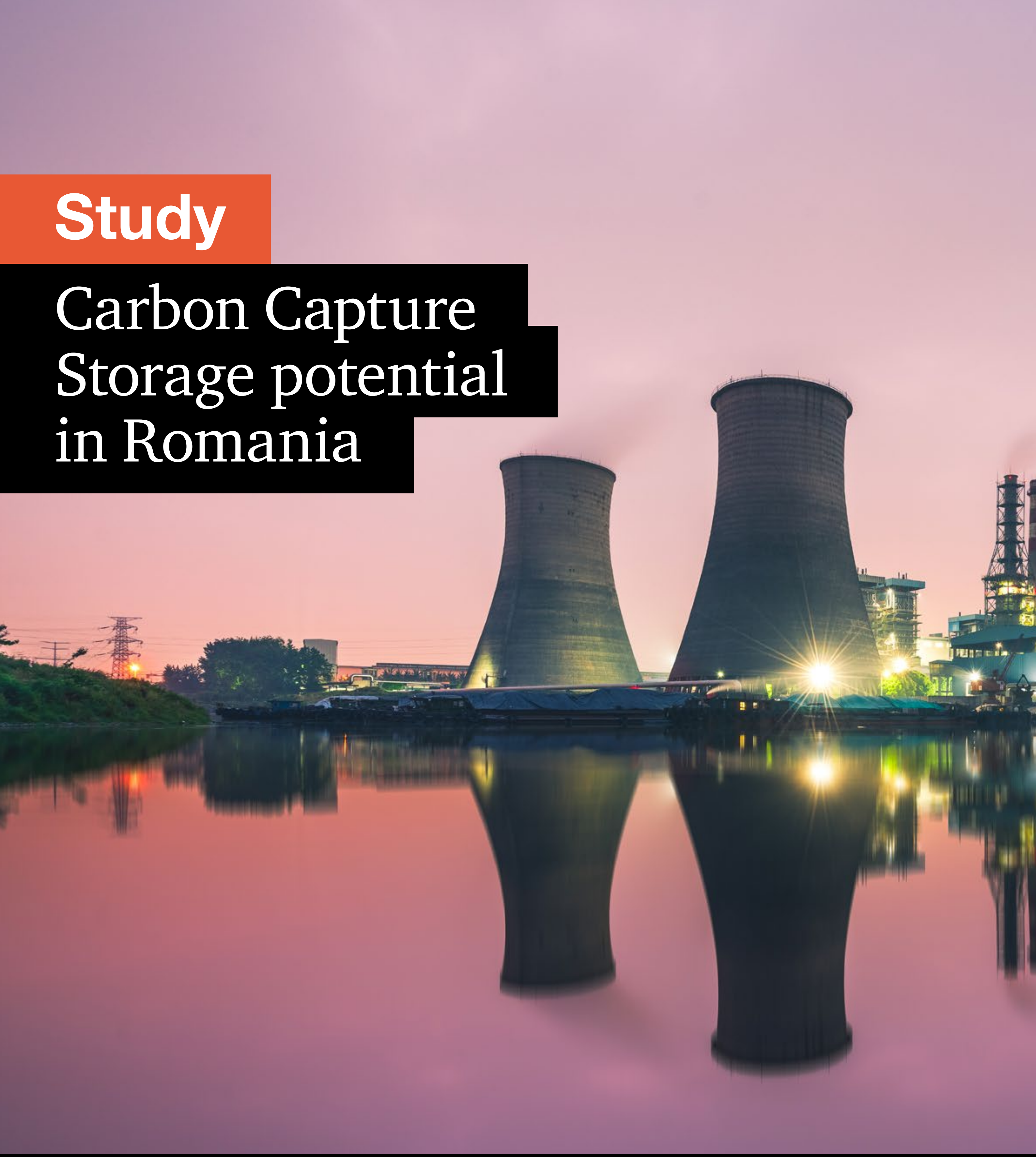
Study

Carbon Capture Storage potential in Romania



Prepared by PwC and EPG for
Federatia Patronala Petrol si Gaze (FPPG)
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The document was prepared by PwC and EPG Consulting SRL between April – June 2022 and refers only to onshore storage capacity based on public available data from 2013.

This document is a preliminary version of the study, based on publicly available data on storage capacity from 2013. According to the preliminary assessments of the holders of oil and gas agreements this represents an optimistic scenario. The content of this study is to be substantiated until October 2022 with data from the institutional portfolio that the relevant authority - National Agency for Mineral Resources – will make available to the consultant (PwC and EPG) until October 2022. This will increase the accuracy of the study.

Following discussions carried out by the project team with the potential storage site operators and the competent authorities, it has been concluded that, at least for the short term, the implementation of CCS projects in Romania is most likely to succeed if the holders of oil and gas agreements analyze the potential storage capacities of their own perimeters. Pending on validating opportunity analyses by the competent authority, the same holders may undertake the operations of those sites.

Contents

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Abbreviations

ANRM	**The National Agency for Mineral Resources**
ACROPO	**The Regulatory Authority for Offshore Petroleum Operation in the Black Sea**
ANRE	**The National Authority for Energy Regulation**
ANPM	**The National Agency for Environmental Protection**
CCU	**Carbon Capture and Utilization**
CCS	**Carbon Capture and Storage**
CEE	**Central and Eastern Europe**
CO2	**Carbon Dioxide**
EC	**European Commission**
EOR	**Enhanced Oil Recovery; a class of techniques used to extract oil which could not have been extracted otherwise**
EGR	**Enhanced Gas Recovery; a class of techniques used to extract gas which could not have been extracted otherwise**
EU ETS	**EU Emissions Trading System: an EU-wide system by which sources of GHG emissions are obliged to pay for a permit for each tonne of GHG they emit above a certain allocation level. Permits can be traded between emitters.**
EU	**European Union**
FDI	**Foreign Direct Investments**
GEO	**Government Emergency Ordinance**
GHG	**Greenhouse Gases**
Gt	**Gigatonnes**
Hydrocarbon reservoirs	**Deposits of oil or natural gas**
IEA	**International Energy Agency**
ISPE	**Institute for Studies and Power Engineering**
IPCC	**International Government Panel on Climate Change**
Kt	**Kilotonnes**
Mt	**Megatonnes**
NGO	**Non-Governmental Organization**
NRRP	**National Resilience and Recovery Plan**
Saline Aquifers	**Geological formations characterised by the presence of water-permeable rocks which are saturated with salt water**
SDS	**Sustainable Development Scenario (Scenario developed by the IEA)**

Executive summary

- The risks associated with climate change to economies are real and imminent as no country today is immune from the impacts of climate change.
- The Paris Climate Agreement is the first-ever universal, legally binding global climate change agreement to stop the temperature to increase by no more than 2.0°C over the pre-industrial level, and ideally by 1.5°C.
- To achieve the Paris Agreement goal, major economies must become climate neutral by mid-century and therefore significantly reduce their GHG emissions by the end of this decade.
- Part of the solution to reducing the atmospheric concentration of CO_2 is to capture CO_2 from industrial processes and fuel combustion and store it underground – this is known as CO_2 capture and geological storage. The strategic importance of CCS in a net-zero emissions future is clear.
- Currently there are 65 CC(U)S facilities worldwide with a storage capacity of 40Mt of CO_2 emissions per year, representing roughly 0.1% of annual emissions.
- Most CC(U)S projects in operation are associated with the oil and gas industry, mainly EOR types.
- The United States is the most important place for CC(U)S by having almost half of the current operational projects and being considered a pioneer in this sector.
- Europe was the second continent to see CC(U)S projects development (in Norway in 1996) and stay the second largest CC(U)S place in the world, thanks to the North Sea storage area. Currently, there are 13 operational and under development CCS facilities located mainly in Norway, the UK and the Netherlands.
- Main challenges in developing CCS projects refer to: high costs within the value chain, no long-term knowledge about effects, lack of supportive public policies and public perception.
- At the EU level, the European CCS Directive was adopted in 2009 to set up the legislative framework for developing these technologies. It includes reporting on the implementation, facilitating exchanges between the competent authorities, publishing guidance documents, and adopting Commission opinions on draft storage permits.
- Norway is the leading European country in CCS development. The Norwegian CCS projects were incentivised by a carbon tax introduced in 1991 as a mechanism to reduce CO_2 emissions from oil and gas activities on the Norwegian Continental Shelf, but also through the regulatory procedures, through which the holder of a petroleum licence may reuse wells for CO_2 injection.
- The EU offers a set of funding programmes to help finance European energy projects, including for CC(U)S. These cover the full range of technology development levels, from research under Horizon 2020 and Horizon Europe to commercial scale projects in the Innovation Fund.
- Public perception has a major role in the CCS development and further deployment. For instance, in Germany, the responsible authority stopped granting CCS storage permits, following strong public opposition. The most frequent factors shaping CCS perception are: trust in institutional actors responsible, offshore vs onshore deployment, specific experiences with prior energy development, knowledge, awareness and communication.
- Following more than a century of industrial oil and gas activity, Romania could position itself as a key provider of CO_2 storage to other nations in the region. Existing wells and redundant gas pipelines may be repurposed to transport and inject CO_2, so the necessary investments may be reduced while increasing the competitive advantage of the country. However, several challenges lay ahead.
- In 2011, the Getica CCS demonstration project succeeded to align public and private support and opened the pathway for a legislative framework on this topic. However, the project was put on hold due to the failure of the Romanian government to renew their support for the project so that it could advance in the next funding rounds of the NER 300. Although no facility was built in the end, Getica remains a flagship project.
- In the past decade, Romanian research entities have consistently been involved in EU funded projects to explore the potential for

CCS and CCU. Currently, two such projects are ongoing, with due dates in 2022 (Strategy CC(U)S and Rex-CO2), which have already published relevant findings.

- The national legislation in force for CCS development appears very fragmented, as every step of the process implies several hurdles. For instance, no bid has taken place or been announced to date regarding storage permits.

- The opportunities for public participation in decision-making on CCS are weak. There is no dedicated public body in Romania responsible for dealing with public engagement in CCS projects.

- Since 1990 Romania's domestic greenhouse gas (GHG) and CO2 emissions have decreased by more than half, primarily due to the closure or operational improvement of inefficient industrial units. As a result, Romania's CO2 emissions have been hovering around the 77-78Mt mark since 2013.

- As with most other countries, the bulk of Romania's CO2 emissions (66 Mt, or 85.5% of total GHG emissions) comes from fuel combustion for energy production.

- A closer look at sector-specific IPPU emissions identifies cement production (4 Mt CO2 in 2019), iron and steel production (4 Mt) and lime and ammonia production (1 Mt each) as the main contributors to Romania's process emissions.

- Out of Romania's total CO2 emissions (77 Mt), 37.3 Mt (approx. 48%) are subject to the EU Emissions Trading System (EU ETS), the EU's carbon market. This means that the installations responsible for these emissions must surrender allowances equivalent to their emissions volumes, and as such pay a price for unabated emissions, including harder-to-abate process emissions.

- The largest emitters making up the emissions of these regions are the Rovinari power station in Gorj county (part of the Oltenia Energy Complex), the Liberty Steel Plant in Galați, several power stations within the Oltenia Energy Complex (Turceni, Ișalnița and SE Craiova II) in Gorj and Dolj counties, the Azomureș fertilizer producer in Mureș county, the Brazi power station and the Petrobrazi refinery in Prahova county, but also several cement producers.

- According to the European CO2 storage database, the total national storage capacity in hydrocarbon deposits is estimated at 514Mt CO2. The split between gas and oil deposits is almost even: 246.78Mt in oil deposits and 267.56Mt in gas deposits.

- Sibiu (1 deposit, 100Mt CO2), Gorj (3 deposits, 90Mt CO2) and Mures (3 deposits, 65Mt CO2) are the counties with the highest storage capacities in hydrocarbon deposits.

- When mapping both the largest CO2 emitters and CO2 storage capacity, we observe six main areas of interest for potential onshore CCS development: (1) Gorj, (2) Dolj, (3) Galati – Buzau, (4) Prahova, (5) Mures and (6) Valcea.

- The initial investment needed for the development of a CCS project with a capacity of 1Mt of CO2 per year in Romania ranges between EUR 326m and EUR 455m. The lifetime of such a project is approximated at 20-25 years. Out of the total cost, the capture process represents almost 80% of the total cost for a CCS project, being more complex.

- For instance, the investment needed for a CCS project (approximately an average of EUR 400m) is similar to the development of a regional hospital covering 807 beds. Moreover, the amount represents 22% of the total pre-primary and primary government expenditures for education or 7.6% out of the total Foreign Direct Investment flow from 2019.

- In the medium term, to reach for example a 4Mt of CO2 storage, representing approximately 10% of the total ETS CO2 emissions, the needed investments are up to EUR 1.3 – 1.8bn.

