been included in the cluster (Bellona, 2023).

4.3.1.2 Emission sources

The region is divided into two (sub)clusters of emission sources: Gdańsk-Pomerania (North)(Figure 4.7) and Kuyavia-Masovia (South)(Figure 4.8) where there are, according to the inventory done in D1.1 (Ringstad et al. 2023), 9 emitters of total 9.06 Mt/yr and 18 emitters of total 13.6 Mt/yr respectively (Table 4-9). These emitters belong to various industry sectors and in case of energy production either predominantly fossil fuels are used with a very minor or unspecified share of biomass co-firing, or predominantly biomass (fossil fuels being replaced with biomass – 2 emitters), or waste of both biogenic and fossil origin (1 emitter). In one cement plant waste (RDF - of both biogenic and fossil origin) co-firing together with hard coal is used. Two modern power installations built and commissioned after EU CCS directive was implemented are located in southern (sub)cluster. Several energy installations in each (sub)cluster were built before EU CCS directive was announced. They are predominantly coal fired (sometimes coal and/or fuel oil or coal and gas fired), undergone some modernisation (i.e. reducing NO_x and sulphur emissions or replacing coal fired boilers with gas and fuel oil fired) and in some cases minor biomass co-firing capabilities have been included, so these installations should be considered with caution in value chain scenarios (marked in italics in Table 4-9).



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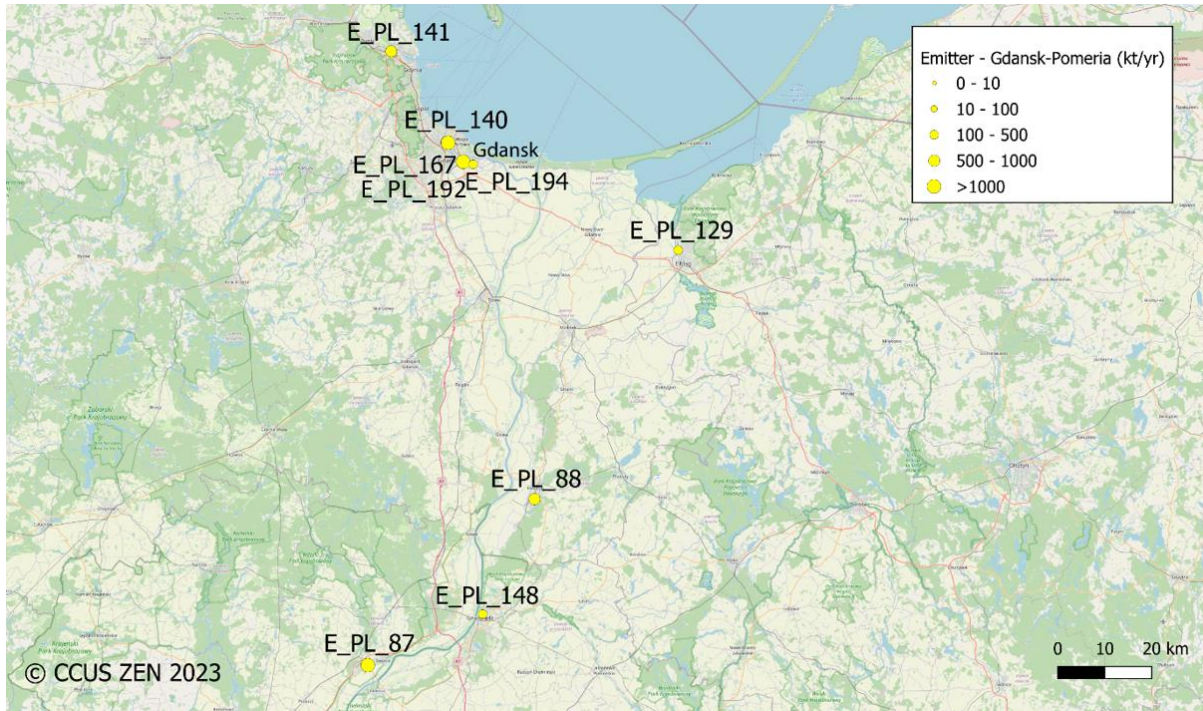


Figure 4.7: GdańskPomerania emissions cluster

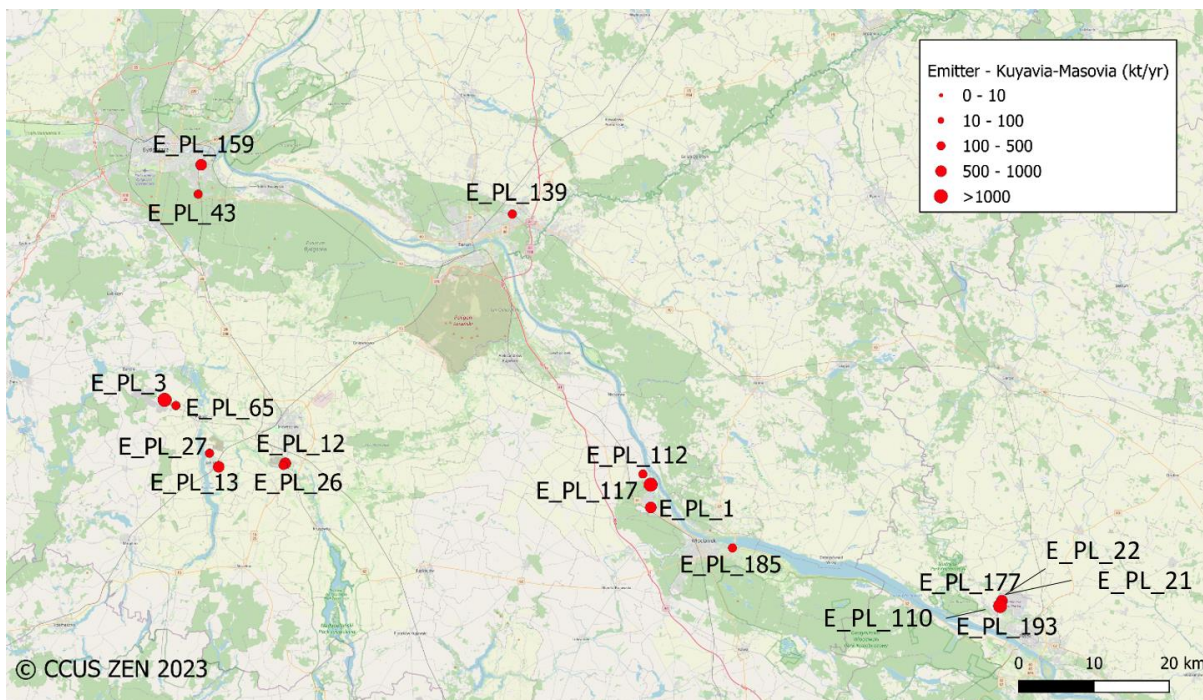


Figure 4.8: Kuyavia-Masovia emissions cluster Table 4-9 The emission sources in the region of Northern Poland –in *italic* are old, predominantly fossil fuel fired energy installations



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CLUSTER NAME	EMITTER ID	FACILITY NAME	COMPANY NAME	CITY	INDUSTRY SECTOR	CO2 REPORTED (t/y)	EMISSION TREND	BIOMASS CO2 (t/y)	WtE CO2 (t/y)	REMARKS
Gdańsk Pomerania cluster	E_PL_129	ELEKTROCIEPŁOWNIA ELBLĄG	ENERGA Kogeneracja	Elbląg	Power - CHP	223312	Falling	57000		biomass cofiring (with coal) replaced oldest coal fired boilers - the remaining to be replaced with gas fired ones; biomass after Endrava, acc. to press biomass emissions are 155000 t CO2
<i>Gdańsk Pomerania cluster</i>	<i>E_PL_167</i>	<i>ELEKTROCIEPŁOWNIA GL S.A.</i>	<i>GRUPA LOTOS S.A.</i>	<i>Gdańsk</i>	<i>Power - CHP</i>	<i>291863</i>	<i>Closing</i>	<i>0</i>		<i>Closed by the end of 2021, to be replaced with a new gas-fired plant</i>
Gdańsk Pomerania cluster	E_PL_192	INSTALACJE RAFINERYJNE	GRUPA LOTOS S.A.	Gdańsk	Refineries	1515849	Stable	0		
Gdańsk Pomerania cluster	E_PL_194	LOTOS ASFALT Sp. z o.o. Zakład Produkcyjny Gdańsk	LOTOS ASFALT sp. z o.o.	Gdańsk	Refineries	211000	Growing	0		upgraded recently; reported emissions after Endrava (2020)
<i>Gdańsk Pomerania cluster</i>	<i>E_PL_140</i>	<i>ODDZIAŁ ELEKTROCIEPŁOWNIA GDAŃSKA</i>	<i>PGE Energia Ciepła S.A.</i>	<i>Gdańsk</i>	<i>Power - CHP</i>	<i>1340356</i>	<i>Growing</i>	<i>5000</i>		<i>biomass cofiring (with coal); biomass emissions after Endrava (likely underestimated)</i>
<i>Gdańsk Pomerania cluster</i>	<i>E_PL_141</i>	<i>ODDZIAŁ ELEKTROCIEPŁOWNIA GDYŃSKA</i>	<i>PGE Energia Ciepła S.A.</i>	<i>Gdynia</i>	<i>Power - CHP</i>	<i>669712</i>	<i>Stable</i>	<i>1000</i>		<i>biomass cofiring (with coal, also fuel oil), biomass emissions after Endrava (likely underestimated)</i>



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Deliverable D1.2. Identifying promising CCUS value chains



Gdańsk Pomerania cluster	E_PL_1 48	ELEKTROCIEPŁOWNIA	OPEC-INEKO Sp. z o.o.	Grudziądz	Power - CHP	146049	Periodic	0		
Gdańsk Pomerania cluster	E_PL_8 8	Produkcja papieru i tektury	International Paper - Kwidzyn sp. z o.o.	Kwidzyn	Paper and pulp	687301	Periodic	0		biomass cofiring
Gdańsk Pomerania cluster	E_PL_8 7	Mondi Świecie Spółka Akcyjna	Mondi Świecie Spółka Akcyjna	Świecie	Paper and pulp	3973015	Growing	3902000		biomass cofiring growing; biomass emissions after Endrava
Kuyavia-Mazovia cluster	E_PL_1 59	Oddział Elektrociepłownia Bydgoszcz II	PGE Energia Ciepła S.A.	Bydgoszcz	Power - CHP	728713	Stable	0		
Kuyavia-Mazovia cluster	E_PL_4 3	Bydgoszcz WtE	MKUO ProNatura Sp. z o.o.	Bydgoszcz	Energy from waste	164400	Stable	0	164400	waste and CO2 stream include components of both biogenic and fossil origin
Kuyavia-Mazovia cluster	E_PL_1 2	ELEKTROCIEPŁOWNIA ZAKŁAD INOWROCŁAW	CIECH Soda Polska S.A.	Inowrocław	Chemicals (other)	836801	Stable	1000		modernisation, incl. reducing NOx and sulphur emissions, biomass after Endrava (likely underestimated); industrial energy installation (Power - CHP)
Kuyavia-Mazovia cluster	E_PL_2 6	Zakład Produkcyjny w Inowrocławiu	CIECH Soda Polska S.A.	Inowrocław	Chemicals (other)	241084	Periodic	0		
Kuyavia-Mazovia cluster	E_PL_1 3	Elektrociepłownia Zakład Janikowo	CIECH Soda Polska S.A.	Janikowo	Chemicals (other)	722517	Falling	0		modernisation, incl. reducing NOx and sulphur emissions; industrial energy installation (Power - CHP)



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Deliverable D1.2. Identifying promising CCUS value chains



Kuyavia-Mazovia cluster	E_PL_27	Zakład Produkcyjny w Janikowie	CIECH Soda Polska S.A.	Janikowo	Chemicals (other)	178916	Periodic	0	
Kuyavia-Mazovia cluster	E_PL_65	Instalacja do produkcji wapna Zakład Kujawy	Trzuskawica S.A.	Piechcin	Other - Lime	195566	Periodic	0	
Kuyavia-Mazovia cluster	E_PL_3	LAFARGE CEMENT S.A. Oddział w Bielawach	LAFARGE CEMENT SPÓŁKA AKCYJNA	Piechcin-Bielawy	Cement	1266102	Periodic	119000	waste cofiring; biomass emissions after Endrava; both LAFARGE plants processed 345900 t of waste in 2020
Kuyavia-Mazovia cluster	E_PL_110	ELEKTROCIĘPŁOWNIA	Polski Koncern Naftowy ORLEN S.A.	Płock	Power	2647189	Periodic	0	
Kuyavia-Mazovia cluster	E_PL_193	Rafineria	Polski Koncern Naftowy ORLEN S.A.	Płock	Refineries	2556613	Periodic	0	
Kuyavia-Mazovia cluster	E_PL_21	Olefiny II	Polski Koncern Naftowy ORLEN S.A.	Płock	Chemicals (other)	721129	Periodic	0	
Kuyavia-Mazovia cluster	E_PL_22	Instalacja do produkcji chemikaliów org. luzem	Polski Koncern Naftowy ORLEN S.A.	Płock	Chemicals (other)	103000	Periodic	0	reported emissions after Endrava (2020; c. 10000 t higher than ETS verified emissions that year)
Kuyavia-Mazovia cluster	E_PL_177	Elektrownia - Blok Gazowo - Parowy Płock	Polski Koncern Naftowy ORLEN S.A.	Płock	Power - CHP	946905	Periodic	0	commissioned several years ago (2018)
Kuyavia-Mazovia cluster	E_PL_139	PGE Toruń S.A. - Elektrociepłownia EC1	PGE Toruń S.A.	Toruń	Power - CHP	268659	Periodic	0	several years ago coal fired boilers were replaced with gas (and fuel oil) fired



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Kuyavia-Mazovia cluster	E_PL_1 85	CIEPŁOWNIA WSCHÓD WŁOCŁAWEK	Miejskie Przedsiębiorst wo Energetyki Ciepłej Spółka z o.o. we Włocławku	Włocław ek	Power - Heating	118513	Stable	0	biomass cofiring
Kuyavia-Mazovia cluster	E_PL_1 12	Tłocznia Gazu I Ssrp Włocławek	SYSTEM GAZOCIĄGÓ W TRANZYTOWY CH EuRoPoL GAZ S.A.	Włocław ek	Power	116000	Falling	0	Oil & gas Processing
Kuyavia-Mazovia cluster	E_PL_1	Instalacja do produkcji amoniaku	ANWIL S. A.	Włocław ek	Ammoni a	790514	Stable	0	In 2017 after Endrava reported emissions of the ammonia plant were c. 45000 t higher than verified ETS emissions (i.e. such was estimate of biomass emissions, but newer data are not available)
Kuyavia-Mazovia cluster	E_PL_1 17	Elektrownia gazowo-parowa CCGT	Polski Koncern Naftowy ORLEN S.A.	Włocław ek	Power	1022344	Growing	0	commissioned several years ago (2017)



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In North, emitters are concentrated in Gdańsk-Gdynia area and scattered in the remaining part of the (sub)cluster (Elbląg, Kwidzyn, Grudziądz, Świecie). In South, there are emitter concentrations in several areas: Bydgoszcz, Piechcin-Inowrocław-Janikowo, Włocławek and Płock and a lone emitter in Toruń (Figure 4.8).

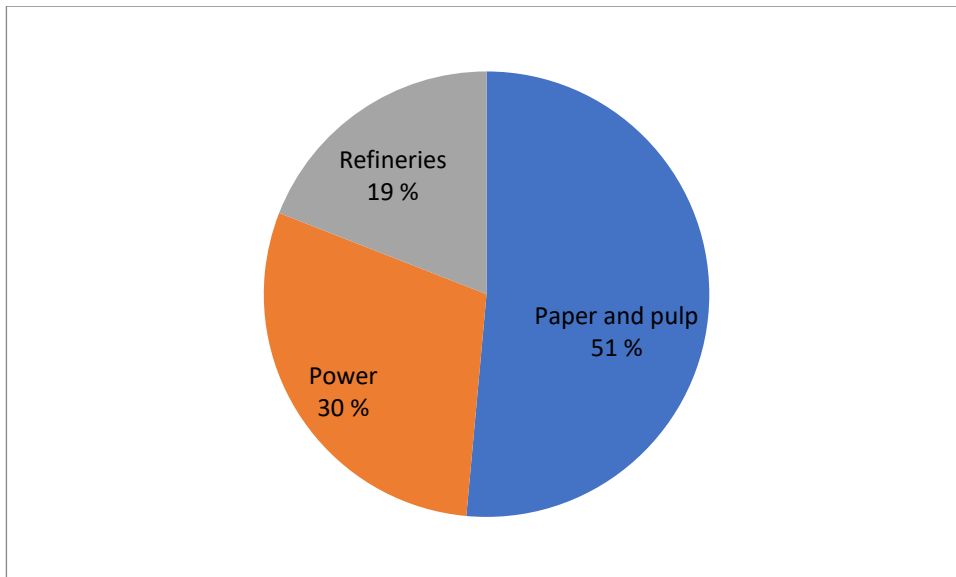


Figure 4.9 Pie chart of the emitters in the northern (sub)cluster – 9 emitters of total 9.06 Mt/yr

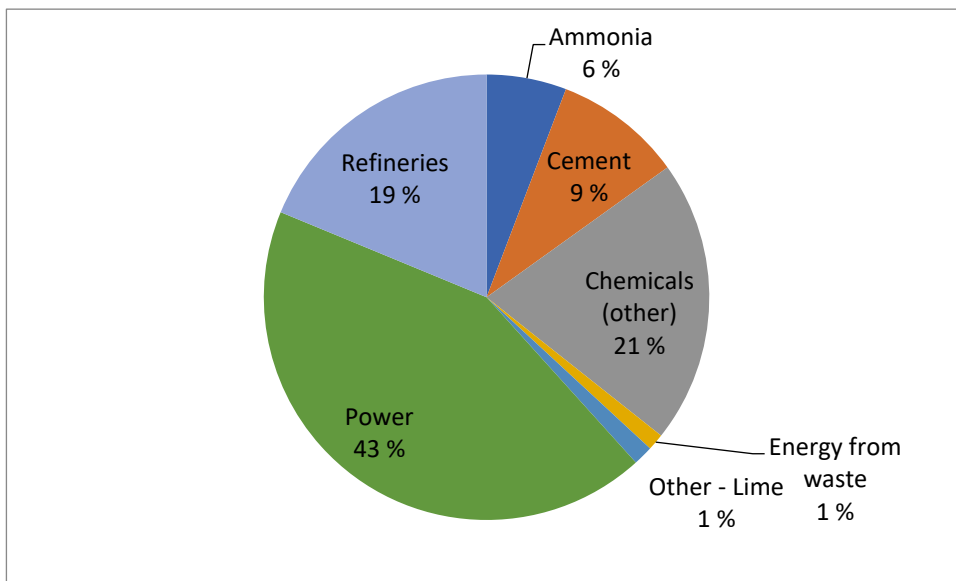


Figure 4.10 Pie chart of the emitters in the southern (sub)cluster – 18 emitters of total 13.6 Mt/yr

In northern (sub)cluster (Figure 4.9) paper and pulp sector makes the bigger share in CO₂ emission volume, mainly because of large emitter Mondi in Świecie where energy for the needs of the industrial complex is almost exclusively produced from biomass combustion and the second emitter is the plant in Kwidzyn. Then power industry (in Gdańsk, Gdynia,



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Elbląg and Grudziądz) makes the second biggest share and the smallest share belongs to LOTOS oil refineries in Gdańsk.

In southern (sub)cluster (Figure 4.10) the picture is more complex. The power industry (in Bydgoszcz, Płock, Toruń and Włocławek) makes the biggest share, then comes chemicals (other) sector (chemical plants of PKN ORLEN in Płock and CIECH in Inowrocław and Janikowo; in the latter also energy for the needs of industrial complexes is produced). PKN ORLEN refinery in Płock makes the third biggest share, then goes Lafarge cement plant in Piechcin-Bielawy and the sixth is Anwil ammonia plant in Włocławek. The smallest shares belong to lime plant in Piechcin and energy from waste plant (RDF fired) in Bydgoszcz.

As mentioned above, various decarbonisation alternatives have been applied in a number of emitters located within both (sub)clusters. Installations where fuel combustion takes place have undergone modernisation or conversion. In many old coal fired power plants systems reducing NO_x and sulphur emissions were installed, some old power blocks or boilers were replaced with new, more energy efficient and “clean” ones, or with blocks or boilers using fuels less carbon-intensive than hard coal (i.e. gas, fuel oil). In case of some new blocks or boilers biomass co-firing capabilities have been included, but in most of power industry sector installations the share of biomass in facility emissions (and energy production) is not significant. The exception is a rather small CHP plant in Elbląg in northern (sub)cluster where old coal fired boilers have been successively replaced with biomass fired ones (and some with gas fired ones), so biomass combustion might presently have the biggest share in the plant total CO₂ emissions. A special case is energy from waste plant in Bydgoszcz (southern (sub)cluster) where CO₂ stream includes components of both biogenic and fossil origin. Regarding other sectors, the paper and pulp plant of Mondi in Świecie (northern (sub)cluster) biomass has almost completely replaced fossil fuels, producing energy for the needs of the industrial complex. The cement plant of Lafarge in Piechcin-Bielawy (southern (sub)cluster) produce waste of both biogenic and fossil fuel origin is co-fired with hard coal. It should be also noted that ammonia plant of Anwil and likely chemical plants of PKN ORLEN and CIECH might be sources of relatively pure CO₂ stream.

Last but not the least, national strategy on energy transformation (MCE, 2021a) mentions CCUS, but often as a subset of Clean Coal Technologies (CCT), or blue hydrogen technologies, or EHR technologies. So, at this moment the national energy strategy might or might not be directly relevant to possible decarbonisation strategies in the studied region, but it should be noted the national Team on Development of CCUS technologies (MCE, 2021b) is working on relevant strategies and roadmaps for all key industry sectors in Poland.

4.3.1.3 Storage potential

The storage options presented in Figure 4.11 and Table 4-10 are generally based on inventory done in Ringstad et al. (2023), with one exception (offshore saline aquifer area in Polish sector of Baltic Sea).

In the frame of the inventory prospective structures which have been studied in Polish national project (Wójcicki et al., 2014) have been identified in Ringstad et al. (2023) by PGI and then relevant information verified, updated and storage capacities recalculated according to CSLF methodology where necessary (volumetric capacity only). There are



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mainly onshore saline aquifer structures within the said region (Table 4-10) and those recommended as possible storage sites of the value chain are marked in red in the Table. The recommended onshore storage sites have been selected basing on proximity to locations where emitters are concentrated. Those not recommended are generally located further, or have a sizeable percentage of protected areas, or are poorly explored. A special case is S_PL17 structure which shall be excluded because brine produced from aquifer in question (Lower Jurassic) is used in balneotherapy at a location within the structure (at Marusza village near Grudziądz), so there is an obvious conflict of use.

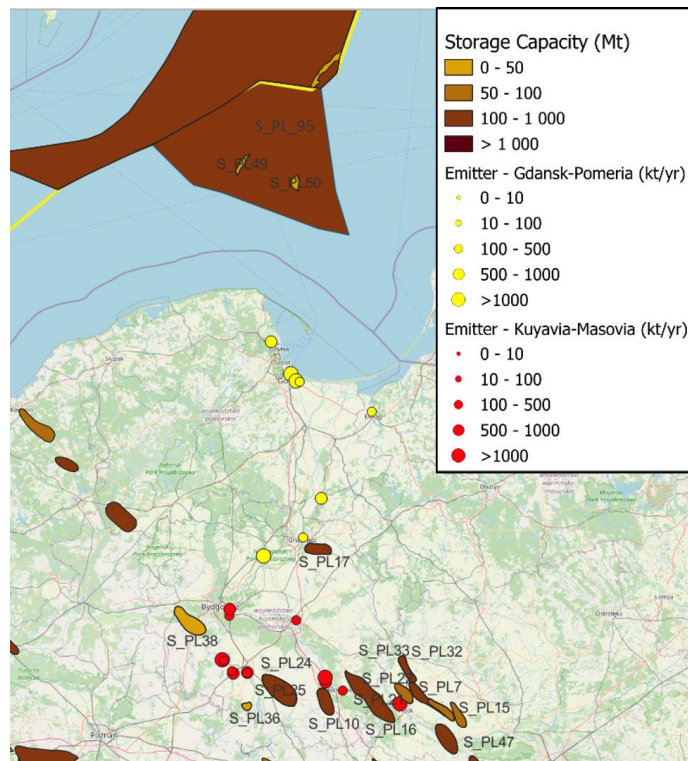


Figure 4.11: Storage options in Northern Poland region.

The onshore saline aquifer structures are concentrated mostly in southernmost part of the region. Five of them are covered, usually in small or very small parts by NATURA2000 areas and nature reserves (mostly within NATURA2000 areas). It should be noted that within the nature reserve areas storage and monitoring infrastructure cannot be built, i.e. no wells to be drilled, as well as seismic acquisition seems unlikely there, but these areas are usually quite small in comparison to entire saline aquifer structures. Within NATURA2000 areas some restrictions might apply pertaining to storage and monitoring infrastructure construction, i.e. environmental impact studies are to be approved by local communities before wells are drilled. The structures are generally insufficiently explored, usually with a handful of wells and sparse 2-D seismic of 1970s or 1980s, rarely of 1990s. Hence the estimations of volumetric storage capacities based on existing data are not very accurate as well as the assumptions on storage complex integrity and safety are based on sparse and insufficient data.



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The investment decision of development of any of these structures into storage sites should be preceded by detailed exploration of particular structure, and preferably at least one backup site. As listed in Table 4-10 there are 16 onshore aquifer structures, but three structures are dual, i.e. include aquifers of two different geological formations in the same place, so we have 13 such sites. The reservoirs are mostly Lower Jurassic (rarely Middle Jurassic) sandstones and Lower Cretaceous Sandstones, and in one case Lower Triassic sandstones. Structures in Jurassic usually have multiple reservoirs and seals. The estimated volumetric storage capacities of all these structures range from 24.57 Mt to 595.6 Mt (Figure 4.12) and in case of the recommended ones 47.39 Mt to 595.6 Mt (Figure 4.13), so 1-2 such sites might be sufficient to store emissions of each (sub)cluster (or even both) for a period up to 30 years.

On the other hand, in SE part of Swedish sector of Baltic Sea prospective Cambrian aquifers within Dalders monocline (central Baltic) have been identified in Ringstad (2023) after Mortensen and Sopher (2021), i.e. Faludden (of the best reservoir properties), När and Viklau, ranging from Middle to Lower Cambrian. Some parts of the saline aquifer in Swedish sector are covered by NATURA2000 areas, so restrictions might apply if storage infrastructure is to be built there.



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Table 4-10 Characterization of storage options considered for the Northern Poland region. Recommended storage sites are marked with red.

STORAGE ID	STORAGE TYPE	STORAGE NAME	ON/OFFSHORE	CAPACITY MEAN	SRL LEVEL	SURFACE_ISSUES	REMARKS
S_PL7	Saline aquifer	Bielsk	onshore	62.5	1	nn	
S_PL8	Saline aquifer	Bielsk-Bodzanów	onshore	193.9	1	nn	
S_PL9	Saline aquifer	Bodzanów	onshore	76.8	1	nn	
S_PL10	Saline aquifer	Brześć Kujawski	onshore	595.9	1	very small area covered by nature reserve (rare plants protected)	largest storage capacity among individual structures (daughter units)
S_PL15	Saline aquifer	Dzierżanowo	onshore	84			
S_PL16	Saline aquifer	Gostynin	onshore	513.45	1	small areas covered by nature reserves (marsh birds and rare plants protected) and NATURA2000, urban area (town) located	
S_PL17	Saline aquifer	Grudziadz	onshore	157.21	1	nn	
S_PL21	Saline aquifer	Kamionki J	onshore	148.72	1	nn	
S_PL22	Saline aquifer	Kamionki K	onshore	99.22	1	nn	



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Deliverable D1.2. Identifying promising CCUS value chains



S_PL24	Saline aquifer	Konary J	onshore	282.24	1	nn	
S_PL25	Saline aquifer	Konary T	onshore	181.91	1	nn	
S_PL32	Saline aquifer	Sierpc J	onshore	151.67	1	reaches to the urban area (town) to the north	
S_PL33	Saline aquifer	Sierpc K	onshore	212.35	1	reaches to the urban area (town) to the north	
S_PL36	Saline aquifer	Strzelno	onshore	24.57	1	small area covered by NATURA2000	
S_PL38	Saline aquifer	Szubin	onshore	47.39	1	very small area covered by NATURA2000	
S_PL47	Saline aquifer	Wyszogród	onshore	315.35	1	areas covered by NATURA2000 and nature reserves (rare water birds protected)	poor 2D seismic coverage
S_PL49	Hydrocarbon field	B 3	offshore	10.61	3	nn	dense 2D seismic and numerous wells; within the aquifer below (same reservoir)
S_PL50	Hydrocarbon field	B 8	offshore	7.91	3	nn	3D seismic
S_SE3&Polish	Saline aquifer	Faludden	offshore	933	1	areas covered by NATURA2000 in Swedish sector	the Cambrian aquifer (Middle Cambrian Faludden fm.) has been



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Deliverable D1.2. Identifying promising CCUS value chains



extension (S_PL95)							mapped in Swedish sector (~745 Mt volumetric capacity) - added Polish extension (Dębowska fm.) - estimated as ~188 Mt
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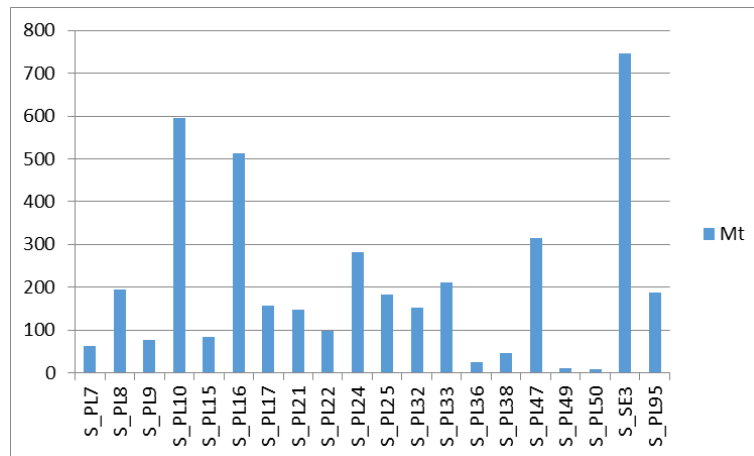


Figure 4.12 Estimated volumetric storage capacities of onshore saline aquifer structures identified in the region.

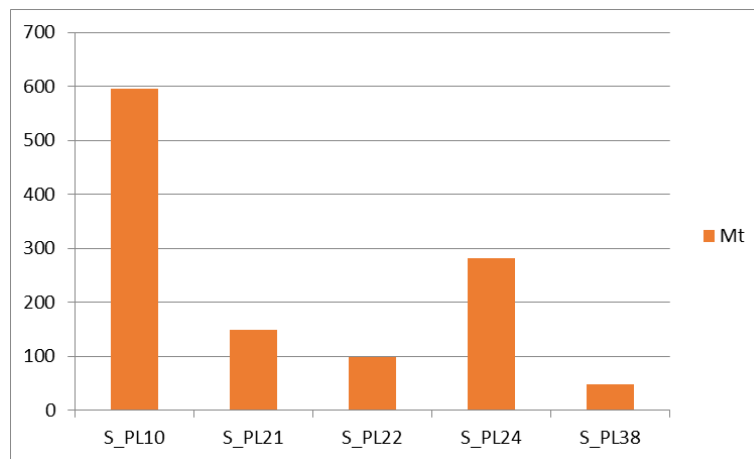


Figure 4.13 Estimated volumetric storage capacities of recommended onshore saline aquifer structures within the region.

Cambrian offshore aquifer in Polish sector has been studied in the Polish national project (Wójcicki et al., 2014) as well, but rather cursory, because of insufficient data availability at that time, hence the aquifer has not been included in Deliverable D1.1 (Ringstad et al. 2023). However, in the frame of D1.2 available publications and reports have been analysed (Paczeńska, 2023) and then area was delineated where sandstone formation (Dębowska fm. of Middle Cambrian – S_PL95) is present (Figure 4.11), corresponding to and being an extension of the best of Swedish aquifers of Dalders Monocline (Faludden fm. of Middle Cambrian – S_SE3; 747 Mt), and its storage capacity calculated (about 188 Mt), assuming a conservative storage efficiency factor (2%), as for a semi-open aquifer of complex geological structure. The obtained storage capacity includes volumetric capacity only, but in such case dissolution capacity might significantly increase the storage potential within decades (IPCC, 2005). The area includes zone where CO₂ storage is allowed presently according to



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regulation of Polish Ministry of Environment (ME, 2014). It should be noted that within the same Middle Cambrian aquifer two depleting hydrocarbon fields are present in structural traps as daughter units (S_PL49 & 50). Additionally, boreholes and seismic data within this offshore area are usually concentrated within and around explored and developed hydrocarbon structures or other explored structures, originally suspected to contain hydrocarbon accumulations.

The offshore Swedish-Polish aquifer (including two depleting hydrocarbon fields within the same reservoir in Polish part) seems to have storage capacity sufficient to store emissions of northern (sub)cluster. It might even serve as a backup option of the emitters in southern (sub)cluster in case onshore storage might be restricted or delayed because of any reasons, but such alternative seems to be costly and unlikely because of distance and possible transport options. It should be also noted CO₂ injected in Polish part will eventually migrate to Swedish part because the aquifer is semi-open and ascending towards NNW, being a part of Dalders monocline (BASTOR2, 2014).

4.3.1.4 The North Poland onshore value chain (selected for WP3)

As mentioned above, the proposed value chain includes southern (sub)cluster (aka Kuyavia-Mazovia) of the region in question as well as a number of adjacent onshore storage sites. According to the D1.1 inventory (emitters exceeding 100 kt/yr) 18 installations of various industry sectors of total emission about 13.6 Mt/yr have been identified there (Table 4-9). If old energy installations, built long before the EU CCS directive was implemented and undergone only some modernisation and of very minor (if any) share of biomass in emissions and energy production, are excluded, the remaining total emission is about 8.2 Mt/yr (Table 4-9). Five onshore Mesozoic saline aquifer structures, or rather three separate and one dual (one within both Lower Jurassic and Lower Cretaceous aquifers at the same location) are recommended (as primary and backup ones) located closely to emitter concentrations (Table 4-10; Figure 4.14;

Table 4-11). Offshore storage option (Middle Cambrian reservoir in Swedish-Polish sector) is not recommended, unless onshore CO₂ storage would be restricted in Poland, but it seems unlikely now.

In

Table 4-11 the selected emitters for the North Poland onshore value chain, storage sites and possible transport options are presented. Regarding the latest, onshore pipelines are preferred. Railway transport (as scheduled in case of mentioned above Lafarge cement plant project) or road transport might be an option in the pilot injection stage but not at industrial stage. River transport along Vistula is generally not recommended because the river is not regulated there, except in the northernmost section in Figure 4.14 (NW/N of Toruń). Some pipeline routes will cross NATURA2000 areas, thus environmental impact studies will have to be approved by relevant local communities, but existing local gas pipelines might to some extent make designing the routes of CO₂ pipelines easier (transport corridors).

The onshore saline aquifer structures located in southern part of the studied region are deemed to be suitable and sufficient as storage sites of the southern (sub)cluster of emitters



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(Kuyavia-Mazovia). Those located close to areas where emitters are concentrated, are considered as recommended storage sites and/or backup sites. Because of likely high storage potential there, the cluster might eventually be expanded and supplemented with other emitters, located nearby. Some onshore saline aquifer structures (e.g., S_PL38, S_PL24) might even serve as a backup option of the northern (sub)cluster of emitters (discussed in the next subchapter) in case offshore storage might be restricted there because of any reasons.

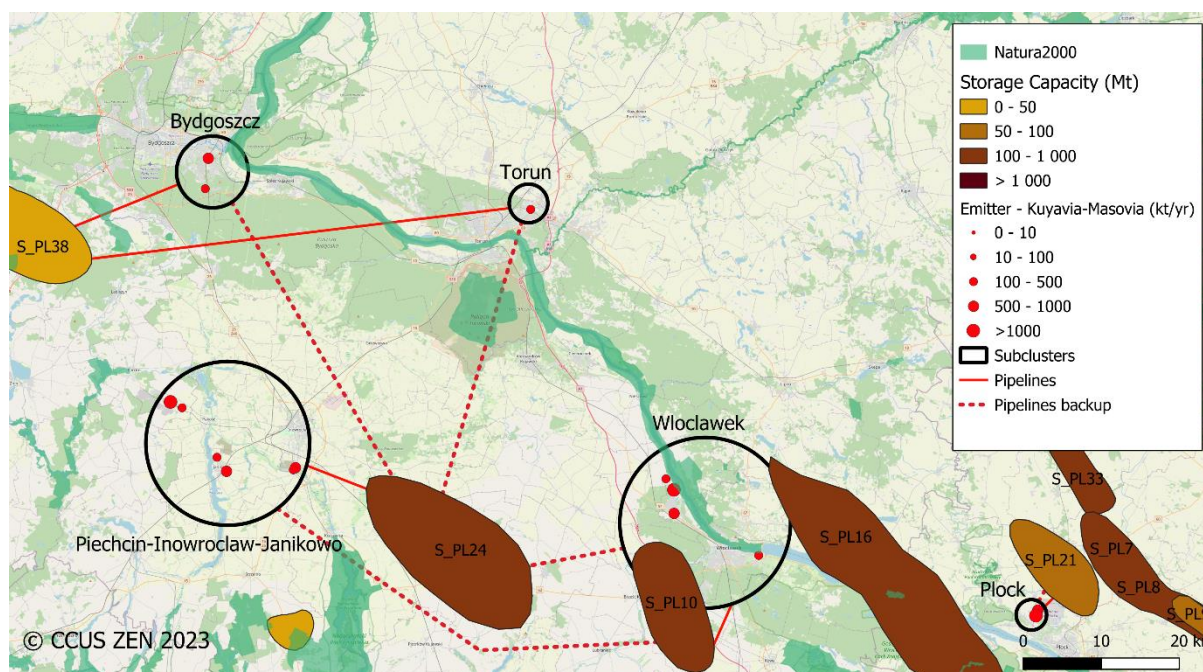


Figure 4.14 The Kuyavia-Mazovia value chain (note – at the same location as storage site S_PL21 there is also S_PL22 – that is a dual structure, listed in Table 4–10). In order to decrease complexity of the value chain it is recommended to assume S_PL24 as storage site for the most of emitter subclusters except easternmost (Plock) where S_PL21(&22) is recommended

Table 4-11 Description of the Kuyavia-Mazovia value chain

EMITTERS (EMISSIONS)	STORAGE SITES (CAPACITIES)	TRANSPORT OPTION (APPR. DISTANCE)	REMARKS
Power – CHP and Energy from waste installation in Bydgoszcz (0.893 Mt/yr)	S_PL38 (47.39 Mt) <i>backup</i> S_PL24 (282.24 Mt)	Pipeline (20 km) <i>backup</i> Pipeline (50 km)	Relatively large CHP plant (hard coal and fuel oil fired) is operating since 1972
Cement, Other – lime, Chemicals – other installations in Piechcin-Bielawy, Piechcin,	S_PL24 (282.24 Mt) <i>backup</i> S_PL10 (595.9 Mt)	Pipeline (15-30 km) <i>backup</i> Pipeline (50-65 km)	Lafarge intends railway transport of some CO2 captured in their cement plant in Piechcin-Bielawy to ship terminal in Gdańsk to



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Inowrocław and Janikowo (3.441 Mt/yr).			store under North Sea, but other storage options will be considered then; industrial CHP plants are quite old (1950-60s) but were modernised in 2010-2012 to reduce S and NOx
Power – CHP plant in Toruń (0.269 Mt/yr)	S_PL38 (47.39 Mt) <i>backup</i> S_PL24 (282.24 Mt)	Pipeline & river (70 km) <i>backup</i> Pipeline (45 km)	Development of transport infrastructure for the needs of one relatively small gas and fuel oil fired energy installation only seems to be questionable
Power – heating, power (oil and gas processing), ammonia and modern power plant in Włocławek (2.047 Mt/yr)	S_PL10 (595.9 Mt) <i>backup</i> S_PL24 (282.24 Mt)	Pipeline (8-15 km) <i>backup</i> Pipeline (25-35 km)	The smallest (barely over 100 kt each) and relatively old energy installations (but gas fired) are unlikely to be equipped with CO ₂ capture systems; Orlen hydrogen hub in development.
Power – CHP, Refineries, Chemicals – other and modern power plants in Płock (6.975 Mt/yr)	S_PL22 (99.22 Mt) <i>backup</i> S_PL21 (148.72 Mt)	Pipeline (5-6 km) <i>backup</i> Pipeline (5-6 km)	Dual structure in saline aquifers – storage either in Lower Cretaceous, or, as backup, in deeper Lower Jurassic in case Lower Cretaceous would appear unsafe after detailed exploration; Petrochemical combine of Orlen, hydrogen hub in development

4.3.1.5 The North Poland offshore value chain

The value chain (Figure 4.15) includes emitters of the northern (sub)cluster (aka Gdańsk Pomerania, but one emitter is actually located in Warmia-Masuria). The primary storage option is the offshore Middle Cambrian Swedish-Polish aquifer/reservoir (including two depleting hydrocarbon fields within the same reservoir in Polish part. Notice that CO₂ for EOR/EHR is not considered as a part of the value chain. The secondary storage option is, as mentioned in previous subchapter, joining the onshore cluster. The total emission of all exceeding 100 kt/yr installations of various industry sectors located there is about 9.06 Mt/yr (6.6 Mt/yr excluding old energy installations of minor, if any, share of biomass in emissions and energy production)(Table 4-9).