- The development of a first pilot CCS project would have an important impact both at the local and national level: (i) about EUR 400m capital inflow for the initial development of the project, (ii) CO2 emissions reduction by about 1Mt per year with a positive impact on the environment and people, (iii) between 200 – 300 new jobs, out of which 50 – 100 in the plant and the additional along the value chain, (iv) high paid new jobs involving technical/specific skills, (v) development of a national competitive advantage in terms of know-how and technology for CCS.

Context

It has been more than three decades since governments and scientists started officially meeting to discuss the need to lower GHG emissions to avoid the danger of climate change. The risks associated with climate change to economies are real and imminent as no country today is immune from the impacts of climate change. Reducing emissions and becoming more resilient are possible, but require major social, economic, and technological changes.

The Paris Climate Agreement of 2015 is the first-ever universal, legally binding global climate change agreement to stop the temperature to increase by no more than 2.0°C over the pre-industrial level, and ideally by 1.5°C (EC, 2022). Already, temperatures are 1°C above the pre-industrial, and they continue to climb, driven for the most part by CO2 of about 43bn tonnes per year. To stand a good chance of scraping under the target, stringent GHG emission cuts are required (The Economist, 2021).

To achieve the Paris Agreement goal, major economies must become climate neutral by mid-century and therefore significantly reduce their GHG emissions by the end of this decade. For instance, the EU aims to reduce its emissions by 55% by 2030 compared to 1990 levels through various policies proposed within the 'Fit for 55' package. Meanwhile, the US plans to reduce its emissions by 50-52% by 2030 compared to 2005 levels, and China wants its CO2 emissions to peak before 2030. Thus, large investments will be needed.

Part of the solution to reducing GHG emissions is to capture CO2 produced by industrial processes and fuel combustion and store it underground – this is known as CO2 capture and geological storage. Beyond high investments in shifting to renewables, both the IPCC and the IEA reports consistently show CCS's major role in economically meeting the net-zero target. For example, the IEA's Sustainable Development Scenario (SDS) describes a future where the United Nations (UN) energy related sustainable development goals for emissions, energy access and air quality are met. The mass of CO2 captured using CCS goes up from around 40Mt of CO2 per year today to around 5.6 Gt in 2050 – a more than 100x increase. Its contribution is significant, accounting for between 16% and 90% of emissions reductions in the iron and steel, cement, chemicals, fuel transformation and power generation sectors. The strategic importance of CCS in a net-zero emissions future is clear.

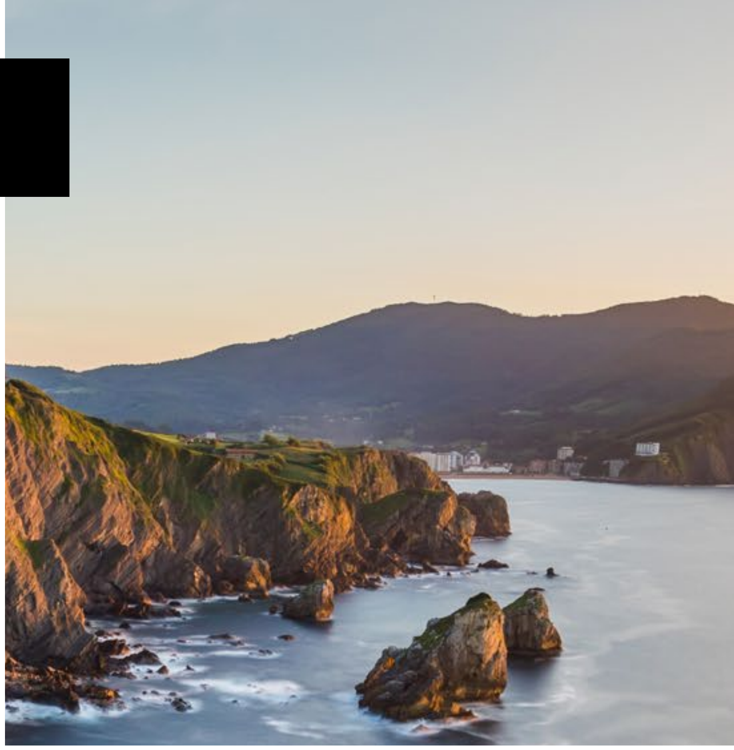
In Romania, the CCS topic has re-started to gain attention following increased EU objectives on GHG emissions reduction with pressure on carbon-intensive industries. For instance, the oil and gas industry is under continuous transformation, with companies starting to focus more and more on the energy transition.

CO2 capture, transport and storage (CCS) represents an important option in terms of decarbonisation for energy-intensive industries (steel, cement, aluminium, etc.), as well as for the energy production sector, the technology being identified by the European Commission as a strategic route in achieving climate goals. Therefore, CCS projects represent new opportunities for oil and gas companies that operate deposits at a high maturity, or in the process of abandonment, as well as for those who operate transport networks.

To address this, the Employers Oil and Gas Federation commissioned PwC and EPG to develop a study assessing CCS potential in Romania.

Introduction to CCS

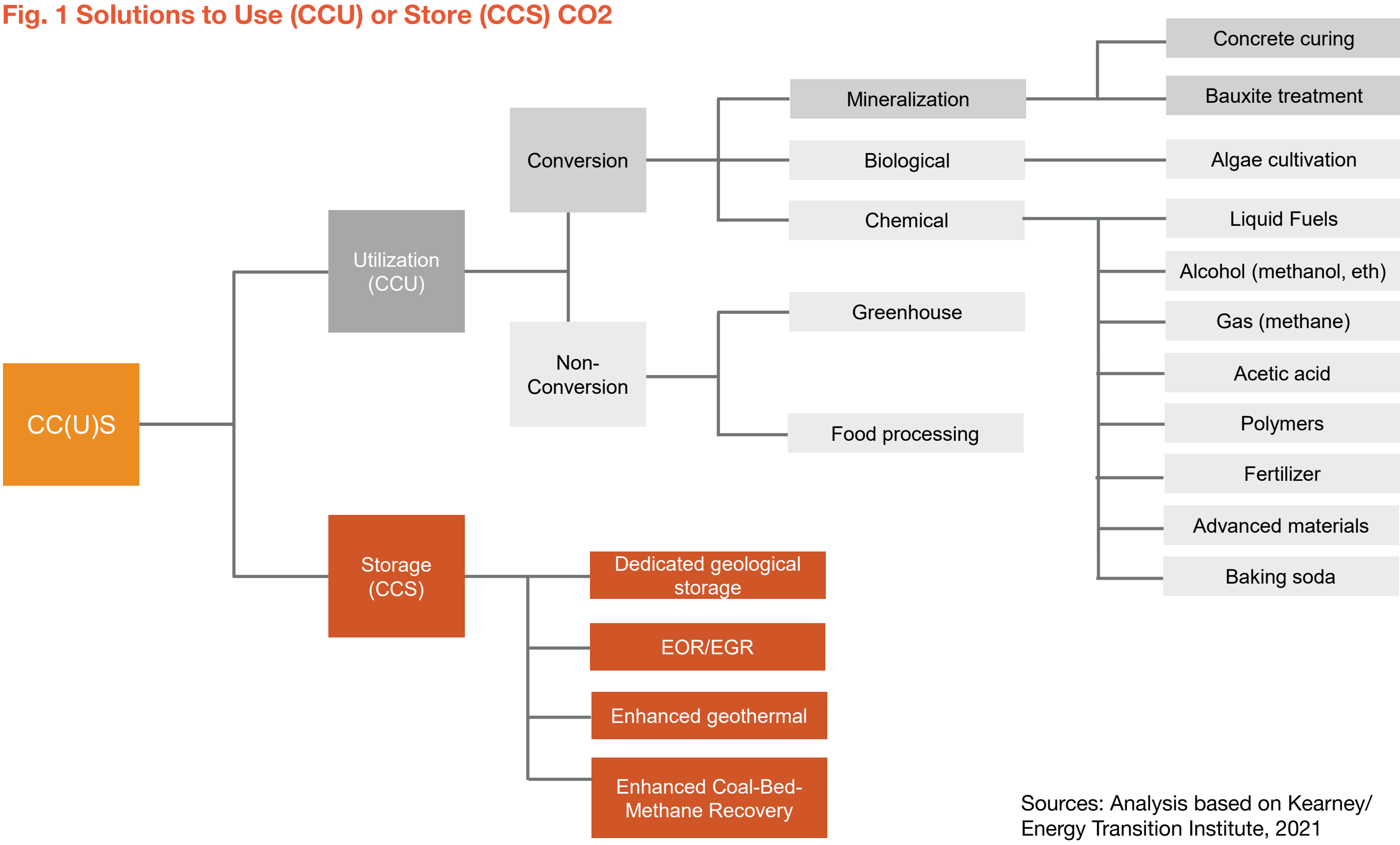
CCS - definition, ways of capture, types of geological storage



Definition

CC(U)S is a technology referring to a set of CO_2 capture, transport, utilization, and storage technologies combined to remove CO_2 emissions. CO_2 is generally captured from large emissions sources (power/industrial plants), transported in a gaseous or liquefied state by pipelines or ships and stored in geological formations or reused to create products or services (IEA, 2021).

Fig. 1 Solutions to Use (CCU) or Store (CCS) CO2



Sources: Analysis based on Kearney/ Energy Transition Institute, 2021

CC(U)S is most cost-effective when applied to large, stationary sources of CO_2 (such as power stations and steelworks).

Within the current climate change context, CC(U)S can play important roles in the transition to net zero:

- Tackling emissions from current energy assets;
- Representing a solution for sectors where emissions are hard to reduce;
- Developing a platform for blue hydrogen.

Ways of capture

The CO2 can be captured from hydrocarbons before, during or after burning. There is also a mature process of CO2 separated from raw natural gas at a gas processing plant.

Thus, there are 4 capture technologies that occur at different steps of the combustion value chain (IEA, 2021, Kearney, 2021):

- **Pre-combustion.** A hydrocarbon fuel source - coal, gas, or biomass - is gasified into shifted syngas (H2/CO2 mix), from which the CO2 is separated. The H2 is then used to fuel the power plant or to produce chemicals or synthetic fuels. In power generation, the pre-combustion process is more energy-efficient than post-combustion but requires a new and expensive plant design, such as an integrated gasification combined cycle.
- **Oxy-combustion.** Fuel is combusted in pure oxygen instead of air, producing a concentrated CO2 stream in the flue gas, which is almost ready to be transported. Oxy-combustion could be retrofitted to existing plants, though with a significant redesign.
- **Post-combustion.** CO2 is separated from flue gas after combustion with air and can be retrofitted to power and heavy industrial plants with relatively high costs and energy penalties. This technology is the most broadly used outside oil and gas.
- **Natural gas sweetening.** In this process, CO2 is separated from raw natural gas at a gas processing plant.