Depending on emitters location transport of carbon dioxide captured in these emitters would be with the use of ships departing from the CO₂ terminal in Gdańsk and pipelines, or barges floating Vistula river and/or pipelines and ships (see Table 4-12). Of course, offshore storage infrastructure capable to collect ship cargo shall be constructed first and maintained in such



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case as well as relevant infrastructure of the emitters. It should be noted that at this moment the CO₂CEE project on CO₂ transport hub in the port Gdańsk of is on early stage of development and only transport to North Sea storage infrastructure is scheduled (Bellona, 2023) but other storage options are not ruled out definitely.

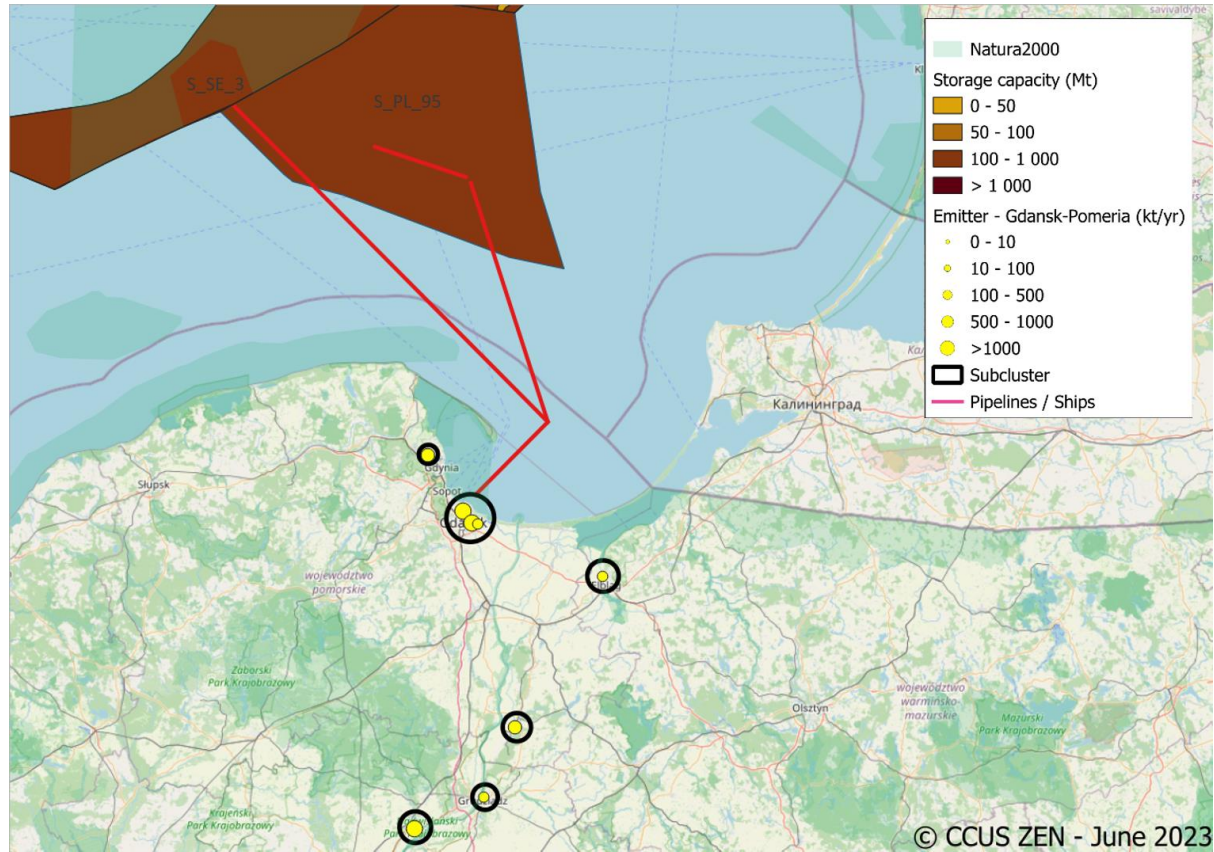


Figure 4.15 The Gdańsk Pomerania value chain.



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Table 4-12 Description of the Gdańsk Pomerania value chain

EMITTERS (EMISSIONS)	STORAGE SITES (CAPACITIES)	TRANSPORT OPTION (APPR. DISTANCE)	REMARKS
Power – CHP installation in Elbląg (0.223 Mt/yr)	S_PL95 & S_SE3 (745+188= 933 Mt)	Onshore pipeline and/or barge to Gdańsk, ship from Gdańsk to the site (~200 km)	The emitter is small but is in process of replacing fossil fuels with biomass completely
Power – CHP plants and refineries in Gdańsk (3.359 Mt/yr).	S_PL95 & S_SE3 (745+188= 933 Mt)	Short onshore pipelines within the city (a couple of km), ship from Gdańsk to the site (~120 km)	There are large emitters but some of them are old energy installations with a small share of biomass co-firing
Power – CHP plant in Gdynia (0.67 Mt/yr)	S_PL95 & S_SE3 (745+188= 933 Mt)	Onshore pipeline to Gdańsk, ship from Gdańsk to the site (~145 km)	Old energy installation with a small share of biomass co-firing
Power – CHP plant in Grudziądz (0.146 Mt/yr)	S_PL95 & S_SE3 (745+188= 933 Mt)	Barges floating Vistula river to Gdańsk, ship from Gdańsk to the site (~220 km)	Old, small energy installation, unlikely to be equipped with CO ₂ capture system
Paper and pulp plant in Kwidzyn (0.687 Mt/yr)	S_PL95 & S_SE3 (745+188= 933 Mt)	Short pipeline (a few km) to Vistula, barges floating Vistula river to Gdańsk, ship from Gdańsk to the site (~195 km)	
Paper and pulp plant in Świecie (3.973 Mt/yr)	S_PL95 & S_SE3 (745+188= 933 Mt)	Barges floating Vistula river to Gdańsk, ship from Gdańsk to the site (~245 km)	Largest biomass-fired installation in Poland (the share of fossil fuels in the facility emissions is negligible there)

4.3.2 North-Western Poland

The value chain was not selected for further studies. It includes an area of North-Western Poland (Szczecin Pomerania), where emission sources are located along or close to Oder river, and where there are several onshore Mesozoic saline aquifer structures, along with adjacent area in Germany (several emitters close to Oder river) as well as adjacent offshore area where several Mesozoic saline aquifer structures/areas are present in Polish, German and Swedish sectors of Baltic Sea (Figure 4.16).



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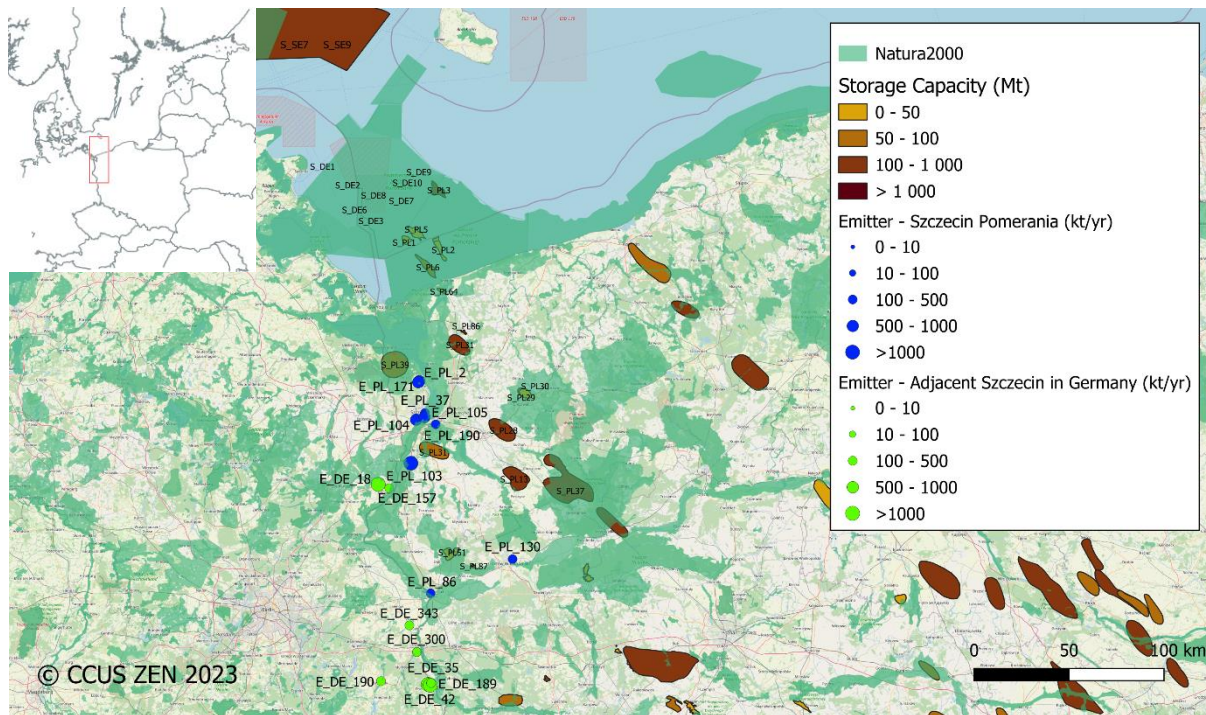


Figure 4.16 The geographical region with features relevant to capture, transport and storage options.

The total emission of Polish installations identified in the region is about 5.8 Mt/yr and in Germany 8.7 Mt/yr (Table 4-13, after D1.1). Within the value chain both onshore and offshore storage options are possible and a couple of structures might be sufficient to store the entire chain emissions for up to 30 years (Table 4-14, after PGI and GEUS in D1.1). Depending on emitters location transport by ship, pipeline, Oder river or a combination of thereof might be possible.



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Table 4-13 The emission sources in the region

CLUSTER NAME	EMITTER_ID	FACILITY_NAME	COMPANY_NAME	CITY	INDUSTRY_SECTOR	CO2_REPORTED	EMISSION_TREND	BIOMASS CO2	WtE CO2 f+b	REMARKS
Szczecin Pomerania cluster	E_PL_130	Oddział Elektrociepłownia Gorzów	PGE Energia Ciepła S.A.	Gorzów_Wlkp	Power - CHP	436336	Periodic	0		old coal fired boilers replaced with gas fired one (now only natural gas is used as fuel; previously it was gas & coal mix)
Szczecin Pomerania cluster	E_PL_86	INSTALACJA PRODUKCJI PAPIERU KOSTRZYN N. ODRA	Arctic Paper Kostrzyn S.A.	Kostrzyn_n/Odra	Paper and pulp	131412	Periodic	0		
Szczecin Pomerania cluster	E_PL_103	PGE GIEK S.A. Oddział Zespół Elektrowni Dolna Odra	PGE Górnictwo i Energetyka Konwencjonalna S.A.	Nowe_Czarnowo	Power	2301558	Falling	32000		several old coal fired blocks were closed, new gas fired blocks are under construction; biomass cofiring; biomass emissions after Endrava
Szczecin Pomerania cluster	E_PL_171	ELEKTROCIEPŁOWNIA EC II	Grupa Azoty Zakłady Chemiczne POLICE S.A.	Police	Power - CHP	631355	Falling	0		
Szczecin Pomerania cluster	E_PL_2	Instalacja do produkcji amoniaku	Grupa Azoty Zakłady Chemiczne POLICE S.A.	Police	Ammonia	824902	Periodic	0		
Szczecin Pomerania cluster	E_PL_104	PGE GIEK S.A. - Elektrownia Pomorzany	PGE Górnictwo i Energetyka Konwencjonalna S.A.	Szczecin	Power	654797	Periodic	0		modernisation, incl. reducing NOx and sulphur emissions



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Deliverable D1.2. Identifying promising CCUS value chains



Szczecin Pomerania cluster	E_PL_105	PGE GIEK S.A. - Elektrownia Szczecin	PGE Górnictwo i Energetyka Konwencjonalna S.A.	Szczecin	Power	500105	Growing	499000		all coal fired blocks have been closed/suspended, large biomass boiler is working; biomass emissions after Endrava
Szczecin Pomerania cluster	E_PL_170	Ciepłownia Rejonowa Dąbska	Szczecińska Energetyka Ciepna Sp. z o.o.	Szczecin	Power - Heating	121761	Falling	0		upgraded several years ago; biomass cofiring
Szczecin Pomerania cluster	E_PL_37	Szczecin ZUO WtE	Zakład Unieszkodliwiania Odpadów Sp. z o.o.	Szczecin	Energy from waste	150000	Stable	0	150000	waste and CO2 stream include components of both biogenic and fossil origin; Endrava provides two reported emission values on this facility - similar or slightly higher than estimated here
adjacent cluster in Germany	E_DE_18	Pck Raffinerie Gmbh Schwedt	Pck Raffinerie Gmbh Schwedt	Schwedt	Refineries	3487000	falling	7000		nn
adjacent cluster in Germany	E_DE_35	Arcelormittal Eisenhüttenstadt Gmbh	Arcelormittal Eisenhüttenstadt Gmbh	Eisenhüttenstadt	Iron & Steel	2039000	growing	0		nn
adjacent cluster in Germany	E_DE_42	Veo Vulkan-Energiewirtschaft - Oderbrücke Gmbh	Veo Vulkan-Energiewirtschaft - Oderbrücke Gmbh	Oderbrücke	Power	1737000	falling	3000		nn
adjacent cluster in Germany	E_DE_157	Leipa Georg Leinfelder Werk Schwedt Süd	Leipa Georg Leinfelder Werk Schwedt Süd	Schwedt	Paper and pulp	429000	growing	351000		nn



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Deliverable D1.2. Identifying promising CCUS value chains



adjacent cluster in Germany	E_DE_189	Progroup Power 1 Gmbh	Progroup Power 1 Gmbh	Eisenhüttenstadt	Energy from waste	333000	falling	332000	nn (<i>organic waste only acc. to Endrava</i>)
adjacent cluster in Germany	E_DE_190	Sonae Arauco Beeskow Gmbh	Sonae Arauco Beeskow Gmbh	Beeskow	Other	333000	falling	318000	Waste and water > Waste management > Hazardous waste incineration
adjacent cluster in Germany	E_DE_300	Stadtwerke Frankfurt (Oder) Gmbh	Stadtwerke Frankfurt (Oder) Gmbh	Frankfurt (Oder)	Power	171000	growing	0	nn
adjacent cluster in Germany	E_DE_343	Gascade Gastransport Gmbh	Gascade Gastransport Gmbh	Lebus	Oil & gas Processing	142000	falling	0	nn



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Table 4-14 Characterization of storage options considered for the region

STORAGE_ID	STORAGE_TYPE	STORAGE_NAME	ON/OFFSHORE	CAPACITY_MEGAN	SRL_LEVEL	SURFACE_ISSUES	REMARKS
S_PL1	Saline aquifer	J_06_POL_H	offshore	47.6	1	within NATURA2000 area	
S_PL2	Saline aquifer	J_14_POL_K	offshore	39.2	1	within NATURA2000 area	
S_PL3	Saline aquifer	J_15_POL_K	offshore	102.2	1	within NATURA2000 area	
S_PL4	Saline aquifer	MBu_19_POL_K	offshore	26.6	1	within NATURA2000 area	small storage capacity
S_PL5	Saline aquifer	MBu_23_POL_K	offshore	36.4	1	within NATURA2000 area	
S_PL6	Saline aquifer	MBu_28_POL_K	offshore	51.8	1	within NATURA2000 area	
S_PL12	Saline aquifer	Chabowo J&T	onshore	98.85	1	small areas covered by NATURA2000	
S_PL13	Saline aquifer	Choszczno	onshore	204.81	2	very small area covered by NATURA2000	modeling in national project (PGI led)
S_PL28	Saline aquifer	Marianowo J&T	onshore	129.46	3	very small areas covered by NATURA2000	3D seismic (considered as strategic gas storage)
S_PL29	Saline aquifer	Oświno J	onshore	22.56	1	within NATURA2000 area	small storage capacity
S_PL30	Saline aquifer	Oświno K	onshore	13.33	1	within NATURA2000 area	small storage capacity



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S_PL31	Saline aquifer	Rokita	onshore	263.74	1	small area covered by NATURA2000	
S_PL37	Saline aquifer	Suliszewo	onshore	508.96	2	covered completely by NATURA2000 and other protected areas	modeling in national project (PGI led)
S_PL39	Saline aquifer	Trzebież	onshore	61.21	1	covered almost completely by NATURA2000 areas	poor 2D seismic coverage
S_PL51	Hydrocarbon field	BMB	onshore	30.02	3	within NATURA2000 area (established after the oil field had been developed)	good well and 3D seismic coverage
S_PL65	Hydrocarbon field	Kamień Pomorski	onshore/offshore	2.82	3	within NATURA2000 area (established after the oil field had been developed)	small storage capacity
S_PL84	Hydrocarbon field	Wysoka Kamieńska	onshore	0.56	3	nn	very small storage capacity
S_DE1	Saline aquifer	J_01_GER_H	offshore	26.6	1	within NATURA2000 area	small storage capacity
S_DE2	Saline aquifer	J_02_GER_H	offshore	46.2	1	within NATURA2000 area	
S_DE3	Saline aquifer	J_03_GER_H	offshore	50.4	1	within NATURA2000 area	
S_DE6	Saline aquifer	MBu_12_GER_H	offshore	53.2	1	within NATURA2000 area	
S_DE7	Saline aquifer	MBu_21_GER_H	offshore	23.8	1	within NATURA2000 area	small storage capacity



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S_DE8	Saline aquifer	MBu_24_GER_H	offshore	28	1	within NATURA2000 area	small storage capacity
S_DE9	Saline aquifer	MBu_25_GER_K	offshore	58.8	1	within NATURA2000 area	
S_DE10	Saline aquifer	MBu_27_GER_K	offshore	64.4	1	within NATURA2000 area	
S_SE9	Saline aquifer	Arnager Greensand Storage Unit	offshore	521	1	nn	open semi-regional aquifer



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4.4 Western Baltic sea: Denmark, Sweden, Germany

4.4.1 Presentation of the geographical region

The selected value chain (Figure 4.17) aims to build a cross-border network for a high CO₂ volume sequestration. The goal of such selection is to create a CCUS system able to capture and store significant quantities of CO₂ to effectively tackle the climate change challenge.

The value chain connects CO₂ emission sources in Germany, Denmark and Sweden to storage sites in Denmark. Clusters of emitters were identified in the following geographic locations, and further analysed in section 4.4.2:

- Sweden
 - Gothenburg Cluster
 - South Sweden (encompassing emitters in areas such as Malmo and Helsingborg)
- Denmark
 - Copenhagen Cluster
 - North-western Zealand Cluster (encompassing the Kalundborg region)
 - Aalborg Cluster
 - Aarhus Cluster
 - Fredericia Cluster
 - Esbjerg Cluster
- Germany
 - Hamburg Cluster
 - Bremen Cluster
 - Hannover Cluster
 - Rostock Cluster

The selected storage sites are located in Denmark and in onshore, nearshore and offshore regions. Considering criteria such as cost-effectiveness, flexibility and convenience, Danish storage sites can be highly regarded especially for Germany, Sweden, Finland and potentially Poland. Although Germany and Sweden have a high CCS potential, Denmark storage sites have higher availability (politically or technically), which make them highly suitable for the most operational business cases.



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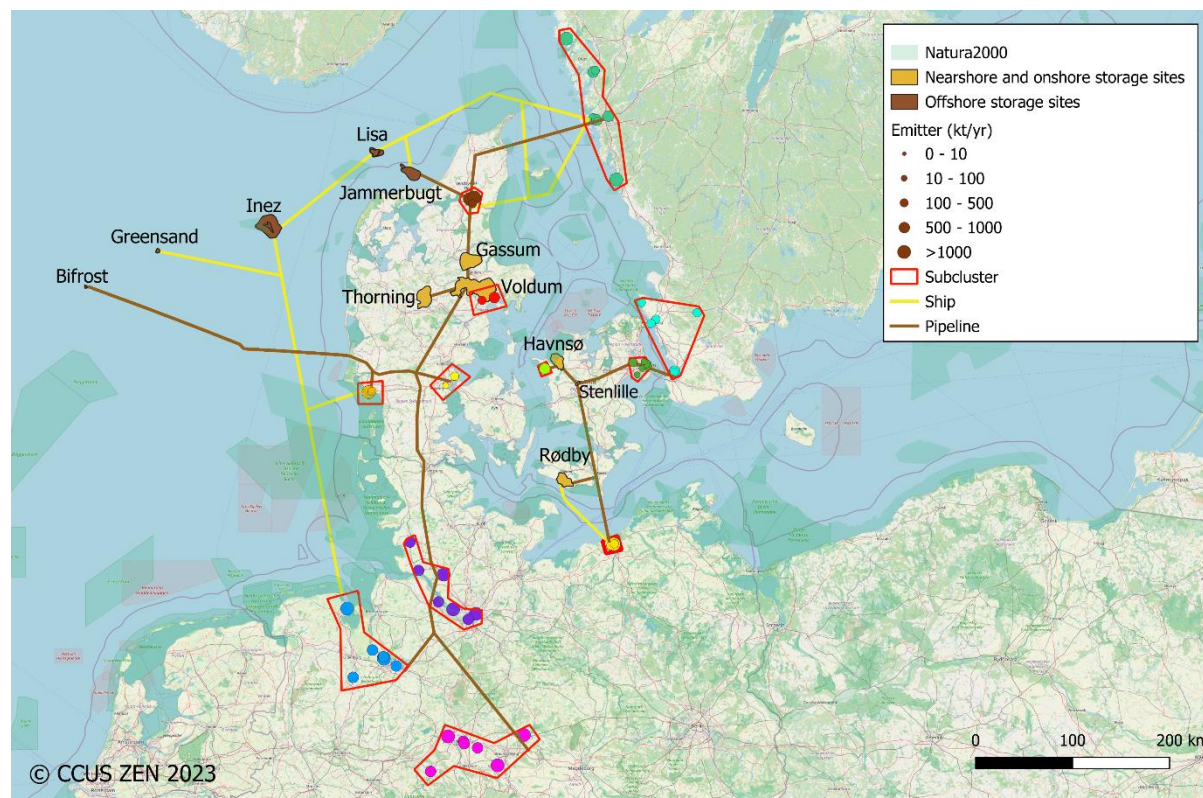


Figure 4.17: Selected value chain for the Western Baltic Sea region. Dots surrounded by red polygons represent emission clusters. Orange and brown forms represent onshore/nearshore and offshore storage sites, respectively. Yellow and brown lines represent shipping and pipeline transportation, respectively.

Sweden expects to achieve carbon neutrality by 2045 and CCS is recognised as a mean to achieve negative emissions, specially through BECCS. 85% of the emissions are envisaged to be cut through emission reduction while the remaining 15% should be covered by additional methods such as CCS. CCS is supported in Sweden by policy measures such as investment and the regulatory framework in development. Swedish perspective over CCS is generally positive, but, as reported in Sweden’s official report on a strategy for negative GHG emissions, storage areas in the country should not be prioritized, but CO₂ export solutions instead. For example, several studies in development focus today on connecting local fossil fuel power generation and industry in the Gothenburg region to a CO₂ export infrastructure to the North Sea storage sites.

Germany is considered one of Europe’s largest emitters and aims to become climate neutral by 2050. Therefore, CCS is considered unavoidable as noted in Germany’s Climate Action programme. A subsidy programme for the raw materials’ industry in Germany to develop CCUS technologies is being prepared. The sector to provide the largest capturable CO₂ volumes is expected to be the power and heat generation, although the iron and steel industry, refineries, chemicals and cement industries can play a substantial role. Germany is not actively pursuing the development of storage sites on national territory, partially due to public scrutiny and opposition to it. Therefore, CO₂ export is considered very likely.



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Denmark aims to become climate neutral by 2050 and CCUS is regarded as a valuable ally for this purpose. There is high political support in Denmark for CCUS projects, including massive investments through subsidies and private initiative as well. Denmark plays an important role for CO₂ storage for the North Sea and Baltic Sea regions. Availability for 12 to 22 billion tonnes of CO₂ storage is advanced by GEUS and Energistyrelsen. This corresponds to 400 to 700 times the Danish annual CO₂ emissions. The combination of offshore, nearshore and onshore storage sites can be paired with multiple CO₂ transportation options, providing flexibility to the full value chain.

4.4.2 Emission sources

Twelve emission clusters were identified in Germany, Denmark and Sweden combined for the selected value chains. As presented in Table 4-15, this totals to 54 emitters and 48.5 million tonnes of CO₂ emissions per year. Per country, German clusters sum 67% of these emissions, while Danish and Swedish clusters sum 17% and 16% respectively. 11% of the total emissions reported in Table 4-15 comes today from biogenic sources.

Table 4-15: Summary of emission clusters

Country	Cluster	Total CO ₂ emissions [ton/yr]	Number of emitters
Germany	Bremen Cluster	9,549,000	7
	Hannover Cluster	14,044,000	7
	Hamburg Cluster	6,163,000	7
	Rostock Cluster	2,515,000	3
Denmark	Copenhagen Cluster	1,360,457	6
	North-western Zealand Cluster	534,000	1
	Fredericia Cluster	439,000	2
	Aarhus Cluster	811,306	2
	Aalborg Cluster	3,808,000	3
	Esbjerg Cluster	1,418,000	2
Sweden	Gothenburg Cluster	6,389,000	8
	South Sweden Cluster	1,495,000	6
Total		48,525,763	54



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Figure 4.18 shows the distribution of CO₂ emissions in the referred clusters per industry sector. The highest contributor to the total emission volumes is the Power industry with 33% of the sum. The Iron & Steel industry also presents a high contribution with 22%.

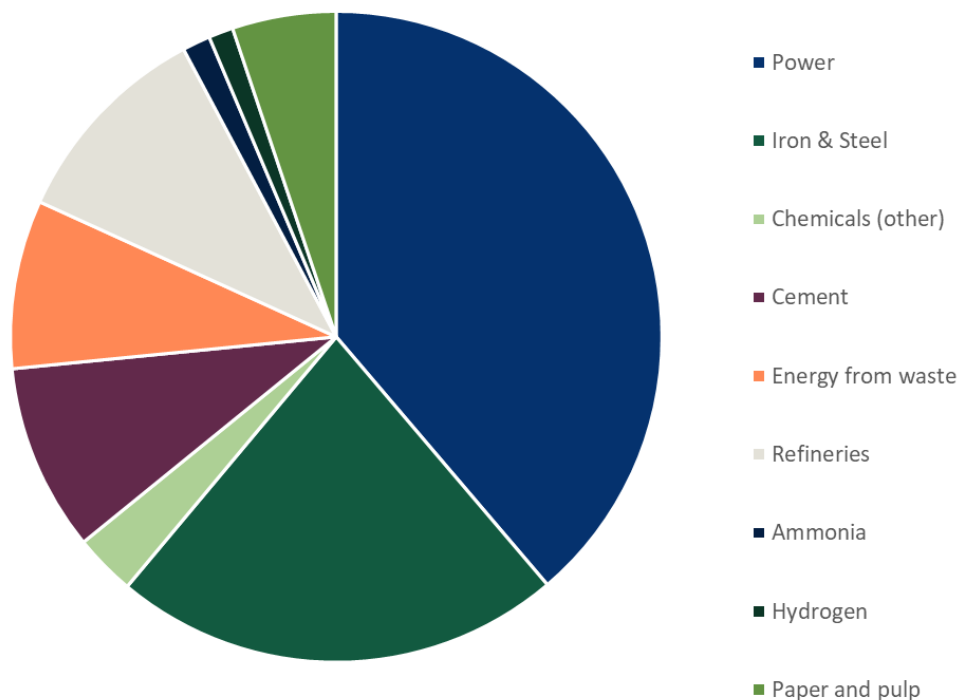


Figure 4.18: Germany, Denmark and Sweden clusters emissions distribution per industry sector

4.4.2.1 Bremen cluster

The selected emitters of the Bremen cluster are presented in



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Table 4-16 and

Figure 4.19. The cluster sums approximately 9.5 million tonnes of CO₂. Its emissions are originated mainly from the Power and Iron & Steel industries. The cluster selection decision is supported not only by its geographical arrangement and the high CO₂ volumes, but also by the fact it is located near a possible CO₂ pipeline connecting Germany to Danish storages which has been studied before and could contribute for the transportation of CO₂ from many emitters in Germany. There is also potential for export in Bremerhaven and Wilhemshaven.



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Table 4-16: Bremen emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ total [t/yr]
E_DE_27	Arcelormittal Bremen Gmbh / Kraftwerk Mittelsbüren / Block 4	Bremen	Power	2,517,000	2,517,000
E_DE_29	Arcelormittal Bremen Gmbh	Bremen	Iron & Steel	2,362,000	2,364,000
E_DE_38	Onyx Kraftwerk Wilhelmshaven Gmbh & Co. Kg	Niedersachsen	Power	1,916,000	1,916,000
E_DE_83	Onyx Kraftwerk Farge Gmbh & Co. Kgaa	Bremen	Power	866,000	866,000
E_DE_102	Empg - Eaa Großenkneten Erdgas-Aufbereitungsanlage	Niedersachsen	Chemicals (other)	715,000	715,000
E_DE_115	Swb Erzeugung Ag & Co. Kg / Heizkraftwerk Hastedt	Bremen	Power	645,000	645,000
E_DE_131	Arcelormittal Bremen Gmbh / Brema Walzwerk Gmbh	Bremen	Iron & Steel	526,000	526,000



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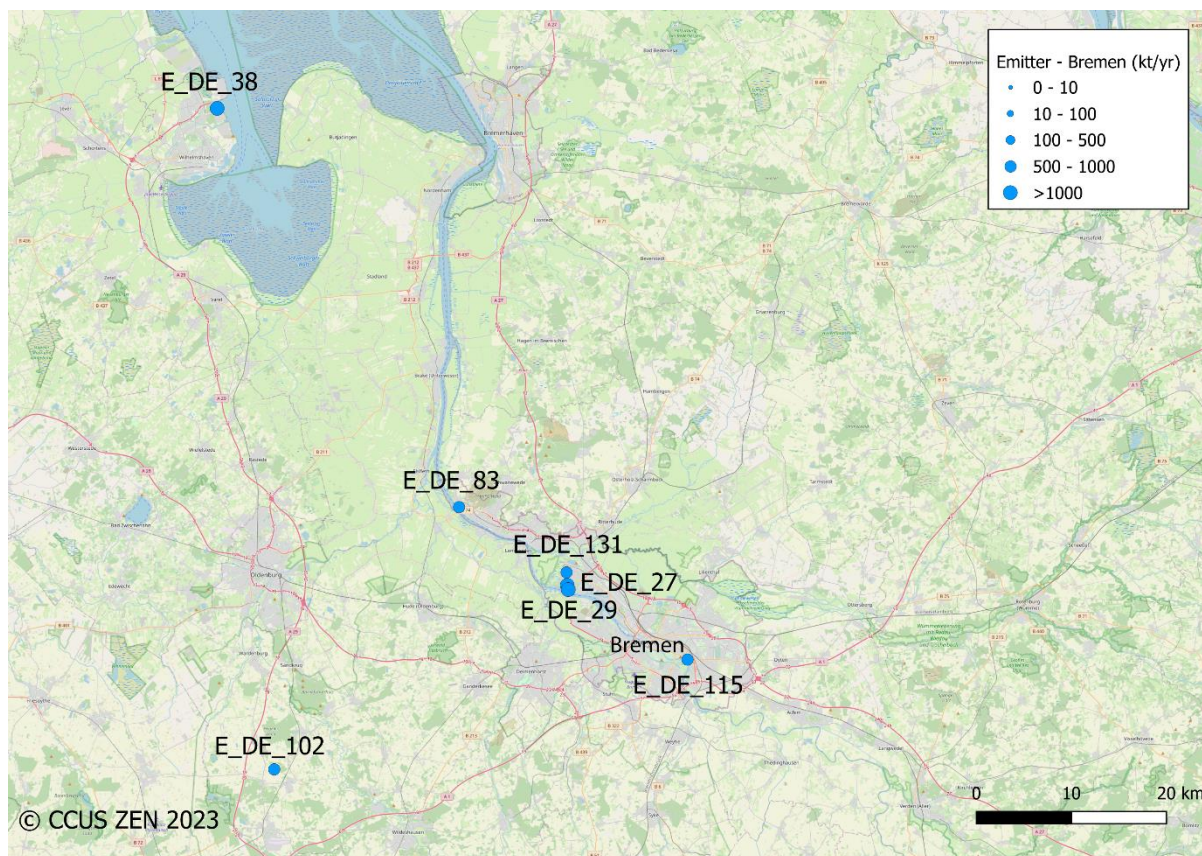


Figure 4.19: Bremen emission cluster.

4.4.2.2 Hannover cluster

The selected emitters of the Hannover cluster are presented in



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Table 4-17 and Figure 4.20. The cluster sums approximately 14 million tonnes of CO₂. Its emissions are originated mainly from the Power and Iron & Steel industries, with a significant contribution of the Cement industry as well. The cluster selection decision is also supported not only by its geographical arrangement and the high CO₂ volumes, but also by the fact it is located near a possible CO₂ pipeline connecting Germany to Danish storages which has been studied before and could contribute for the transportation of CO₂ from many emitters in Germany.



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Table 4-17: Hannover emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DE_8	Salzgitter Flachstahl Gmbh	Niedersachsen	Iron & Steel	7,678,000	7,732,000
S_DE_30	Volkswagen Ag Werk Wolfsburg	Niedersachsen	Power	2,279,000	2,318,000
S_DE_53	Gkh - Gemeinschaftskraftwerk Hannover Gmbh	Niedersachsen	Power	1,354,000	1,354,000
S_DE_82	Kraftwerk Mehrum Gmbh	Niedersachsen	Power	877,000	877,000
S_DE_116	Heidelbergcement Ag Zementwerke Hannover	Niedersachsen	Cement	586,000	638,000
S_DE_124	Holcim (Deutschland) Gmbh Werk Höver	Niedersachsen	Cement	522,000	574,000
S_DE_130	Enertec Hameln Gmbh	Niedersachsen	Energy from waste	185,000	551,000



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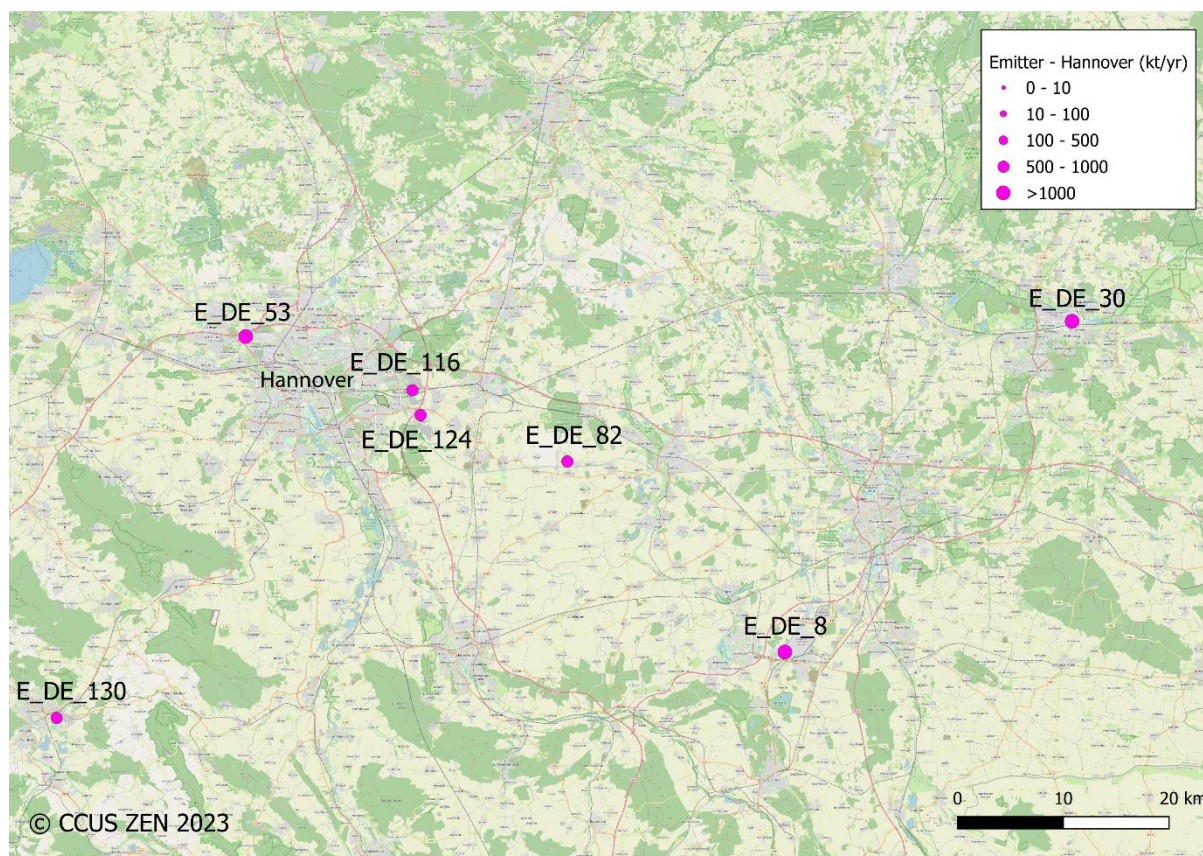


Figure 4.20: Hannover emission cluster

4.4.2.3 Hamburg cluster

The selected emitters of the Hamburg cluster are presented in



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Table 4-18 and Figure 4.21. The cluster sums approximately 6 million tonnes of CO₂. Its emissions are originated mainly from the Power, Cement industries and Refineries. The cluster selection decision is also supported not only by its geographical arrangement and the high CO₂ volumes, but also by the fact it is located near a possible CO₂ pipeline connecting Germany to Danish storages which has been studied before and could contribute for the transportation of CO₂ from many emitters in Germany. Hamburg has also a good potential for ship export and CO₂ utilisation in the region.



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Table 4-18: Hamburg emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DE_62	Wärme Hamburg Gmbh Heizkraftwerk Tiefstack	Hamburg	Power	1,119,000	1,119,000
S_DE_70	Holcim (Deutschland) Gmbh	Schleswig -Holstein	Cement	1,051,000	1,051,000
S_DE_72	Wärme Hamburg Gmbh	Niedersac hsen	Power	1,039,000	1,042,000
S_DE_77	Raffinerie Heide Gmbh	Schleswig -Holstein	Refineries	944,000	944,000
S_DE_98	Holborn Europa Raffinerie Gmbh	Hamburg	Refineries	740,000	740,000
S_DE_107	Yara Brunsbüttel Gmbh	Schleswig -Holstein	Ammonia	676,000	676,000
S_DE_123	Dow Deutschland Anlagenges. Mbh Werk Stade	Niedersac hsen	Hydrogen	516,000	591,000



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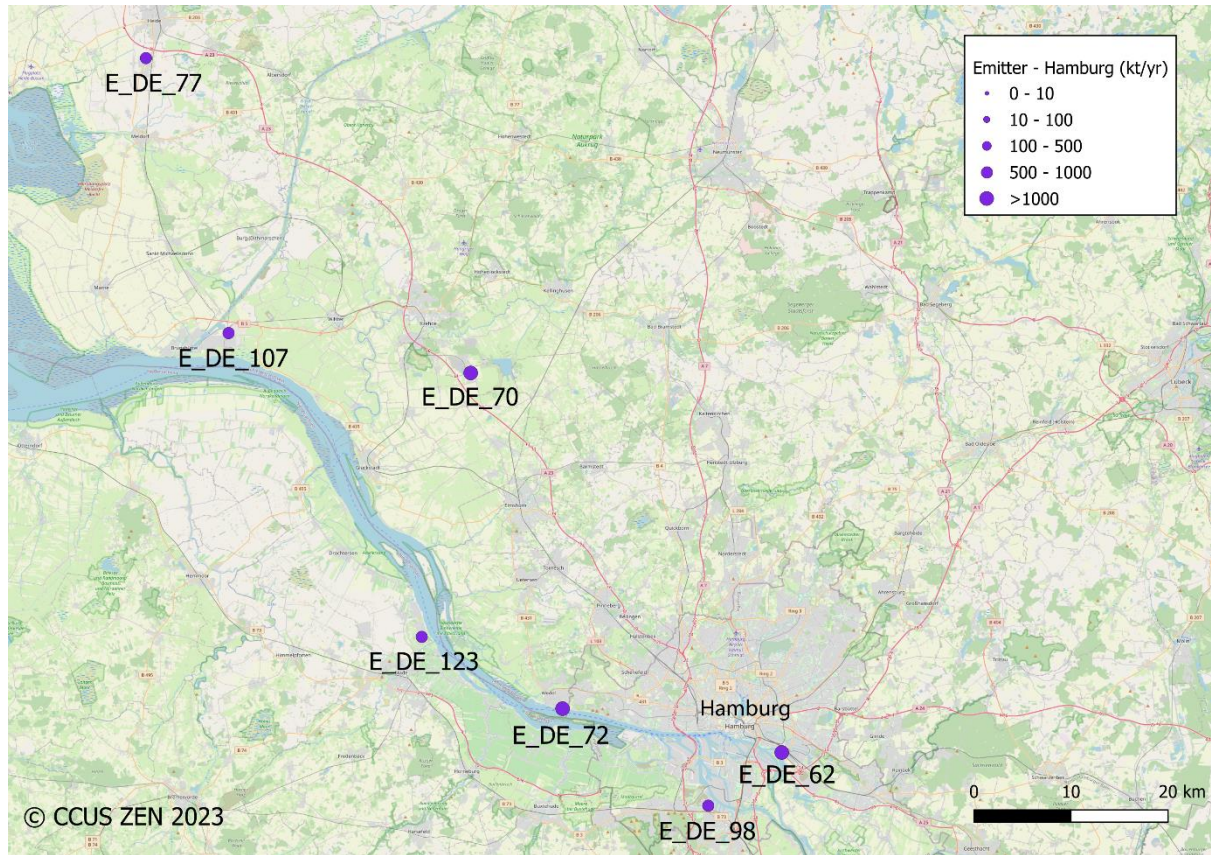


Figure 4.21: Hamburg emission cluster



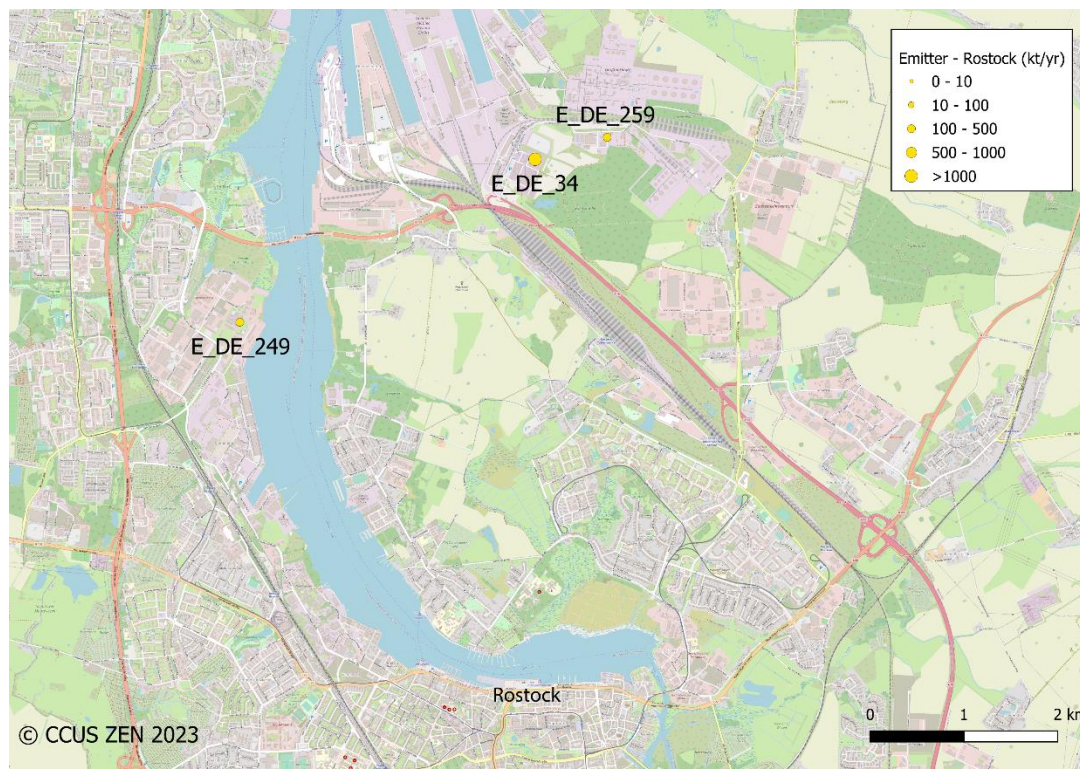
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4.4.2.4 Rostock cluster

The selected emitters of the Rostock cluster are presented in



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Table 4-19 and Figure 4.22. The cluster sums approximately 2.5 million tonnes of CO₂. Its emissions are originated mainly from the Power industry. Besides the geographical arrangement and CO₂ volumes, Rostock may develop to an important CO₂ export region for Eastern Germany and can provide a good connection to promising storage sites in Denmark, such as the Rødby storage site.

Figure 4.22: Rostock emission cluster



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Table 4-19: Rostock emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
E_DE_34	Kng Kraftwerks- Und Netzgesellschaft Mbh Kraftwerk Rostock	Mecklenburg-Vorpommern	Power	2,061,000	2,061,000
E_DE_249	Stadtwerke Rostock Ag	Mecklenburg-Vorpommern	Power	234,000	234,000
E_DE_259	Vattenfall Europe New Energy Ecopower GmbH Betriebsstätte HKW Rostock	Mecklenburg-Vorpommern	Energy from waste	220,000	220,000

4.4.2.5 *Copenhagen cluster*

The selected emitters of the Copenhagen cluster are presented in



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Table 4-20 and Figure 4.23. The cluster sums approximately 1.4 million tonnes of CO₂. Its emissions are originated mainly from the Energy from Waste industry. Although the emission volumes of this cluster are lower than the German or Swedish clusters, its proximity to prominent storage sites justifies its selection. Copenhagen can also serve as an import hub of CO₂ from Sweden or other Baltic countries. Consortiums such as C4 – Carbon Capture Cluster Copenhagen translate a similar application of the Copenhagen cluster analysed.



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Table 4-20: Copenhagen emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
E_DK_5	I/S Amager Ressourcecenter	Hovedstaden	Energy from waste	166,457	615,457
E_DK_8	I/S Vestforbrænding, Glostrup	Hovedstaden	Energy from waste	185,000	474,000
E_DK_32	BIOFOS A/S Renseanlæg Lynetten	Hovedstaden	Energy from waste	102,000	102,000
E_DK_39	Avedøreværket	Hovedstaden	Power	81,000	81,000
E_DK_47	H.C. Ørsted Værket	Hovedstaden	Power	60,000	60,000
E_DK_52	Dong Energy Power A/S - Svanemølleværket	Hovedstaden	Power	28,000	28,000



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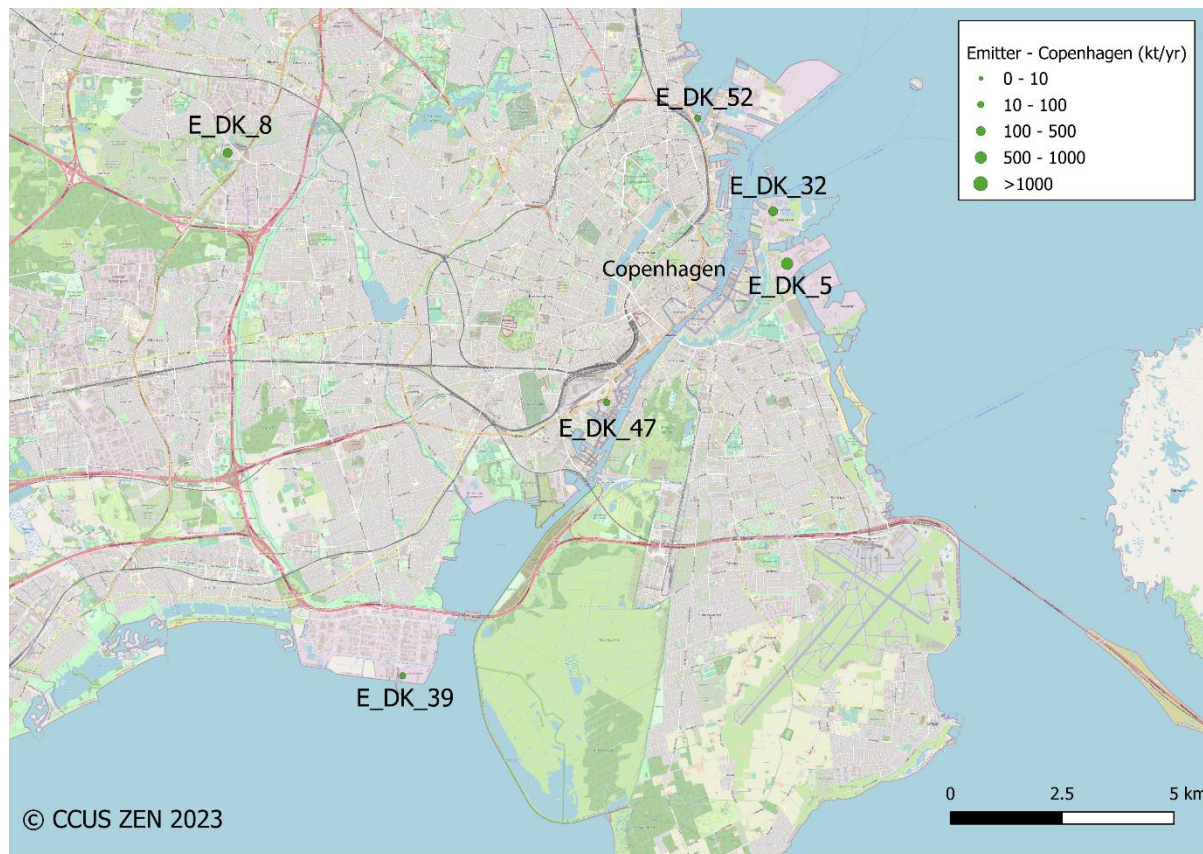


Figure 4.23: Copenhagen emission cluster

4.4.2.6 North-western Zealand cluster

The selected emitter of the North-western Zealand cluster is presented in



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Table 4-21 and Figure 4.24. The cluster sums approximately 0.5 million tonnes of CO₂ per year. Its emissions are originated from a Refinery. Although one emitter only was selected, the region may be used as a CO₂ import hub due to proximity both to shipping areas and to the Havnsø storage site.



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Table 4-21: North-western Zealand emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DK_7	Equinor Refining Denmark A/S	Sjælland	Refineries	534,000	534,000

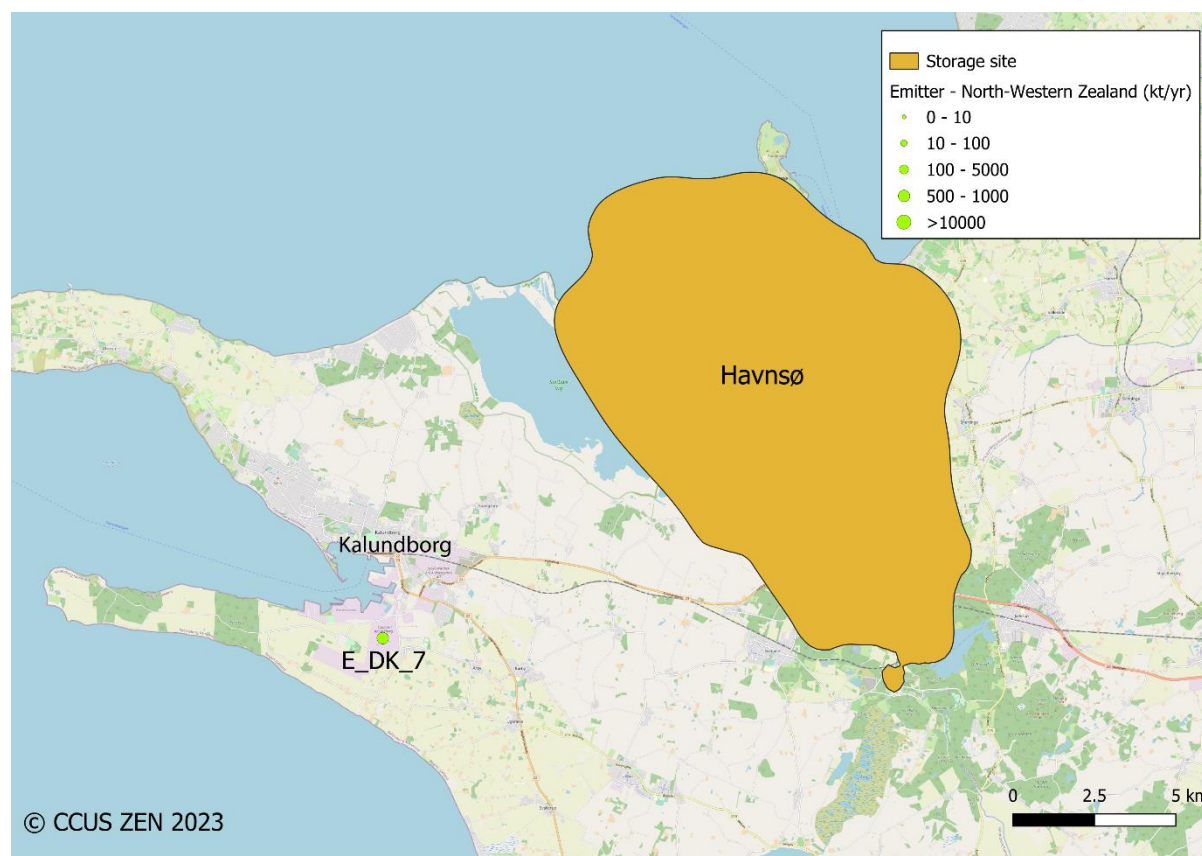


Figure 4.24: North-western Zealand cluster

4.4.2.7 Fredericia cluster

The selected emitters of the Fredericia cluster are presented in Table 4-22 and Figure 4.25. The cluster sums approximately 0.5 million tonnes of CO₂. Its emissions are originated mainly from a Refinery. Although the emission volumes of this cluster are lower than the German, Swedish or other Danish clusters, there is a number of emitters in the area that have highly committed to CCUS possibility and have been developing promising projects. The Fredericia would also benefit from a potential CO₂ pipeline network in Denmark since is an entrance of CO₂ to Jutland from the East. Such a pipeline network has been discussed as a potential driver of an effective CCUS network.



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Table 4-22: Fredericia emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DK_9	A/S Dansk Shell	Syddanmark	Refineries	427,000	427,000
S_DK_54	Ørsted Skærbækværket	Syddanmark	Power	12,000	12,000

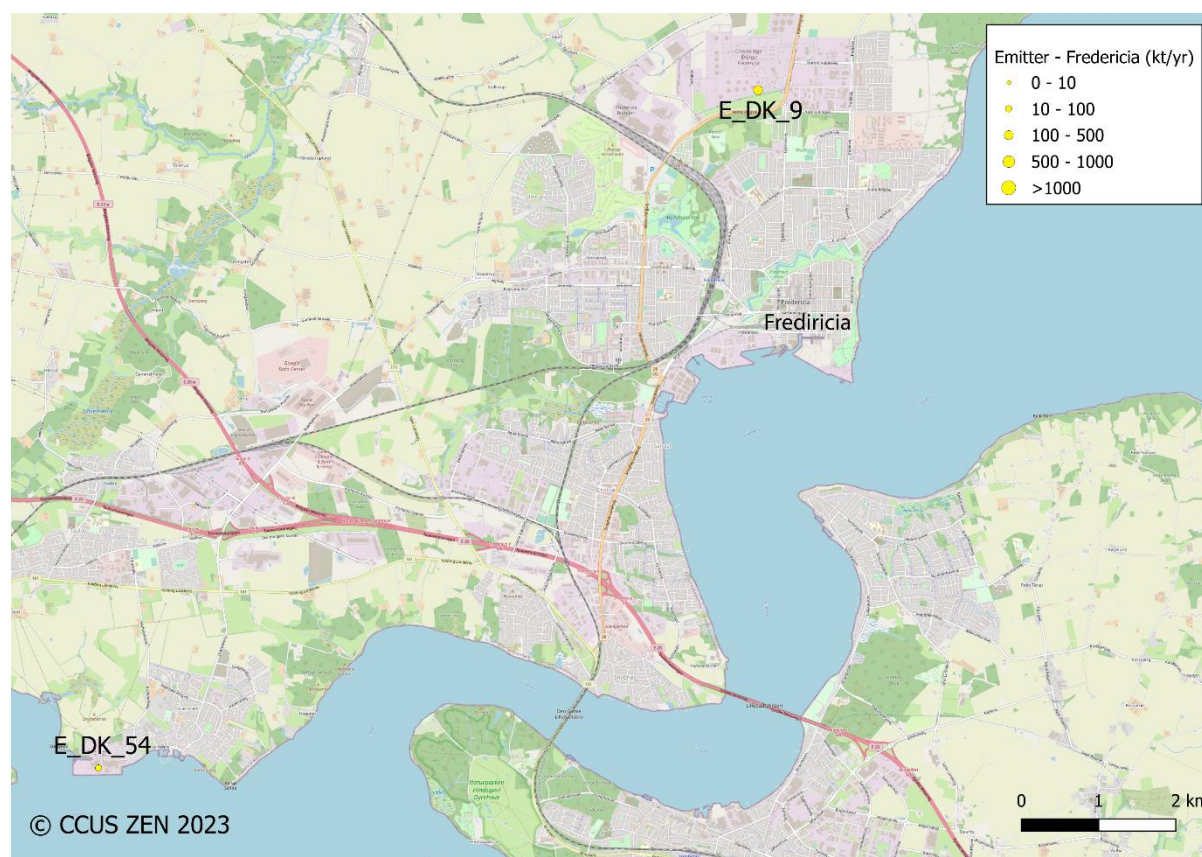


Figure 4.25: Fredericia emission cluster

4.4.2.8 Aarhus cluster

The selected emitters of the Aarhus cluster are presented in Table 4-23 and Figure 4.26. The cluster sums approximately 0.8 million tonnes of CO₂. Its emissions are originated mainly from the Power and Energy from waste industries. Although the emission volumes of this cluster are lower than the German, Swedish or other Danish clusters, there is high proximity to the Voldum storage area, from which the local emitters could benefit.



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Table 4-23: Aarhus emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DK_4	Ørsted Bioenergy & Thermal Power A/S, Studstrupvær	Midtjylland	Power	683,000	684,000
S_DK_22	Affaldscenter Århus, Forbrændingsanlægget	Midtjylland	Energy from waste	127,306	127,306

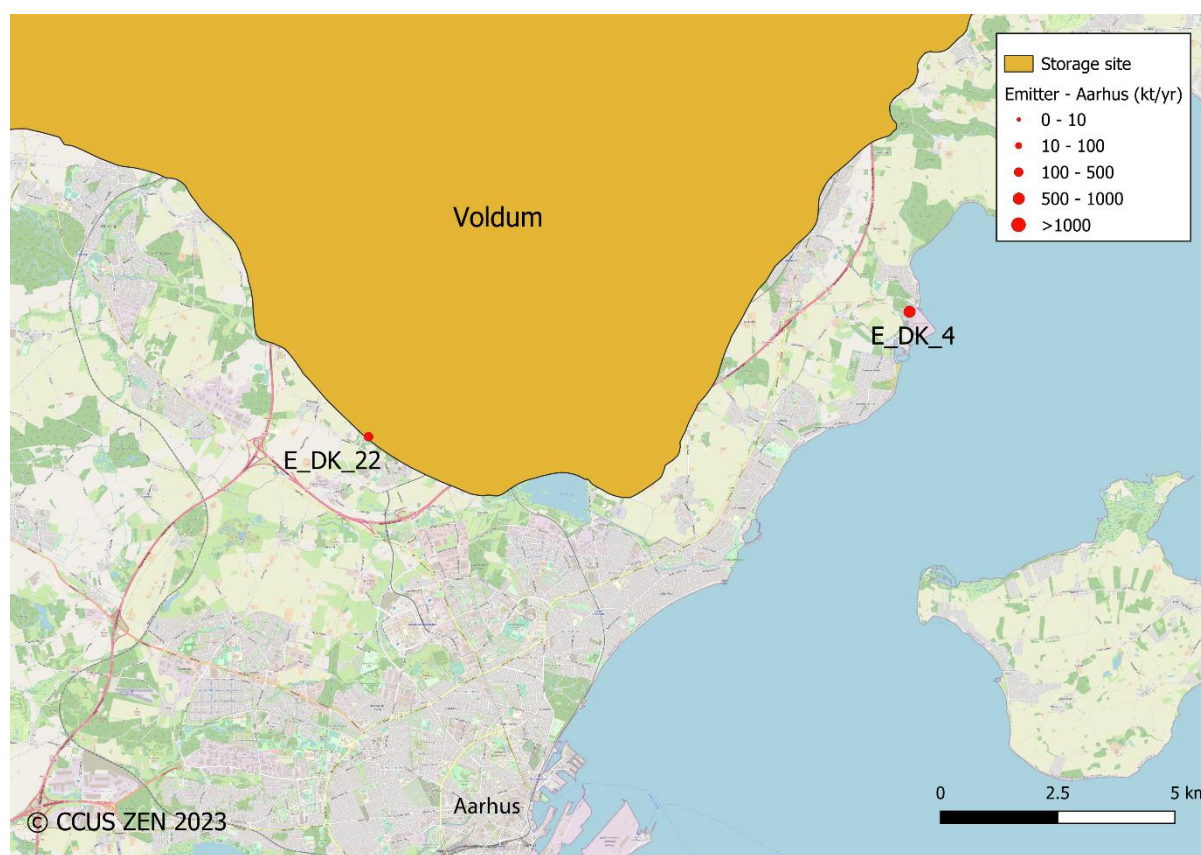


Figure 4.26: Aarhus emission cluster

4.4.2.9 Aalborg cluster

The selected emitters of the Aalborg cluster are presented in Table 4-24 and Figure 4.27. The cluster sums approximately 3.8 million tonnes of CO₂. Its emissions are originated mainly from the Cement and Power industries. Aalborg is envisaged to be a very important import hub in Denmark to receive CO₂ by shipping from different geographies and exporting it by pipeline to the promising CO₂ storage site in Gassum to the south.



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Table 4-24: Aalborg emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DK_1	Aalborg Portland A/S	Nordjylland	Cement	2,248,000	2,248,000
S_DK_2	Nordjyllandsværket	Nordjylland	Power	1,315,000	1,315,000
S_DK_13	I/S Reno-Nord, Energianlægget Aalborg	Nordjylland	Energy from waste	106,000	245,000

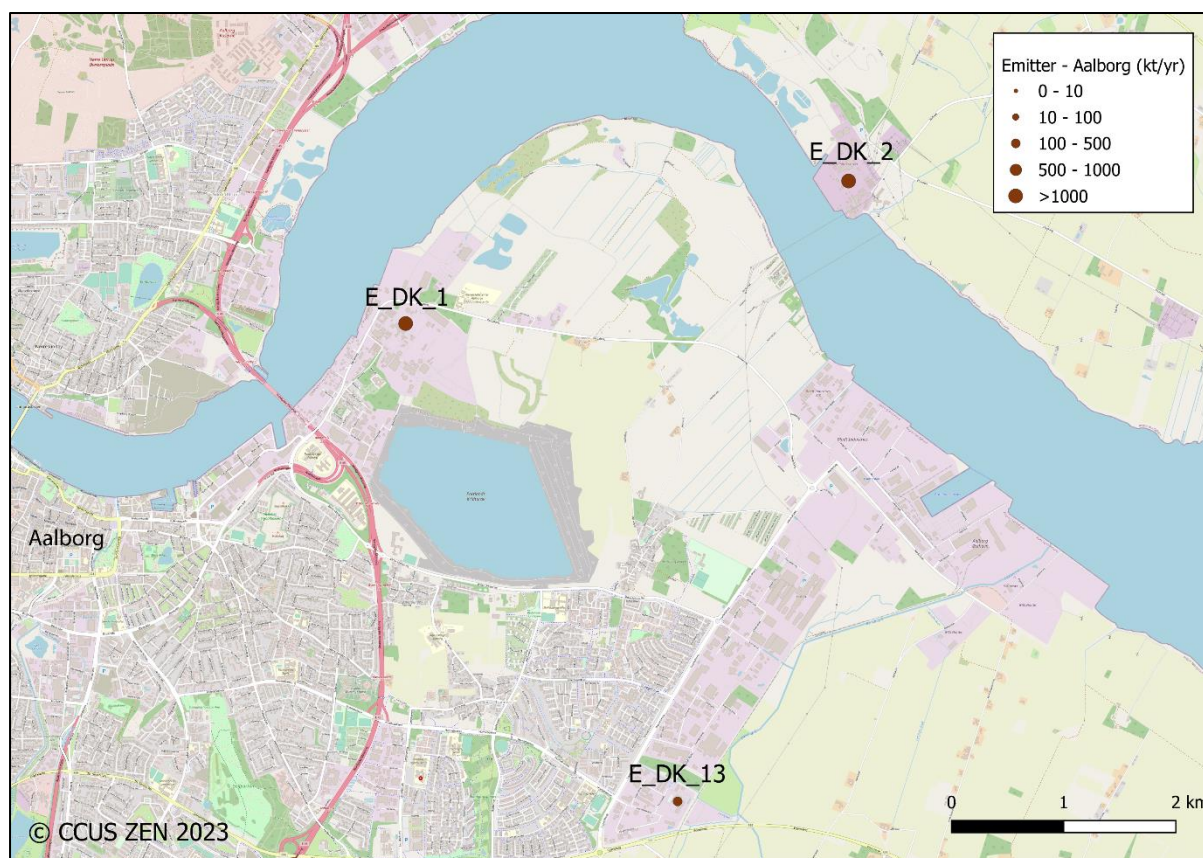


Figure 4.27: Aalborg emission cluster



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4.4.2.10 Esbjerg cluster

The selected emitters of the Esbjerg cluster are presented in Table 4-25 and Figure 4.28. The cluster sums approximately 1.4 million tonnes of CO₂. Its emissions are originated mainly from the Power and Energy from waste industries. Esbjerg is located in the western coast of Jutland and can provide a good connection to promising offshore storage sites in the Danish North Sea. One of them is Bifrost, for which the repurposing of an existing pipeline from Jutland to the storage site may be envisaged. The Esbjerg cluster could benefit from such a transportation opportunity.

Table 4-25: Esbjerg emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_DK_3	Ørsted Bioenergy & Thermal Power A/S, Esbjergværket	Syddanmark	Power	1,185,000	1,185,000
S_DK_14	Energist Esbjerg	Syddanmark	Energy from waste	109,000	233,000



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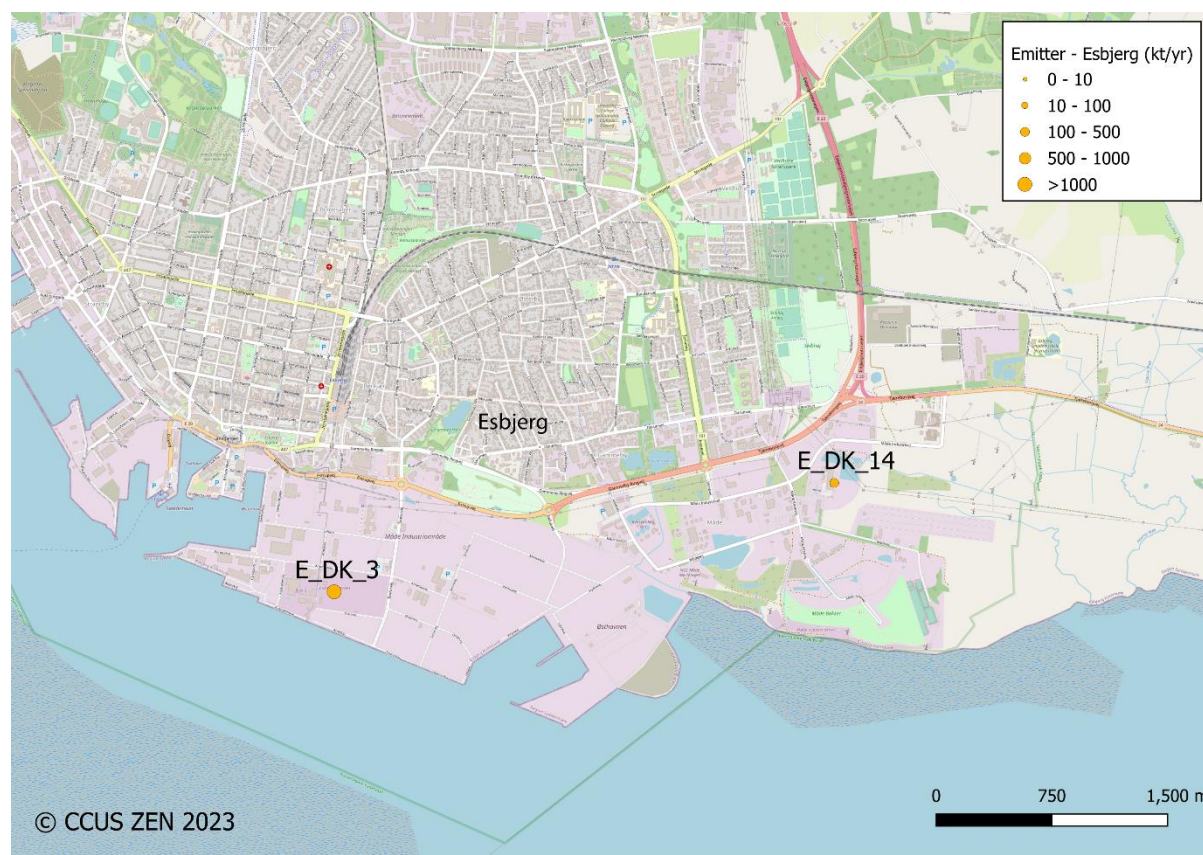


Figure 4.28: Esbjerg emission cluster

4.4.2.11 Gothenburg cluster

The selected emitters of the Gothenburg cluster are presented in Table 4-26 and Figure 4.29. The cluster sums approximately 6.4 million tonnes of CO₂. Its emissions are originated mainly from the Refineries and the Chemical industry. The cluster selection decision is supported not only by its geographical arrangement and the high CO₂ volumes, but also by the fact that it may provide a good CO₂ export solution from Western Sweden either by ship or a potential pipeline. Projects such as CinfraCap, also located in the same region translate the goal of this cluster selection.



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Table 4-26: Gothenburg emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_SE_3	Södra Cell Värö	Halland	Paper and pulp	10,000	2,500,000
S_SE_9	Preemraff, Lysekil	Västra Götaland	Refineries	1,384,000	1,384,000
S_SE_29	Borealis Krackeranl.	Västra Götaland	Chemicals (other)	635,000	635,000
S_SE_31	Sävenäs	Västra Götaland	Energy from waste	209,000	569,000
S_SE_33	Preem Ab Preemraff Göteborg	Västra Götaland	Refineries	527,000	527,000
S_SE_34	St1 Refinery Ab	Västra Götaland	Refineries	506,000	506,000
S_SE_73	Rya Gaskraftvärmeverk	Västra Götaland	Power	138,000	138,000
S_SE_79	Perstorp Oxo Ab, Stenungsund	Västra Götaland	Chemicals (other)	130,000	130,000



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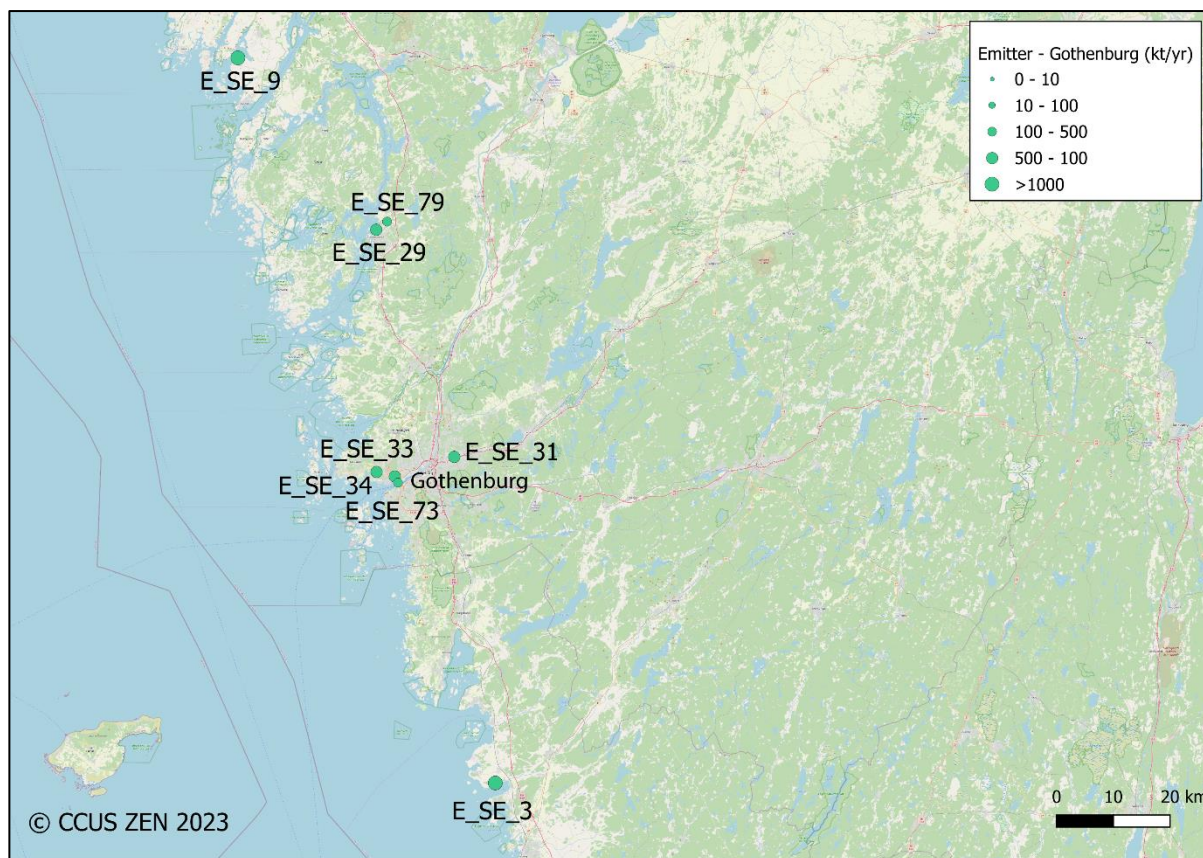


Figure 4.29: Gothenburg emission cluster

4.4.2.12 South Sweden cluster

The selected emitters of the South Sweden cluster are presented in Table 4-27 and Figure 4.30. The cluster sums approximately 1.5 million tonnes of CO₂. Its emissions are originated mainly from the Energy from waste and Power industries. The cluster selection decision is supported not only by its geographical arrangement and the high CO₂ volumes, but also by the fact that it may provide a good CO₂ export solution from Southern Sweden to a potential Copenhagen hub. Projects such as CCSNet, located in the same region translate the goal of this cluster selection.



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Table 4-27: South Sweden emission cluster

Emitter ID	Facility name	Region	Sector	CO ₂ fossil [t/yr]	CO ₂ _total [t/yr]
S_SE_25	Sysavs Avfallsförbränningsanläggning	Skåne	Energy from waste	277,000	691,000
S_SE_50	Filborna Kraftvärmeverk	Skåne	Energy from waste	89,000	236,000
S_SE_57	Höganäs Sweden Ab	Skåne	Iron & Steel	202,000	202,000
S_SE_77	Ångcentralen	Skåne	Power	37,000	134,000
S_SE_81	Västhamnsverket, (Vhv)	Skåne	Power	1,000	125,000
S_SE_90	Öresundsverket, (Övt) - Kraftvärme	Skåne	Power	107,000	107,000

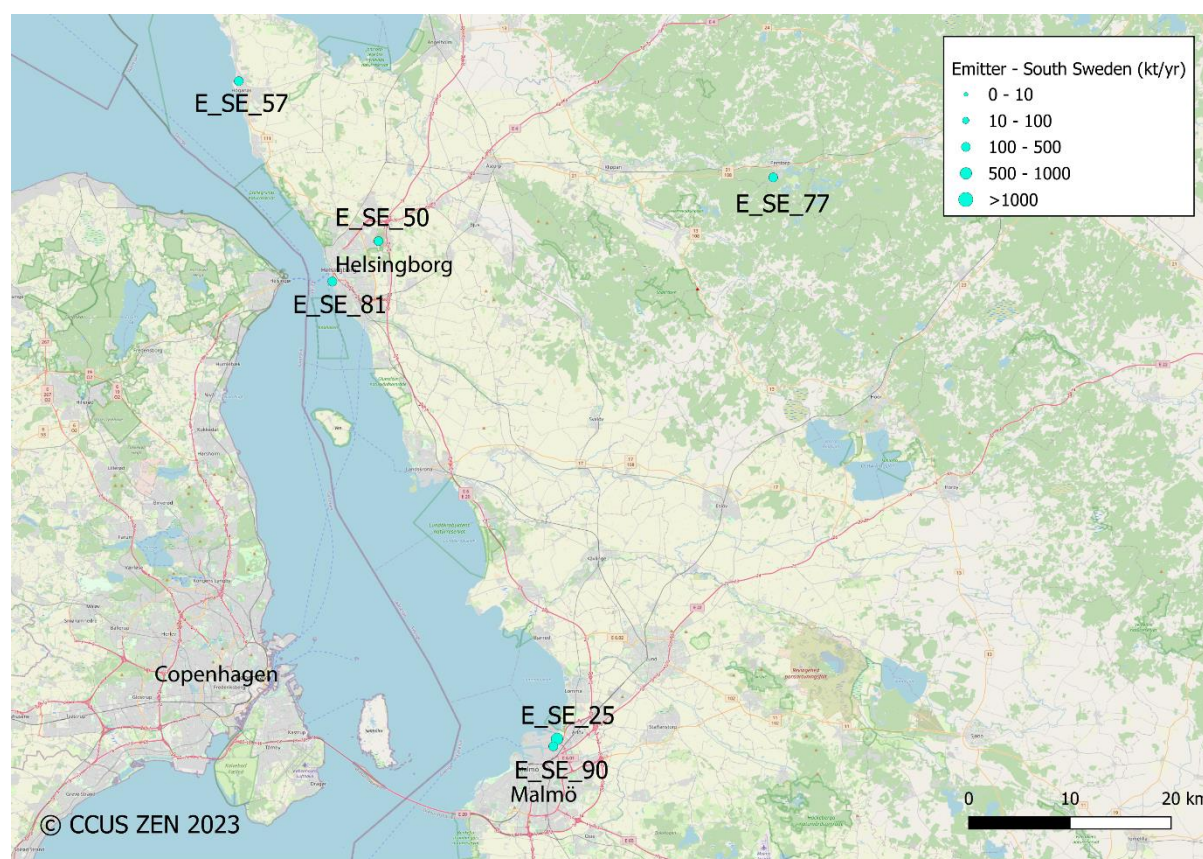


Figure 4.30: South Sweden emission cluster



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4.4.3 Storage potential

The most prominent storage sites mapped for CO₂ injection are located in Denmark. These include onshore, nearshore and offshore structures. As previously mentioned, availability for 12 to 22 billion tonnes of CO₂ storage is advanced by GEUS and Energistyrelsen, corresponding to 400 to 700 times the Danish annual CO₂ emissions. Denmark is also internationally recognized for the progress in establishing a legal framework for CO₂ storage and for supporting the repurposing of the depleted oil and gas fields (e.g., Greensand and Bifrost) into permanent shelters for carbon dioxide.