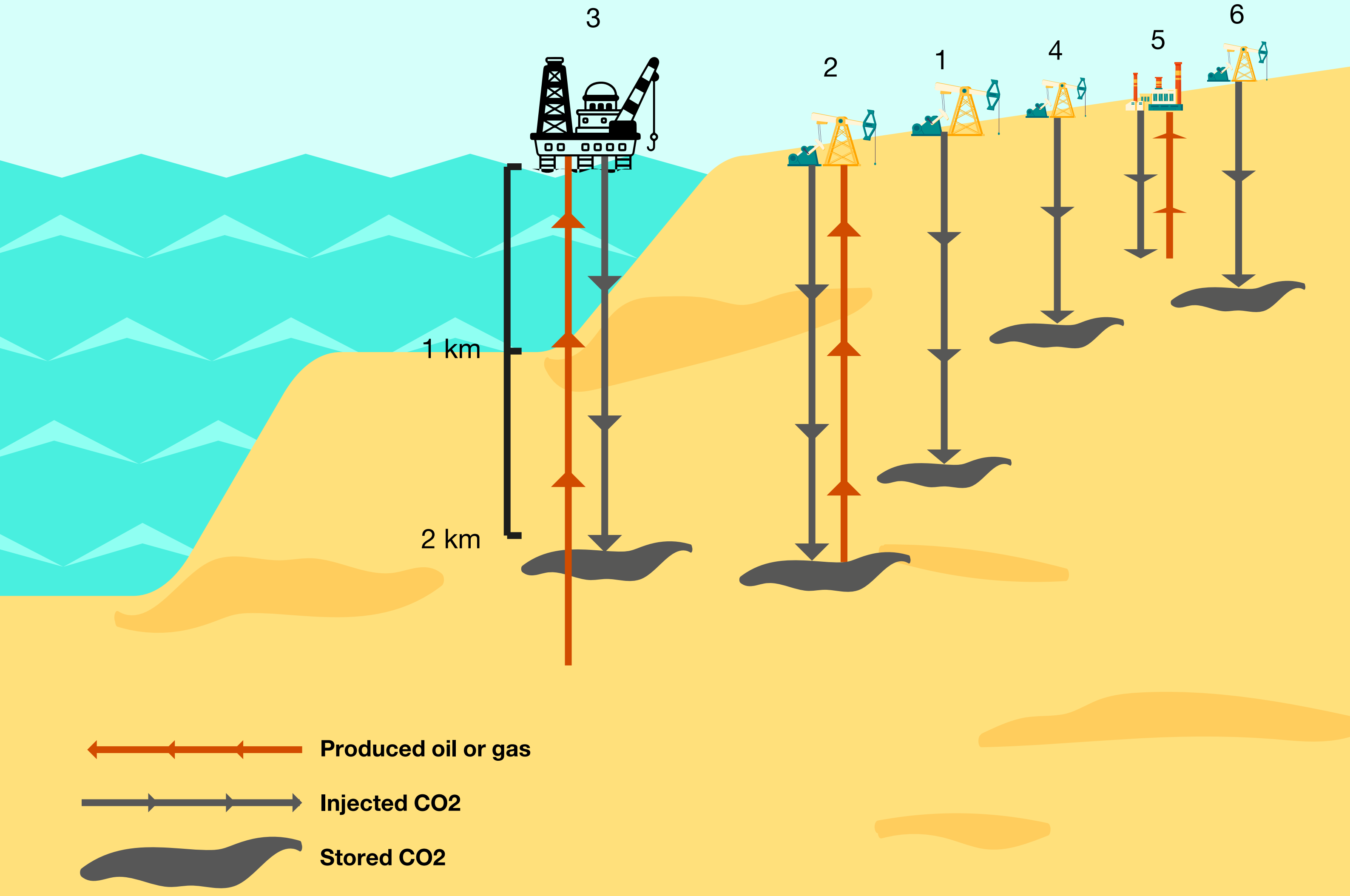
Types of geological storage

CCS enables the industry to continue to operate while emitting few CO_2 emissions, making it a powerful tool for addressing the mitigation of anthropogenic CO_2 in the atmosphere. However, storage must be safe, environmentally sustainable, and cost-effective. Suitable storage formations can occur in both onshore and offshore settings, and each type of geologic formation presents different opportunities and challenges. Geologic storage is defined as the placement of CO_2 into a subsurface formation so that it will remain safely and permanently stored. Types of geological storage:

- Deep saline formations;
- Depleted oil and natural gas reservoirs;
- Unmineable coal seams;
- Basalt formations.

Geological Storage Optimisations for CO2

1. Depleted oil and gas reservoirs
2. Use of CO_2 in enhanced oil recovery
3. Deep unused saline water-saturated reservoir rocks
4. Deep unmineable coal seams
5. Use of CO_2 in enhanced coal bed methane recovery
6. Other suggested options (basalts, oil shales, cavities)



Sources: Analysis based on Meeting the Dual Challenge: A Roadmap to At-Scale Deployment of CCUS, "Ch. 2: CCUS Supply Chains and Economics; The Costs of CO2 Transport Post-Demonstration CCUS in the EU," Zero Emission Platform 2011, CO2 Underground Sequestration, Intergovernmental Panel on Climate Change, Strogen, Dominic, Opportunities for Underground Geological Storage of CO2 in New Zealand, Report CCS 08/7, Onshore Taranaki Neogene reservoirs; Kearney Energy Transition Institute.

EOR - EGR

According to scientific papers in the field (Hamza et al., 2021), saline aquifers can store between 1,000 and 10,000 Gt of CO2 whereas the storing capability of depleted oil and gas formations is up to 900 Gt (Bourg et al., 2015). Notably, injection of CO2 into hydrocarbon reservoirs can provide large underground storage for CO2 while enhancing hydrocarbon recovery which cuts down the expenses.

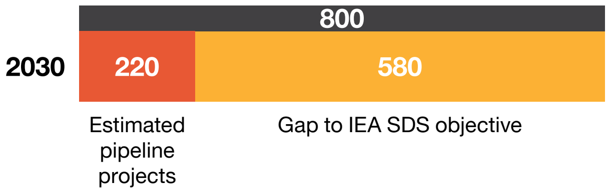
Although less than saline aquifers, depleted gas reservoirs are considered to have a high potential to sequester CO2. Depleted conventional and unconventional gas reservoirs have large pore space after natural gas production and pressure reduction. Moreover, their ability to store hydrocarbons for many years inside the sealed reservoir with impermeable cap rocks provides safer options than saline aquifers or other geological traps. Incremental recovery of residual natural gas after injecting CO2 could decrease the cost of the process.

Carbon dioxide improves the microscopic displacement efficiency by oil swelling and decreasing the viscosity of crude oil (Tunio et al., 2011). Similarly, CO2 is implemented in gas reservoirs to enhance gas recovery (EGR); however, the process is complex because of the absorption of the gas on the surface of reservoir rocks, the miscibility of CO2 and natural gas, and thus the possibility of CO2 breaking through production wells (Honari et al., 2015; Patel et al., 2016). Depleted gas reservoirs showed a larger capacity to store CO2 compared to oil reservoirs because of the high primary recovery factor in the gas reservoirs (>60%), which is almost twice the oil recovery (Kuhn and Munch, 2013). Moreover, CO2 has to be stored under supercritical conditions.

According to international institutions, ongoing CCS developments are below the required targets to achieve net zero.

Even though the CO2 capture capacity is expected to sharply increase in the following years, the global capacity remains low compared to IEA objectives and the sustainable development scenario (SDS). According to Kearney Energy Transition Institute, the capture capacity of the current pipeline of projects needs to be multiplied by approximately 4x by 2030.

Fig. 3 Potential CO2 capture capacity by 2030 (Mt/year) of announced projects`



Sources: Analysis based on GCCSI and NREL databases, IEA Energy Technology Perspective 2020 (2020); Kearney Energy Transition Institute Analysis.

Global CCS hubs and clusters

According to the Global CCS Institute (2020), there are 65 commercial CC(U)S facilities globally, out of which:

- 26 are operating;
- 2 have suspended operations (economic downturn & fire);
- 3 are under construction;
- 13 are in advanced development and
- 21 are in early development.

CCS facilities in operation capture about 40Mt of CO2 emissions per year, roughly 0.1% of annual emissions.

The United States is the most important place for CC(U)S by having almost half of the current operational projects and being considered a pioneer in this sector. Although the region has more than 40 in-development projects, about 35 projects have been cancelled in the past, mostly for economic reasons and lack of public acceptance.

Europe was the second continent to see CC(U)S projects development (in Norway in 1996) and stay the second largest CC(U)S place, thanks to the North Sea storage area. Australia, China, and Japan are catching up with Europe either in numbers of operational or in-development CC(U)S projects but have fewer completed projects so far.

The current pipeline of CC(U)S projects is expected to double the number of projects in the coming years in OECD countries.

Despite the oil and gas legacy of the Middle East and its huge EOR application potential, there has been little CC(U)S development so far.

Fig.4 Most CC(U)S projects in operation are associated with the oil and gas industry

1998 - 2010	Shute Creek (USA)	Sleipner (Norway)	Val Verde (USA)	Great Plains Synfuel (USA)	In Salah (Algeria)	Snøhvit (Norway)	Century Plant (USA)
1. Operation year	1986	1996	1999	2000	2004	2007	2010
2. Plant owner	ExxonMobil, Chevron, Anadarko	Statoil	Sandridge Energy, Occidental Petroleum	Dakota Gasification, Cenovus, Apache	BP, Sonatrach, Statoil	Statoil	Occidental Petroleum, Sandridge
3. Plant type	Gas processing	Gas processing	Gas processing	Synthetic natural gas	Gas processing	Gas processing	Gas processing
4. CO_2 storage rate ($MtCO_2$ per year)	7	0.85	1.3	3	1 (injection currently suspended)	0.7	5 (8.4 maximum)
5. Rationale for investment	EOR revenues	Carbon tax	EOR revenues	EOR revenues	CERs	Carbon tax	EOR revenues

2013 - 2015	Air Products SMR (USA)	Coffeyville (USA)	Lost Cabin (USA)	Lula Oil Field (Brazil)	Boundary Dam (Canada)	Quest (Canada)	Uthmaniyah (Saudi Arabia)
1. Operation year	2013	2013	2013	2013	2014	2015	2015
2. Plant owner	Air Products	Coffeyville Resources Nitrogen Fertilizers LLC	Conoco Phillips	Petrobras	SaskPower	Shell	-
3. Plant type	Hydrogen production	Fertiliser	Gas processing	Gas processing	Coal power plant	Hydrogen production for oil sand upgrader	Gas processing
4. CO_2 storage rate ($MtCO_2$ per year)	1	1	0.9	0.7	1	1.1	0.8
5. Rationale for investment	EOR revenues and public grant	EOR revenues	EOR revenues	EOR revenues	EOR revenues and public grant	Public grant	EOR revenues

Sources: Analysis based on GCCSI and Kearney/ Energy Transition Institute (2021).

Main challenges[1] for CCS development

CCS projects have limited favourable public opinion because they are pretty new and misunderstood.

The main challenges in achieving support for the development of such projects rely on:

- High costs within the entire value chain;
- No long-term knowledge about potential effects;
- Increased use of fossil fuels;
- According to some experts in the energy transition, CCS should have been done a long time ago; thus, the current focus should be on renewable and clean options, however, there are not applicable for certain industries (e.g. cement);
- Lack of supportive public policies, especially CCS specific laws;
- Lack of financial support from the Government to fill the gap between costs and revenues (at least in the short term) – such projects require high investments and incur high risks.

1 Source: Analysis based on National Petroleum Council -Meeting the Dual Challenge a Roadmap To At-scale Deployment Of CARBON CAPTURE, USE, AND STORAGE (2020); Energy Procedia -Local acceptance and communication as crucial elements for realizing CCS in the Nordic region (2016), Kearney/ Energy Transition Institute (2021).

European CCS facilities

According to the Global CCS Institute (2020), there are 13 CCS commercial facilities operational and under development in Europe:

- 1 in Ireland, 1 in the Netherlands, 4 in Norway & 7 in the UK (Table 1);
- 2020 saw the launch of the first call for projects under the EU's EUR 10bn Innovation Fund; expected to be a major source of funding for both the planning and the construction and operation of CC(U)S across the EU.
- UK continues the CC(U)S deployment action plan. There is a dedicated GBP 800m funding to establish CC(U)S clusters in at least two UK sites until 2030.

One of the most advanced hubs in development is the Northern Lights Project. In the North Sea, this Norwegian CCS hub aggregates CO2 streams, beginning with foundation sources from cement plants (combined capacity of 0.8 Mtpa of CO2). Developed by Equinor, Shell and Total, the project will compress and liquefy CO2 at source plants before transport by a dedicated CO2 ship, to a storage site. The project is targeting a 2024 commissioning date.

#	Facility title	Status	Country	Operation date	Industry	Capture capacity (Mtpa) (MAX)	Capture type	Storage type
1	Ervia Cork CCS	Early Development	Ireland	2028	Power generation and Oil Refinery	2.5	Industrial Separation	Dedicated Geological Storage
2	Hydrogen 2 Magnum (H2M)	Early Development	Netherlands	2024	Power Generation	2.00	Industrial Separation	Dedicated Geological Storage
3	Sleipner CO2 Storage	Operational	Norway	1996	Natural gas processing	1.00	Industrial Separation	Dedicated Geological Storage
4	Snøhvit CO2 Storage	Operational	Norway	2008	Natural gas processing	0.70	Industrial Separation	Dedicated Geological Storage
5	Fortum Oslo Varme - Langskip	Advanced Development	Norway	2023-2024	Waste-to-Energy	0.40	Post-combustion Capture	Dedicated Geological Storage
6	Brevik Norcem - Langskip	Advanced Development	Norway	2023-2024	Cement Production	0.40	Industrial Separation	Dedicated Geological Storage
7	Acorn Scalable CCS Development	Early Development	United Kingdom	2020s	Oil Refining	4.00	Industrial Separation	Dedicated Geological Storage
8	Caledonia Clean Energy	Early Development	United Kingdom	2024	Power generation with potential for coproduction of Hydrogen for heat and transport applications	3.00	Post-combustion Capture	Dedicated Geological Storage
9	HyNet North West	Early Development	United Kingdom	Mid 2020s	Hydrogen Production	1.50	Industrial Separation	Dedicated Geological Storage
10	Net Zero Teesside - CCGT Facility	Early Development	United Kingdom	2025	Power Generation	6.00	Post-combustion Capture	Dedicated Geological Storage
11	Northern Gas Network H21 North of England	Early Development	United Kingdom	2026	Hydrogen Production	1.50	Industrial Separation	Dedicated Geological Storage
12	Hydrogen to Humber Saltend	Early Development	United Kingdom	2026-2027	Hydrogen Production	1.4	Industrial Separation	Dedicated Geological Storage
13	Drax BECCS Project	Early Development	United Kingdom	2027	Power Generation	4	Industrial Separation	Dedicated Geological Storage

Sources: Analysis based on GCCSI (2020).