	Project name	Operator	Capacity ¹ (Mtpa)	Committed ² (Mtpa)	Start	Status	Comments	Type
1	 Greensand	INEOS & Wintershall Dea	1.5	Not available	2025	Planned	Ramp up to 8 Mtpa from 2030	
2	 Bifrost	TotalEnergies & Noreco	5.0	Not available	2030	Planned	Original plan from 3 Mtpa by 2026 has been adjusted	
3	 On- & nearshore	Diverse	Not available	Not available	mid 2020's	Developing	First projects could start on 2025	

Figure 4.31: Overview of the main Danish CO₂ storage projects. (1) Expected injection capacity. (2) Secured volume of captured CO₂ from partnerships with emitters. (3) Additional to the 1.5 Mtpa from phase 1. Source: Global CCS Institute, IOG Europe, websites of individual projects and companies, University of Edinburgh, CCUS Hub, and interview with CCS Association.

Figure 4.32 shows the selected storage sites for further analysis. It contains:

- Five offshore storage options
 - Bifrost
 - Greensand
 - Inez
 - Lisa
 - Jammerbugt
- One nearshore storage option
 - Havnsø
- Five onshore storage options
 - Gassum
 - Voldum
 - Thorning
 - Stenlille
 - Rødby



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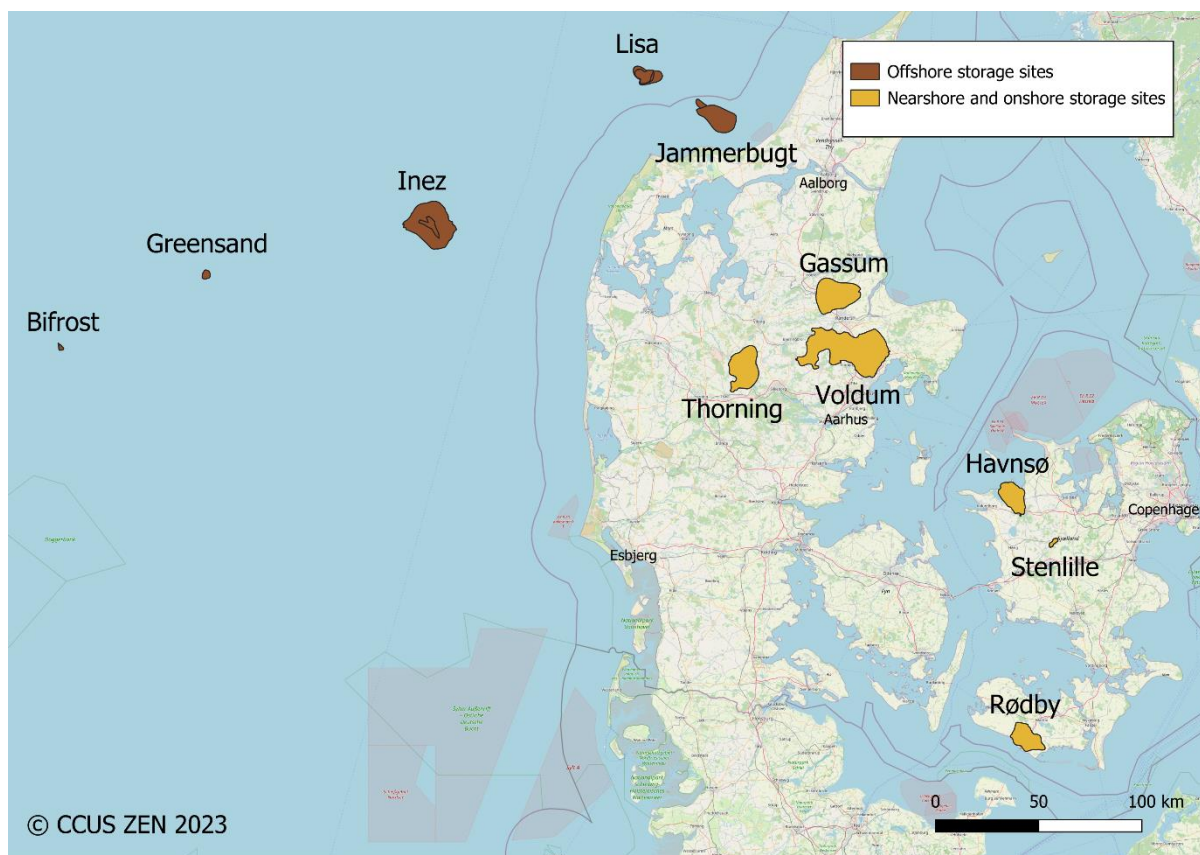


Figure 4.32: Selected storage sites. Offshore storages in brown. Nearshore and onshore storages in orange.

Both Bifrost and Greensand storage sites have already received permits for CO₂ storage and Greensand initiated in 2023 the world’s first cross-border offshore CO₂ pilot injection for climate change mitigation. Greensand expects an injection of 1.5 million tonnes per year by 2025/2026 with an increase up to 8 million tonnes per year by 2030. Its capacity is estimated for 500 years of the Danish current emissions. Bifrost expects an injection rate of 5 million tonnes per year by 2030.

The remaining storage sites are also regarded as promising options and are subject to further evaluations, such as acquisition of new seismic data. The selected fields constitute either saline aquifers or depleted oil and gas structures.

The depleted oil and gas fields operated by private entities and it may be a challenge to acquire specific storage structure data. This should not hinder a project of considering such storages sites due to their maturation and readiness.

Hjelm et al (2020) provide reported data on most of the selected storage sites in this section which is reproduced in Table 4-28. Storage capacity estimations are not publicly available for the offshore units yet. Greensand and Bifrost are assumed to have a very high capacity (up



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to 500 years of today's Danish emissions in Greensand as mentioned). For the remaining offshore sites, further estimations are expected to be publicised along with the current investigations performed. For the onshore storage sites, the capacity mean estimation and storage readiness level is presented in Table 4-29.

Table 4-28: Selected storage sites data, from Hjelm et al. (2020).

Structure	Area		Gross Thickness (m)		Net/Gross		Porosity		CO ₂ density (kg/m ³)		Depth (m)	Permeability (mD)	
	Name	min	max	min	max	min	max	min	max	min		max	min
Gassum GF	117	303	100	150	0.27	0.45	0.15	0.30	714	790	-1802	49	1024
Havnsø GF	59	154	140	240	0.35	0.73	0.15	0.25	610	793	-1500	49	461
Rødby BF	69	179	205	307	0.19	0.31	0.17	0.29	630	770	-1300	81	856
Voldum GF	280	728	102	154	0.18	0.50	0.08	0.30	573	701	-1898	3	1024
Thorning GF	105	273	100	150	0.27	0.50	0.08	0.21	584	646	-1670	3	215

Table 4-29: Storage capacity of selected fields

Storage type	Storage name	On/offshore	Capacity mean (million tonnes)		Storage Readiness Level
			P90	P10	
Deep Saline Aquifer	Gassum	Onshore	412	777	3.1
Deep Saline Aquifer	Havnsø	Nearshore	204	423	4.2
Deep Saline Aquifer	Rødby	Onshore	242	449	3.1
Deep Saline Aquifer	Thorning	Offshore	202	397	3.1
Deep Saline Aquifer	Voldum	Onshore	531	1224	3.1
Deep Saline Aquifer	Stenlille	Onshore	10 (mean)		4



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Due to geographic proximity, some of the storage sites can form storage clusters, which may bring logistical advantages to the value chain. These include:

- Storage cluster 1: Gassum, Voldum and Thorning
- Storage cluster 2: Havnsø, Stenlille and Rødby

4.4.4 The Denmark/Sweden/Germany Jutland value chain (selected for WP3)

The emission clusters included in this value chain are presented in Table 4-30:

Table 4-30: Summary of emission clusters for the Jutland value chain

Country	Cluster	Total CO ₂ emissions [ton/yr]	Number of emitters
Germany	Bremen Cluster	9,549,000	7
	Hannover Cluster	14,044,000	7
	Hamburg Cluster	6,163,000	7
Denmark	Fredericia Cluster	439,000	2
	Aarhus Cluster	811,306	2
	Aalborg Cluster	3,808,000	3
	Esbjerg Cluster	1,418,000	2
Sweden	Gothenburg Cluster	6,389,000	8
Total		42,621,306	38

The Jutland value chain utilises the selected storages onshore in Jutland and all the selected offshore storages:

- Gassum
- Thorning
- Voldum
- Jammerbugt
- Lisa
- Inez
- Greensand
- Bifrost



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The measurable total capacity at this stage provides a range of 1145 to 2398 million tonnes of CO₂ (Gassum + Thorning + Voldum). Summing with the offshore storage sites, the potential capacity would result in a significantly high availability. Therefore, capacity should not be regarded as a limiting characteristic of the value chain, but the transportation availability.

For CO₂ transportation, the value chain may use a shipping connection and a pipeline network. Due to the higher flexibility of shipping connections over the pipeline network, the transportation can be assumed to start with the most flexible solution initially to be developed to the most efficient if needed.

The shipping lines, in yellow in Figure 4.33 can connect the Bremen cluster to the offshore storage sites (Greensand, Inez, Lisa, Jammerbugt). This is carried out by an import hub in Aalborg, where the CO₂ would be transported to the storage sites, to a Esbjerg hub to be pipelined to Bifrost or to a Gothenburg hub to be later shipped or pipelined to Aalborg. The same shipping routes can be used from the Gothenburg hub to the storage sites or Esbjerg or Aalborg import hubs.

The pipeline infrastructure, represented in brown in Figure 4.33 will be essential to efficiently transport the CO₂ volumes addressed in this value chain. It corresponds to a mixture of existing infrastructure, planned (or envisaged) in multiple studies or newly proposed. The offshore pipeline to the Bifrost storage site, operated by Ørsted, is an existing infrastructure which has been addressed for the transportation of CO₂. It's prolonging to the Fredericia will allow the Fredericia cluster to use this storage option as well.

From Germany, studies have investigated the possibility of a new pipeline connection from Hannover to Denmark. This would gather the CO₂ emitted in the Hannover, Bremen and Hamburg clusters. One alternative is also to repurpose the existing DEUDAN gas pipeline which connects Germany and Denmark by Jutland or taking advantage of its route for a new pipeline for CO₂. The pipeline from Germany can connect to the proposed pipeline between the Fredericia and Esbjerg cluster or continue north to the Gassum, Voldum, Thorning storage sites.

These storage sites can form a storage cluster which could provide logistical opportunities. Therefore, a pipeline connection between these storage fields is also proposed. The Aarhus cluster and the Aalborg cluster can also be connected to this storage cluster by pipeline. A pipeline from Aalborg to Gassum has been subject to studies due to the high prominence of the Gassum storage site and the possibility of an import hub in Aalborg.

The Aalborg hub may also receive the emissions from the Gothenburg hub through pipeline. It can either send the CO₂ south to the storage cluster, or to the Jammerbugt storage site.

The proposed value chain is able to effectively tackle the climate change mitigation task due to the high CO₂ volumes sequestered and promote a cross-border cooperation.



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Table 4-31 Main features of the Jutland value chain

Value chain	Cluster(s)	Annual CO2 emissions (kt/y)	Storage site(s)	On/offshore	Capacity	Distance (km)	Transport scenario A	Transport scenario B
Jutland value chain	Bremen Cluster	9,549,000	Gassum Thorning Voldum Jammerbugt Lisa Inez Greensand Bifrost	Onshore / Offshore	Virtually unlimited	Up to ~750 km	Pipeline	Ship to storage
	Hannover Cluster	14,044,000					Pipeline	Ship to storage
	Hamburg Cluster	6,163,000					Pipeline	Ship to storage
	Fredericia Cluster	439,000					Pipeline	-
	Aarhus Cluster	811,306					Pipeline	-
	Aalborg Cluster	3,808,000					Pipeline	-
	Esbjerg Cluster	1,418,000					Pipeline	Ship to storage
	Gothenburg Cluster	6,389,000					Pipeline	Ship to storage
	TOTAL	42,621,306					-	-

The Germany/Denmark/Sweden cluster shows interesting potential for the energetic strand of CCU applications with projects like Next Gate (fuels and synthetic waxes from CO₂) in Hamburg; or Carbon2Business in Längerdorf and the WestKüste100 cluster at the Heide refinery, both targeting synthetic aviation fuels for the Hamburg airport; or project project AIR near Gothenburg for the production of CO₂-based methanol. Some of those projects are funded by the Innovation Fund for operational start within the next 4-5 years. The Danish part of this value chain also presents interest with the Power-to-X facility in Skive.



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Figure 4.33: Jutland value chain. Dots surrounded by red polygons represent emission clusters. Orange and brown forms represent onshore and offshore storage sites, respectively. Yellow and brown lines represent shipping and pipeline transportation, respectively.



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4.4.5 The Copenhagen hub value chain (selected for WP3)

The emission clusters included in this value chain are presented in Table 4-32.

Table 4-32: Summary of emission clusters for the Copenhagen hub value chain

Country	Cluster	Total CO ₂ emissions [ton/yr]	Number of emitters
Germany	Rostock Cluster	2,515,000	3
Denmark	Copenhagen Cluster	1,360,457	6
	North-western Zealand Cluster	534,000	1
Sweden	South Sweden Cluster	1,495,000	6
Total		5,904,457	16

The Copenhagen hub value chain utilises the selected storages onshore and nearshore in Zealand and Lolland:

- Havnsø
- Stenlille
- Rødby

The total storage capacity varies approximately from 450 to 882 million tonnes of CO₂.

For CO₂ transportation, the value chain envisages a pipeline network connecting the three storage sites potentiating a storage cluster, which would be an advantage from a logistical perspective.

For the Rostock cluster in Germany, the pipeline to the storage cluster may need to be phased with an initial stage of shipping before a pipeline is constructed. Therefore, a shipping line in the value chain, during the initial stage would transport the CO₂ to the Rødby storage site. On a further stage, a pipeline could transport the CO₂ from the Rostock cluster to any of the three storage sites selected.

For the Copenhagen cluster, besides its own emitters, it can serve as an import hub of CO₂ from other geographies. In the value chain, this is translated by a connection from the South Sweden Cluster, by pipeline. The CO₂ would thereafter be pipelined to the storage cluster. This value chain segment has been studied in multiple projects such as the C4 – Carbon Capture Cluster Copenhagen for the storage sites of Stenlille and Havnsø.



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The North-western Zealand cluster, although only one relevant emitter is presented, represents the possibility of an import hub to collect CO₂ from multiple geographies by ship and send it to the Havnsø storage site.

The proposed value chain is a smaller version of the Jutland value chain presented in section 4.4.4. It also promotes cross-border cooperation for three countries and translates potential investment possibilities being studied today by multiple parties.

The Copenhagen cluster shows also interesting potential for the CCU strand with the Lighthouse project of [Green fuels for Denmark](#) receiving IPCEI funding or the [Vordingborg port project](#) for the production of CCU fuels from captured CO₂ and renewable hydrogen.

Table 4-33 Main features of the Copenhagen hub value chain

Value chain	Cluster(s)	Annual CO2 emissions (kt/y)	Storage site(s)	On/off shore	Capacity	Distance (km)	Transport scenario A	Transport scenario B
Copenhagen hub value chain	Rostock Cluster	2,515,000	Stenlille Havnsø Rødby	Onshore	~657	Up to ~115 km	Offshore pipeline	Ship to storage
	Copenhagen Cluster	1,360,457					Pipeline	-
	North-western Zealand Cluster	534,000					Pipeline	-
	South Sweden Cluster	1,495,000					Pipeline	Ship + Pipeline
	TOTAL	5,904,457					-	-



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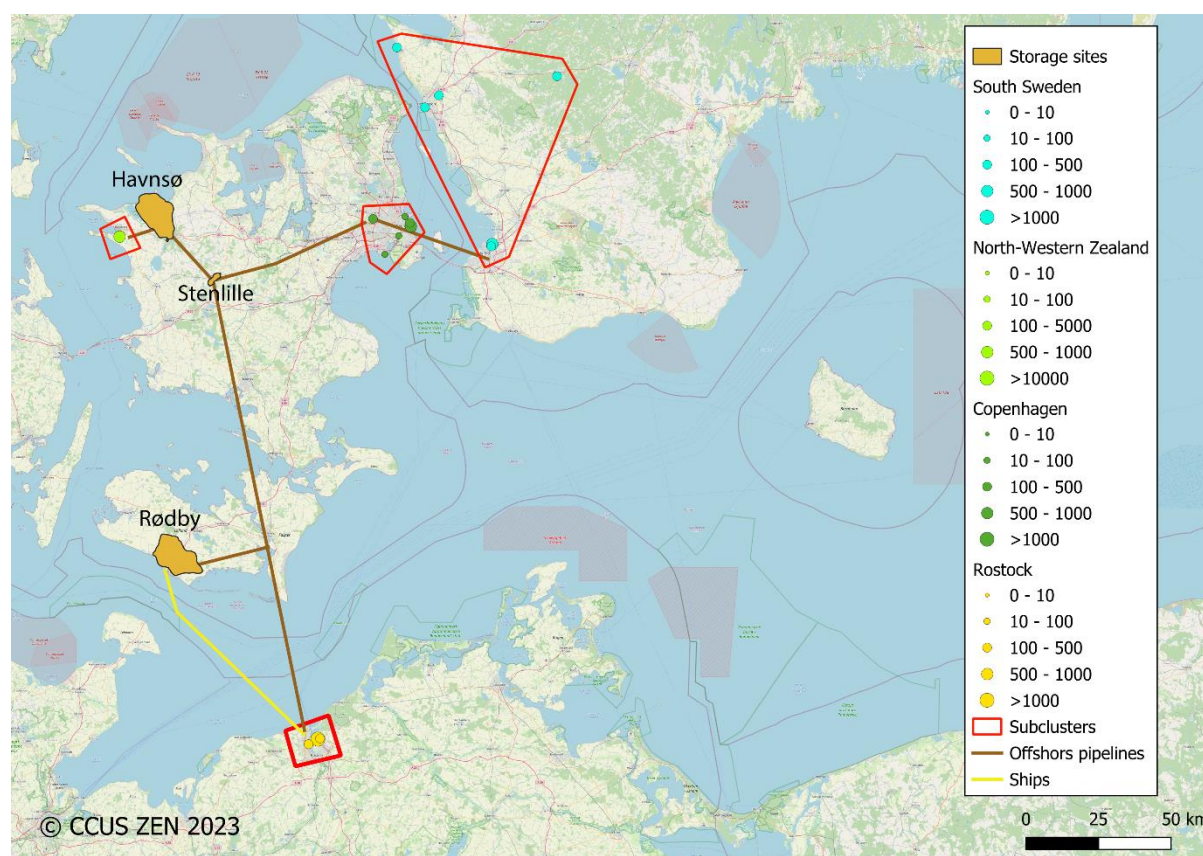


Figure 4.34: Copenhagen hub value chain. Dots surrounded by red polygons represent emission clusters. Orange forms represent onshore/nearshore storage sites. Yellow and brown lines represent shipping and pipeline transportation, respectively.

5 Analysis in the Mediterranean Sea region

5.1 Eastern Mediterranean Sea: Türkiye and Greece

5.1.1 Presentation of the geographical region

The emission sources in Türkiye are mainly concentrated in Marmara region and Aegean region, which include the largest industrial facilities such as thermal power plants, iron and steel factories, cement facilities and refineries (Figure 5.1). On the other hand, storage locations in Türkiye are located mainly Southeastern part of Türkiye, although some fields are available in the Marmara Region. All the storage sites available in Türkiye are hydrocarbon fields and regulations exist just for the usage of CO₂ for enhanced oil recovery. As a result, onshore/offshore storage sites in Greece are included in the value chains. Although there is a considerable volume of emissions in the Marmara Region, the transportation of these emissions requires the ships to pass through the Çanakkale Strait to



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reach to the Aegean Sea. Therefore, a more convenient path from İzmir Aliğa to the basins located in Greece is preferred.

The emission sources in Aegean region are grouped into two clusters, which have the largest emission amount in the whole region. Accordingly, the clusters are named as İzmir Aliğa cluster and Soma cluster based on their geographical locations (Figure 5.1). Figure 5.2 and Figure 5.3 map in detail both clusters.

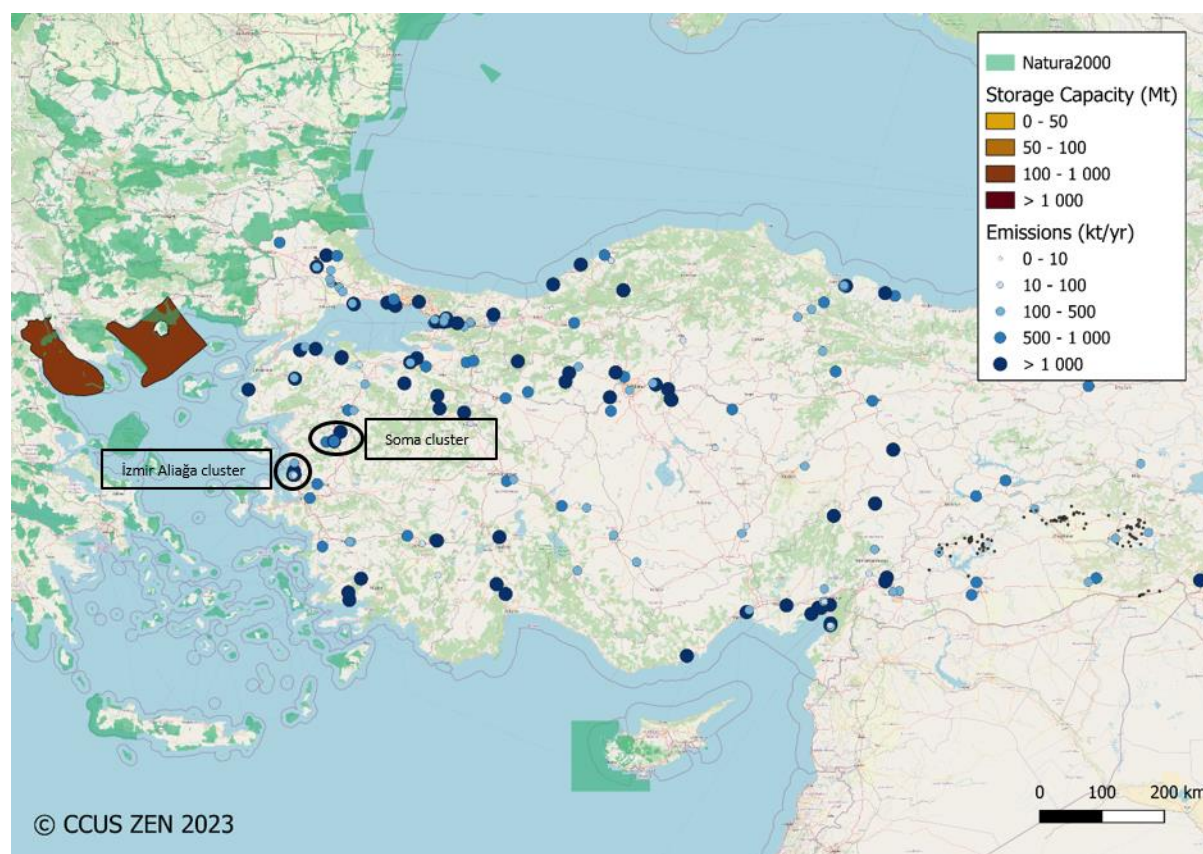


Figure 5.1 Emission sources and storage sites in the Türkiye/Greece region



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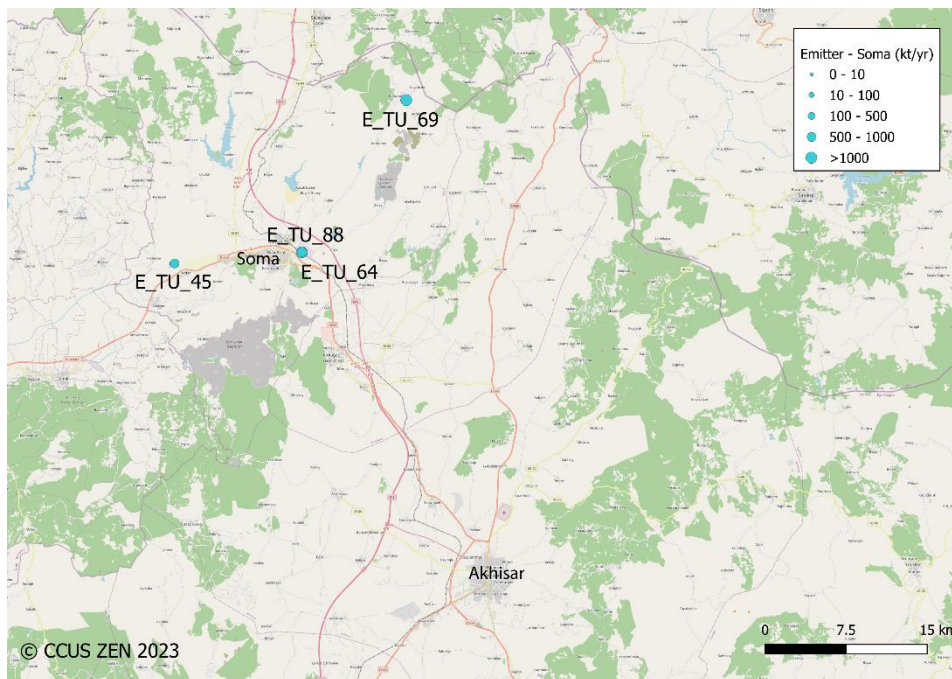


Figure 5.2 Map of Soma cluster - Türkiye

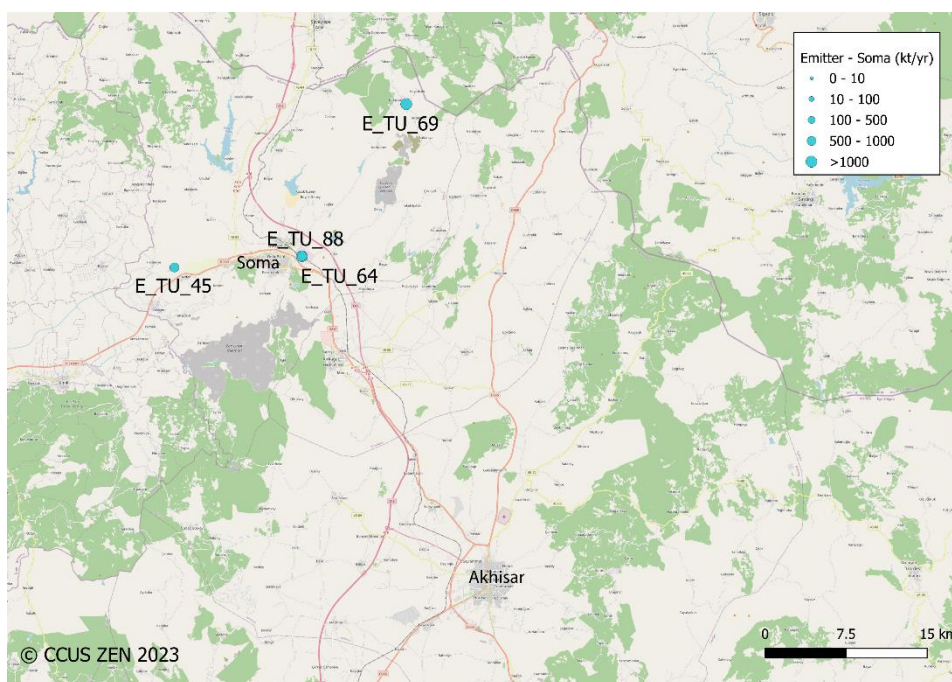


Figure 5.3 Map of the Aliğa cluster - Türkiye

Although Türkiye has recently signed the Paris Agreement, neither ETS mechanism nor any legal requirements exist for reducing the CO₂ emissions. On the other hand, the monitoring



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and reporting of CO₂ emissions by the specified companies stated in the legislations is mandatory. Despite that, companies are eager to reduce their emissions to fulfil the international trade market requirements.

5.1.2 Emission sources

Emitters in Aegean region are tabulated in Table 5-1. As indicated in pie charts (Figure 5.4 and Figure 5.5), the main sector leading to largest CO₂ emissions (tons/years) both in İzmir Aliağa cluster (66 % of total CO₂ emissions) and Soma cluster (96 % of total emissions) is power industry (thermal power plants). Refineries, chemicals, iron & steel facilities constitute the rest of CO₂ emissions (34 % of total emissions) in İzmir Aliağa cluster. On the other hand, a cement facility generates the minor amount of CO₂ emissions (4 % of total emissions) in Soma cluster.

Table 5-1 Emitters in Aegean region

CLUSTER NAME	EMITTER ID	FACILITY NAME	COMPANY NAME	LATITUDE	LONGITUDE	INDUSTRY SECTOR	CO ₂ EMISSIONS (Mton/year)
İzmir Aliağa Cluster	S_TU_75	İzdemir Enerji Aliağa Termik Santrali	İzmir Demir Çelik	38,74241	26,92952	Power	5.32
	S_TU_111	Enka İzmir Doğalgaz Santrali	Enka Elektrik	38,74367	26,95654	Power	4.94
	S_TU_116	Habaş Aliağa Doğalgaz Termik Santrali	Habaş Enerji	38,74097	26,94657	Power	3.39
	S_TU_135	Petkim Petrokimya Termik Santrali	Petkim	38,79085	26,93119	Power	0.72
	S_TU_147	TÜPRAŞ Aliağa Termik Santrali	TÜPRAŞ	38,80544	26,94039	Power	0.30
	S_TU_167	İzmir Rafinerisi	TÜPRAŞ	38,80712	26,94027	Refineries	2.35
	S_TU_169	Star Rafinerisi	SOCAR	38,79801	26,93266	Refineries	2.44
	S_TU_170	PETKİM	SOCAR	38,78988	26.94648 0	Chemicals (other)	1.98



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	S_TU_174	Habaş	Habaş Grup	38,75171	26,95091	Iron & Steel	0.36
	TU_180	Ege Çelik Endüstrisi San ve Tic A.Ş	Ege Çelik	38,73091	26,94103	Iron & Steel	0.16
	S_TU_183	İzmir Demir Çelik Sanayi A.Ş	Şahin-Koç Demir Çelik Sanayi A.Ş	38,73788	26,92666	Iron & Steel	0.11
	TU_188	Özkan Demir Çelik Sanayi A.Ş	Özkan Demir Çelik	38,73756	26,95059	Iron & Steel	0.10
	Total Emissions of İzmir Aliğa Cluster						
Soma Cluster	S_TU_45	Soma Çimento	Soma Çimento Madencilik Beton Sanayi ve Ticaret A.Ş.	39,18223	27,50151	Cement	0.68
	S_TU_64	Soma B Termik Santrali	Soma Çimento Madencilik Beton Sanayi ve Ticaret A.Ş.	39,19143	27,63744	Power	11.05
	S_TU_69	Soma Kolin Termik Santrali	Kolin Enerji	39,31696	27,74877	Power	5.69
	S_TU_88	Soma A Termik Santrali	EÜAŞ	39,19167	27,63779	Power	0.42
	Total Emissions of Soma Cluster						



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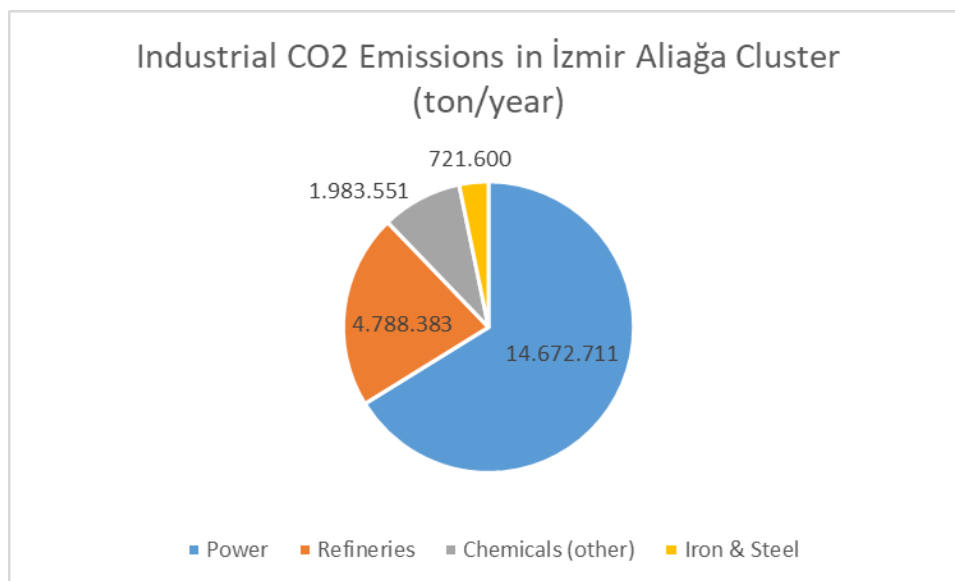


Figure 5.4 Industrial CO2 Emissions in İzmir Aliğa Cluster (ton/year).

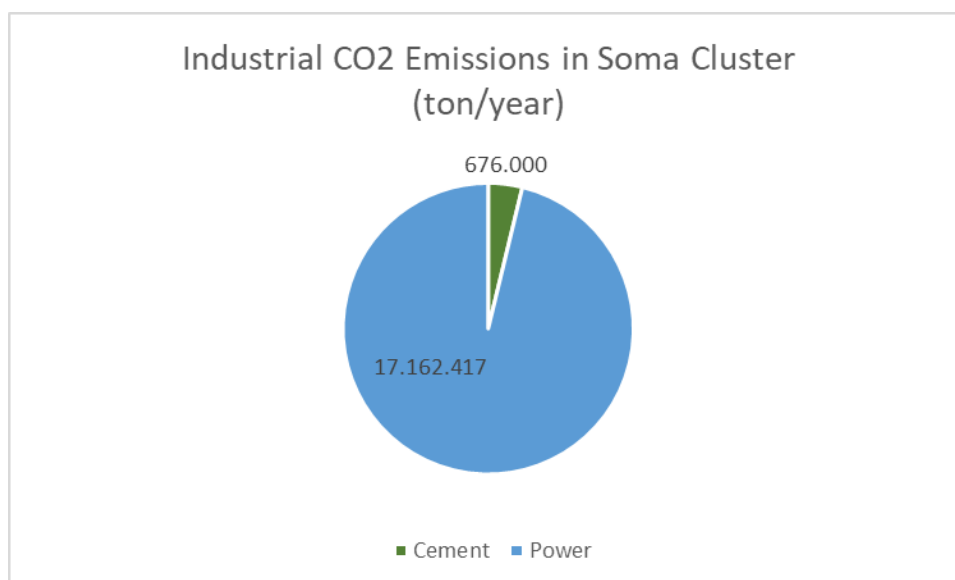


Figure 5.5 Industrial CO2 Emissions in Soma Cluster (ton/year).

5.1.3 Storage potential

In Greece, large saline aquifers have been identified and reported in Geocapacity and CO2STOP projects (Figure 5.6). They show high-capacity values, but the maturity of the capacity estimates is low (Table 5-2). There also exist hydrocarbon fields with low-capacity values. For this project, the offshore Thessaloniki and Prinos sedimentary basins are considered the most prospective sites for storage because of their capacity and location.



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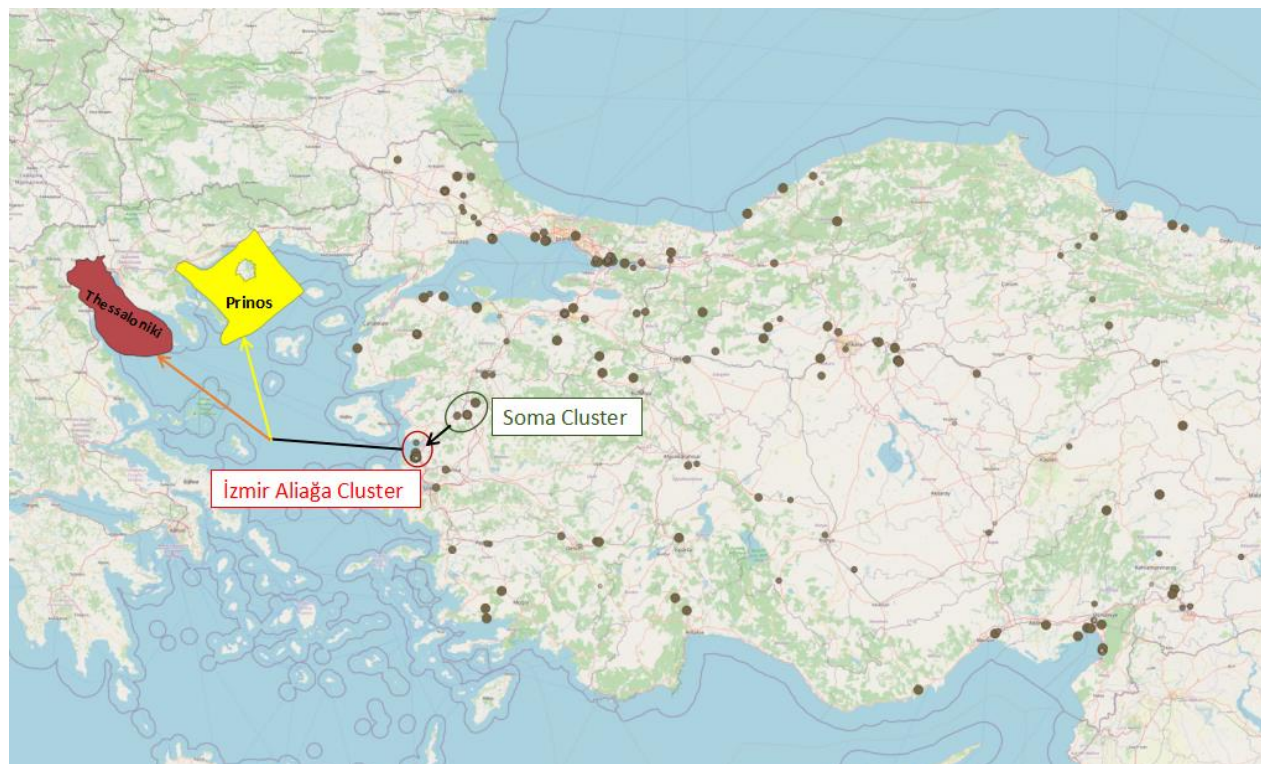


Figure 5.6 Suggested value chains for Eastern Mediterranean Sea

Table 5-2 Storage Capacities in Greece

Storage ID	Name	Type	On/offshore	Capacity mean (Mt)	SRL level	Surface issues
S_GR6	Deep Saline Aquifer (DSA)	Prinos Basin	Offshore	1000	1	nn
S_GR3	Deep Saline Aquifer (DSA)	Thessaloniki	Onshore-offshore	610	1	nn

5.1.4 The Soma - İzmir Aliğa - Prinos value chain (selected for WP3)

Joining the emissions from Soma cluster to İzmir-Aliğa cluster by an approximately 120 km pipeline and then transporting the CO₂ to the Prinos Basin via tankers to inject into the saline aquifers is considered as the most promising value chain. Soma cluster emissions reach to 18 million tons CO₂ per year. Including the İzmir- Aliğa cluster emissions, potential CO₂ volume that can be captured becomes 40 million tons of CO₂ per year. Having a higher storage capacity and closer location (Figure 5.7) to İzmir- Aliğa port, Prinos Basin is selected as the storage medium for the value chain.



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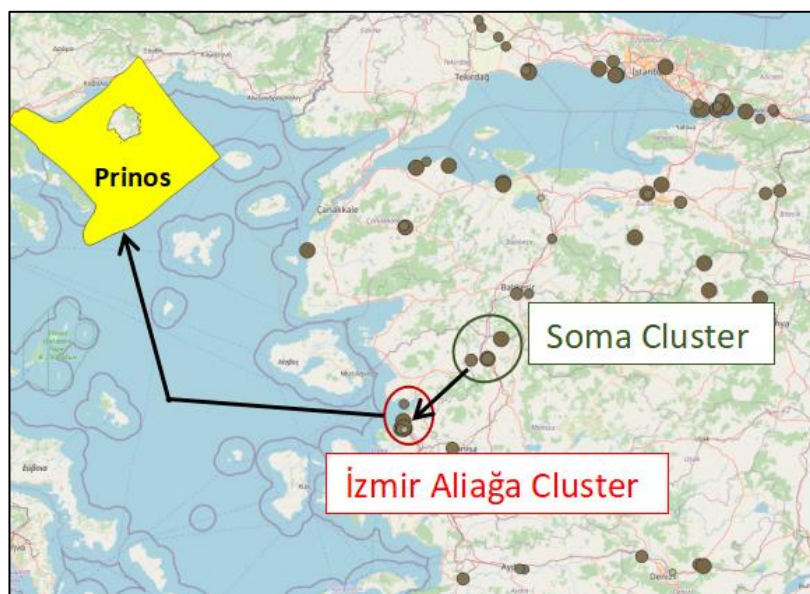


Figure 5.7 Selected value chain for Türkiye-Greece

Some early potential for CCU projects is showcased by CO2Fokus² (production of DME with a demo facility in Izmir) or the COZMOS³ project with mid-TRL production of methanol in Kocaeli. At the eastern part of Greece's mainland, projects like ConsenCUS⁴ (capture and conversion to formic acid in Northern Greece) or Herccules⁵ (mineralisation for the production of binders in central-eastern Greece) showcase also the potential for a variety of CCU applications.

5.1.5 The İzmir Aliğa - Prinos value chain

In case of transportation from Soma cluster to İzmir-Aliğa cluster is found to be inconvenient, the emissions solely from the İzmir- Aliğa cluster (22 million ton CO₂/year) can be stored in the Prinos basin.

5.1.6 The Soma - İzmir Aliğa - Thessaloniki value chain

Thessaloniki Basin, which also constitutes of onshore fields, can be an alternative to the Prinos Basin to store the emissions sourced from both Soma and İzmir- Aliğa clusters.

5.1.7 The İzmir-Aliğa/Thessaloniki value chain

² <https://www.co2fokus.eu/>

³ <https://www.spire2030.eu/cozmos>

⁴ <http://www.consensus.eu/>

⁵ <https://www.herccules.eu/>



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It could be more convenient and practical to transport the emissions from İzmir-Aliğa cluster and to inject into the onshore fields of the Thessaloniki Basin.



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5.2 Italy

5.2.1 Presentation of the geographical region

In the southern part of the Mediterranean region, the CCUZ Zen project will focus on southern part of Italy. A geographical map of Italy is shown in Figure 5.8. The overview map presents the largest emission sources and CO₂ storage sites marked, as mapped in Ringstad et al. (2023). For the potential CO₂ storage sites, only the onshore storage sites are included in the CCUS Zen report. Donda et al. (2011), Civile et al. (2013) and Barison et al. (2023) present potential storage units offshore Italy, including also carbonate storage units that will not be discussed in this report.

Italy has in the National Energy and Climate Plan (NECP, 2019) set national targets to 2030 in line with the 2030 EU Climate and Energy Package, which aim to reduce EU-wide net GHG emissions by 40% from 1990 levels. The European Green Deal and the 2021 European Climate Law raised this target to -55% by 2030 compared to 1990 levels. The EC proposed a legislation package, the so-called “Fit-for-55”, to achieve the new -55% target. Italy will have to update its NECP in 2023 and align it with the enhanced EU targets (Italy 2023 Energy Policy Review, IEA report 2023).

CCS projects and storage sites have been planned and evaluated in Italy for the last decades, however no one has been carried out in full scale till now. The Brindisi CCS Project in southern Italy were evaluated by Enel and ENI using post-combustional technology. However, the project was stopped in 2016⁶.

At present, the first CCS Hub in Italy; the Ravenna Carbon Capture and Storage (CCS) project is planned to start in 2024, in northeast Italy, by Eni and Snam as operators. A joint venture is formed between Eni and Snam, and for phase 1, 25000 tons of CO₂ emitted from Eni’s natural gas treatment plant in Casalbosetti (Ravenna) will be transported by pipeline and stored offshore Ravenna in a depleted gas field. The initial emitter source will be power, but potential sources will be steel, chemicals, ceramics, cement, waste to energy. It will aim to serve as a storage site for the Po Valley area. At present the phase 1 is in construction, and it is planned to be in operations by Q1 2024⁷. The potential impact will be 10 MtCO₂/year by 2030.

Since the Ravenna CCS project is an ongoing project in the northern part of Italy, we have chosen to focus the mapping of possible CCUS value chain in the southern part of Italy. One of the main concerns for CCS in Italy, in addition to economic constraints that will naturally have a large impact on all projects, is the effect of earthquake. We will evaluate this effect on the projects.

⁶ [Carbon Capture and Sequestration Technologies @ MIT](#)

⁷ [Ravenna CCS - The CCUS Hub \(ogci.com\)](#)



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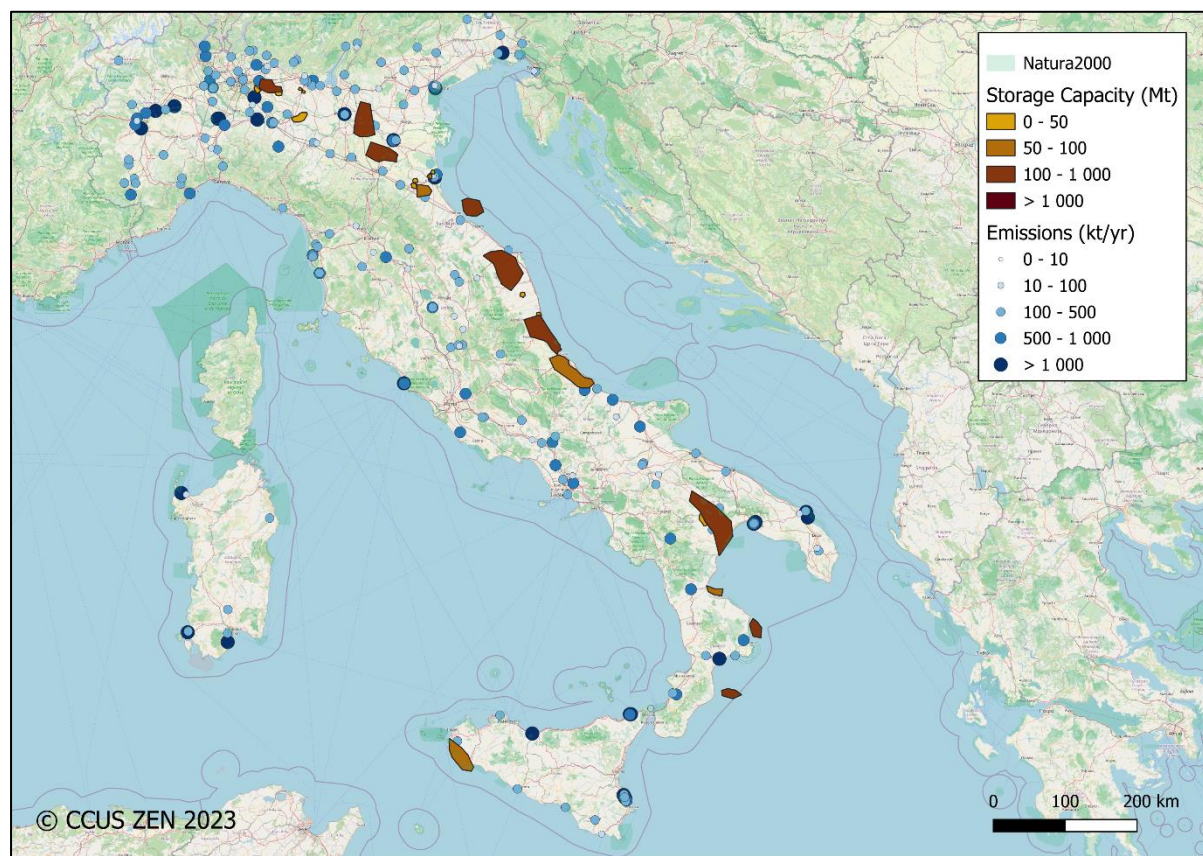


Figure 5.8 Overview map of Italy with CO₂ storage sites and emissions sources marked.

5.2.2 Emission sources

In this report we are evaluating three different emission clusters in the southern part of Italy, since this area is less mature coming to CO₂ hub development. The emission clusters that will be focus on are Taranto, Brindisi and Priolo Garallo emission cluster.

5.2.2.1 Taranto emission cluster

The Taranto cluster situated in southern Italy around the Taranto city (Figure 5.9) could be an emission cluster. Taranto is a coastal city in Apulica, southern Italy with around 200 000 inhabitants, and serve as an important commercial port as the main Italian naval base.

One of the largest steel plants in Europe, is based in Taranto. The ArcelorMittal (Ilva steelworks) is one of the largest point emitters in Italy of CO₂. The numbers listed in this report shows 5.2 MtCO₂/year, while unofficial calculations, including the two thermoelectric power plans (CET2 and CET3), sums up to around 10 Mt/year of CO₂ (based on the the Environmental Declaration verified by EMAS in 2016) (see also The Ilva steelworks is a climate monster (peacelink.it)). Thus, by only including official numbers, there are several emitters in the area e.g. three refineries and one power plant, that also to be part of a CCS hub (see Figure 5.9, Table 5-3). Figure 5.10 shows a pie chart for Taranto cluster, including



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also the two smallest emitters. The Taranto cluster then sum up to 12.4 Mt/year with the main sources from iron & steel plan, power, and refineries.

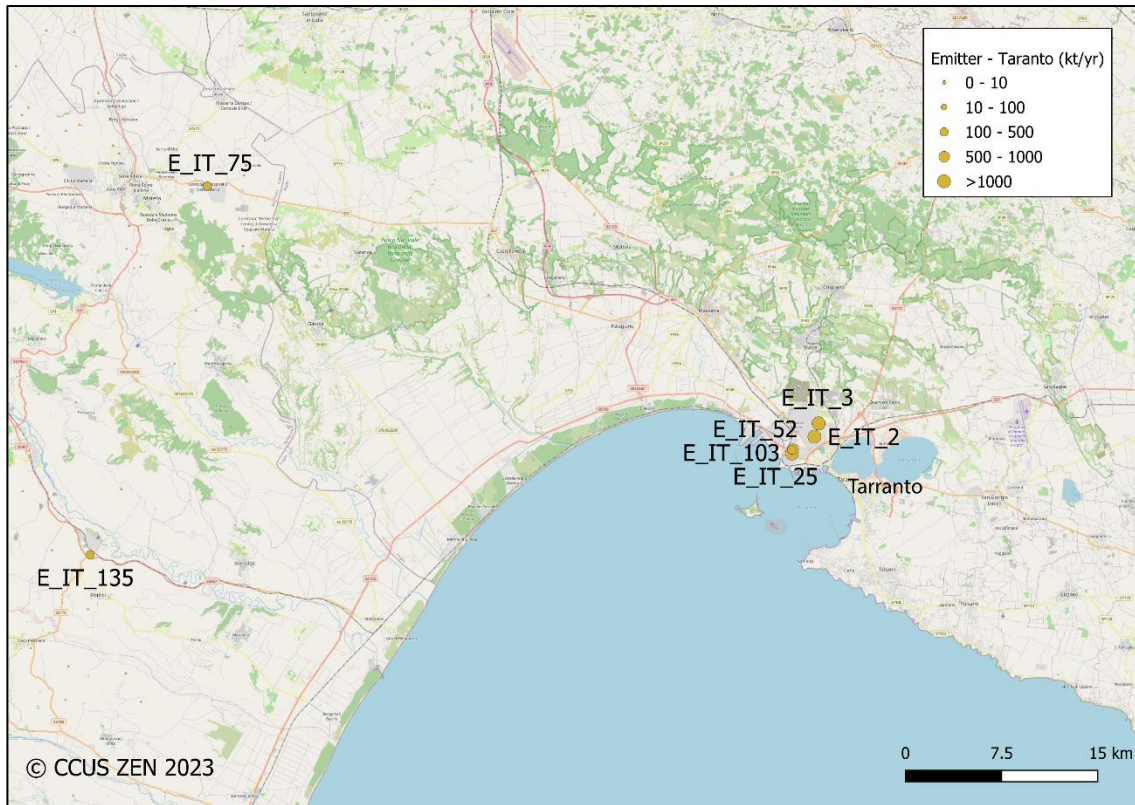


Figure 5.9 Example of possible emission cluster in Taranto.



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Table 5-3 Overview of emission from the Taranto emission cluster, data from Endrava database.

EMITTER ID	FACILITY NAME	COMPANY NAME	STATE	INDUSTRY SECTOR	EMISSION TREND	CO2 EMISSIONS (t/y)
E_IT_2	ArcelorMittal Italia	ArcelorMittal Italia	Taranto	Iron & Steel	falling	5 246 000
E_IT_3	Arcelormittal Italy Energy S.R.L.	Taranto Energia S.R.L. In Amministrazione Straordinaria	Taranto	Power	growing	4 405 000
E_IT_25	Eni S.P.A.	Eni S.P.A.	Taranto	Refineries	growing	1 113 764
E_IT_52	Raffineria Di Taranto	Eni S.P.A.	Taranto	Refineries	falling	680 000
E_IT_75	Italcementi Di Matera	Italcementi Spa	Matera	Cement	growing	478 000
E_IT_103	Eni S.P.A.	Eni S.P.A.	Taranto	Refineries	growing	306 000
E_IT_135	Tecnoparco Valbasento S.P.A.	Tecnoparco Valbasento S.P.A.	Matera	Power	growing	182 000
Total Taranto cluster						12 410 764

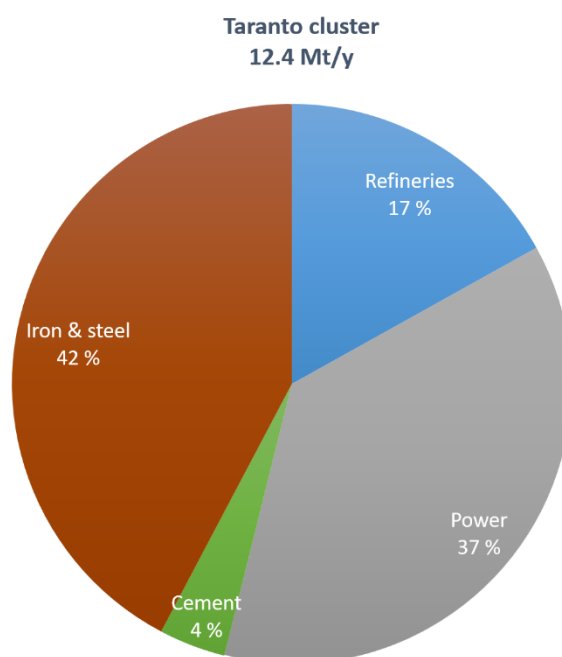


Figure 5.10 Pie Chart presenting emission sources in the Taranto cluster, dominated by iron and steel industry and power. Refineries are also important (17%), while the cement industry have a small share.



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5.2.2.2 Brindisi emission cluster

Brindisi is a coastal city with around 87 000 inhabitants, situated in southeastern Italy, east of Taranto. The port of Brindisi is used for tourism, commercial and industrial shipping in the Adriatic Sea.

The city has two large CO₂ emitters from the power sectors with a yearly CO₂ emission in scale of 3.8 Mt/year and 2.6 Mt/year, respectively and two smaller emitters in chemical and oil and gas processing (Figure 5.11 and Figure 5.12, Table 5-4).



Figure 5.11 Map of Brindisi with the emitters in the hub marked. The nomenclature corresponds to Table 5-4.



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Table 5-4 Overview of emission sources from the Brindisi cluster, data from 2021, from Endrava.

EMITTER ID	FACILITY NAME	COMPANY NAME	STATE	INDUSTRY SECTOR	EMISSION TREND	CO2 EMISSIONS (t/y)
E_IT_5	Enel Produziane S.P.A.	Enel Produziane S.P.A.	Brindisi	Power	Falling	3 856 000
E_IT_6	Enipower S.P.A.	Enipower S.P.A.	Brindisi	Power	Growing	2.623 000
E_IT_92	Versalis S.P.A.	Versalis S.P.A.	Brindisi	Chemicals	Falling	370 000
E_IT_227	Firenze Fpso	Firenze Fpso	Brindisi	Oil & gas processing	Falling	42 000
Total Brindisi cluster						6 891 000

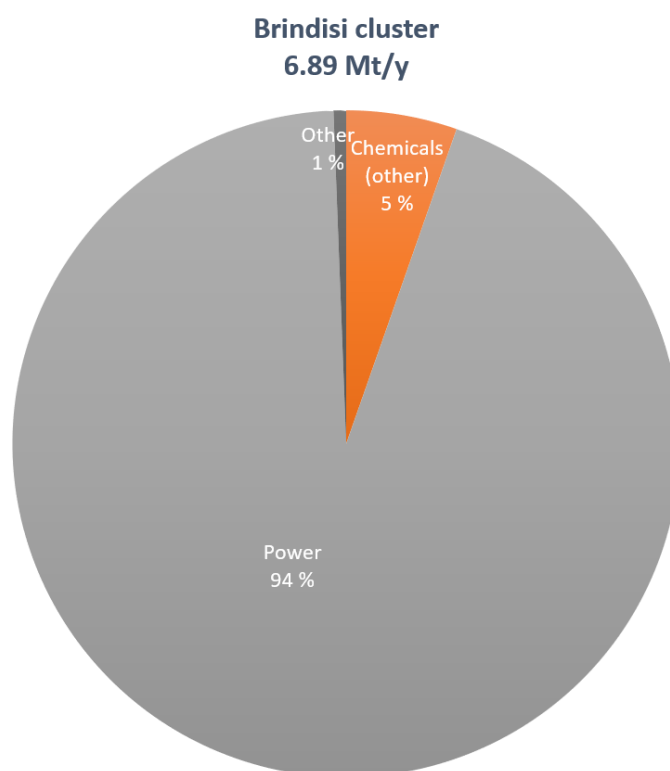


Figure 5.12 Pie chart for Brindisi cluster, summing up to 6,89 Mt/year, mainly from power plants.



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5.2.2.3 Priolo Gargallo emission cluster

At Sicily, the commune Priolo Garallo is situated in the Province of Syracuse, southern Italy. It is about 190 kilometres south of Palermo, and 13 km northwest of Syracuse. The commune has important economic activity and industries in refineries and petrochemical plants.

The Endrava database reports nine CO₂ emitters, situated in a small area, close to the harbour (see Figure 5.13). 51% of the emissions comes from two refineries, but also power plants, and chemical and cement contribute to large emissions (



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Table 5-5, Figure 5.14). The Priolo Gargallo emission cluster have a yearly CO₂ emission of 7.2 million tonnes.

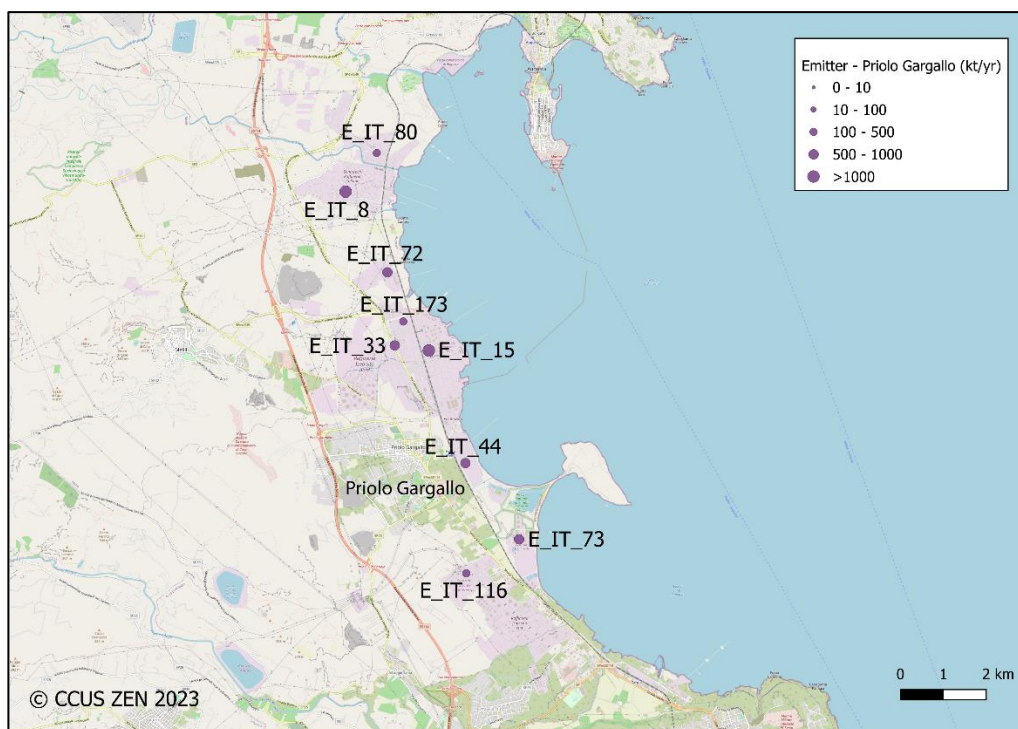


Figure 5.13 Map presenting the emission points in the Priolo Gargallo cluster.



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Table 5-5 Overview of point emitters in the Priolo Gargallo cluster. From Endrava database, 2021.

EMITTER ID	FACILITY NAME	COMPANY NAME	STATE	INDUSTRY SECTOR	EMISSION TREND	CO2 EMISSIONS (t/y)
E_IT_8	Esso Italiana S.R.L.	Esso Italiana S.R.L.	Siracusa	Refineries	growing	2 008 000
E_IT_15	Isab S.R.L.	Isab S.R.L.	Siracusa	Refineries	falling	1 677 000
E_IT_33	Erg Power S.R.L.	Erg Power S.R.L.	Siracusa	Power	falling	921 000
E_IT_44	Versalis S.P.A.	Versalis S.P.A.	Siracusa	Chemicals (other)	growing	805 000
E_IT_72	Cementeria Di Augusta	Buzzi Unicem Spa	Siracusa	Cement	growing	510 000
E_IT_73	Enel Produzione S.P.A.	Enel Produzione S.P.A.	Siracusa	Power	growing	510 000
E_IT_80	Sasol Italy S.P.A.	Sasol Italy S.P.A.	Siracusa	Chemicals (other)	growing	450 000
E_IT_116	Isab S.R.L.	Isab S.R.L.	Siracusa	Power	falling	208 000
E_IT_173	Air Liquide Italia Produzione S.R.L.	Air Liquide Italia Produzione S.R.L.	Siracusa	Hydrogen	falling	125 000
Total Priolo Gargallo cluster						7 214 000



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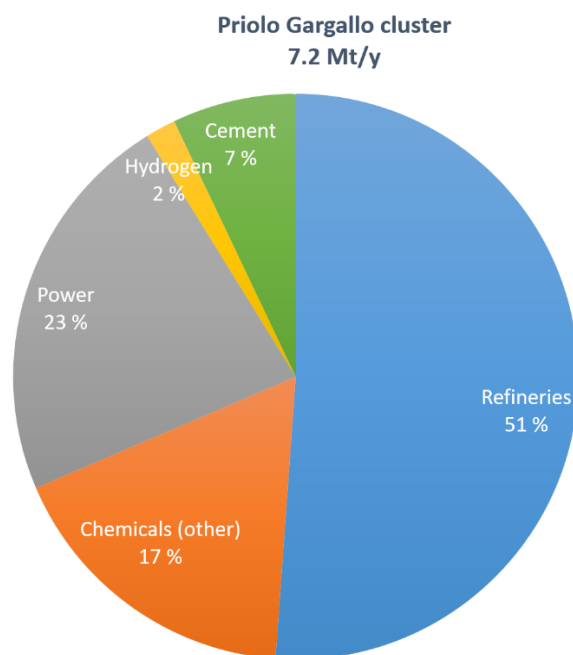


Figure 5.14 Pie chart illustrating the percent distribution of CO₂ emitters in the Priolo Garallo cluster.

5.2.3 Storage potential

There are several potential CO₂ storage sites in Italy, both onland and offshore that have been mapped the last decay (Donda et al. 2011, Barison et al. 2023). If we focus on the southern part of Italy, the “Bradánica” site, is situated close to Taranto city, and could be a possible storage site. Figure 5.15a show the outline of the Bradánica storage unit in map view, while Figure 5.15b shows a SW-NE oriented seismic section, with the interpreted reservoir and caprock units. The potential storage reservoir consists of Late Pliocene sands and silty sands with marl and conglomerates in places, pinching out towards the eastern carbonate platform (Donda et al. 2011). The deposits have been interpreted as basin floor sandstone lobes (Patacca & Scandone 2001), where flexure deformation in Plio-Pleistocene. The reservoir unit is locally more than 800 thick, with effective thickness of 650 m. The assumed caprock, clay and silty clay deposited from Late Pliocene, are more than 1500 thick in places, see Figure 5.15c and more details in Donda et al. (2011).

From the CO₂ storage capacity estimates in Donda et al. (2011), the reservoir has a storage capacity - with efficiency of 1% - of 344 Mt. If assuming a storage efficient of 4%, 1376 Mt can be stored, assuming a porosity of 25%.



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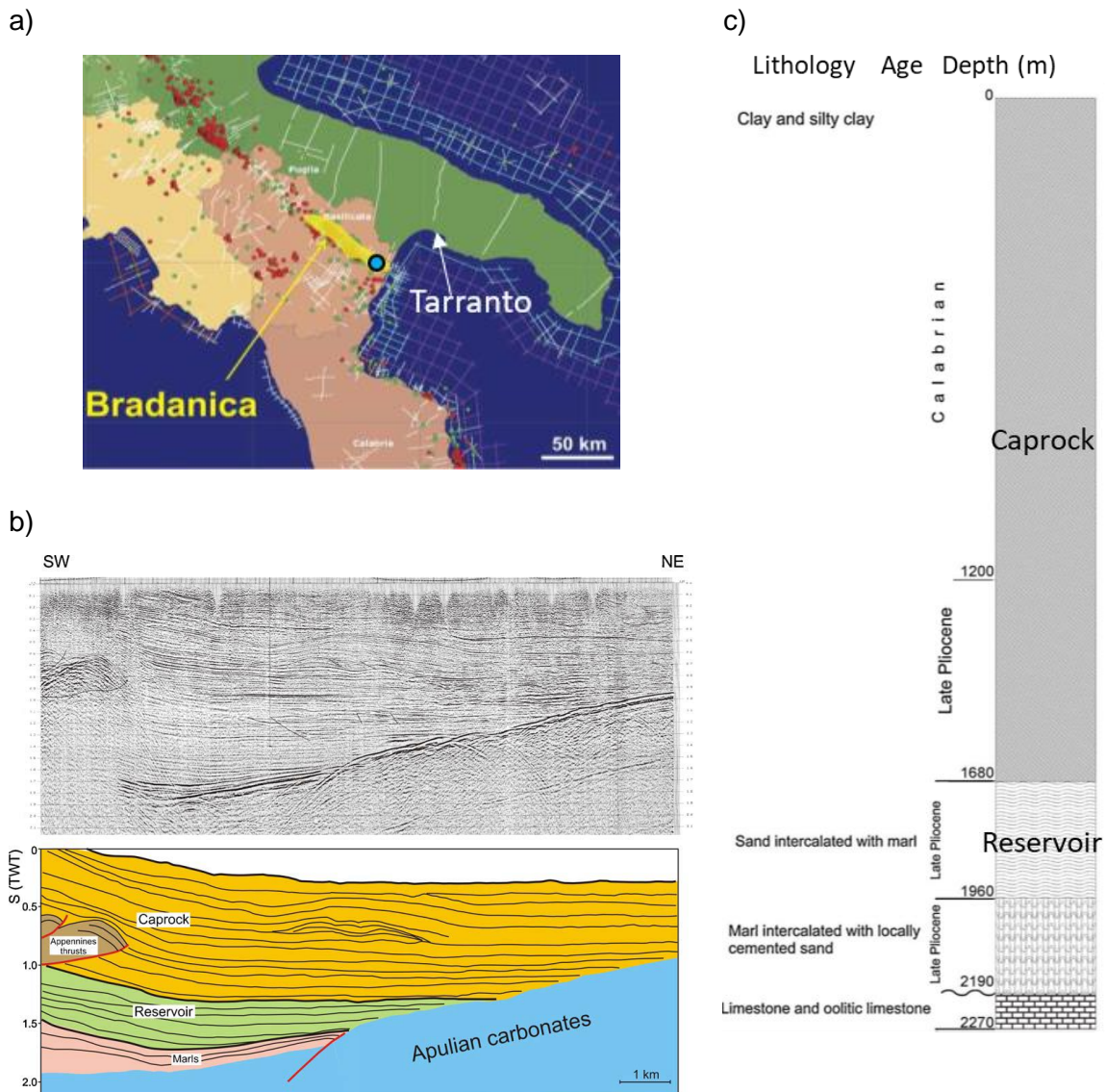


Figure 5.15 a) Map with storage site Bradanica marked in yellow. b) SW-NE oriented seismic line with interpretation showing the reservoir in a flexural deformed anticline below a thick caprock. c) Schematic sketch of a composite log from well Saladra 1 (see location blue dot on a) with lithology, age and depth marked. Reworked figures from Donda et al. (2011).



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5.2.4 The South Italy value chain (selected for WP3)

Figure 5.16 gives an overview of the selected value chain for the southern Italy. To reduce cost, we suggest including only one storage site; the one named Bradanica reservoir units, as presented in the previous subchapter. This storage unit is situated onshore only 50 km from one of major emitters in Italy in the Taranto cluster. If one builds a pipeline from Taranto, westwards to Bradanica storage site, one can later extend the pipeline eastwards to the neighbouring Brindisi cluster. By this, two major emission clusters, the Taranto and Brindisi, can be stored in Bradanica storage site, using only a pipeline of around 110 km (see



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Table 5-6). These two clusters have annual emission in range of 19.3 Mt/year. If we remove the smallest emitters <1 Mt/year, these two clusters will still have emission in range of 17.2 Mt/year.

The storage capacity is around 344 Mt assuming a storage efficiency of 1%, while using a storage efficiency of 4% result in around 1 276 Mt CO₂. Assuming an injection rate in two wells of 3 Mt/year, the storage site could be used for minimum 57 years. If we are less conservative, assuming a storage efficiency of 2%, the site could store for over hundred years. Most likely, more injection wells could be an option, but to resolve this and de-risking the storage site, detailed reservoir modelling should be carried out.



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Table 5-6 presents a scenario B, which also includes the Priolo Gargallo cluster, using ship transport till Taranto. This is an option if the storage site has storage efficiency closer to 4%. The number of injection wells and the injection rate that can be realistic, are out of scope in this report (see Figure 5.16).

As part of the de-risking, two other possible showstoppers should be evaluated. The onshore storage area is situated close to Natura 2000 area (Figure 5.16), and possible risk of leakage should be evaluated in detail. However, the clay and silty clay forming the caprock units are up to 1500 m thick, which is promising for storage containment. The second possible showstopper is the risk for earthquakes. Figure 5.17a shows a seismic hazard map for Italy, with low risk marked for the Bradanica storage site. Figure 5.17b shows historically earthquakes since 1900 for Italy, and some earthquakes have been active northwest of the Bradanica storage site. The risk of earthquakes should be evaluated further in more detail.



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Table 5-6 Summary table for value chain for Southern Italy

Value chain	Emission cluster(s)	Annual CO2 emissions (kt/y)	Storage site(s)	On/off shore	Capacity (Mt)	Distance (km)	Transport scenario A	Transport scenario B	Comments
Southern Italy	Taranto	12,411	S_IT8	Onshore	344-1376	50	pipeline	pipeline	Need to evaluate the route
	Brindisi	6,891				110	pipeline	pipeline	Scenario A: cheaper with only one pipeline
	Priolo Garallo	7,205				450	-	Ship and pipeline	Close to the coast on both sites
	TOTAL	26,50				610	-	-	

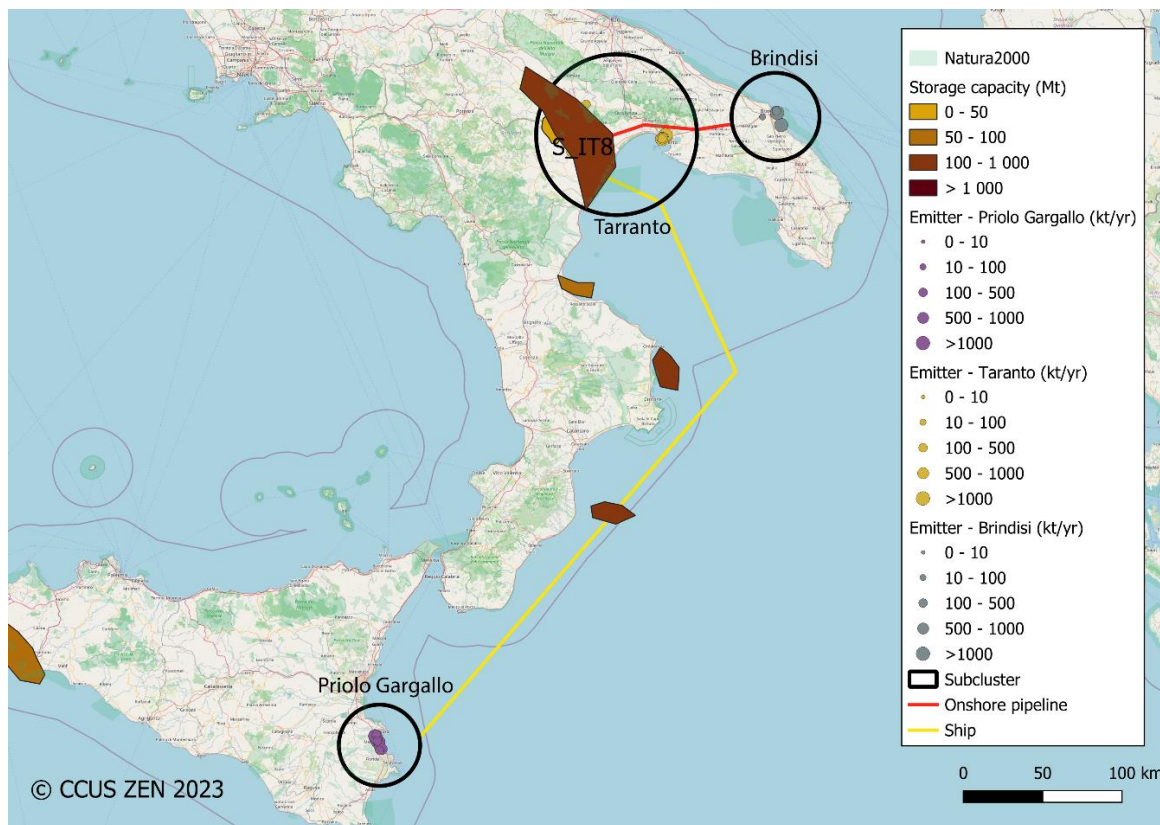


Figure 5.16 Map presenting the CCS chain, with three emitters clusters; Brindisi, Taranto and Priolo Gargallo and with joint storage in the Bradanica storage site(S_IT8). Ship transport is marked from Priolo Gargallo emitters hub, and pipelines from Brindisi and Taranto emitters hubs.



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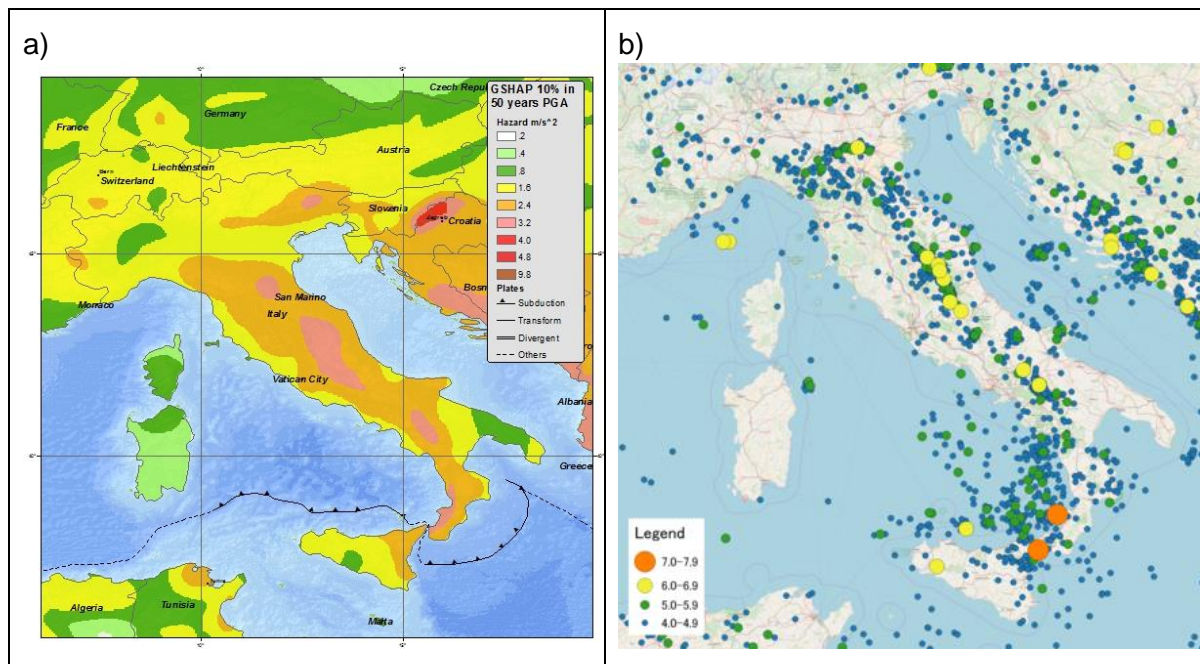


Figure 5.17 a) Seismic hazard map of Italy showing the probability of seismic activity. At the Bradanica site the risk is low. b) Map of earthquakes in Italy from 1900-2017. Some smaller earthquakes are reported northwest of the Bradanica storage site. From Wikipedia/List of earthquakes in Italy.



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5.3 Western Mediterranean Sea: Spain and France

5.3.1 Presentation of the geographical region

Concerning the western part of the Mediterranean region, the CCUS ZEN studies will focus on the Southern France and the North-eastern Spain, in order to propose CCUS scenarios oriented to the Mediterranean Sea. The geographical extent of this region is shown on Figure 5.18.

Located in southern part of France, Marseille city and Lyon city are respectively the second and third biggest cities of France. The Rhone River, one of France's main rivers, flows through Lyon towards Marseille, where it flows into the Mediterranean Sea (Rhone delta). The Rhone valley represents a 300 km long corridor between Lyon and Marseille.