Policy and regulation

The European Commission is responsible to ensure the coherent implementation of the CCS Directive among EU member states (MS). These include reporting on the implementation, facilitating exchanges between the competent authorities, publishing guidance documents, and adopting Commission opinions on draft storage permits.

The CCS Directive 2009/31/EC (main highlights in Figure 5) includes reporting requirements for EU countries and the European Commission:

Every 4 years, Member States report to the Commission on the implementation of the Directive.

Fig. 5 EU CSS Directive – key aspects

Scope

- Shall apply to the geological storage of CO_2 in the territory of the MS, their exclusive economic zones and on their continental shelves
- Shall not apply to geological storage of CO_2 < 100Kt, undertaken for research, development or testing

Selection of storage sites

- MS shall retain the right to determine the areas from which storage sites may be selected
- MS which intend to allow geological storage of CO_2 in their territory shall undertake an assessment of the storage capacity available in parts or in the whole of their territory, including by allowing exploration

Exploration permits

- MS shall ensure that the procedures for the granting of exploration permits are open to all entities possessing the necessary capacities and that the permits are granted or refused on the basis of objective, published and nondiscriminatory criteria
- The duration of a permit shall not exceed the period necessary to carry out the exploration for which it is granted
- Exploration permits shall be granted in respect of a limited volume area

Storage permits

- MS shall ensure that no storage site is operated without a storage permit, (only one operator for each storage site)
- MS shall ensure that the procedures for the granting of storage permits are open to all entities (published and transparent criteria)
- **Priority for the granting of a storage permit for a particular site shall be given to the holder of the exploration permit for that site (under certain criteria)**

Commission review of draft storage permits

- MS shall make the permit applications available to the Commission within one month after receipt
- Within 4 months after receipt of the draft storage permit, the Commission may issue a non-binding opinion on it
- The competent authority shall notify the final decision to the Commission

Operation, closure & post-closure obligation

- Monitoring
- Reporting – at a frequency determined by the competent authority, and in any event at least once a year
- Inspections – organized by competent authorities
- Closure and post-closure obligations
- Transfer of responsibility

Other provisions:
Competent authority, information to the public, reporting by MS, penalties, etc.

Sources: Analysis based on the CCS Directive (eur-lex.europa.eu).

European CCS framework - best practices

The Report Assessment of current state, past experiences and potential for CCS deployment in the CEE region – Romania, 2022, developed by the Energy Policy Group, presented the following best practices within Europe:

- **The Norwegian CCS** projects were incentivised by a carbon tax introduced in 1991 as a mechanism to reduce CO2 emissions from oil and gas activities on the Norwegian Continental Shelf (NCS). For Sleipner and Snøhvit projects, the CO2 is separated from produced natural gas and re-injected into the subsurface in operation in the North Sea.

  The Norwegian Petroleum Directorate has done the initial mapping of the entire Norwegian Continental Shelf for potential sites for CCS. In 2011, Gassnova was given the mandate to explore the possibility of full-scale CCS on NCS. Thus, the Northern Lights project was developed with partners such as Equinor, Shell and Total.

  As outlined in the Norwegian model for re-using existing wells, if CO2 injection is a part of a petroleum operation, the holder of a petroleum licence may re-use wells for CO2 injection. Change of ownership of existing infrastructure is permitted, but the original owner will maintain secondary liability for decommissioning of the infrastructure at the change of ownership.

- **The Dutch government included CO2 storage in its national decarbonisation strategies.** Previously, the Dutch Mining Act required the decommissioning of all infrastructure after use. This requirement was raised as a potential barrier to the deployment of CCS. The government's involvement in the decommissioning process and initiatives was fundamental. Established in 2017, NextStep is a joint initiative between EBN (the Dutch state participation in domestic exploration and production operations) and the Dutch oil and gas industry, which aims to stimulate and organize the reuse of oil and gas infrastructure in the Netherlands.

- **The UK's Department for Business, Energy and Industrial Strategy (BEIS)** is responsible for developing policies related to CCS across the board. BEIS conducted a consultation process to support the development of a new policy relating to the re-use of existing oil and gas infrastructure for CC(U)S. Among the recommendations available since August 2020 for a timely ramp-up of CCS, the UK is committed to ensuring regulatory coordination on CCS and hydrogen development (i.e., to provide proactive regulatory support for CCS and hydrogen projects, ensuring guidance to permit the timely execution of pilots and subsequent ramp-up of these novel technologies in the 2020s).

EU Financing

The EU offers a set of funding programmes to help finance European energy projects, including CC(U)S. These cover the full range of technology development levels, from research under Horizon 2020 and Horizon Europe to commercial-scale projects in the Innovation Fund. Current EU funding schemes dedicated to supporting CC(U)S are the following programmes:

- The Innovation Fund aims to allocate EUR 25bn towards low-carbon technologies by 2030. Seven projects were selected for funding under the first Innovation Fund call for large-scale projects, i.e. projects with total capital costs above EUR 7.5m. They were evaluated by independent experts for their ability to reduce GHG emissions compared to conventional technologies and to innovate beyond the state-of-the-art while being sufficiently mature to enable their quick deployment. Other selection criteria included the projects and the potential for scalability and cost effectiveness. On 26 October 2021, the Commission launched the second call for large-scale projects with a deadline of 3 March 2022 encouraging all the projects that were not successful in the first call to re-apply.

- Connecting Europe Facility (CEF) supports cross-border CO2 transport networks. It is a European Commission funding initiative which has a series of calls aimed at developing cross-border CO2 infrastructure. There is a strong portfolio of projects from the 3rd CO2 infrastructure call which have secured CEF funding or PCI status, including the Porthos, Acorn and Northern Lights projects.

- The Recovery and Resilience Facility (RRF) aims to mitigate the economic and social impact of the coronavirus pandemic through investments in flagship areas such as clean technologies and renewables, e.g. CC(U)S.

- The Just Transition Fund (JTF) provides support to territories facing serious socio-economic challenges arising from the transition towards climate neutrality, such as support for CC(U)S technologies.

- Horizon Europe supports research, pilots and small-scale demonstration projects related to carbon capture, utilisation, and storage.

Not directly an EU funding source, but state aid is also possible to support CCS projects. Given that it's the Commission that approves it, and that it can come from EU funds under National Operational Programmes.

European public perception of CCS

Public perception has a major role in the CCS development and further deployment. For instance, in Germany, the responsible authority stopped granting CCS storage permits, following strong public opposition.

Relevant conclusions on public perceptions of CCS in Europe in 2019, following assessment of scientific literature:

- Support for CCS is often contingent on CCS being not only safe but also just one part of a wider strategy for achieving cuts in CO2 emissions.
- The key factors involved in community support for CCS include the characteristics of the project; the engagement process; risk perceptions; the actions of the stakeholders; the characteristics of the community, and the socio-political context.
- From the cross-cultural studies that have been conducted in Europe, it seems that awareness is particularly high in the Netherlands (potentially due to the high profile nature of the Barendrecht case; Bellona, 2010), whereas elsewhere awareness is lower, with Europeans typically holding fairly mixed and ambivalent views towards CCS.
- There are, however, notable differences between continents. For example, Canadians seem to be more accepting than the Swiss public, perhaps due to their different experience of (and dependence on) fossil fuel industries. Even within individual countries, research points to regional variations in perceptions, with one German study finding those living closer to actual or proposed sites less supportive of CCS.
- In a survey conducted in the UK, US, Canada, Norway and the Netherlands, allowing for cross-cultural comparison (countries were selected because (a) they reflect different stages of CCS development (including offshore and onshore storage), which were expected to influence perceptions and (b) because they had sufficient national and local sample representation in online participant panels, findings showed:
    - Public awareness of CCS is low, although there are cross-national differences in awareness, with the Norway sample showing the highest levels and the US sample the lowest.
- Despite more awareness in Norway, the greatest support for CCS is evident in the UK.
- The lowest support is found in the Netherlands. Local samples (i.e. close to current or potential CCS sites) are more supportive of CCS being implemented than national samples, particularly in the UK.
- Communities hosting CCS projects would stand to benefit economically from the jobs and revenue the industry would provide.
- The areas in which CCS facilities are likely to be built are typically sites where there is an existing (analogous) industry. Subjective familiarity with such an industry could serve to reduce the perceived risks associated with new infrastructure, thus yielding a greater acceptance of CCS within 'host' communities.
- Pairing CCS with bioenergy (i.e., 'BECCS') leads to more support; while we also find fossil fuel and industry pairings see CCS less supported, suggesting BECCS is likely to be more widely accepted than most current (fossil) CCS schemes. Given the importance of BECCS to many climate change mitigation scenarios, this is encouraging.
- Compared to support for CCS implementation before costs are mentioned, support reduces when CCS costs per household were mentioned (and the focus of the information is on future greater costs being avoided through CCS implementation now). This highlights a need for caution when discussing costs; if the public has no expectation that CCS will have cost implications for households, then even stressing the lower costs of CCS than alternative mitigation options may backfire and reduce support.

Most frequent factors shaping CCS perceptions

- Trust in institutional actors responsible for implementing or regulating CCS projects.
- Perceptions differ between areas with potential for CC(U)S/CCS implementation and areas with little potential, offshore vs onshore deployment, the source from which the carbon came, and the stage of the project – capture, transport, use, or storage (studies concluded elevated risk perceptions and lower support in Germany and the Netherlands compared to the UK, possibly because of more concerns about lack of local benefits, and lack of support or acceptance for projects close to prospective development sites).
- Specific experiences with prior energy development – such as coal mining – could generate comparisons to previous industrial problems (in tourism, cultural heritage, job prospects) or accidents, or to loss of trust in industrial actors that were not good neighbours to local communities. The reasons for local opposition are often complex, but mean that context-specific understanding is essential for assessing the viability of specific projects.
- Acceptance of offshore versus onshore projects: offshore experience higher acceptance.
- Relevance of the source of carbon - public perceptions are related to carbon captured from the use of fossil fuels, predominantly at coal-fired power plants. The studies that examine carbon captured from other sources – such as the steel industry and biomass plants – show that acceptance can be higher and risks seen as lower/fewer in such cases.
- The stage in the project development strongly affects risk perceptions, support, and acceptance. Concerns are generally associated with storage and transport. Higher acceptance of industrial use of carbon exists, compared to storage, and the process of carbon capture is not viewed as particularly problematic (unless the source of carbon is problematic, as above).
- Knowledge, awareness, and communication vary cross-nationally and regionally within countries (places with more exposure to industrial projects or government discourse and planning show higher knowledge). A common finding is that public understanding of CC(U)S/CCS is quite limited. If people are poorly informed about new technologies, then this may be considered as leading to generally flexible public attitudes. There might be potential for further information, and targeted communication, to influence the level of support and acceptance. The need for effective communication on this topic – identifying messages, messengers, visuals, dissemination pathways, and specific language that will lead to higher public acceptance - is deemed to have a key role in the development of such projects.

Main factors shaping the negative perception

(“Framing effects on public support for carbon capture and storage, 2019”)

- As CCS involves trapping CO2 from power generation and heavy industrial processes and directing it into long-term geological storage, in doing so, CCS could facilitate global carbon abatement efforts, but it remains controversial with high-profile public opposition to particular CCS developments.
- Costs of deploying CCS can lead to lower support. Discussing CCS costs should be done in the context of costs of broader energy system transformation and of not mitigating climate change so that the public can deliberate on the relative risks and benefits of CCS and alternatives in the context of broader sustainability pathways.

CCS potential in Romania

Introduction

Concrete discussions on CCS based on coherent strategies and detailed actions have not reached the Romanian public agenda for over a decade. Following the recent discussions on carbon capture driven by the NRRP and the increase in EU ETS carbon price, Romania has managed to revive discussions, but has failed to propose a holistic approach (CCS4CEE country report: Romania, 2021).

In 2011, the Getica CCS demonstration project succeeded to align public and private support and opened the pathway for a legislative framework on this topic. However, the project was put on hold due to the failure of the Romanian government to renew their support for the project so that it could advance in the next funding rounds of the NER 300. Although no facility was built in the end, Getica remains a flagship project (CCS4CEE country report: Romania, 2021).

Getica demonstration project

Romania's first demonstrative CCS project, Getica (2011) emerged following the EU's developments on the legal framework for demonstrative CCS projects at the EU level, the CCS Directive respectively.