The port of Marseille is France's main trading seaport and could offer a shipping route to CO₂. Marseille area is one of the most industrialised regions in France, with the industrial port in Fos-sur-Mer and many industrial sites installed in close proximity and around the Etang de Berre. Lyon area is also an industrialised region, also on a smaller scale than Marseille. It presents the particularity to include chemical industry, mainly located South of Lyon along the Rhone River (Roussillon area). There is a clear willingness in these areas for industry decarbonation and proactive stakeholders. Besides, these areas have strategies for hydrogen development. There are plans to develop a pipeline to transport hydrogen from Spain to Marseille, and along the Rhone Valley. French government issued in June 2023 a CCUS strategy document⁸ describing CCS quick deployment path. Concerning the Fos-sur-Mer cluster, short-term plan is to ship captured CO₂ to offshore site in Italian Adriatic Sea, Ravenna, developed by ENI S.p.A., in the frame of the PCI CALLISTO Mediterranean CO₂ Network. The Rhone Valley (from Lyon to Marseille) was one of the regions studied in the H2020 STRATEGY CCUS project. Domestic scenario for CCUS development were studied, where CO₂ captured from Fos industrial cluster were stored into geological reservoir in the region (small capacity) and/or in the Paris basin (larger storage capacities) (Coussy, 2021; Coussy, 2022).

In Spain, the selected region is the Northeastern part of the country, around the Ebro basin, which a major sedimentary basin in country. Barcelona and Tarragona are the main cities of the region. Barcelona is the engine of the Catalonia economy, being Tarragona the second one, both based on the service sector (including tourist) and industry (mainly chemical, textile and food industry). Both areas are very well communicated by road, train, international airport, and industrial ports (containers, raw materials and passengers) (Coussy, 2021). The industrial area around Tarragona and Barcelona in one with the highest CO₂ emissions from the National inventory of Spain (2019). The Ebro basin was also one of the regions previously studied in the H2020 STRATEGY CCUS project. Domestic scenario

⁸ https://www.conseil-national-industrie.gouv.fr/files_cni/files/actualite/20230623_consultation_ccus.pdf



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for CCUS development were studied, where CO₂ captured from Tarragona and Barcelona industrial clusters were stored into onshore geological reservoirs in the region (Coussy, 2022). Besides, the Ebro basin is currently under study in the H2020 PilotSTRATEGY with the objective of characterizing a reservoir for a CO₂ storage pilot (Rubio, 2022).

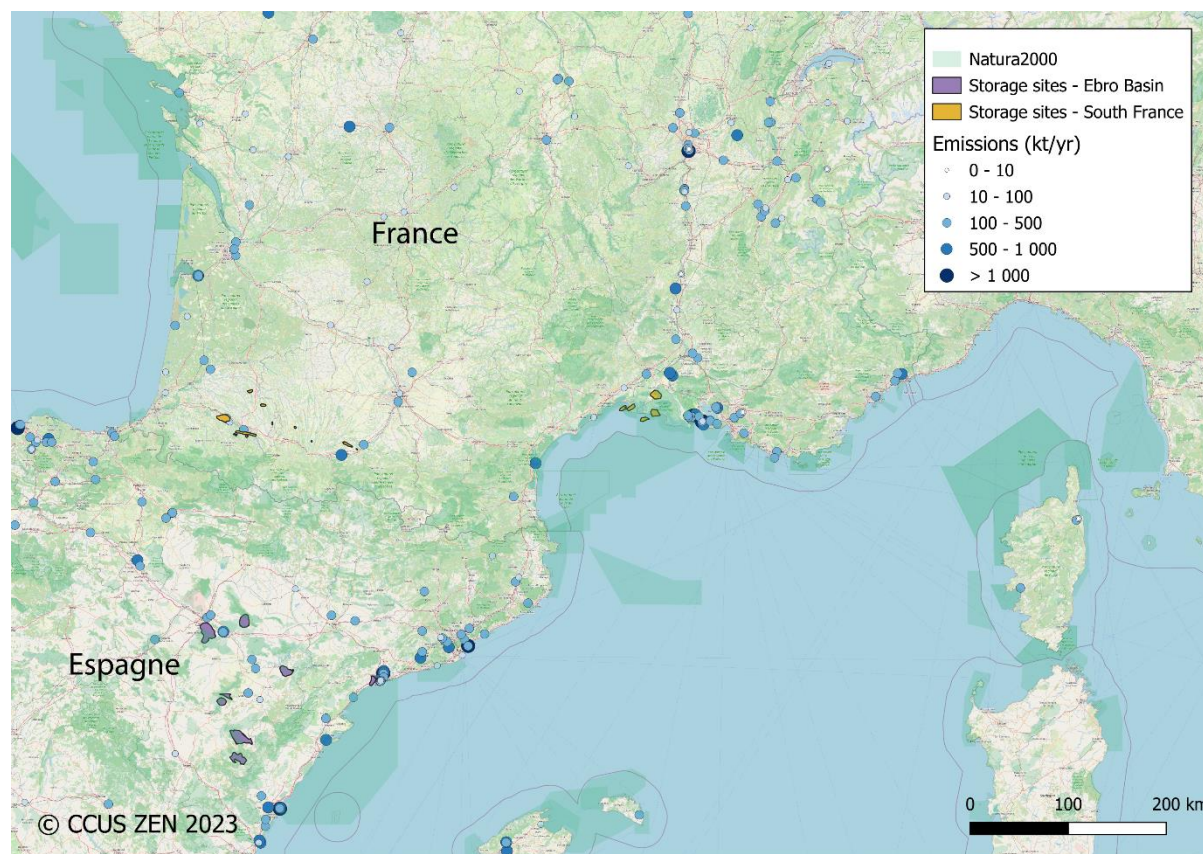


Figure 5.18: Geographical extent of the Western Mediterranean Sea region. Coloured polygons indicate identified potential storage sites and blue dots represent the emissions sites, in particular, the industrial clusters of Tarragona, Barcelona, Marseille and Lyon.

5.3.2 Emission sources

This section describes the different emissions sources that are promising for developing CCUS value chains in the Western Mediterranean Sea region. The emitters are mainly grouped into clusters, which is the case for the industrial clusters of Tarragona, Barcelona, Fos and Lyon. However, some standalone sites or two-plants “clusters” have also been identified as of interest for CCUS value chains deployment in the region.

5.3.2.1 Barcelona cluster

The Barcelona cluster is located in Spain on the Mediterranean shore, around Barcelona city. This cluster groups together 14 carbon-emitting sites, totalling 4.7 Mt of annual CO₂ emissions. Their location is displayed on Figure 5.19 and the features of each site is listed in Table 5-7. All emitters emit more than 100 kt of CO₂ per year, except E_ES_206, which is



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just below (94 kt/y), and E_ES_232, which is very small emitter (19 kt/y) located on the port of Barcelona and thus could benefit from clustering. The two largest emitters emit around 1 Mt/y each: a power plant (E_ES_13) emitting 1.19 Mt/y; and a cement plant (E_ES_20) emitting 0.95 Mt/y. These only two sites are responsible of 45% of the whole cluster's emissions. This explains the breakdown by industrial sector of the cluster's emissions, shown on Figure 5.20. Emissions mainly come from the power sector (43%), the cement industry (29%). Waste-to-energy sector stands in third place (9%) with 2 plants listed in the cluster (E_ES_140 emitting 167 kt/y; E_ES_103 emitting 243 kt/y). Surprisingly, no biomass emission is reported for E_ES_140 in the database. So, considering a share of 50% of waste emission being biogenic, an estimate of 83 kt/y has been taken (in *italic* in the table).

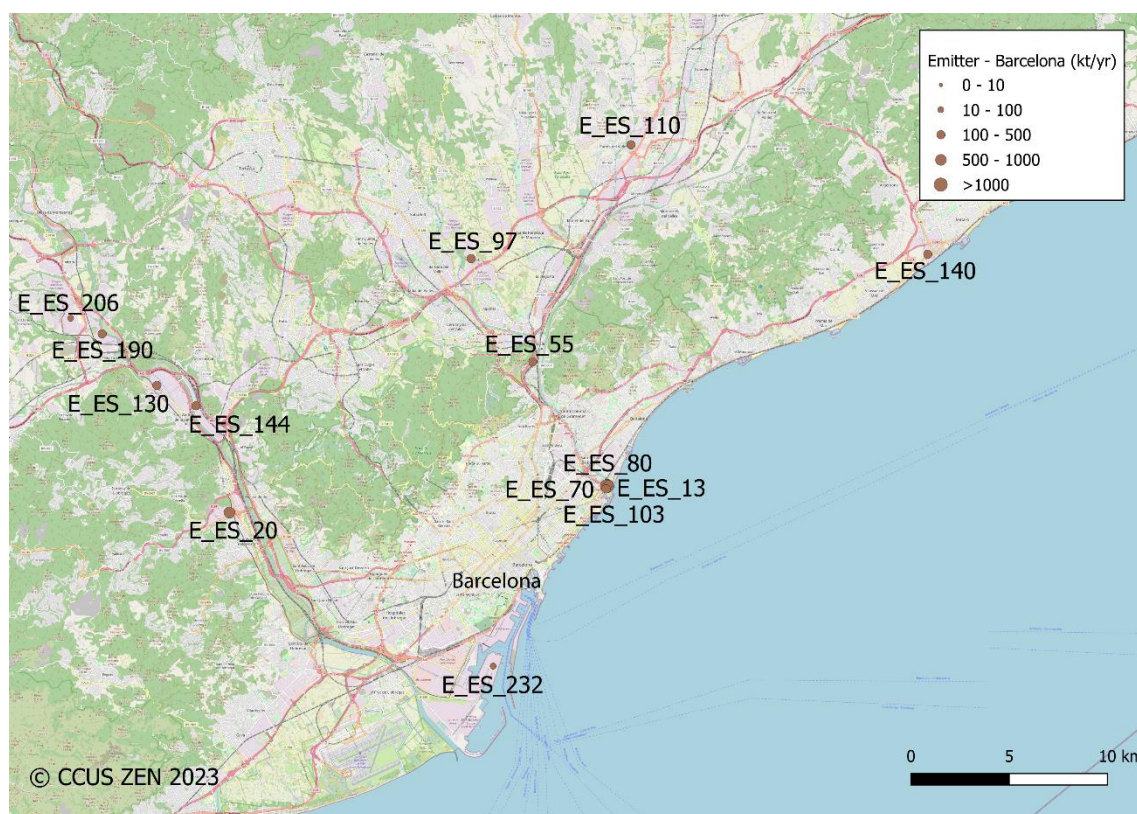


Figure 5.19: Location of Barcelona cluster



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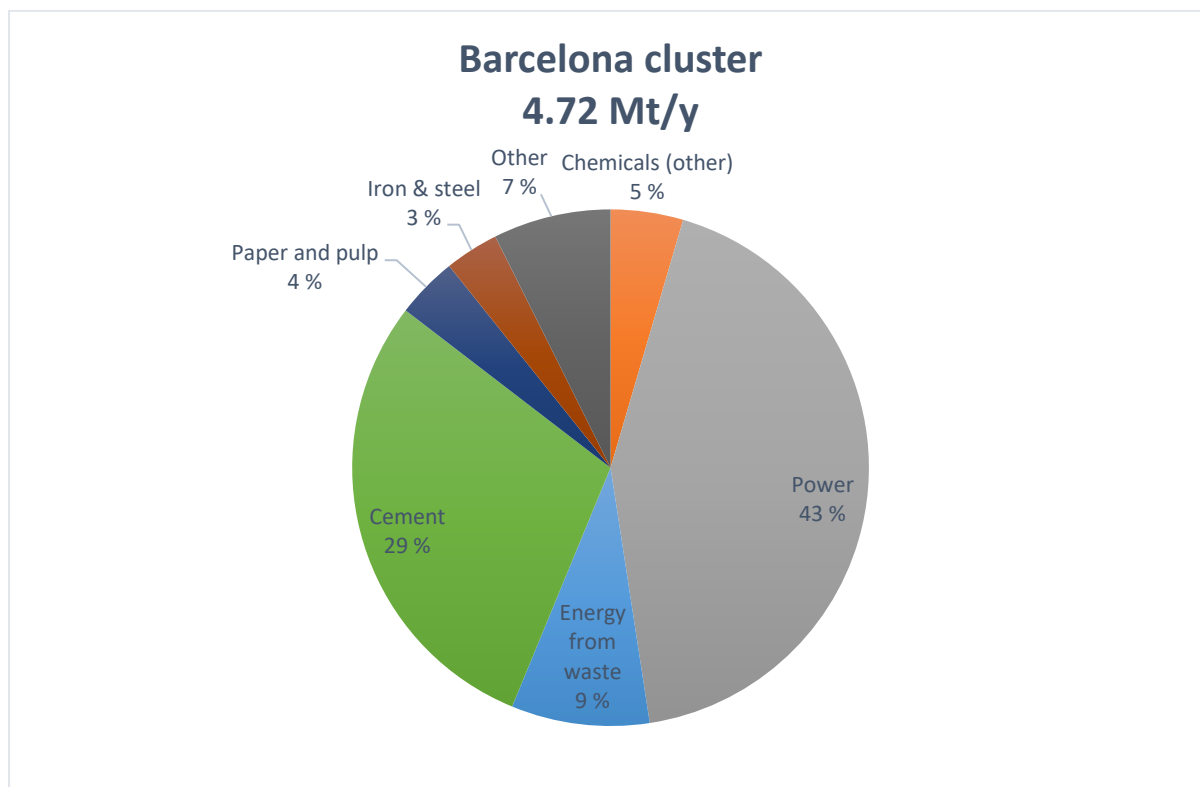


Figure 5.20: Emissions breakdown by industrial sector for the Barcelona cluster

Table 5-7: Barcelona cluster - Features of CO₂ emission sites

Emitter ID	Facility name	City	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (Kt/y)
E_ES_13	Central Termica De Cicle Combinat (Sant Adrià De Besòs - Grup 4)	Barcelona	41.41860283	2.229018739	Power	1 196	growing	0
E_ES_19	Cementos Portland Valderrivas (Santa Margarida I Els Monjos)	Barcelona	41.31291836	1.66378292	Cement	953	falling	0
E_ES_20	Cementos Molins Industrial	Barcelona	41.40654041	1.999563027	Cement	948	falling	122



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	(Sant Vicenç Dels Horts)							
E_ES_55	Fàbrica De Montcada (Lafargeholcim España Sau)	Barcelona	41.47511045	2.183859511	Cement	436	falling	76
E_ES_70	Central Termica De Cicle Combinat (Sant Adrià De Besòs - Grup 3)	Barcelona	41.41811415	2.228584293	Power	378	Stable	0
E_ES_80	Central Termica De Cicle Combinat (Sant Adrià De Besòs - Grup 5)	Barcelona	41.41927529	2.229765094	Power	337	falling	0
E_ES_97	Ritrama	Barcelona	41.52200321	2.146386573	Other	255	Stable	0
E_ES_103	Planta De Valoritzacio Energetica De Sant Adria De Besos	Barcelona	41.41727878	2.228450617	Energy from waste	243	Falling	122
E_ES_110	Stahl Iberica	Barcelona	41.57371785	2.24353947	Chemicals (other)	215	Stable	0
E_ES_130	Barcelona Cartonboard	Barcelona	41.46438473	1.955476915	Paper and pulp	182	falling	0
E_ES_140	CENTRE INTEGRAL DE VALORITZACIO DE RESIDUS DEL MARESME (ABANS UTE TRACTAMENTS)	Barcelona	41.52400992	2.423799394	Energy from waste	167	Stable	83



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	ECOLOGICS DEL MARESME)							
E_ES_144	Compañia Española De Laminacion (Celsa 1-4)	Barcelona	41.45511683	1.979221475	Iron & Steel	160	falling	0
E_ES_190	Cofely Energia Martorell	Barcelona	41.48782516	1.922257418	Power	110	growing	0
E_ES_191	Cales De Pachs	Barcelona	41.3650646	1.684524954	Other	108	growing	0
E_ES_206	Seat	Barcelona	41.49486586	1.90307108	Other	94	falling	0
E_ES_232	Central Termica De Cicle Combinat (Port De Barcelona)	Barcelona	41.33660000 54	2.159758201 5	Power	19	falling	0
Total Barcelona cluster						4 740		407

5.3.2.2 Tarragona cluster

The Tarragona cluster is located in Spain on the Mediterranean shore, Around Tarragona city. This cluster groups together 11 carbon-emitting sites, totalling 5.39 Mt of annual CO₂ emissions. Their location is displayed on Figure 5.21 and the features of each site are listed in Table 5-8. Eight out of these 11 emitters emit more than 100 kt of CO₂ per year. The refinery E_ES_4 is the major emitter of the cluster, with 2.2 Mt annual emissions, representing 42% of the cluster's emissions. The cluster also includes three small-scale emitters, below 100 kt/y: two chemical plants (E_ES_213 emitting 83 kt/y; E_ES_220 emitting 64 kt/y); and a powerplant (E_ES_231) emitting 26 kt/y. These emitters are located on industrial plateforms with other larger emitters. Thus, capture on these sites may still be interesting. Figure 5.22 shows the breakdown by industrial sector of the cluster's emissions. Emissions mainly come from the refining industry (42% - 1 plant) and from the chemical industry (39% - 3 plants). Other sectors represented in the cluster are power (10%), Hydrogen (6%) and Energy from waste (3%).



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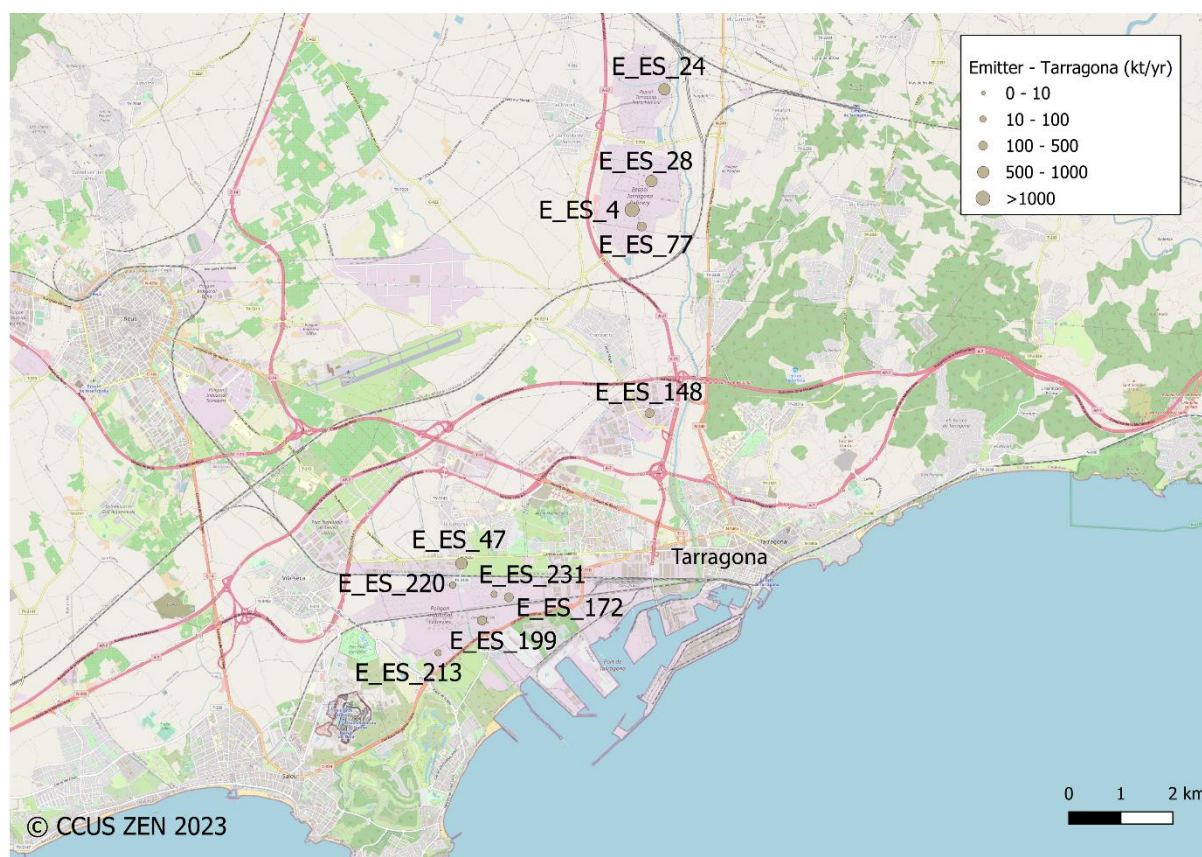


Figure 5.21 Location of emission sources - Tarragona cluster

Table 5-8: Tarragona cluster - Features of CO₂ emission sites

Emitter ID	Facility name	City	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (Kt/y)
E_ES_4	Repsol Refineria Tarragona	Tarragona	41.17434858	1.222360431	Refinerie s	2 246	growing	2
E_ES_24	Repsol Quimica	Tarragona	41.19508193	1.229753082	Chemical s (other)	878	growing	1
E_ES_28	Dow Chemical Iberica (Dow Nord)	Tarragona	41.17929066	1.226764165	Chemical s (other)	829	falling	0
E_ES_47	Tarragona Power	Tarragona	41.11345044	1.183319513	Power	538	growing	0



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E_ES_77	Hyco (La Pobla De Mafument)	Tarragona	41.17146627	1.224562283	Hydrogen	348	falling	0
E_ES_148	INCINERADOR A DE TARRAGONA	Tarragona	41.1393403	1.226341582	Energy from waste	154	Stable	0
E_ES_172	Industrias Quimicas Del Oxido De Etileno (La Canonja)	Tarragona	41.10763572	1.194172306	Chemicals (other)	120	growing	0
E_ES_199	Dow Chemical Iberica (Dow Sud)	Tarragona	41.10365799	1.188037868	Chemicals (other)	101	Stable	0
E_ES_213	Ercros (Fàbrica De Vila-Seca li)	Tarragona	41.09806713	1.177991102	Chemicals (other)	83	growing	0
E_ES_220	Basf Sonatrach Propanchem	Tarragona	41.1097532067	1.1813148753	Chemicals (other)	64	falling	0
E_ES_231	Central Termica De Cicle Combinat Tarragona 1	Tarragona	41.1081532454	1.1908093488	Power	26	Stable	0
Total Tarragona cluster						5 387		3



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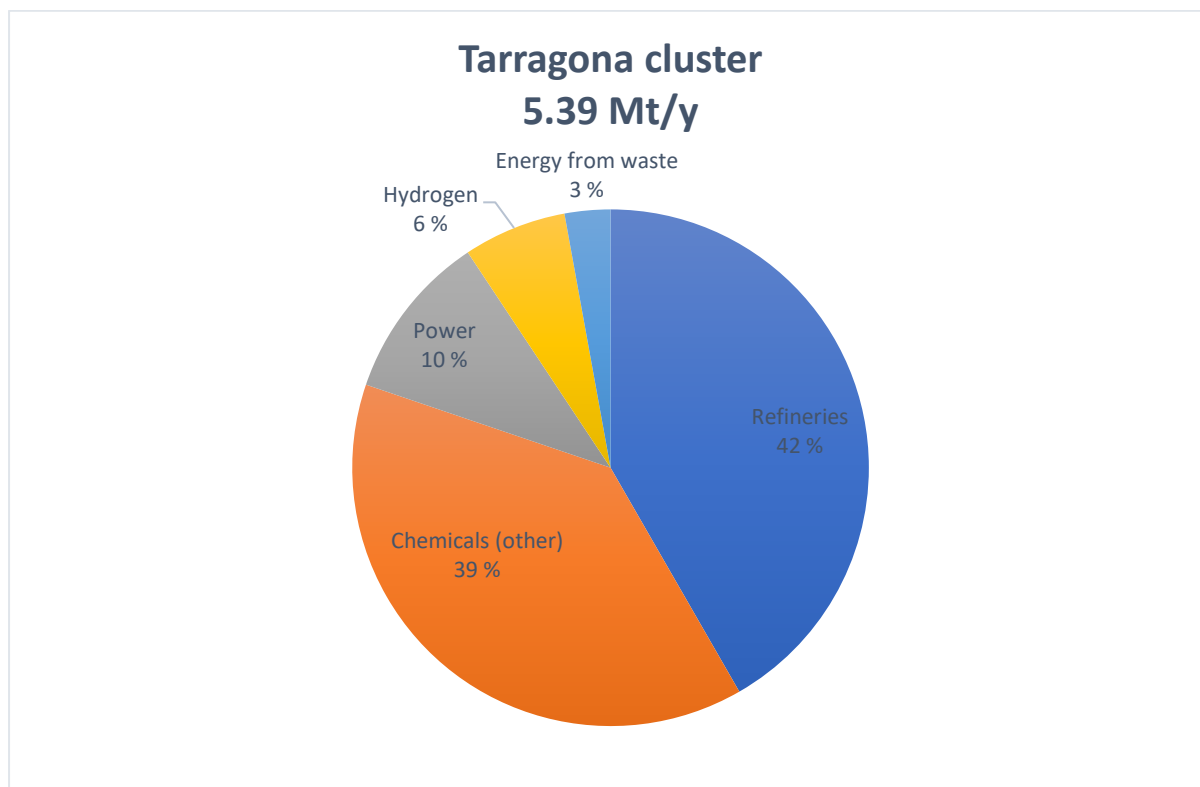


Figure 5.22: Emissions breakdown by industrial sector for the Tarragona cluster

5.3.2.3 Vilafranca cluster

Located halfway between Barcelona and Tarragona, the Vilafranca cluster regroups only two sites: a cement plant (E_FR_38) and a paper plant (E_FR_36), totalling CO₂ emissions of 1.17 Mt/y. Location is displayed on Figure 5.23 and the features of each site is listed in Table 5-9.



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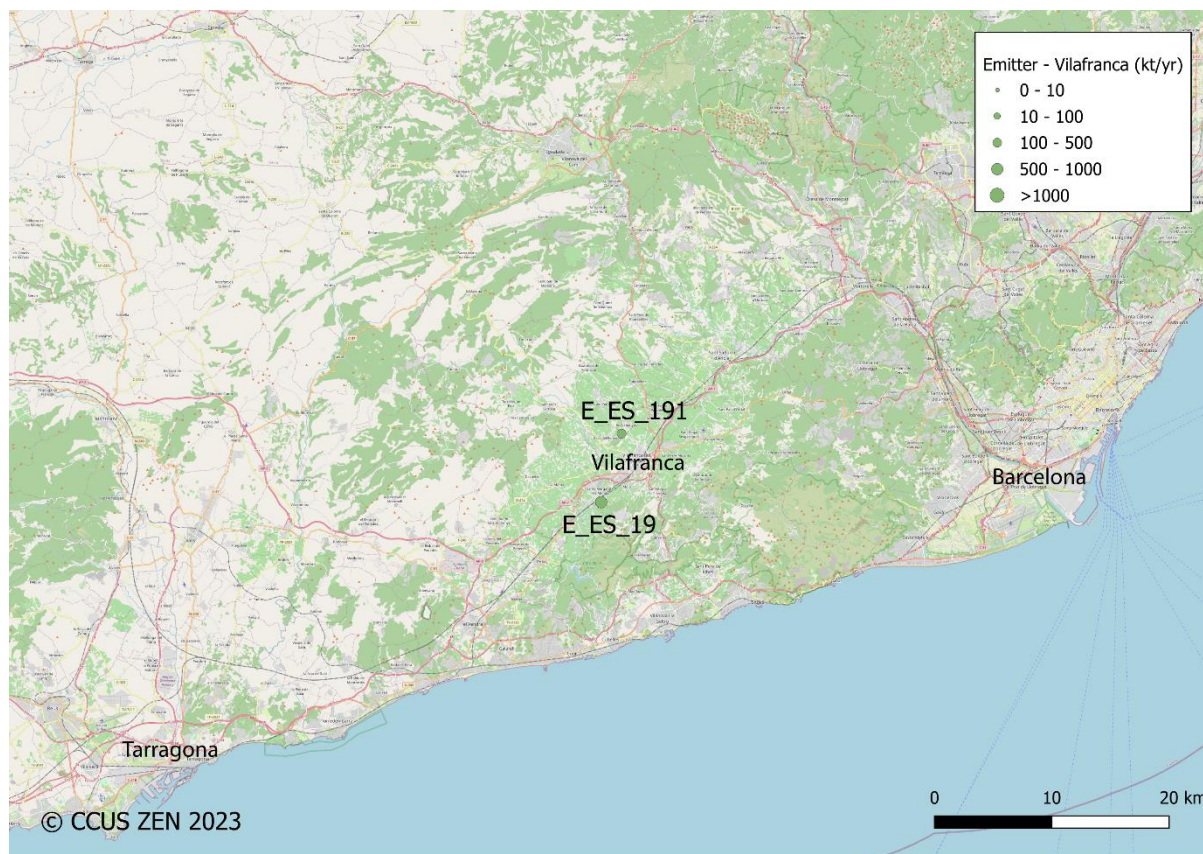


Figure 5.23: Location of the emissions sites - Vilafranca cluster

Table 5-9: Vilafranca cluster - Features of CO₂ emission sites

Emitter ID	Facility name	City	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (Kt/y)
E_ES_19	Cementos Portland Valderrivas (Santa Margarida I Els Monjos)	Vilafranca del Penedes	41.312918364	1.6637829203	Cement	953	falling	0
E_ES_191	Cales De Pachs	Vilafranca del Penedes	41.3650645975	1.6845249543	Other	108	growing	0
Total Vilafranca cluster						1 061		0



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5.3.2.4 Alcanar site

Located on the Mediterranean shore, 80 km South of Tarragona, close to Alcanar (see Figure 5.24), the Cemex cement plant is an important carbon emitter in the region (885 kt/y) and should be included in potential value chains (Table 5-10).

Table 5-10: Alcanar site - Features of CO₂ emission sites

Emitter ID	Facility name	City	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (Kt/y)
E_ES_23	Cemex Espana Operaciones (Alcanar)	Alcanar	40.5763278021	0.544414476	Cement	885000	growing	-

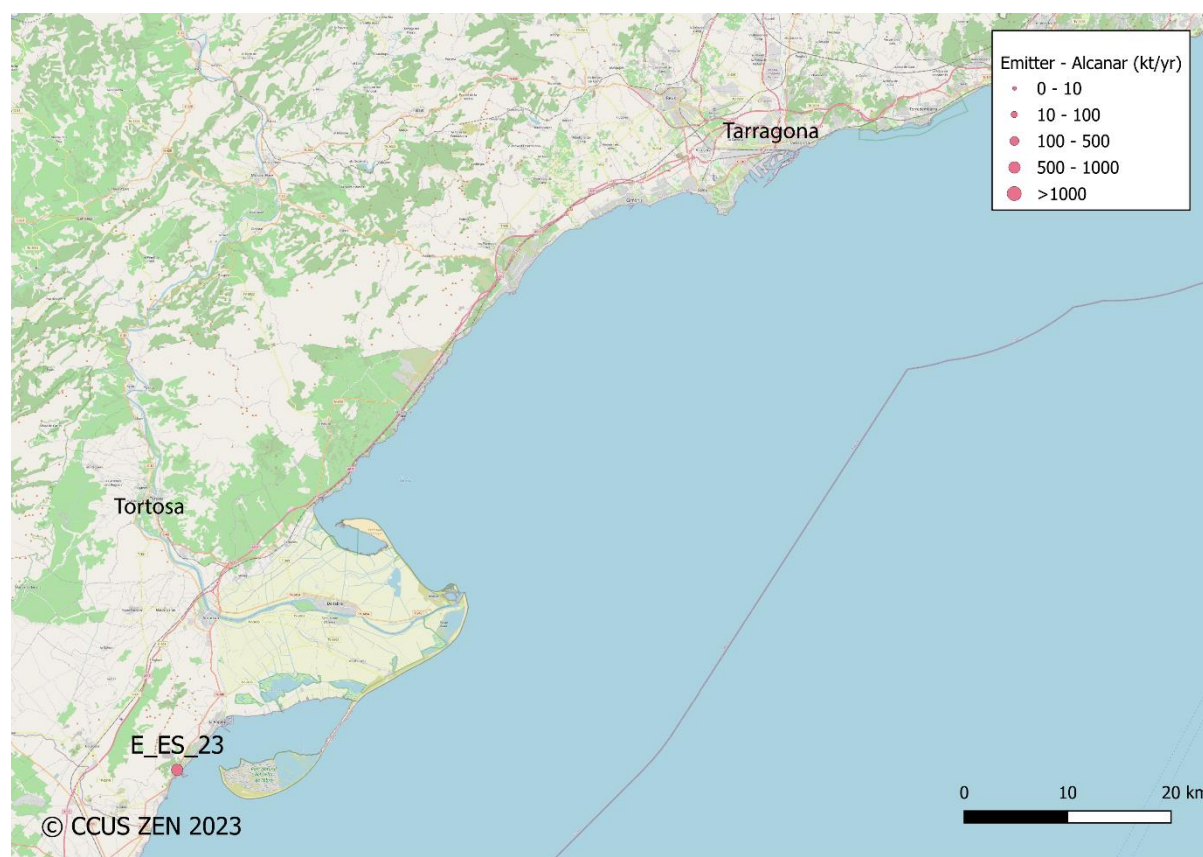


Figure 5.24: Location of the emitter sites of the Alcanar standalone site



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5.3.2.5 Fos-Marseille cluster

The Fos-Marseille cluster is located in France on the Mediterranean shore, close to Marseille city. This cluster groups together 22 carbon-emitting sites, totalling 16 Mt of annual CO₂ emissions. Their location is displayed on Figure 5.25 and the features of each site is listed in Table 5-11. All emitters emit more than 100 kt of CO₂ per year, except E_FR_306 (76 kt/y) which is located in an industrial plateform with other large emitters. Thus, capture on this site may still be interesting. There are three major emitters, above 1 Mt/y: an iron & steel plant (E_FR_2) emitting 6.9 Mt/y; a chemical plant (E_FR_8) emitting 1.6 Mt/y; and a refinery (E_FR_10) emitting 1.2 Mt/y. These only three sites are responsible of 60% of the whole cluster’s emissions. This explains the breakdown by industrial sector of the cluster’s emissions, shown on Figure 5.26. Emissions mainly come from the iron & steel industry (43%), refinery (14%) and chemical industry (12%). Yet, the second highest emitting sector is power (20%) with 7 power plants in the cluster. As far as the waste-to-energy sector is concerned, one plant is listed in the cluster (E_FR_63; 399 kt/y). Surprisingly, no biomass emission is reported for this site in the database. So, considering a share of 50% of waste emission being biogenic, an estimate of 200 kt/y has been taken (in *italic* in the table).

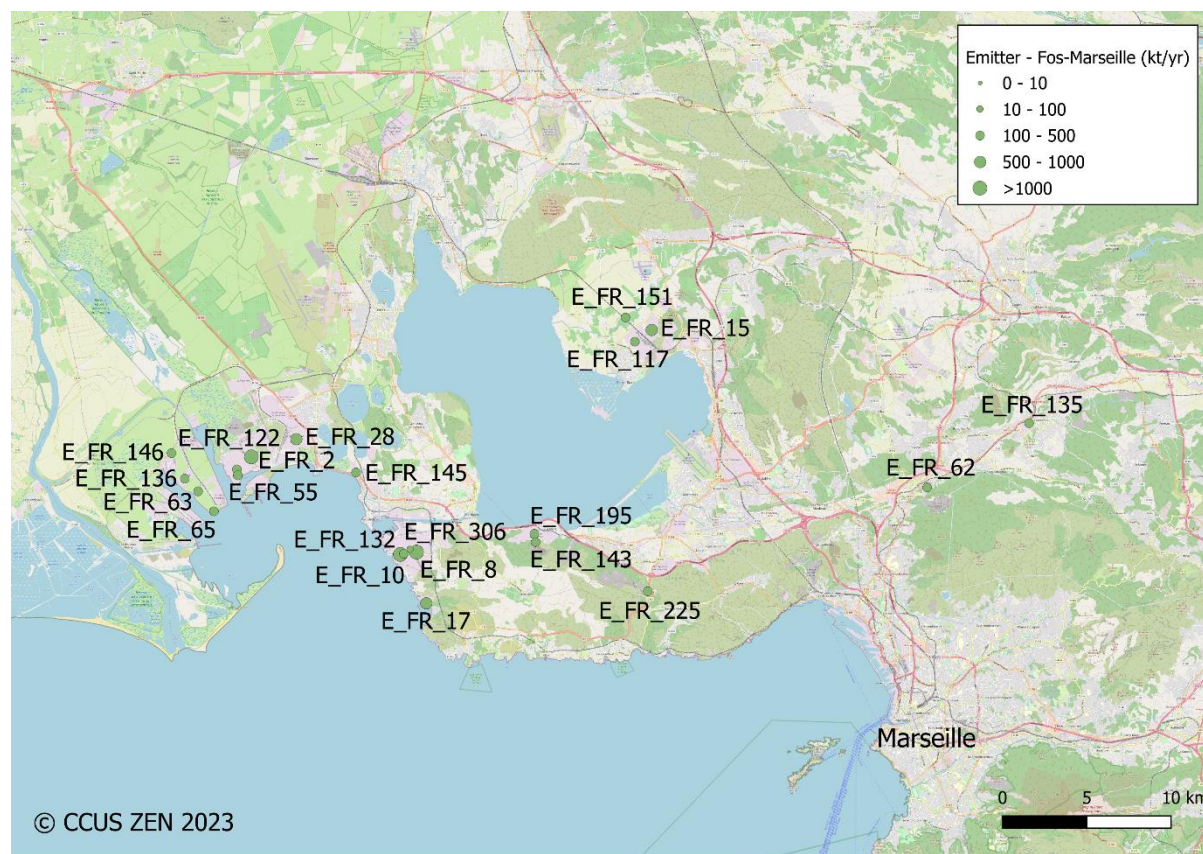


Figure 5.25: Location of the emitter sites of the Fos-Marseille cluster.



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Table 5-11 Emitters sites features of the Fos-Marseille cluster

Emitter ID	Facility name	Department	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (kt/y)
E_FR_2	Arcelormittal Mediterranee	Bouches -du-Rhone	43.436189	4.893738785	Iron & Steel	6 902	falling	0
E_FR_8	Naphtachimie	Bouches -du-Rhone	43.385646991	5.0144296633	Chemicals (other)	1 617	growing	0
E_FR_10	Petroineos Manufacturing France Sas	Bouches -du-Rhone	43.38441933	5.0025968869	Refineries	1 216	falling	0
E_FR_15	Basell Polyolefines France Sas	Bouches -du-Rhone	43.503385048	5.1862072371	Power	968	growing	0
E_FR_17	Edf Ccg De Martigues	Bouches -du-Rhone	43.358478018	5.0215716804	Power	894	falling	0
E_FR_28	Esso Raffinage Sas	Bouches -du-Rhone	43.445569167	4.9266376953	Refineries	702	falling	0
E_FR_55	Gdf Suez Thermique France	Bouches -du-Rhone	43.429498199	4.8831852447	Power	468	falling	0
E_FR_62	Lafargeholcim Ciments	Bouches -du-Rhone	43.419977177	5.3874351907	Cement	429	growing	22
E_FR_63	Evere Sas	Bouches -du-Rhone	43.417883949	4.8548234894	Energy from waste	399	growing	200
E_FR_65	Engie Thermique France	Bouches -du-Rhone	43.407274265	4.8664215104	Power	394	falling	0
E_FR_95	Total Raffinage France	Bouches -du-Rhone	43.395361454	5.1005115404	Refineries	250	growing	0



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E_FR_117	Compagnie Petrochimique De Berre Sas	Bouches -du- Rhone	43.497196893	5.1740031367	Power	200	falling	194
E_FR_122	Cifc	Bouches -du- Rhone	43.42634777	4.8838176173	Other	197	growing	0
E_FR_132	Air Liquide France Industrie (Alfi)	Bouches -du- Rhone	43.384840977	5.0052062771	Hydrogen	185	falling	1
E_FR_135	Alteo Gardanne	Bouches -du- Rhone	43.454001743	5.461977397	Non iron metals	184	falling	0
E_FR_136	Lyondell Chimie France Sas	Bouches -du- Rhone	43.424589083	4.8451349559	Chemicals (other)	182	falling	0
E_FR_143	Chaux De Provence Sacam	Bouches -du- Rhone	43.390915594	5.1013578002	Other	173	growing	0
E_FR_145	Imerys Aluminates Sa	Bouches -du- Rhone	43.427894984	4.9702620257	Other	171	growing	0
E_FR_146	Kem One France	Bouches -du- Rhone	43.438141912	4.8354947126	Chemicals (other)	170	growing	4
E_FR_151	Lyondell Basell Services France Sas	Bouches -du- Rhone	43.51	5.1671	Power	163	falling	0
E_FR_225	Chaux De La Tour	Bouches -du- Rhone	43.364847836	5.1834242105	Other	109	falling	6
E_FR_306	Lavera Energies	Bouches -du- Rhone	43.387105543	5.0096502673	Power	76	falling	0
Total cluster						16 049		427



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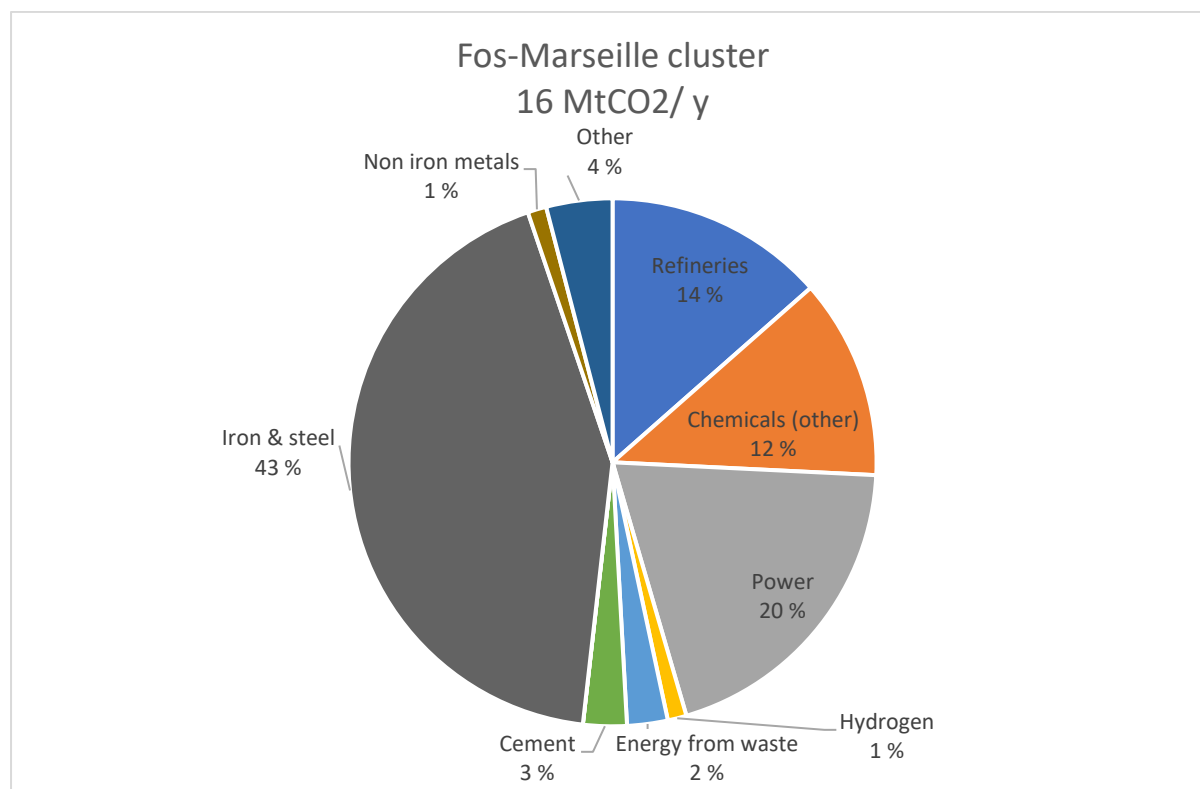


Figure 5.26: Emissions breakdown by industrial sector for the Fos-Marseille cluster.

5.3.2.6 Beaucaire cluster

Located 45 km northwest from Fos-sur-Mer, the Beaucaire cluster regroups only two sites: a cement plant (E_FR_38) and a paper plant (E_FR_36), totalling CO₂ emissions of 1.17 Mt/y. Location is displayed on Figure 5.27 and the features of each site is listed in Table 5-12.

Table 5-12 Beaucaire cluster - Emitters sites feature.

Emitter ID	Facility name	Department	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (Kt/y)
E_FR_36	Fibre Excellence Tarascon	Bouches -du- Rhone	43.78037787 4	4.652963953 6	Paper and pulp	590	falling	541
E_FR_38	Ciments Calcia	Gard	43.80399815 4	4.620830246 2	Cement	578	growing	31
Total Beaucaire cluster						1 168		572



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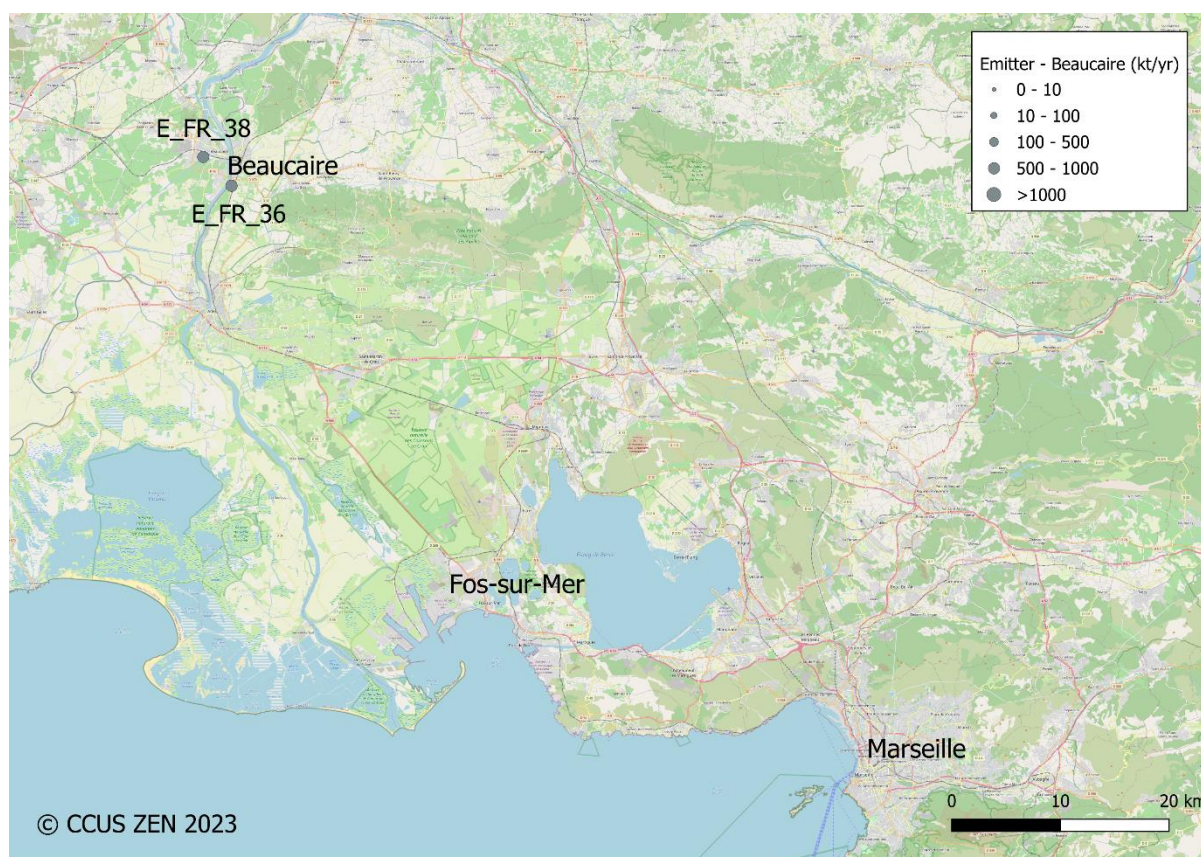


Figure 5.27: Location of the emitter sites of the Beaucaire cluster.

5.3.2.7 Lyon cluster

The Lyon cluster is located in France on the Rhone River, 300 km North from Marseille city. This cluster groups together 19 carbon-emitting sites, totalling 4.2 Mt of annual CO₂ emissions. Their location is displayed on Figure 5.28 and the features of each site is listed in Table 5-13. In this cluster, 13 sites emit more than 100 kt of CO₂ per year, and 5 sites emit between 77 and 99 kt/y. One small site is included in the cluster, E_FR_343, whose annual emissions amount to 19 kt/y. Although it will be probably challenging to capture on such small-scale site, this site may be still considered, since its emissions mainly come from biomass and it could benefit from clustering. In the Lyon cluster, only one emitter is above 1 Mt/y: a refinery (E_FR_12) emitting around 1 Mt/y. The breakdown by industrial sector of the cluster's emissions, shown on Figure 5.29. Emissions mainly come from the cement industry (27%) with 2 cement plants, refinery (25%) due to the Feyzin refinery, and energy from waste (19%) with 5 sites in the cluster. Surprisingly, no biomass emission is reported for these last 5 sites in the database. Considering a share of 50% of waste emission being biogenic, estimates has been made (in *italic* in the table).



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Chemical industry represents 8% of the emissions, with plants in the Lyon area and in the Roussillon area, southwards along the Rhone River. Additionally, there are two glass factories in the cluster: E_FR_260 (99kt/y) and E_FR_295 (82 kt/y).

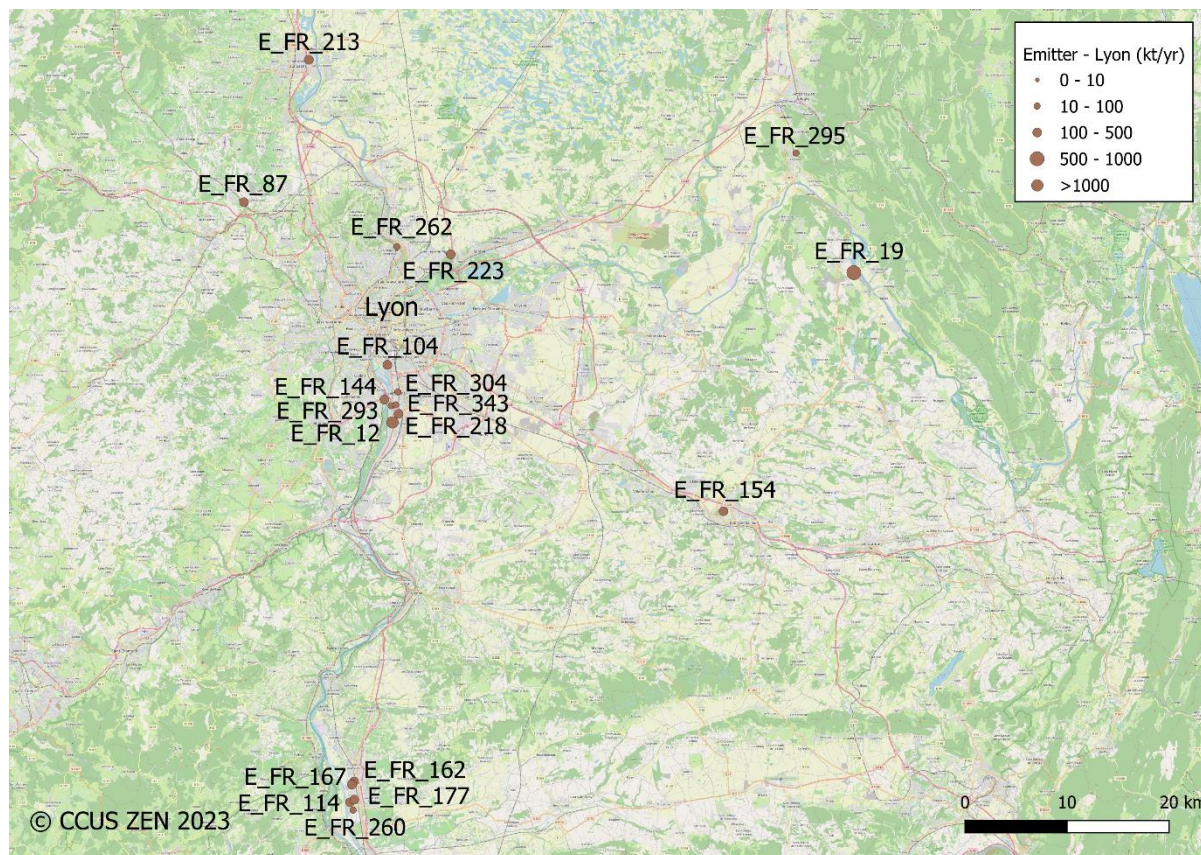


Figure 5.28: Location of the emitter sites of the Lyon cluster



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Table 5-13: Lyon cluster - Emitters sites features.

Emitter ID	Facility name	Department	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (kt/y)
E_FR_12	Total Raffinage France	Rhone	45.674460211	4.8444865268	Refineries	1 057	growing	0
E_FR_19	Vicat	Isere	45.804904011	5.4209963104	Cement	868	growing	114
E_FR_87	Lafarge Ciments	Rhone	45.866275845	4.6589845179	Cement	272	falling	17
E_FR_104	Metropole De Lyon - Unite De Traitement De De Valorisation Energetique Des Dechets Urbains De Lyon Sud	Rhone	45.724641323	4.8380748474	Energy from waste	233	growing	116
E_FR_114	Tredi	Isere	45.341888824	4.7914700849	Other	213	falling	0
E_FR_144	METROPOLE DE LYON	Rhone	45.6943	4.83447	Energy from waste	173	stable	86
E_FR_154	Sitom Nord-Isere (Nouvelle Unite)	Isere	45.596863656	5.2580880492	Energy from waste	159	falling	80
E_FR_162	Adisseo France Sas	Isere	45.360126935	4.7965114071	Chemicals (other)	147	growing	124
E_FR_167	Osiris Gie	Isere	45.357582945	4.7938891086	Power	140	falling	0
E_FR_177	Suez Rr lws Chemicals France	Isere	45.344309962	4.7968302236	Other	133	growing	0



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E_FR_213	SYTRAIVAL	Rhone	45.99	4.74	Energy from waste	116	stable	58
E_FR_218	Air Liquide France Industrie	Rhone	45.681824	4.851887	Chemicals (other)	113	growing	0
E_FR_223	Neovaly	Ain	45.8209358 54	4.91718888 62	Energy from waste	110	falling	55
E_FR_260	Eurofloat	Isere	45.3351184 65	4.79513463 73	Glass	99	growing	0
E_FR_262	Rhodia Operations	Rhone	45.8274599 27	4.84992914 3	Other	98	growing	0
E_FR_293	Polytechnyl Pi Belle-Etoile	Rhone	45.689014	4.842875	Chemicals (other)	83	falling	0
E_FR_295	Verallia Lagnieu	Ain	45.9089563 899999	5.34875404 2	Glass	82	falling	0
E_FR_304	Rhodia Operations	Rhone	45.7009706 25	4.85115935 47	Power	77	falling	0
E_FR_343	Step St-Fons Grand Lyon	Rhone	45.689698	4.848624	Other	19	stable	17
Total cluster						4 192		667



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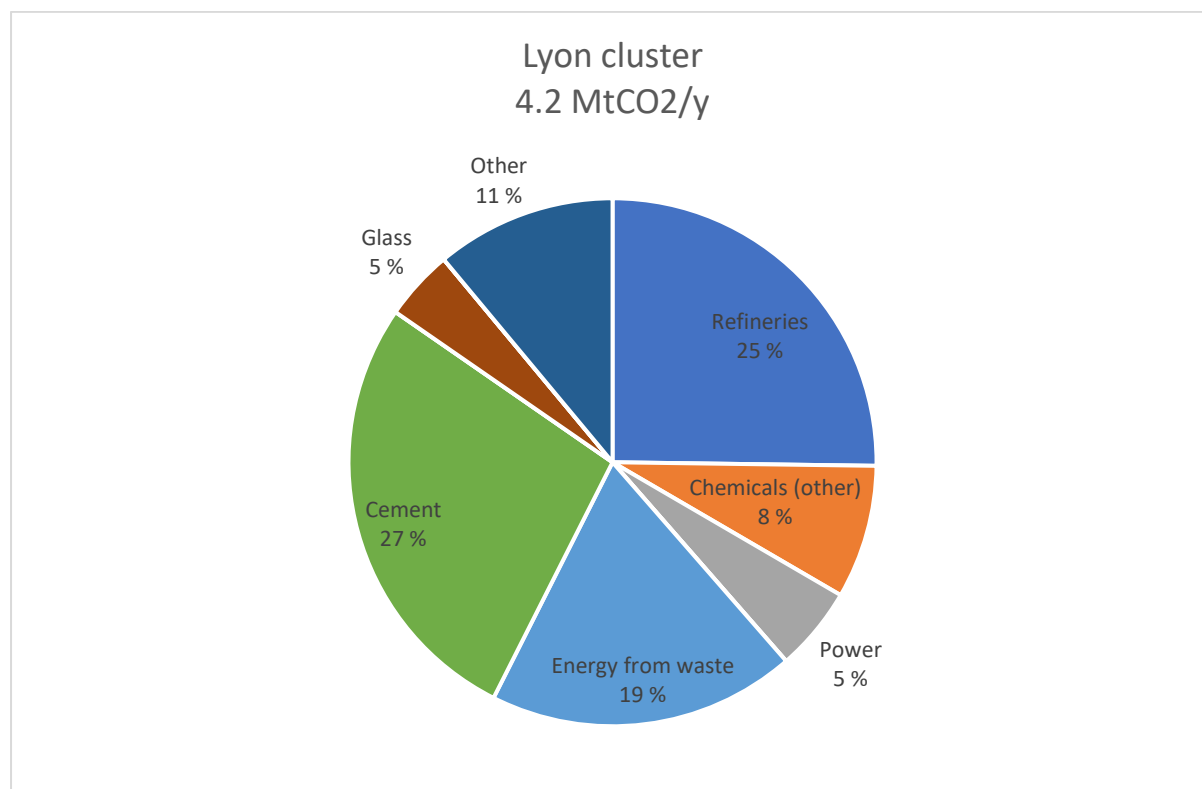


Figure 5.29: Emissions breakdown by industrial sector for the Lyon cluster

5.3.2.8 Montélimar site

Located halfway between Lyon and Marseille along the Rhone River close to Montélimar (see Figure 5.30), the Le Teil cement plant is an important carbon emitter in the region (679 kt/y). Located on the route from Lyon to Marseille, this site could be linked to a CO₂ transport network and become part of potential value chains. Besides, Holcim’s project to develop CCU (carbon capture to produce e-methanol) on this plant has been selected for EU Innovation Fund⁹.

⁹ https://www.holcim.com/sites/holcim/files/2023-07/20230714_press-holcim_-_eu_innovation_fund_2023_en.pdf



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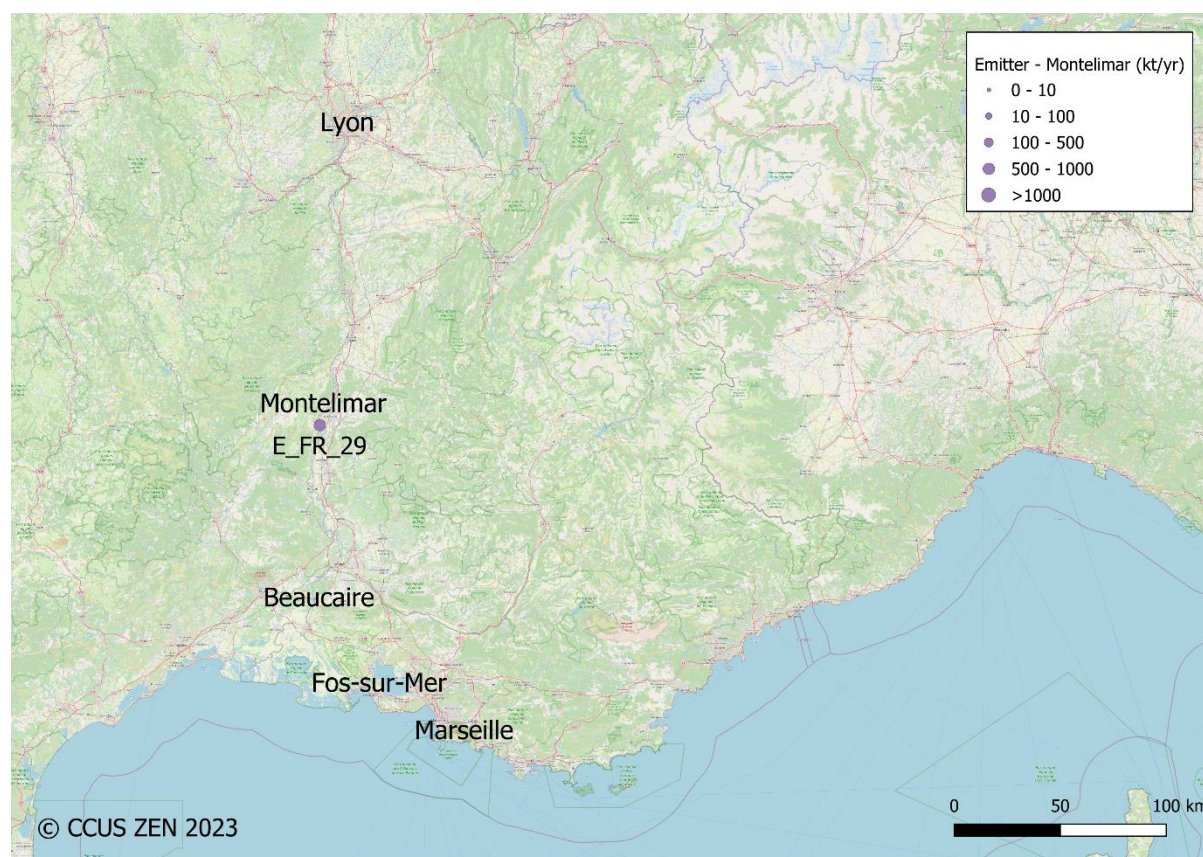


Figure 5.30: Location of the Montélimar site

Table 5-14 Montélimar site - Emitter site features

Emitter ID	Facility name	Department	Latitude	Longitude	Sector	CO ₂ emissions (kt/y)	Emissions trend	CO ₂ from biomass (kt/y)
E_FR_29	Lafarge Ciments	Ardeche	44.521740705	4.6898892977	Cement	679	growing	60

5.3.3 Storage potential

5.3.3.1 Ebro basin

The geological storage opportunities in the Ebro Basin are provided by onshore deep saline aquifers. Nine storage units in deep saline aquifers were identified, totalling a storage capacity of 321 Mt. There is one storage unit near the coastline, unit Reus (S_ES7) but the vast majority of the storage capacity is provided by units located tens to more than 100 km from the coast where most of the CO₂ sources are located (Figure 5.31).



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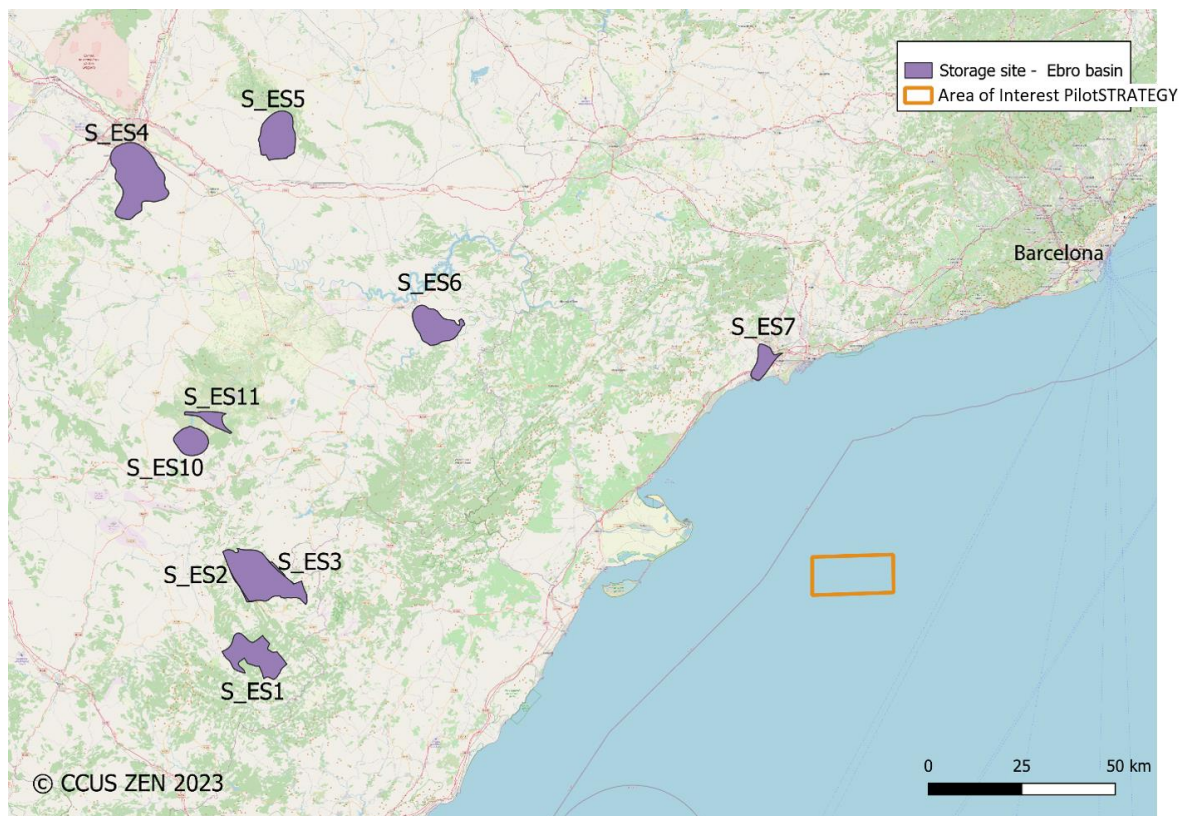


Figure 5.31: Location of the identified storage units in the Ebro basin, Spain



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Table 5-15: Storage sites - Northeastern Spain

Storage ID	Name	Type	On/offshore	Capacity mean (Mt)	SRL level
S_ES7	Reus	Aquifer	Onshore	21.03	1
S_ES5	Monegrillo	Aquifer	Onshore	24.84	1
S_ES3	Maestrazgo 3	Aquifer	Onshore	103.43	1
S_ES2	Maestrazgo 2	Aquifer	Onshore	21.82	1
S_ES1	Maestrazgo 1	Aquifer	Onshore	12.76	1
S_ES4	Lopin	Aquifer	Onshore	29.01	1
S_ES6	Caspe Mayals	Aquifer	Onshore	41.99	1
S_ES10	Obon-Oliete B	Aquifer	Onshore	24.9	2
S_ES11	Obon-Oliete A	Aquifer	Onshore	41.77	2

The 321 Mt total capacity is very unevenly distributed between the storage units. A single storage unit, the Maestrazgo-3 (S_ES3) in the Buntsandstein Facies (SRL1), provides 103 Mt capacity. Within the Maestrazgo structure there are two other storage units (Maestrazgo-1 S_ES1 and Maestrazgo-2 S_ES2) that add another 34.6 Mt of storage capacity.



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Additional storage site, not mapped in Ringstad (2023), could be the offshore reservoir studied in the ongoing H2020 PilotSTRATEGY project (Fleury, 2023a; Fleury, 2023b). However, few public information is available. The area of interest is shown on Figure 5.32. The targeted reservoir is located in the upper Miocene Castellón Sandstones, which runs from approximately 1600 m to 1900 m, overlain by the Ebro shales. Analysis of neighbour wells data predicted promising properties for reservoir and sealing. Though, no capacity estimate is available at this stage.

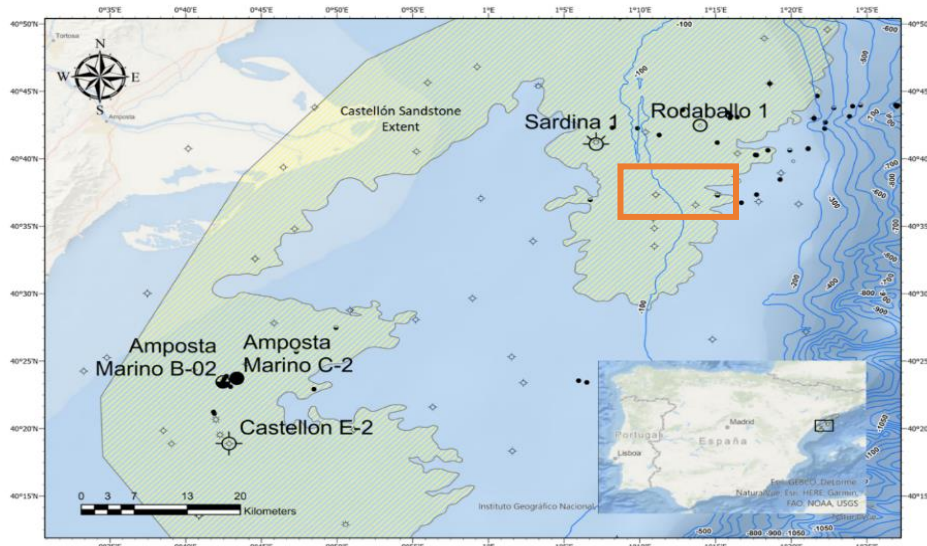


Figure 5.32: Location of the Area of Interest studied for offshore storage in PilotSTRATEGY project. From Fleury, 2023.

5.3.3.2 Southern France

Identified storage potential in Southern France is located in two distinct areas. Around the Rhone delta, 4 structures in deep saline aquifers lie at a distance of 40 to 60 km from Fos (S_FR1, S_FR2, S_FR3, S_FR4). The other storage units are depleted hydrocarbons fields located in the Aquitain Basin, 350 to 450 km west from Fos.

Data about the storage structures in Rhone delta come from the VASCO project which carried out a screening of a vast area around Marseille, onshore and near offshore. They identified targets in Upper Jurassic carbonate-reservoirs in “structural horst” (Grataloup et al., 2012).

There is a rising interest from the Fos industrial cluster for an offshore option for CO₂ storage. The Jurassic Formation, targeted onshore in the VASCO project, seems to be present offshore outside of protected areas and in favorable conditions for dense phase CO₂ storage. However, no public data on offshore potential is available.



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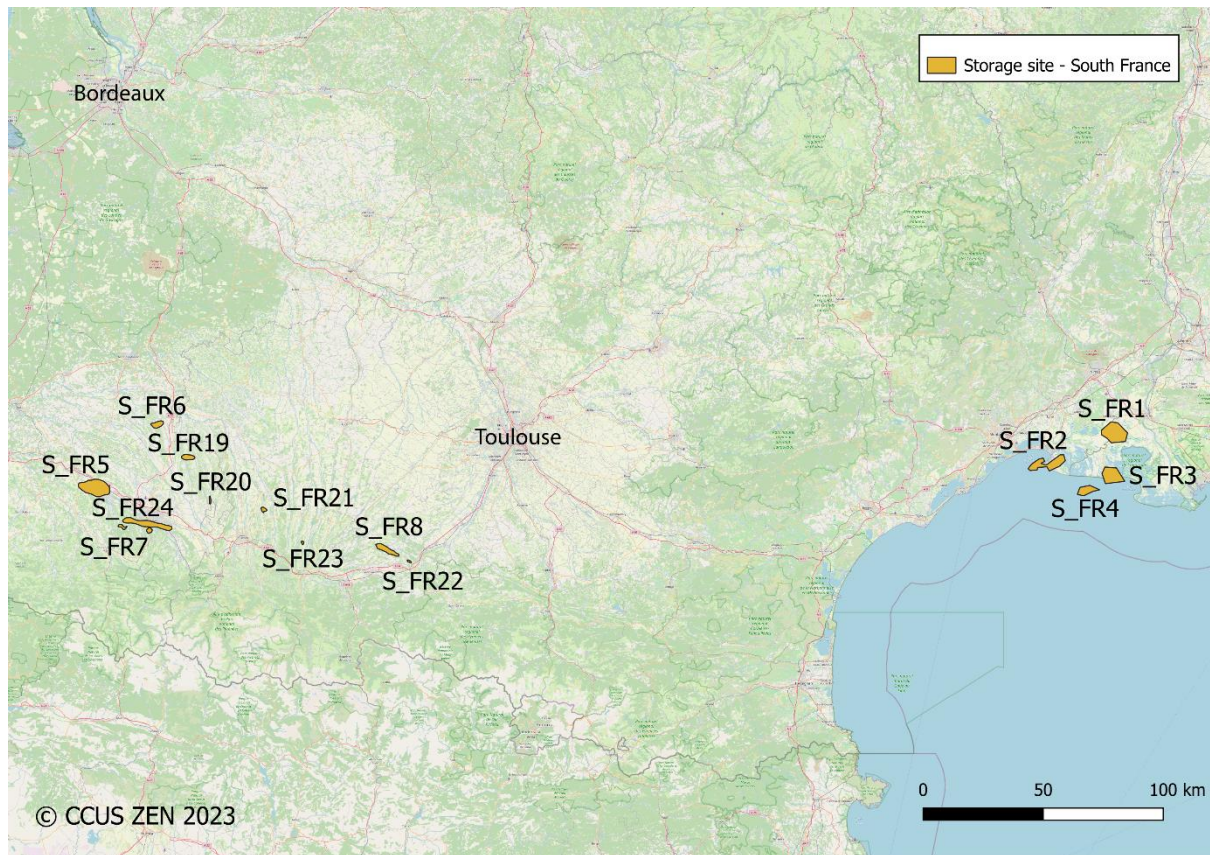


Figure 5.33: Location of the identified storage units in Southern France



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Table 5-16: Storage sites - Southern France

Storage ID	Name	Type	On/offshore	Capacity mean (Mt)	SRL level
S_FR1	Haut d'Albaron	Aquifer	Onshore	34	2
S_FR2	Structure de Mas-de-Madame	Aquifer	Onshore	37	2
S_FR3	Structure de Saintes-Maries-de-la-Mer	Aquifer	Onshore	14	2
S_FR4	Structure de Cicendele	Aquifer	Onshore	1	2
S_FR5	Lacq	Hydrocarbon field	Onshore	366,65	3
S_FR6	Pecorade	Hydrocarbon field	Onshore	13,04	3
S_FR7	Meillon 2	Hydrocarbon field	Onshore	1,84	3
S_FR8	St-Marcet-Proupiary	Hydrocarbon field	Onshore	6,28	3
S_FR19	Vic-Bilh	Hydrocarbon field	Onshore	23,61	3
S_FR20	Lagrange	Hydrocarbon field	Onshore	15,92	3
S_FR21	Laméac	Hydrocarbon field	Onshore	2,36	3
S_FR22	Auzas	Hydrocarbon field	Onshore	0,55	3
S_FR23	Bonrepos-Montastruc	Hydrocarbon field	Onshore	0,93	3
S_FR24	Meillon 1	Hydrocarbon field	Onshore	5,11	3

5.3.4 The Spain offshore value chain (selected for WP3)



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The Spain offshore value chain proposed by CCUS ZEN considers an offshore storage in the Ebro basin to store the emissions from the Tarragona and Barcelona clusters, and from the French clusters as well. Previous H2020 STRATEGY CCUS project already studied the development of onshore scenarios, where the Tarragona and Barcelona emissions were stored in the Reus unit (close to Tarragona) and the Maestrazgo unit (larger capacities) (Coussy, 2021). Ongoing H2020 PilotSTRATEGY is carrying out the characterization of the storage resource for a CO₂ storage pilot in the Lopin formation, in the area of Zaragoza (Rubio, 2022). The Spain offshore value chain is then complementary to past and current projects. Besides, developing on offshore storage in Ebro basin is prone to foster development of CCUS in Spain, at commercial scale.

The storage site considered for this value chain is the one studied in the PilotSTRATEGY project. Carbon dioxide would be captured at the Tarragona, Vilafranca, Barcelona, Fos-Marseille and Lyon clusters, and at Alcanar and Montelimar standalone emitters. In each cluster, all the flow would be collected in a hub and then transported through a trunk line. Transport from the Tarragona cluster to the storage site could be either by offshore pipeline (option A) or by ship (option B), as the distance is short, around 50 km. Transport from Barcelona and Fos ports would be shipping to the storage site or to Tarragona port, depending on the option. Transport from the Vilafranca cluster to Tarragona port would be by pipeline. In France, from Lyon to Fos, transport along the Rhone River could be by pipelines, as there are currently unused oil pipelines on this route, which could be repurposed for CO₂ transport (Coussy, 2021). The Montelimar cement plant could link to the Lyon-Fos pipeline. Table 5-17 recapitulates the features of the value chain.

Table 5-17 Main features of the Ebro offshore value chain

Value chain	Cluster(s)	Annual CO ₂ emissions (kt/y)	Storage site(s)	On/offshore	Capacity	Distance (km)	Transport scenario A	Transport scenario B	Comments
Ebro offshore	Tarragona cluster	5,387	Pilot STRATEGY Ebro offshore	Offshore	nn	57	offshore pipeline	ship to storage	
	Barcelona cluster	4,721				100	ship to Tarragona	ship to storage	
	Alcanar	885				100	-	ship to storage	
	Vilafranca cluster	1,061				50	pipeline to Tarragona	pipeline to Tarragona	



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	Lyon cluster	4,192			280	pipeline to Fos	pipeline to Fos	repurpose oil pipeline
	Montélimar	679			140	pipeline to Fos	pipeline to Fos	Via Lyon-Fos pipeline
	Fos-Berre cluster	16,049			450	ship to Tarragona	ship to storage	
	TOTAL	32,974			-	-	-	

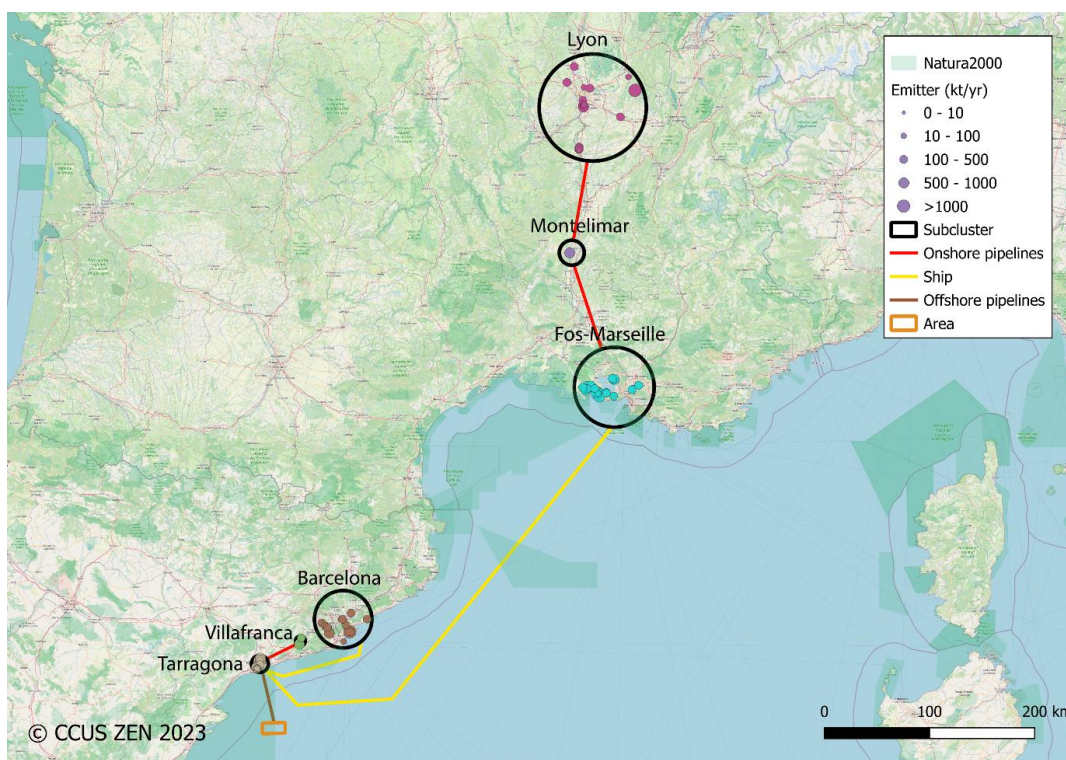


Figure 5.34 The Spain offshore scenario - Option A



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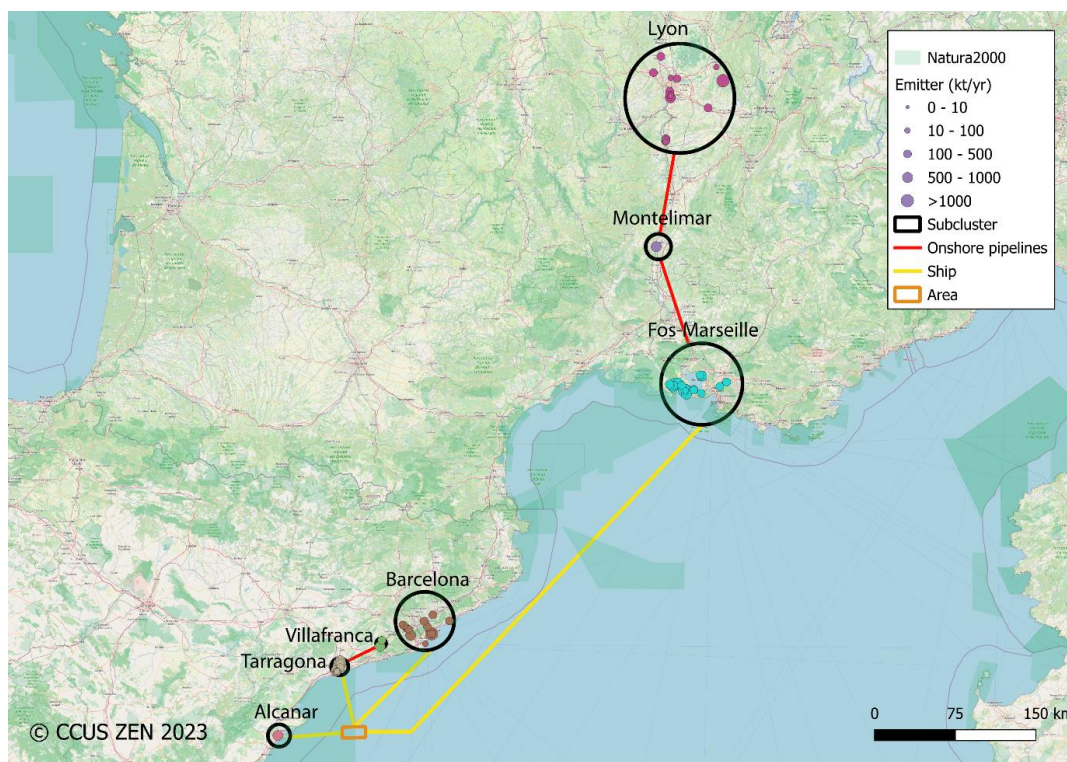


Figure 5.35 The Spain offshore scenario - Option B

Marseille is a region with increased CCU potential: One of the first Power-to-gas installations are already operating at demo scale within the Jupiter1000 project or the HYNOVERA project targeting liquid fuels for the transport sector. Close to Lyon, the Hynovi project aims to produce methanol for captured CO₂. Also in the Rhône Valley, the project eM-Rhone recently selected by the Innovation fund aims at producing CO₂-based renewable methanol for the transport sector. In Spain, CCU projects are concentrated mostly in the central and western regions. However, enabler projects for the production of renewable hydrogen like the T-HYNET project in Tarragona coupled with the emissions of the cluster indicate attractive perspectives for CCU applications also in the Eastern part of the country.