Main highlights of the project (CCS4CEE country report: Romania, 2021):

- First national integrated CCS demonstrative project covering full CCS chain of capture, transport and storage of CO_2.
- **Project owners:** consortium of Turceni Energy Complex SA (in charge of CO_2 capture), SNTGN Transgaz (the transport operator), and SNGN Romgaz (the CO_2 storage operator).
- **Selected region for implementation:** Oltenia, large, industrialized area responsible for a high share of Romania's CO_2 emissions.
- **Project operation timeline:** 2016 – 2030.
- **Capture capacity:** up to 1.5 Mt CO_2/year from Turceni's Unit 6 by retrofitting a carbon capture installation to the lignite-fired 330MW unit.
- **Estimated costs of the project:** EUR 1bn, with 50% as financial support from the EU under the NER300 programme.
- **Transport:** the amount of CO_2 would have been transported within 50 km of the capture site for storage at a depth of approximately 800m in onshore saline aquifers.
- **GeoEcoMar together with ISPE contributed to the project development:** the first entity with research, while the second with the development of the communication programmes to boost public acceptance in the region.
- **Financial and institutional support for the feasibility study** was provided by the Ministry of Economy, Trade and the Business Environment (METBE) and the Global CCS Institute. The latter put forward a EUR 2.5m grant for the feasibility study.
- In addition to the feasibility study, a permitting report and a regulatory toolkit for authorities (workshop and matrix) were compiled and submitted to the Global CCS Institute.
- **Getica's development took place in a high-trust climate**, considering the political will and synergies efforts of companies and research-oriented entities. Prior to Getica's application for funding under the EU NER300 Programme (2011), the government expressed its commitment to CCS through several important actions (i.e. the "Action Plan to prepare for the Energy-Climate Change EU legislative package implementation," endorsed by the Prime Minister. As part of this package, the Ministry of Economy (METBE) released the "Action Plan for implementing a Demo Project regarding CCS in Romania", followed by a national call for proposals for CCS projects attached to emissions-intensive industries in Romania.
- **Romania began to draft a national regulatory framework for CO_2 storage to support Getica's chances to obtain financial support from the EU.** The transposition of the EU CCS Directive came into force through GEO 64/2011. However, it was more a formality than an effective enacting piece of legislation, a formal framework to facilitate the Getica project rather than a comprehensive set of regulations.
- **The project was put on hold due to lack of funding.** Getica competed with 15 other projects that applied for the first call of NER300. It did not progress past the competition's technical and financial evaluation stage, because of **the lack of reconfirmation of government support**, which was due to be sent to the EC in 2012. The main cause was the volatility of the political context, following the 2008 financial crisis.

In the past decade, Romanian research entities have consistently been involved in EU funded projects to explore the potential for CCS and CCU. Currently, two such projects are ongoing, with due dates in 2022 (Strategy CCUS and Rex-CO2), which have already published relevant findings. These research studies have brought a deeper understanding of potential storage sites, transport options and available technologies for CCS and CCU. However, they cannot provide the sort of fundamental know-how that can only stem from pilot projects and their real-world demonstration capabilities (CCS4CEE country report: Romania, 2021).

Recent research projects, according to the EPG Report Assessment of current state, past experiences and potential for CCS deployment in the CEE region – Romania, 2021:

1. **Strategy CCUS project (2019-2022)** – aiming to analyse the potential of CCUS development within eight specific regions from seven EU member states are promising for CCUS development. For Romania, the port region of Galați was selected, out of 174 identified industrial and power facilities with total CO2 emissions of over 121.5 Mt/year. The area met several key criteria: the presence of an industrial cluster, possibilities for CO2 storage and/or utilization, potential for coupling with hydrogen production and use, existing studies, and political openness. The largest GHG emitter (92% of total emissions at the county level), Liberty Steel Galati, provides the potential to be part of a CC(U)S major project within the region. Moreover, Liberty Steel representatives highlighted the company's aim to become carbon-neutral by 2030. Within this project, Romania is represented by the National School of Political Studies and Public Administration (SNSPA), and the National Institute for Research and Development on Marine Geology and Geo-ecology (GeoEcoMar). The project is funded by the EU's Horizon 2020 research and innovation programme.

2. **Rex-CO2: Re-use of existing wells for large-scale CO2 storage** – the project started in September 2019, aiming to develop a specific procedure and tools for evaluating the re-use potential of existing hydrocarbon fields and wells. 32 project partners provide inputs on technical, environmental, economic, and social aspects for the assessment of the existing well infrastructure to potentially reuse it for CO2 storage. The consortium comprises several research institutions, operators, and regulatory authorities from six countries (US, UK, NL, FR, NO, RO). From Romania, the participant institution is GeoEcoMar. As the 2019 project report highlighted, the first selected case study for Romania is the Salonta depleted gas field in Oltenia, given existing analyses on the geological CO2 storage potential for the region. According to the 2020 project report, the case study was supported by ANRM and coordinated by GeoEcoMar. The projects' outcomes are expected to facilitate large-scale CC(U)S implementation by providing a tool to evaluate and rank the CO2 re-use potential of hydrocarbon fields.

3. **ECO-BASE: Establishing CO2 enhanced oil recovery Business advantages in south-eastern Europe – SEE – (2017 to 2020)**, the project assessed the potential for CC(U)S through CO2-EOR using an inventory of CO2 sources (potential capture projects) and sinks in Romania and Turkey. The project's 2019 deliverables included an economic study for the development of a CO2-EOR chain for Romania, an analysis of legislative aspects and the potential for financial incentives, best practice guides for the implementation of a project of CO2-EOR and dissemination activities. The CO2-EOR study development was prepared for the Romania Isalnita-Bradesti site in Dolj County. Following the selection area, 2 scenarios were developed: (1) a business-as-usual reference case (unabated CO2 emissions and water injection in the Bradesti field), and (2) a CO2-EOR involving CO2 capture from the Isalnita plant, pipeline transport and CO2 injection for storage and EOR in the Bradesti geological structure. The main conclusions of the analyses highlighted the need for public support (central authorities – referring to legislative framework and local authorities for population acceptance). The project was funded by the EU's Horizon 2020 research and innovation programme and the Romanian partners were GeoEcoMar, CO2Club, and Picoil Consult.

Policy and regulation

The CCS topic represented a real interest at the national level during the development of the Getica project, notably in 2011, with strong coordination among authorities to transpose the CCS EU Directive and set up the legislative framework for future investments in these types of technologies.

Although the GEO 64/2011 was approved in a timely manner, the piece of legislation granted mainly the institutional set-up without clear provisions on the exploration or storage processes. The GEO's supporting note stated that "within 12 months from the entry into force of the GEO, the Ministry of Economy will issue a Government Decision on the supporting schemes dedicated to carbon capture, transport and storage of CO2 technologies." However, such a support scheme has never been introduced (CCS4CEE country report: Romania, 2021).

Between 2011 and 2017 were adopted the procedures for granting the exploration and storage permit for geological storage of CO2 (Figure 6) and in 2018 was issued the Guideline for preparing the documentation by operators/owners: Notification regarding the abandonment of offshore wells and disaffecting the facilities (ACROPO). According to the ANRM Procedure 16/2017, the owner of a petroleum agreement can also directly obtain a CO2 storage permit if they submit the application before the end of the agreement, provided all the conditions specified in it were fulfilled. On the other hand, ANRM can grant storage permits competitively, by means of a bidding process (process detailed within the procedure), yet no bid has taken place or been announced to date regarding storage permits (CCS4CEE country report: Romania, 2021).

In terms of policies/strategies, CC(U)S projects are notably absent from Romania's National Energy Strategy and National Energy and Climate Plan 2021-2030. Two carbon capture and utilization projects were proposed as part of Romania's Recovery and Resilience Plan, involving the injection of hydrogen into gas turbines, capturing CO2 released from combustion, and transporting it to local greenhouses for use. The rationale behind these projects, proposed as hydrogen demonstrators, is unclear, and indeed they have been criticized for lack of transparency within the public consultation process (CCS4CEE country report: Romania, 2021).

Fig. 6 National legislative framework for CCS

2011

GEO 64/2011 regarding the geological storage of CO_2

- Romania's transposition of the CCS Directive
- The Ministry of Environment coordinated the WG (ANRM, ANRE, various Ministries, ISPE, GNM) in charge of the transposition process
- GEO 64/2011 aimed to facilitate the implementation of the Getica project
- Provides mainly the institutional procedures

2013

Law 114/2013 for the approval of the GEO 64/2011

- Few additional clarifications were brought regarding the use of geological formation for oil and gas operations and storage and related regulatory aspects during the exploration licence.
- ANRM - the responsible authority for geological storage started to develop a dedicated Unit for these types of projects.

2015

Procedure for granting the exploration permit for CO_2 geological storage (ANRM)

- Operators may ask ANRM for an opportunity analysis for underground storage in selected perimeters.
- Alternatively, ANRM can issue a list of relevant perimeters for geological storage (following internal opportunity analysis) and call for exploration offers.
- The selection of offers is based on criteria established by ANRM.

2017

Procedure for granting the storage permit for CO_2 geological storage (ANRM)

- Established through the ANRM President Decision 16/2017.
- The holder of an exploration license can directly obtain the storage permit by submitting the application during the validity of the exploration license and provided meeting all obligations.
- However, ANRM can grant storage permits competitively, by means of a bidding process.

Sources: Analysis based on Legislation published on ANRM website – GEO/Law and relevant Procedures.

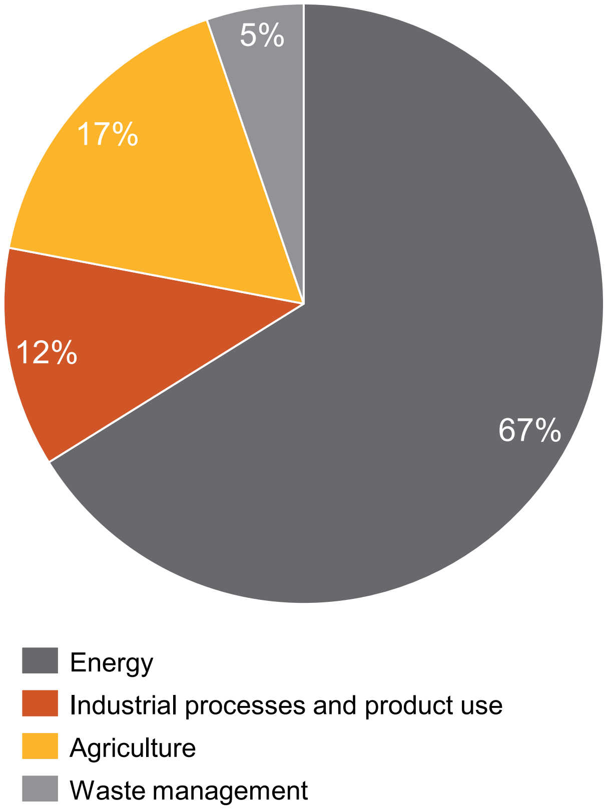
Overview of GHG and CO2 emissions in Romania

Total national GHG and CO2 emissions

Understanding Romania's domestic emissions of carbon dioxide (CO2) is key to estimating the "supply" side of the national CO2 market and the related potential for carbon capture.

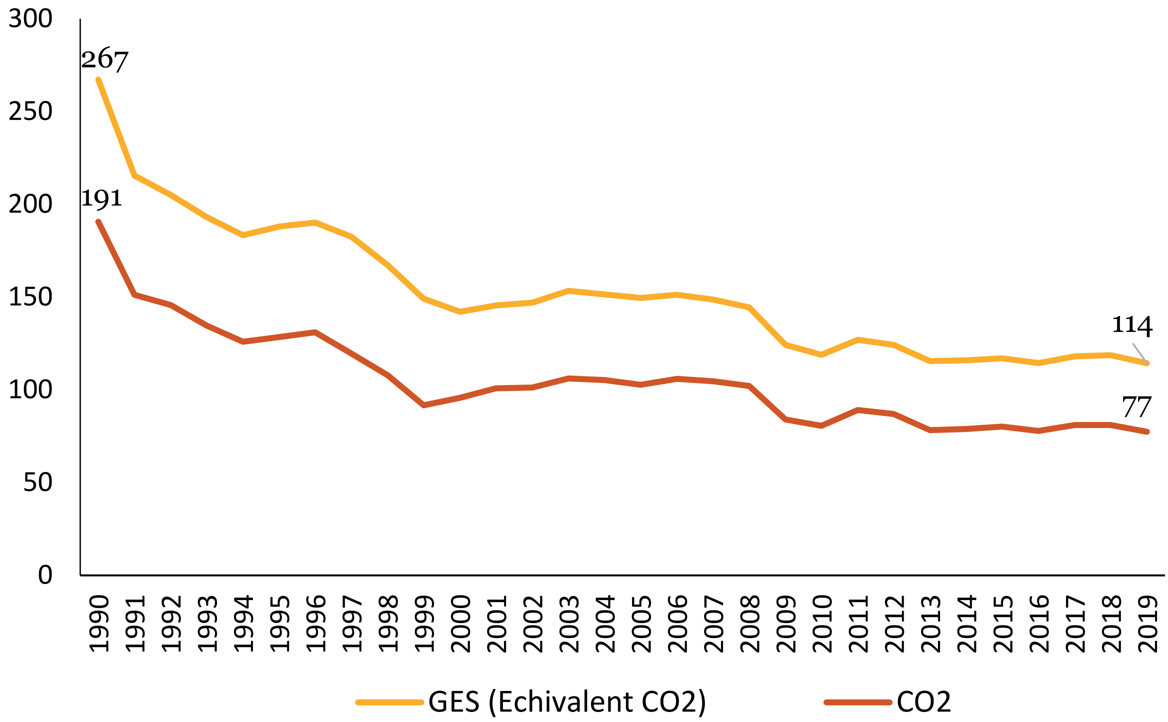
Since 1990, Romania's domestic greenhouse gas (GHG) and CO2 emissions have decreased by more than half, primarily due to the closure or operational improvement of inefficient industrial units. However, as closures are completed and efficiency improvements converge towards a technical limit, this decrease in emissions tends to stagnate. As a result, Romania's CO2 emissions have been hovering around the 77-78Mt mark since 2013[4].