5.3.5 The Beaucaire value chain (selected for WP3)

The screening carried out in the previous sections showed a high number of emitters around the Rhone delta area, but small potential storage capacities, with low maturity. Indeed, accommodating emissions from the whole Fos industrial clusters will require high storage capacities, that were not identified in the region yet. Further exploration of the region's potential, especially onshore, would greatly benefit to the deployment of CCUS in the Fos region.

Meanwhile, a local value chain could be developed in the Beaucaire area, see Table 5-18 and Figure 5.36:



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- Capture CO₂ from the two plants of the Beaucaire cluster, in total 1.17 Mt/y;
- Store into the S_FR1 storage unit, which presents a 34 Mt capacity (SRL 2);
- Transport CO₂ via a pipeline (the distance is around 30 km, as crow flies)

Development of CO₂ storage and transport in this area could be challenging due to protected areas around. However, such a project could allow to store the local emissions for 30 years.

Table 5-18 Main features of the Beaucaire value chain

Value chain	Cluster(s)	Annual CO ₂ emissions (t/y)	Storage site(s)	On/offshore	Capacity (Mt)	Distance (km)	Transport scenario
Beaucaire	Beaucaire cluster	1,168,000	S_FR1	Onshore	34	27	pipeline

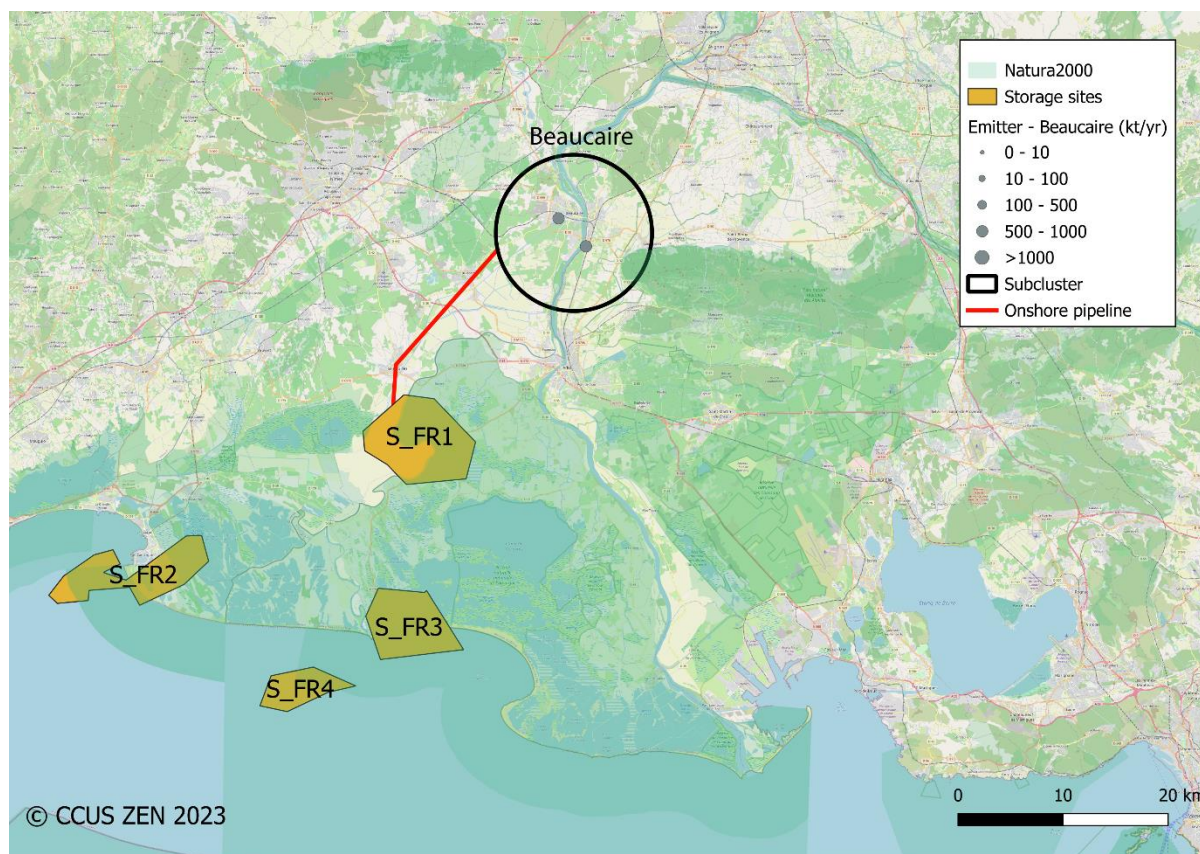


Figure 5.36 Beaucaire value chain - Southern France



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6 Conclusion

Based on the mapping work carried out in Deliverable D1.1 (Ringstad et al. 2023), the current report aimed at identifying promising clusters, hubs, and CCUS value chains in the two regions to be explored by CCUS ZEN: the Baltic Sea region and the Mediterranean Sea region. A first screening of the mapped information, enabled to identify promising emissions clusters, as well as storage options for the captured emissions, and transport and intermediate storage solutions to connect the industrial cluster(s) with the potential storage site(s). This led to the definition of several promising value chains, as showed in Figure 6.1.

A list of eight CCUS value chains are recommended for further analyses in WP3. These were selected based on the emission clusters potential (including volume of emissions, distance between sites, capture projects), on the geological storage potential (including existing studies, storage capacities, potential for development), and also on the ability to bring out new regions and potential PCI compared to those where projects are already on tracks. The potential for carbon utilisation is also tackled, looking at the existing projects around the value chains. The recommended value chains are listed in Table 6-1. Four value chains are located in the Baltic region and four in the Mediterranean region.

In next step of the CCUS ZEN project, the identified value chains will be further analysed with integration of prospective CO₂ uses, development of CCUS value chain scenarios and technical modelling. Based on a SWOT analysis, the most promising CCUS value chain in each region will be selected for further development, including local business models.



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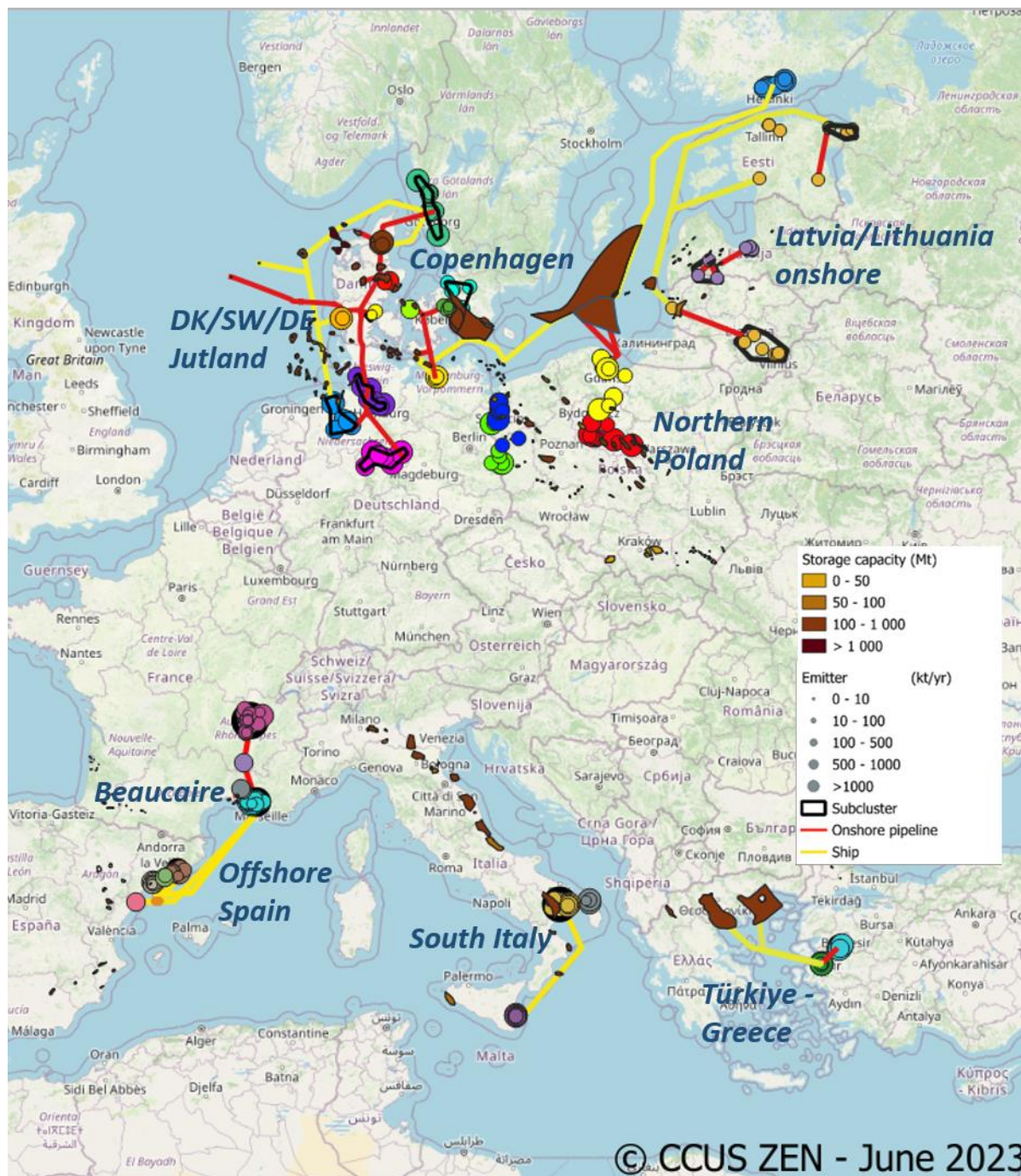


Figure 6.1: Location of identified CCUS value chains in the CCSU ZEN regions (Baltic sea and Mediterranean sea).



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Table 6-1 Identified value chains for further analysis in WP3

Value chain name	Industrial clusters	Total clusters CO2 emissions, t/y	Storage sites	On/offshore	Total capacities, Mt	Distance emission to storage, km	Transport option(s)
Baltic Lat-Lit-Onshore (a+b)	Baltic Lat-Lit	4,253,069	North Blidene, Blidene and Dobele	Onshore	403	9-150	Pipeline
DE DK SWE Jutland network	Bremen, Hannover, Hamburg, Fredericia, Aarhus, Aalborg, Esbjerg, Gothenburg	42,621,306	S_DK1 S_DK10 Jammerbugt Inez Bifrost Greensand Lisa S_DK7	Onshore Offshore	1,734	750	Pipeline Ship
Copenhagen	Rostock Cluster, Copenhagen Cluster, North-western Zealand Cluster, South Sweden Cluster	5,904,457	S_DK6 S_DK2 Stenlille	Onshore Offshore	657	115	Pipeline Ship
North Poland onshore	Kuyavia-Mazovia	13,625,000	S_PL38 S_PL24 S_PL10 S_PL22 S_PL21	Onshore	1025	5-70	Pipeline
Soma - İzmir Aliağa - Prinos	Soma, İzmir- Aliağa	58,000,000	S_GR6	Offshore	1000	120-360	Pipeline Ship
Ebro offshore	Taragona, Barcelona, Fos-Marseille, Lyon	32,974,000	Castellon	Offshore	TDB	50-450	Pipeline Ship



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Beaucaire	Beaucaire	1,168,000	S_FR2	Onshore	37	27	Pipeline
Southern Italy	Taranto, Brindisi, Priolo Garalo	26,506,74	S_IT8	Onshore	344 - 1376	50 - 450	Pipeline and ship

7 References

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8 Appendix



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Table 8-1 CCUS projects in Denmark

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
C4 – Carbon Capture Cluster Copenhagen	Demonstration	ARC, Argo, BIOFOS, Copenhagen Malmö Port (CMP), CTR, HOFOR, Vestforbrænding, VEKS and Ørsted	CCUS project aimed at reducing CO ₂ emissions by ~3Mt/yr from large power plants in the Copenhagen metropolitan area with geological storage options in the Danish North Sea.	3	2025
Project Bifrost	Demonstration	TotalEnergies, Noreco, Nordsøfonden, Ørsted, The Technical University of Denmark (DTU), BlueNord	CCS research and demonstration project to evaluate the potential for CO ₂ transport and storage at the Harald field in the Danish North Sea.	3	Unknown
Kredsløb Power CCS project	Commercial	Kredsløb	CCS project aiming to capture and sequester 450ktCO ₂ /yr from Kredsløb's multi-fuelled power station in Lisbjerg.	0.45	Unknown
Project Ruby	Commercial	Unknown	CCS project aiming to store up to 10MtCO ₂ /yr in the Danish subsurface onshore.	1	2027
EU2NSEA (Copenhagen)	Commercial	Equinor, Fluxys, Wintershall Dea	CCS project aimed at developing a large-scale, cross-border, pan-Europe CO ₂ transport and storage infrastructure covering 8 member states.	Unknown	2029
In Design					
Project Norne	Commercial	Fidelis New Energy, ROSS Energy, Gas Storage Denmark, Rambøll, Port of Aalborg, Port of Kalundborg	CCUS project aiming to develop a CO ₂ transport & storage network utilising existing natural reservoirs.	4	2026



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Deliverable D1.2 Identification of promising CCUS value chains



Greenport Scandinavia	Commercial	INEOS Energy, Wintershall DEA, Port of Hirtshals, Biocarb Solution, Evida, Greenport North, Aalborg Portland	CCS project aiming to develop a CO2 transport & storage project that aims to establish the Port of Hirtshals as an intermediate CO2 storage and shipping hub for domestic and international sources of CO2.	1.5	2026
Aalborg Portland (CORT) CCS Project	Pilot	Cementir, Aalborg University, Ørsted, Pentair	CCS project with small-scale pilot plant on Cementir's Aalborg Portland cement plant capturing 1t/day, with the potential to capture up to 400kt/yr by 2030.	0.4	2023
Glostrup EfW project	Commercial	I/S Vestforbrænding, Technip Energies	CCS project aiming to capture at least 450ktCO2/yr from the I/S Vestforbrænding EfW facility in Glostrup.	0.45	2026
In Build					
Ørsted Kalundborg Hub	Commercial	Ørsted, Northern Lights JV	BECCS project with carbon capture at Ørsted's wood chip-fired Asnæs Power Station in Kalundborg in western Zealand and Avedøre Power Station's straw-fired boiler in the Greater Copenhagen area.	0.4	2025
Fortum Nyborg CCU Project	Pilot	Fortum Recycling & Waste, Aker Carbon Capture	CCS pilot project to test Aker's special amine technology on the flue gas from Fortum's high-temperature hazardous industrial waste incineration plant.	0	Unknown
Tønder Biogas	Commercial	Copenhagen Infrastructure Partners, Ammongas, European Energy	CCU project based on a CO2 capture facility on the ENVO Biogas plant in Tønder.	0	2025
Stenlille CO2 Storage Project	Demonstration	Gas Storage Denmark	CCS demonstration project investigating the potential for Danish onshore CO2 storage.	0.4	2025
Pilot					
Project Greensand	Demonstration	INEOS Energy, Wintershall Dea, Maersk Drilling, GEUS	CCS project aimed at repurposing legacy oil and gas infrastructure for CO2 geological storage off the coast of Denmark.	1.5	2025



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Table 8-2 CCUS projects in Sweden

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
Lysekil Refinery CCS	Commercial	Preem	CCS project aiming to capture ~1.4MtCO ₂ /yr from low-carbon H ₂ production at the Preem Lysekil refinery.	1.4	2027
Norvik Infrastructure CCS East Sweden (NICE)	Commercial	Ports of Stockholm, Stockholm Exergi, Mälarenergi, Söderenergi, Vattenfall, Heidelberg Materials, Nordkalk, Plagazi	CCS project aiming to develop a strategic regional hub for CO ₂ capture, interim storage, and transportation at the new port of Stockholm Norvik in eastern Sweden	Unknown	Unknown
Cinfracap	Commercial	Nordion Energi, Göteborg Energi, Renova, Gothenburg Port Authority, Preem, St1	CO ₂ transport & storage project in development since 2022 that aims to establish the Port of Gothenburg as an intermediate CO ₂ storage and shipping hub for large point sources of CO ₂ .	4	Unknown
Igelsta BECCS CHP	Commercial	Söderenergi	BECCS project aiming to capture up to 500kt biogenic CO ₂ /yr from the Söderenergi Igelsta biomass CHP plant in Södertälje.	0.5	2029
In Design					
Beccs Stockholm	Commercial	Stockholm Exergi	BECCS project aiming to retrofit a carbon capture plant to Stockholm Exergi's Värtan CHP plant which incinerates wood waste.	0.8	2026
Skellefteå Kraft BECCS	Commercial	Skellefteå Kraft AB	BECCS project aiming to capture biogenic CO ₂ from the Skellefteå Kraft biomass power plant.	Unknown	Unknown



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Deliverable D1.2 Identification of promising CCUS value chains



Slite cement plant	Commercial	HeidelbergCement	CCS project aiming to capture up to 1.8MtCO ₂ /yr from the Slite cement plant on the island of Gotland.	1.8	2030
FlagshipTWO	Commercial	Liquid Wind, Sundsvall Energi	CCUS project aiming to produce e-methanol, for use as a green maritime fuel, from renewable H ₂ and biogenic CO ₂ captured from the Korstaverket EfW plant in Sundsvall.	0.1	2026
FlagshipTHREE	Commercial	Liquid Wind, Umeå Energi	CCUS project aiming to produce e-methanol, for use as a green maritime fuel, from renewable H ₂ and biogenic CO ₂ captured from the Däva cogeneration EfW/biomass plant in Umeå.	0.1	2026
Project Air	Commercial	Perstorp, Uniper	CCU project aiming to produce sustainable methanol, for use as a low-carbon chemical feedstock, from renewable H ₂ provided by Uniper and CO ₂ - including biogenic CO ₂ - captured from across Perstorp's operations at its chemicals manufacturing plant in Stenungsund.	0	2026
In Build					
FlagshipONE	Commercial	Ørsted, Övik Energi, Siemens Energy, Carbon Clean, Topsoe	CCU project aiming to produce e-methanol, for use as a green maritime fuel, from renewable H ₂ and biogenic CO ₂ captured from the Hörneborgsverket biomass CHP plant in Örnsköldsvik.	0	2025
SigmaRoc lime kiln CCS project	Pilot	SigmaRoc plc, Aqualung Carbon Capture AS	CCUS project aiming to capture CO ₂ from Nordkalk's lime kiln process emissions.	Unknown	2023



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Table 8-3 CCUS projects in Finland

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO2/yr)	Project intended start date
In Planning					
SHARC	Commercial	Neste	CCUS project aiming to decarbonise the Porvoo refinery via H2 production (blue and green).	0.4	2025
St1 Power-to-Methanol Lappeenranta project	Pilot	St1, Finnsementti, Aker Carbon Capture	CCU commercial-scale pilot project aiming to develop a blueprint for a scalable synthetic methanol production process.	0	2026
Operational					
Riihimäki EfW CCU Project	Pilot	Fortum	CCU pilot project running in 2022 aimed at capturing CO2 from the Riihimäki EfW plant and combining it with H2 to produce methane, which could be used as a chemical feedstock.	0	2022



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Table 8-4 CCUS projects in Germany

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO2/yr)	Project intended start date
H2morrow	Demonstration	thyssenkrupp Steel Europe, Equinor, Open Grid Europe	Joint feasibility study to investigate potential for blue hydrogen production at thyssenkrupp's steel plant in Duisburg and permanent offshore geological storage of the resulting CO2 emissions.	Unknown	2027
CO2 liquefaction and buffer storage in Wilhelmshaven	Pilot	European Energy Logistics Park	Project aimed at investigating and piloting an 'open access' CO2 liquefaction and buffer storage infrastructure for up to 1MtCO2/yr in the Energy Park in Wilhelmshaven, Germany.	1	2026
CO2nnectNow	Commercial	Wintershall Dea, HES Wilhelmshaven Tank Terminal	CO2 transport and storage hub project with onward transport via 900km pipeline to permanent geological storage facilities in the Danish and Norwegian North Sea areas.	8	2028
Bremen CO2 capture and storage hub	Commercial	CO2 Management AS (CO2M), bremenports GmbH & Co. KG	CCUS project aiming to develop a CO2 transport and temporary storage hub at the port in Bremen.	Unknown	2027
CO2-Netz	Commercial	Open Grid Europe GmbH, Tree Energy Solutions (TES)	CCUS project aimed at developing a pan-Germany CO2 transport pipeline infrastructure connecting sources of CO2 with temporary storage and transportation hubs, whereby CO2 will either be shipped onwards for permanent geological storage or used for other industrial purposes as part of a circular carbon economy.	Unknown	Unknown
Westküste 100	Demonstration	EDF Germany, Holcim Germany, OGE, Ørsted, Raffinerie Heide, Stadtwerke Heide, thyssenkrupp Industrial Solutions, Thüga, Westküste University of Applied Science	CCU project aimed at capturing and reusing CO2 from cement production processes.	Unknown	2025



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Deliverable D1.2 Identification of promising CCUS value chains



C Zero	Commercial	Unknown	CCS project aimed at developing the Port of Duisburg as a CO2 hub providing temporary storage, shipping up the Rhine to the Port of Rotterdam before onward shipping to North Sea storage facilities.	3	2030
BlueHyNow	Commercial	Wintershall Dea, Nord-West Oelleitung (NWO)	CCS project aimed at developing a low-carbon H2 production facility, whereby H2 is produced from natural gas via steam methane reforming.	Unknown	2028
H2GE Rostock	Commercial	VNG Handel & Vertrieb GmbH, Equinor	CCUS project aimed at establishing a low-carbon H2 and CO2 hub at the the Port of Rostock.	2	2029
EU2NSEA (Wilhelmshaven)	Commercial	Equinor, Fluxys, Wintershall Dea	CCS project aimed at developing a large-scale, cross-border, pan-Europe CO2 transport and storage infrastructure covering 8 member states.	Unknown	2029
EU2NSEA (Rostock)	Commercial	Equinor, Fluxys, Wintershall Dea	CCS project aimed at developing a large-scale, cross-border, pan-Europe CO2 transport and storage infrastructure covering 8 member states.	Unknown	2029
In Design					
LEILAC2 Demonstration Plant	Demonstration	HeidelbergCement, Cimpor, Lhoist, IKN, Calix, Certh, Politecnico di Milano, BGR, GSB-RBINS, Engie Laborelec, Portos	CCUS project aimed at building a demonstration plant that will separate 20% of a regular plant's process emissions - around 100 ktpa of CO2.	0	2023
CAP2U	Commercial	Heidelberg Materials, Linde	CCU project aimed at capturing ~70ktCO2/yr from cement manufacturing process, to be used in the food and chemical sectors.	0	2025
Carbon2Business project	Pilot	Holcim, Thyssenkrupp Industrial Solutions AG, Linde	CCU project aimed at capturing 1.2MtCO2/yr from the cement manufacturing process at the Holcim cement plant in Lägerdorf, to be converted into methanol or used as a feedstock for the chemicals sector.	0	2029
CEMEX Rüdersdorf cement plant	Commercial	Cemex, CarbonClean, KBR	CCU project aimed at capturing CO2 from cement production process emissions at Cemex' Rüdersdorf cement plant, to be combined with green H2 to produce synthetic hydrocarbons that can be used in other industries.	0	2026



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Deliverable D1.2 Identification of promising CCUS value chains



WH2V	Commercial	Tree Energy Solutions (TES)	CCUS project aimed at developing a green port hub infrastructure at the Port of Wilhelmshaven for the handling and temporary storage of CO2 and green synthetic methane.	10	2029
In Build					
Holcim Cement Höver Project	Commercial	Cool Planet Technologies (CPT), Holcim (Germany) GmbH	CCUS project aimed at capturing CO2 from flue gases at Holcim's Höver cement plant.	Unknown	2023
ACCSESS HeidelbergCement	Pilot	HeidelbergCement	CCS project - part of the larger 4-year ACCSESS R&D project - aimed at piloting and reducing the costs of CCS technology on cement plant processes.	Unknown	2025
EEW Hannover EfW project	Demonstration	EEW, Capsol Technologies	CCUS project aimed at demonstrating Capsol Technologies' CapsolGo® capture technology on the EEW EfW plant in Hanover.	Unknown	2023
Pilot					
Heyden Pilot Plant	Pilot	E.On, Cansolv	Modular pilot plant provided by Cansolv to test capture from 20,000 m3/h flue gas slipstream at E.On's Heyden power station.	0	2009
Wilhelmshaven Pilot Plant	Pilot	E.ON Kraftwerke, Fluor	Pilot plant at E.On's Wilhelmshaven power station using slip-stream (3.5MW equivalent) to demonstrate Fluor's Econamine FG+ scrubbing technology.	0	2012
EnBW Pilot Plant	Pilot	EnBW	Pilot plant testing Aker's solvent systems (and others?) attached to EnBW's Heilbron CHP plant.	0	2011
Herne Pilot Plant	Pilot	Evonik and subsidiaries Steag, Creavis	Small glass pilot unit testing novel amine and amino acid absorbents on flue gas from Herne coal-burning CHP plant.	0	2012
Operational					



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Deliverable D1.2 Identification of promising CCUS value chains



Rohrdorf cement plant	Pilot	ANDRITZ, Rohrdorfer	CCU project aimed at capturing ~500ktCO ₂ /yr (1.5kt/day) from cement manufacturing process and converted into formic acid, to be used as a feedstock in the hygiene, food and pharmaceutical sectors.	0	2022
Holcim Cement Beckum CCUS Research Project	Pilot	Holcim Germany, Thyssenkrupp Uhde, Technische Universität Berlin	CCU project aimed at capturing CO ₂ from cement production process emissions at Holcim's Beckum cement plant.	0	2023



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Table 8-5 CCUS projects in Estonia

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
CCU-4-PCC	Commercial	Ragn-Sells, Eesti Energia AS, Estonian Enterprise, Archimedes Foundation, Tarkett, Gealan	CCU project aimed at capturing 250ktCO ₂ /yr from a shale oil power plant and combining it with the residual oil shale ash to produce low-carbon calcium carbonate.	0	Unknown
Enefit CCU project	Commercial	Eesti Energia, Tallinn University of Technology	CCU project aimed at capturing CO ₂ emissions from pyrolysis power plants using oil shale rock and waste plastics and tyres as feedstock.	0	2025

Table 8-6 CCUS projects in Latvia

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
CCS BALTIC CONSORTIUM	Commercial	Klaipēdos Nafta AB	CCS project aimed at developing a multimodal liquid CO ₂ (LCO ₂) export/import at Klaipēda with a maximum handling capacity of 4MtCO ₂ /yr.	4	2030
Latvenergo CCS project		Latvenergo	CO ₂ capture from the natural gas power plants and storage in Dobeles structure	0.9	2030



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Deliverable D1.2 Identification of promising CCUS value chains



Schwenk Latvia CCS project		Schwenk Latvia	CO2 capture from the cement plant/plants and storage in North Blidene or Dobeles structures	0.7	2030
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Table 8-7 CCUS projects in Lithuania

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
ECO2CEE	Commercial	Air Liquide Polska Sp., Zarzad Morskiego Portu Gdansk S.A., Polski Koncern Naftowy ORLEN S.A., Lafarge Cement S.A., Sogestran Shipping	CCS project aimed at developing the Port of Gdańsk as a CO ₂ hub providing temporary storage before onward shipping to North Sea storage facilities, and others should they be developed, e.g. Baltic Sea.	9	2026
CCS BALTIC CONSORTIUM	Commercial	Klaipėdos Nafta AB	CCS project aimed at developing a multimodal liquid CO ₂ (LCO ₂) export/import at Klaipėda with a maximum handling capacity of 4MtCO ₂ /yr.	4	2030



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Table 8-8 CCUS projects in Poland

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
Speculative					
CHP station in Przemyśl	Commercial	Polskie Górnictwo Naftowe i Gazownictwo S.A. (Polish Oil Mining and Gas Extraction – PGNiG)	CCUS project aimed at capturing CO ₂ from a new gas-fired CHP plant in Przemyśl and potentially injecting it into nearby depleted gas reservoirs for enhance gas recovery.	Unknown	2022
Kozienice power station	Commercial	Grupa Energetyczna Enea SA	Prospective CCUS project aimed at capturing CO ₂ from the Kozienice coal-fired power station.	Unknown	Unknown
Opole power station	Commercial	Polska Grupa Energetyczna (PGE)	Prospective CCUS project aimed at capturing CO ₂ from the Kozienice coal-fired power station.	Unknown	Unknown
Jaworzno power station	Commercial	Tauron Polska Energia	Prospective CCUS project aimed at capturing CO ₂ from the Kozienice coal-fired power station.	Unknown	Unknown
Bełchatów power station	Commercial	Polska Grupa Energetyczna (PGE)	Prospective CCUS project aimed at capturing CO ₂ from the Kozienice coal-fired power station.	Unknown	Unknown
In Planning					
ECO2CEE	Commercial	Air Liquide Polska Sp., Zarząd Morskiego Portu Gdansk S.A., Polski Koncern Naftowy ORLEN S.A., Lafarge Cement S.A., Sogestran Shipping	CCS project aimed at developing the Port of Gdańsk as a CO ₂ hub providing temporary storage before onward shipping to North Sea storage facilities, and others should they be developed, e.g. Baltic Sea.	9	2026
In Build					



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Deliverable D1.2 Identification of promising CCUS value chains



Go4ECOPlanet project	Commercial	LafargeHolcim	CCS project aimed at capturing and permanently storing 100% of the CO2 emissions arising from cement production at the LafargeHolcim cement plant in Kujawy.	1	2027
ACCSESS Górażdże cement plant	Pilot	HeidelbergCement	CCS project - part of the larger 4-year ACCSESS R&D project - aimed at piloting a novel enzyme-based capture technology on cement plant processes.	Unknown	2025
Operational					
Borzecin Acid Gas Injection	Pilot	PGNiG SA (Polish Oil and Gas Mining)	Small sour gas separation plant with re-injection of CO2 and H2S directly into an aquifer close to the separation site.	Unknown	1996



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Table 8-9 CCUS projects in France

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
In Planning					
EU2NSEA (Dunkirk)	Commercial	Equinor, Fluxys, Wintershall Dea	CCS project aimed at developing a large-scale, cross-border, pan-Europe CO ₂ transport and storage infrastructure covering 8 member states.	Unknown	2029
PYCASO	Commercial	Terega SA	CCS project aimed at developing an industrial CO ₂ capture, transport and storage hub covering sites in south-western France (Bordeaux and Toulouse) and north-eastern Spain (Saragosse and Bilbao) and centred around geological storage in the Lacq basin in France.	3.4	2030
In Design					
K6 Program	Demonstration	Eqiom, Air Liquide	CCS project aimed at capturing ~0.8MtCO ₂ /yr from the cement production process at the Eqiom plant in Lumbres	0.8	2028
D'artagnan	Demonstration	Air Liquide	CCS project aimed at developing the Port of Dunkirk as a CO ₂ hub providing temporary storage before onward shipping to North Sea storage facilities.	4.4	2026
ECO2 Normandy	Demonstration	Air Liquide	CCS project aimed at developing the Port of Le Havre as a CO ₂ hub for the Seine basin industry cluster providing temporary storage before onward shipping to North Sea storage facilities	3	2028
CALLISTO	Commercial	Air Liquide France Industrie, Eni S.p.A.	CCS project aimed at developing a Mediterranean industrial CO ₂ capture, transport and storage hub covering sites in the south of France (Rhône Valley, Fos, Marseille) and north-eastern Italy (Marghera, Ferrara, Ravenna) and centred around geological storage in the Adriatic Sea as part of the Ravenna CCS/Hub project.	6.4	2027



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Deliverable D1.2 Identification of promising CCUS value chains



In Build					
CalCC	Demonstration	Air Liquide, Lhoist	CCS project aimed at capturing CO2 emissions from lime production - part of the cement production process - at Lhoist's Réty site.	0.6	2027
Pilot					
DMX Demonstration in Dunkirk	Pilot	ArcelorMittal, Axens, IFPEN, Total, ACP, Brevik Engineering, CMI, DTU, Gassco, RWTH and Uetikon	The project aims to have a full-scale 1.5MtCO2/yr CCS plant operational by around 2025, which will form the basis of a Dunkirk-North Sea CCS cluster by 2035 capable of storing 10MtCO2/yr.	1.5	2021
Operational					
Port-Jérôme Low-carbon Hydrogen - Cryocap	Commercial	Air Liquide	CCU project capturing ~100ktCO2/yr from certified low-carbon H2 production (steam methane reforming of methane), which is then conditioned to food grade standard and made available to industrial users, e.g. agri-food and water treatment.	0	2015



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Table 8-10 CCUS projects in Spain

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO2/yr)	Project intended start date
In Planning					
PYCASO	Commercial	Terega SA	CCS project aimed at developing an industrial CO2 capture, transport and storage hub covering sites in south-western France (Bordeaux and Toulouse) and north-eastern Spain (Saragosse and Bilbao) and centred around geological storage in the Lacq basin in France.	3.4	2030
CEMEX Alicante CCU Project	Commercial	Cemex, ETFuels	CCU project aimed at capturing ~450ktCO2/yr from the cement production process, which will then be made combined with green H2 to produce e-methanol.	0	Unknown
Green methanol - Meiga	Commercial	Iberdrola, Foresa	CCU project aimed at capturing biogenic CO2 from biomass power plants, to be combined with green H2 produced by new, purpose-built green H2 production plant to produce e-methanol.	0	Unknown
In Build					
ECCO2	Commercial	LafargeHolcim, Carbon Clean, Sistemas de Calor	CCU project aimed at capturing an initial ~70ktCO2/yr from the cement production process, which will then be made available to industrial users in the food/agricultural sector.	0	2023
Pilot					
Compostilla Phase I	Pilot	Endesa	Pilot plant complex including a 20MWth pulverized-coal oxyfuel boiler, a 15-30MWth circulating fluidised bed oxyfuel boiler, and a biomass gasifier.	0	2011
Operational					



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Deliverable D1.2 Identification of promising CCUS value chains



Neulicem CCUS project	Demonstration	FYM-HeidelbergCement, VOLBAS, Tecalia Research & Innovation	CCU 14-month R&D project aimed at demonstrating CO2 capture from flue gasses via mineralisation using alkaline waste such as steel slag.	0	2022
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Innovate



Table 8-11 CCUS projects in Italy

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
Colleferro Oxyfuel Demonstration	Demonstration	HeidelbergCement, LafargeHolcim	Project to establish ECRA oxyfuel technology at demonstration scale on cement kiln at HeidelbergCement's (Italcementi) Colleferro plant in Italy.	0	2020
AUGUSTA C2	Commercial	Buzzi Unicem Spa	CCUS project aimed at developing a 200ktCO ₂ /yr full-chain hub that is based around the Buzzi Unicem Augusta cement plant in Sicily and offshore CO ₂ storage in Greece as part of the Prinos CO ₂ Storage Project (see separate entry).	0.2	2029
In Design					
CALLISTO	Commercial	Air Liquide France Industrie, Eni S.p.A.	CCS project aimed at developing a Mediterranean industrial CO ₂ capture, transport and storage hub covering sites in the south of France (Rhône Valley, Fos, Marseille) and north-eastern Italy (Marghera, Ferrara, Ravenna) and centred around geological storage in the Adriatic Sea as part of the Ravenna CCS/Hub project.	6.4	2027
Tenaris CCU project	Commercial	Tenaris, Saipem, SIAD	CCU project aimed at capturing 30tCO ₂ /day (11kt/yr) from the gas-fired Tenaris Dalmine power plant serving the Tenaris steel plant, to be used in the food, drinks and metals processing sectors.	0	2025
In Build					
Ravenna CCS	Commercial	Eni, Snam	CCS project aimed at developing a CO ₂ transport and storage solution for industry in the Mediterranean region. CO ₂ will be imported from domestic and international sources to be permanently stored in the depleted Porto Corsini Mare Ovest gas field.	10	2022
Pilot					



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Deliverable D1.2 Identification of promising CCUS value chains



Brindisi Pilot Plant	Pilot	Enel	Pilot post-combustion capture test facility capturing 2.5t CO ₂ /hr from unit 4 of Enel's Federico II coal power plant. CO ₂ liquefied and stored in tanks for use in pilot storage facility under development by ENI/Stogit at a site in Cortemaggiore, northern Italy.	Unknown	2011
Operational					
Energy Dome CO ₂ Battery	Demonstration	Energy Dome	CCU initiative aimed at developing a global 'fleet' of CO ₂ batteries producing clean electricity in a closed-loop system.	0	2022

Table 8-12 CCUS projects in Greece

Project name	Scale	Project lead(s)	Project description	Injection capacity (MtCO ₂ /yr)	Project intended start date
Prinos CO ₂ Storage Project	Commercial	Energiean	CCS project aimed at developing a Mediterranean industrial CO ₂ capture, transport and storage hub servicing sites in/around Kavala in Greece with permanent geological offshore storage in the Prinos formation in the Aegean Sea.	1	2025



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