Fig. 8 Share of GHG emissions in Romania by sector (%, 2019)



Source: Eurostat

Fig. 7 Evolution of GHG emissions in Romania (Mt, 1990 - 2019)



Source: Eurostat

4 CCS4CEE country report: Romania (2021).

The Energy sector is the largest GHG emitter accounting for 67% of total GHG, followed by Agriculture (17%) and Industrial processes and product use (12%), while the Waste Management sector emits 5% out of the total GHG. Within the Energy sector structure, fuel combustion for energy and transport are the major contributors to the total GHG of the sector (for more details, please see Table 2, below).

Table 2. GHG emissions by sector

Greenhouse gas emissions (Mt in CO_2 equivalent)	1990	2019
CRF1 - Energy	**194.8**	**76.0**
CRF1A1 - Fuel combustion in energy industries	70.9	21.4
CRF1A2 - Fuel combustion in manufacturing industries and construction	68.2	14.6
CRF1A3 - Fuel combustion in transport	12.4	18.9
CRF1A4 - Other fuel combustion sectors	11.3	11.8
CRF1A5 - Other fuel combustion sectors n.e.c.	1.2	0.6
CRF1B - Fuels - fugitive emissions	30.7	8.6
CRF2 - Industrial processes and product use	**32.6**	**13.1**
CRF2A - Mineral industry	6.1	5.0
CRF2B - Chemical industry	9.7	1.1
CRF2C - Metal industry	16.1	4.2
CRF2D - Non-energy products from fuels and solvent use	0.7	0.5
CRF2F - Product uses as substitutes for ozone depleting substances	0.0	2.3
CRF3 - Agriculture	**33.9**	**18.8**
CRF3A - Enteric fermentation	15.0	7.3
CRF3B - Manure management	3.8	1.7
CRF3C - Rice cultivation	0.1	0.0
CRF3D - Managed agricultural soils	14.1	9.2
CRF3F - Field burning of agricultural residues	0.7	0.4
CRF5 - Waste management	**5.1**	**6.0**

Source: Eurostat

Carbon intensity of the economy

The GHG emissions reduction over the years is mirrored by a drop in Romania's carbon intensity (i.e., the amount of CO2 emitted to produce a single unit of GDP) of approximately 78% between 1990 and 2018 (Figure 10). At the same time, the country's economy has been growing at a similar rate (approximately 87% nominal growth between 1990 and 2018) (Figure 9). This highlights a positive trend in decoupling economic growth from CO2 emissions. However, Romania's carbon intensity remains well above the EU average (0.18 kgCO2/constant 2015 US$), similar to other Eastern European countries such as Hungary, the Czech Republic and Slovakia. Similarly, Romania's share of fossil fuels in gross inland energy consumption is higher than the EU average (71.96% vs. 69.04%). This further highlights the continued significant CO2 emissions and related decarbonization needs across the Romanian economy.

Fig. 9 Romania's GDP (constant 2015, bn USD)

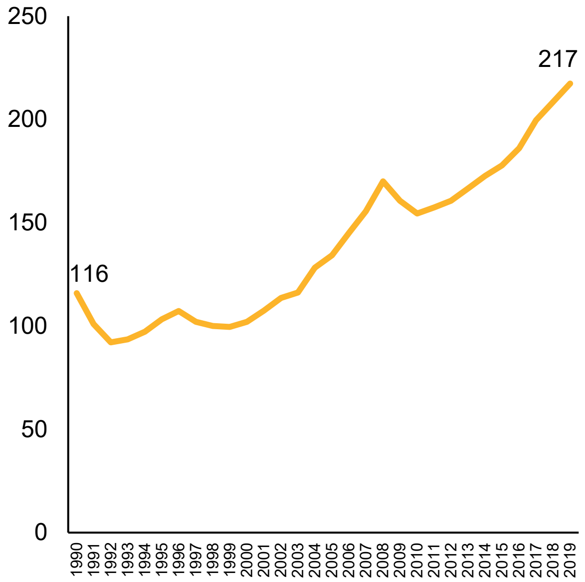
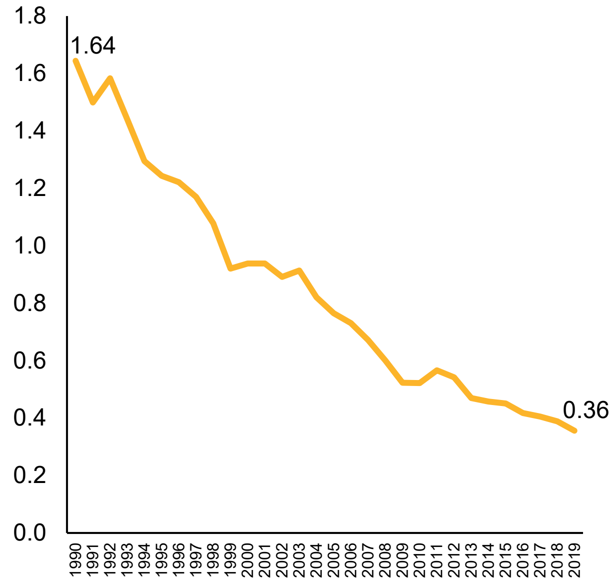
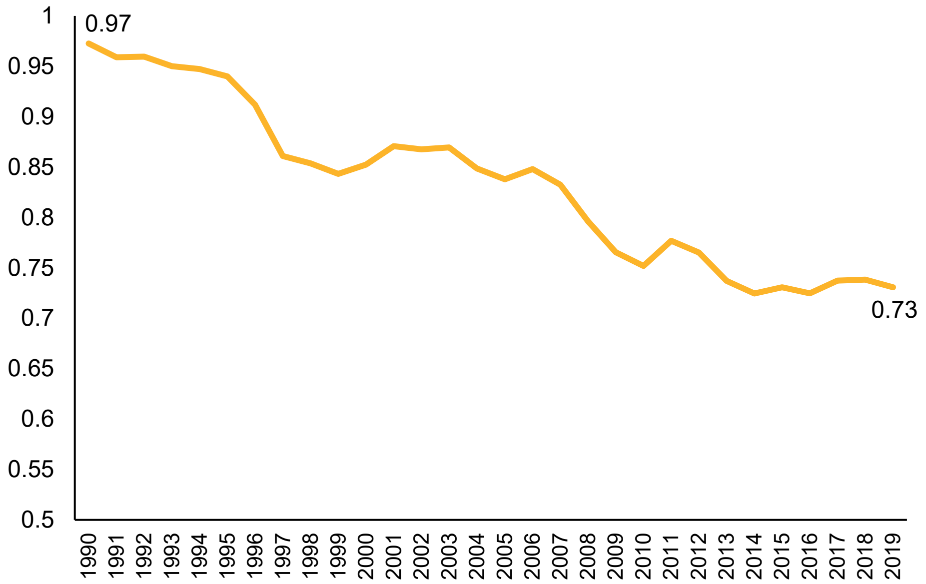


Fig. 10 Romania's Carbon intensity (kg CO2/constant 2015 USD)



Source: World Bank

Fig. 11 Share of gross inland energy consumption from fossil fuels (1=100%)



Source: Eurostat

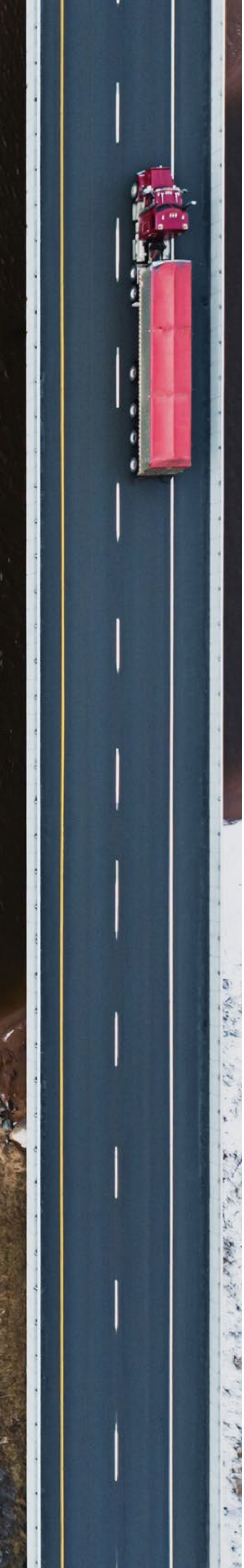


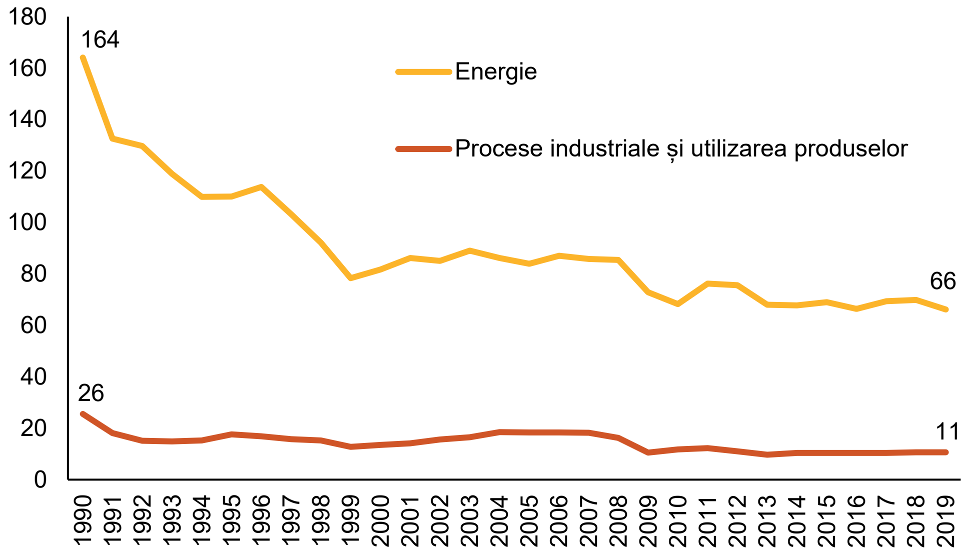
Table 3. CO2 emissions by sector

CO_2 emissions (Mt)	1990	2019
CRF1 - Energy	**164.1**	**66.2**
CRF1A1 - Fuel combustion in energy industries	70.7	21.3
CRF1A2 - Fuel combustion in manufacturing industries and construction	68.1	14.5
CRF1A3 - Fuel combustion in transport	12.1	18.7
CRF1A4 - Other fuel combustion sectors	10.8	10.5
CRF1A5 - Other fuel combustion sectors n.e.c.	1.2	0.6
CRF1B - Fuels - fugitive emissions	1.2	0.6
CRF2 - Industrial processes and product use	**25.5**	**10.6**
CRF2A - Mineral industry	6.1	5.0
CRF2B - Chemical industry	5.6	1.0
CRF2C - Metal industry	13.2	4.2
CRF2D - Non-energy products from fuels and solvent use	0.7	0.5
CRF2F - Product uses as substitutes for ozone depleting substances	-	-
CRF3 - Agriculture	**0.2**	**0.1**
CRF3A - Enteric fermentation	-	-
CRF3B - Manure management	-	-
CRF3C - Rice cultivation	-	-
CRF3D - Managed agricultural soils	-	-
CRF3F - Field burning of agricultural residues	-	-
CRF5 - Waste management	**0.0**	**0.0**
Others	**0.8**	**0.5**
TOTAL	**190.6**	**77.4**

Source: Eurostat

As with most other countries, the bulk of Romania's CO2 emissions (66 Mt, or 85.5% of total GHG emissions) comes from fuel combustion for energy production. These emissions have seen a steep decline since 1990 (by nearly 60%). A further 11 Mt (13.8% of emissions) are the result of industrial processes and product use (IPPU) – which have also decreased by 57% since 1990. The relative shares of energy- and IPPU-related emissions in Romania's CO2 emissions have thus remained relatively constant since 1990.

Fig. 12 CO2 emissions in Energy and IPPU (Mt)

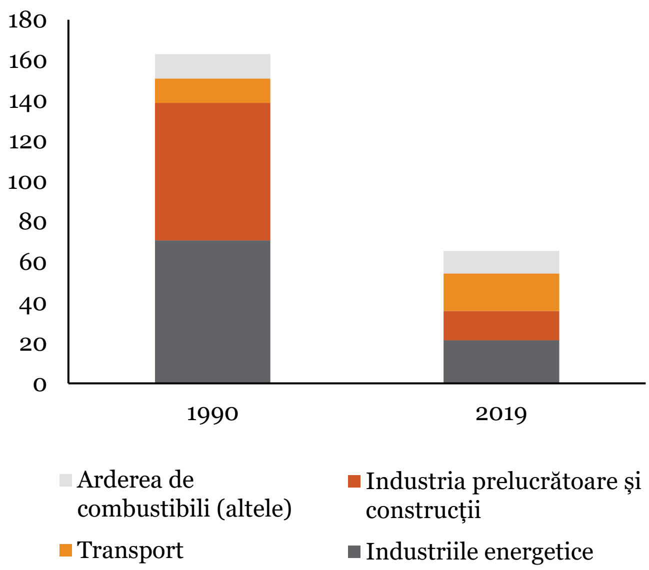


Source: Eurostat

CO2 emissions from fuel combustion

Romania's 66 Mt of CO2 emissions from fuel combustion originate primarily in the energy industries (i.e., the production of energy for utilities) (33%), in the transport sector (28%) and manufacturing industries and construction (i.e., the production of energy for fueling industrial processes) (22%). As shown in Figure 13, the reduction in fuel combustion-related emissions in the past 3 decades is primarily due to a shrinking of those originating in the energy and manufacturing industries. Transport-related emissions, on the other hand, have increased in both absolute and relative values.

Fig. 13 CO2 emissions from fuel used for energy (Mt)



Source: Eurostat

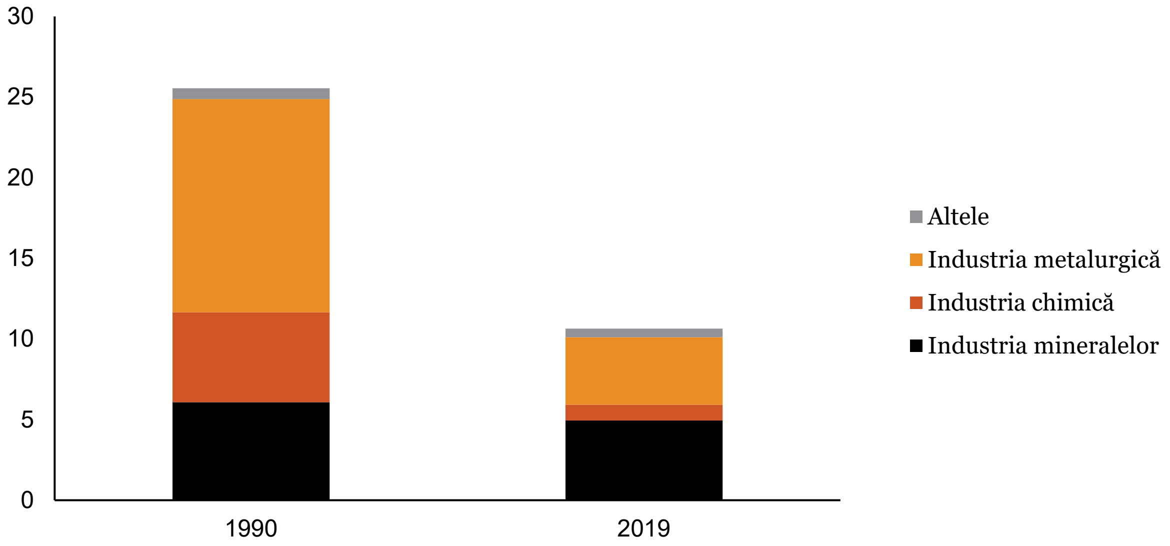
As presented in Table 4, the bulk of emissions from fuel combustion in energy industries comes from the use of fossil fuels for producing public electricity and heat. Petroleum refining, an economically important sector for Romania, is also responsible for approximately 10% of energy industries' CO2 emissions. Within emissions from fuel combustion in manufacturing industries and construction, Table 4 shows that while emissions from some sectors (such as iron and steel, and chemicals) have decreased in both absolute and relative terms, emissions from others have increased. By 2019, emissions from fuel combustion in the manufacture of non-metallic mineral products (including cement and lime) made up approx. 21% of fuel combustion-related emissions in all manufacturing industries and construction.

Table 5. CO2 emissions from fuel used for energy

CO2 emissions (Mt)	1990	2019
CRF1A1 - Fuel combustion in energy industries	**70.7**	**21.3**
CRF1A1A - Fuel combustion in public electricity and heat production	66.3	18.4
CRF1A1B - Fuel combustion in petroleum refining	4.3	1.8
CRF1A1C - Fuel combustion in manufacture of solid fuels and other energy industries	0.1	1.1
CRF1A2 - Fuel combustion in manufacturing industries and construction	**68.1**	**14.5**
CRF1A2A - Fuel combustion in manufacture of iron and steel	7.1	0.8
CRF1A2B - Fuel combustion in manufacture of non-ferrous metals	0.1	0.4
CRF1A2C - Fuel combustion in manufacture of chemicals	17.9	2.2
CRF1A2D - Fuel combustion in manufacture of pulp, paper and printing	0.0	0.2
CRF1A2E - Fuel combustion in manufacture of food, beverages and tobacco	0.1	0.9
CRF1A2F - Fuel combustion in manufacture of non-metallic mineral products	0.3	3.2
CRF1A2G - Fuel combustion in other manufacturing industries and construction	42.7	6.8
CRF1A3 - Fuel combustion in transport	**12.1**	**18.7**
CRF1A4-5 - Other fuel combustion sectors	**12.0**	**11.0**

Source: Eurostat

Fig. 14 CO2 emissions from industrial processes and product use (Mt)

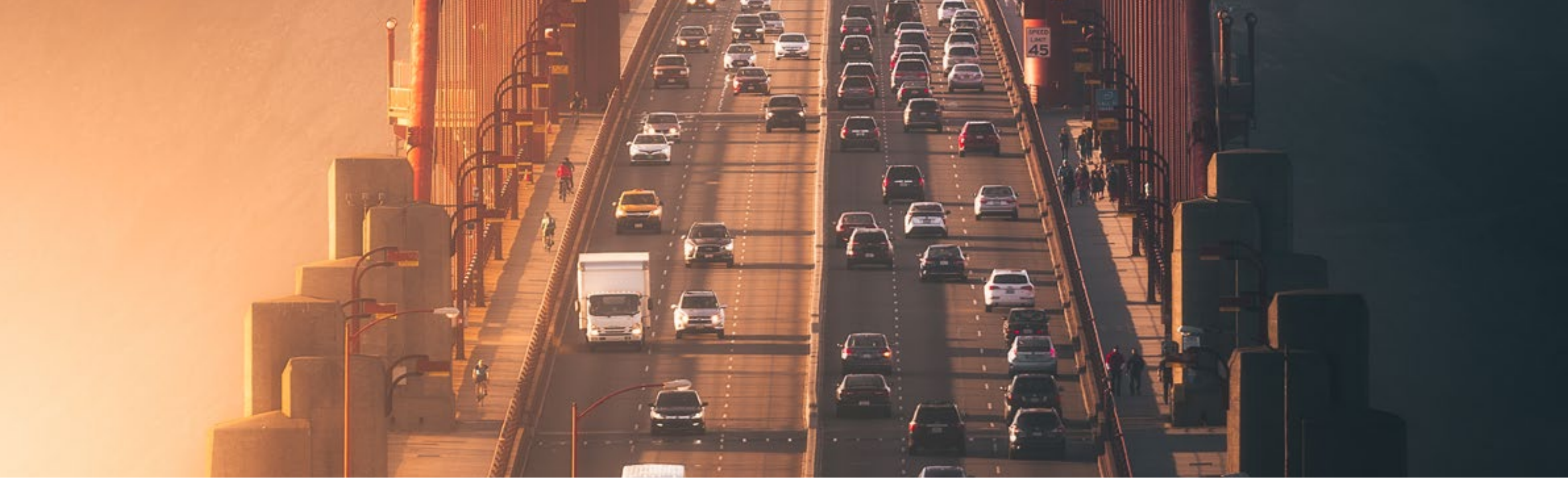


Source: Eurostat

A closer look at sector-specific IPPU emissions identifies cement production (4Mt CO2 in 2019), iron and steel production (4Mt) and lime and ammonia production (1Mt each) as the main contributors to Romania's process emissions. While iron and steel manufacturing and ammonia production have decreased their IPPU emissions in absolute terms in the last 3 decades, those of cement and lime production have remained constant. For more details, please see Table 5 below.

Table 5. CO2 emissions by sector specific IPPU

CO_2 emissions (Mt)	1990	2019
CRF2A - Mineral industry	**6.1**	**5.0**
CRF2A1 - Cement production	4.4	3.8
CRF2A2 - Lime production	1.4	0.8
CRF2A3 - Glass production	0.1	0.0
CRF2A4 - Other process uses of carbonates	0.0	0.3
CRF2B - Chemical industry	**5.6**	**1.0**
CRF2B1 - Ammonia production	4.7	0.9
CRF2B2 - Nitric acid production	:	:
CRF2B3 - Adipic acid production	:	0.0
CRF2B4 - Caprolactam, glyoxal and glyoxylic acid production	:	0.0
CRF2B5 - Carbide production	0.2	0.0
CRF2B6 - Titanium dioxide production	0.0	0.0
CRF2B7 - Soda ash production	0.1	0.0
CRF2B8 - Petrochemical and carbon black production	0.6	0.0
CRF2B9 - Fluorochemical production	:	:
CRF2B10 - Other chemical industry	0.0	0.0
CRF2C - Metal industry	**13.2**	**4.2**
CRF2C1 - Iron and steel production	12.6	3.8
CRF2C2 - Ferroalloys production	0.3	0.0
CRF2C3 - Aluminium production	0.3	0.3
CRF2C4 - Magnesium production	0.0	0.0
CRF2C5 - Lead production	0.0	0.0
CRF2C6 - Zinc production	0.0	0.0
CRF2C7 - Other metal industry	0.0	0.0
CRF2D - Non-energy products from fuels and solvent use	**0.7**	**0.5**

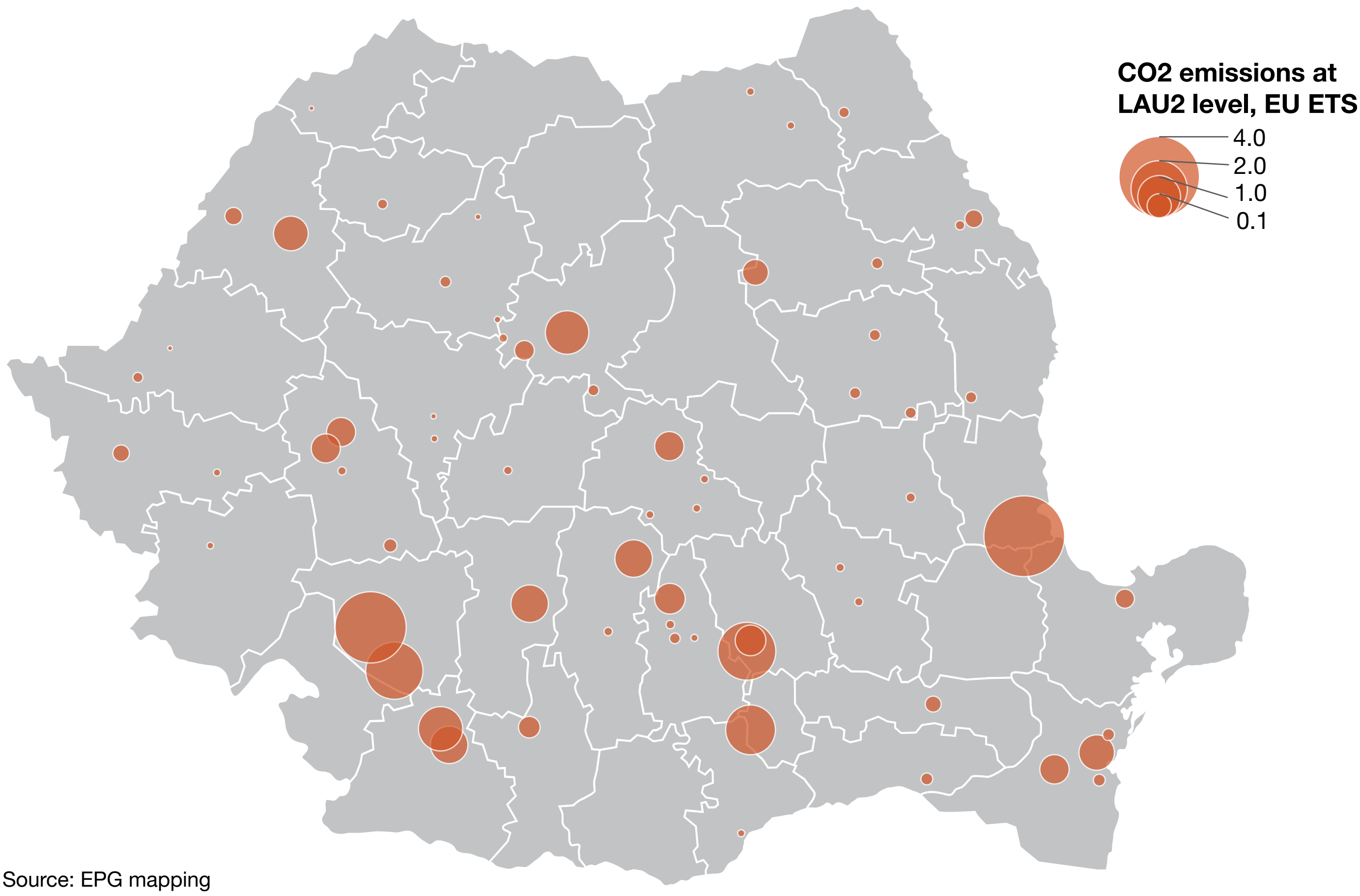


CO2 emissions covered by the EU ETS

Out of Romania's total CO2 emissions (77Mt), 37.3Mt (approx. 48%) are subject to the EU Emissions Trading System (EU ETS), the EU's carbon market. This means that the installations responsible for these emissions must surrender allowances equivalent to their emissions volumes, and as such pay a price for unabated emissions, including those harder to reduce, such as process emissions. In total, there are 158 installations covered by the EU ETS in Romania. The largest installations (those emitting more than 100,000 tonnes of CO2-equivalent[8] in 2019) are presented in Figure 15. As highlighted in the Map, geographical areas with a higher concentration of large emitters are in Gorj, Dolj, Galați and Prahova counties, as well as the Bucharest capital region.

The largest emitters making up the emissions of these regions are the Rovinari power station in Gorj county (part of the Oltenia Energy Complex), the Liberty Steel Plant in Galați, several power stations within the Oltenia Energy Complex (Turceni, Isalnita and SE Craiova II) in Gorj and Dolj counties, the Azomures fertilizer producer in Mures county, the Brazi power station and the Petrobrazi refinery in Prahova county, but also several cement producers. Table 13 in the Appendix presents the full list of emitters with 2019 emissions of over 100,000 tonnes of CO2-equivalent.

Fig. 15 CO2 emmissions at LAU2 level, EU ETS (Mt, 2019)



Source: EPG mapping

8 The EU ETS covers emissions of several GHGs, primarily CO2, nitrous oxide and perfluorocarbons. The climate warming potential of non-CO2 GHGs is standardized to units of "CO2-equivalent" and aggregated with CO2 emissions to produce a single emissions figure for each installation.

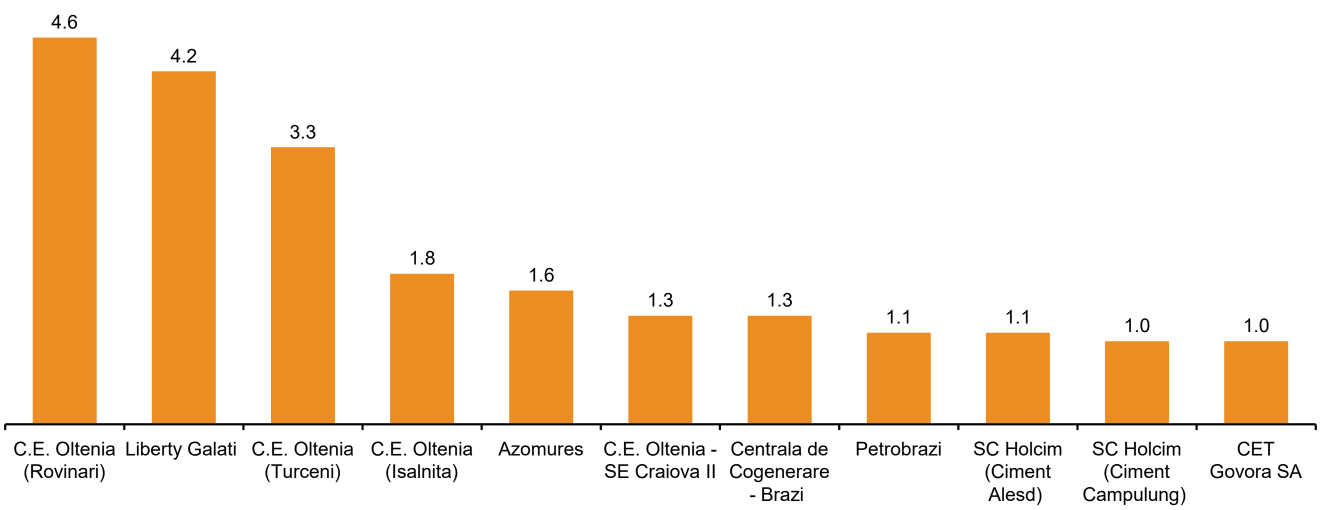
Knowing the difference in viable decarbonization solutions between fuel combustion and IPPU emissions, it is useful to understand the primary economic activities of large ETS emitters (Table 6). The electricity production sector is the largest contributor to total CO2 emissions (40%), and a relatively important economic sector among those covered by the EU ETS. The third- and fourth-most important economic sectors of those covered by the ETS (by % of national turnover), iron and steel and cement production, also contribute significantly to total CO2 emissions (12% and 16%, respectively). However, the most economically important ETS sector for Romania, by % of national turnover, is the manufacture of refined petroleum products, whose contribution to CO2 emissions (5% of national emissions) is relatively reduced compared to other sectors.

Table 6. Sectors with the highest emissions in ETS in 2019

Sector by NACE Rev. 2 code		CO2 emissions (tonnes), 2019	CO2 emissions (% in total CO2 emissions including LULUCF), 2019	% of total national turnover
3511	Production of electricity	14,755,541	40%	0.91%
2351	Manufacture of cement	5,900,471	16%	0.23%
2410	Manufacture of basic iron and steel and of ferro-alloys	4,424,259	12%	0.55%
2015	Manufacture of fertilisers and nitrogen compounds	1,801,648	5%	0.12%
1920	Manufacture of refined petroleum products	1,689,037	5%	1.29%
2352	Manufacture of lime and plaster	511,179	1%	0.01%
2013	Manufacture of other inorganic basic chemicals	268,300	1%	0.11%
2332	Manufacture of bricks, tiles, and construction products, in baked clay	231,714	1%	0.05%
1712	Manufacture of paper and paperboard	48,984	0%	0.12%
2311	Manufacture of flat glass	70,662	0%	0.04%

Source: Eurostat

Fig. 16 Ranking of companies with CO2 emissions over 1Mt in 2019



Source: EPG analysis based on ETS data

Estimation of CO2 storage capacities in depleted and active onshore oil and natural gas reservoirs

According to European CO2 storage database: CO2 Storage Potential in Europe (2013) the total storage capacity in hydrocarbon deposits is estimated at 514Mt CO2. The split between gas and oil deposits is almost even: 246.78Mt in oil deposits and 267.56Mt in gas deposits.

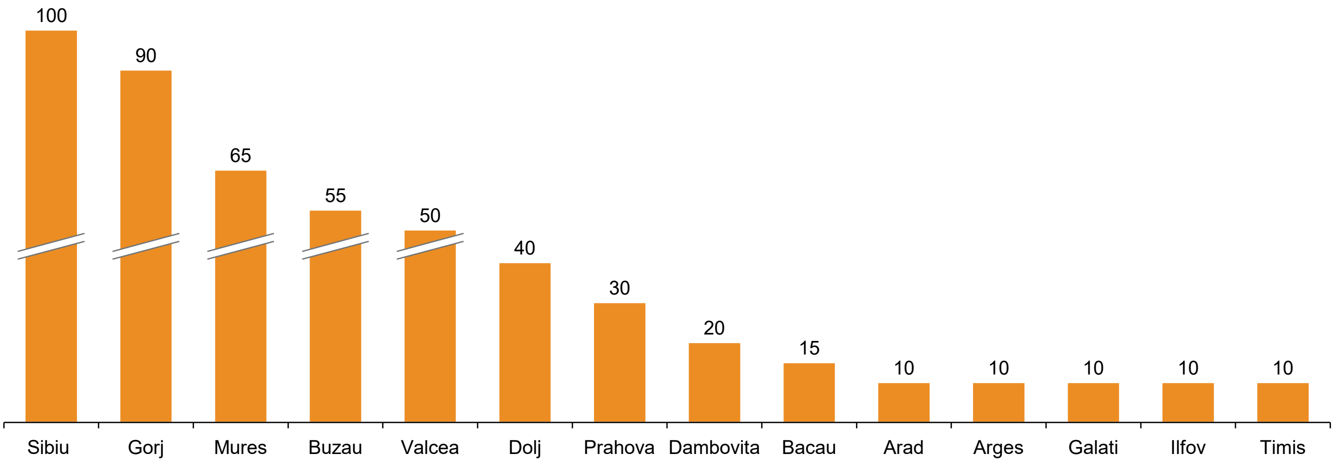
The publicly available data show that there are 29 hydrocarbon deposits that can be used to store CO2. The largest deposit is a gas field near Copsa Mica in Sibiu having an estimated capacity of 100Mt CO2, followed by 3 deposits, each with an estimated capacity of 50Mt located in Ghergheasa (gas deposit in Buzau county), Babeni (oil deposit in Valcea county), Bibesti-Bulbuceni (oil deposit in Gorj).

Sibiu (1 deposit), Gorj (3 deposits) and Mures (3 deposits) are the counties with the highest storage capacities in hydrocarbon deposits as in Figure 17.

When looking at storage capacity by type of deposit, oil or gas respectively, we observe the following:

- For gas deposits, the highest CO2 storage capacities are in Copsa Mica (Sibiu, 100Mt), Ghergheasa (Buzau, 50Mt) and Targu Mures Dome and Sangeorgiu de Padure (Mures, 25Mt per site).
- For oil deposits, the highest CO2 storage capacities are in Babeni (Valcea, 50Mt), Bibesti- Bulbuceni (Gorj, 50Mt) and Targu Jiu (Gorj, 15Mt).

Fig. 17 County ranking by total storage capacity (Mt CO2)



Source: European CO2 storage database: CO2 Storage Potential in Europe

Table 7. Gas deposits

#	Gas deposit name	Mt CO2	Status in 2013	County
1	Copsa Mica	100		Sibiu
2	Ghergheasa	50	Depleted	Buzau
3	Targu Mures Dome	25		Mures
4	Sangeorgiu de Padure	25		Mures
5	Stramba-Rogojelu	25	Suspended	Gorj
6	Teis-Viforata	20		Dambovita
7	Iernut	15	Producing	Mures
8	Turnu	4	Producing	Arad
9	Malu Mare	3.56	Depleted	Dolj
-	**TOTAL**	**267.56**		

Source: European CO2 storage database: CO2 Storage Potential in Europe

Table 8. Oil deposits

#	Oil deposit name	Mt CO2	Status as of 2013	County
1	Babeni	50		Valcea
2	Bibesti-Bulbuceni	50		Gorj
3	Targu Jiu	15		Gorj
4	Simnic	15		Dolj
5	Tataru	15		Prahova
6	Calinesti-Oarja	10		Arges
7	Aricesti	10		Prahova
8	Ghercesti	9.59	Depleted	Dolj
9	Carcea	8.75		Dolj
10	Turnu	6	Producing	Arad
11	Bacau	5		Bacau
12	Tescani	5		Bacau
13	Gradinari	5		Ilfov
14	Catelu	5		Ilfov
15	Independenta	5		Galati
16	Tepu	5	Depleted	Galati
17	Glavanesti	5		Bacau
18	Tintea-Baicoi-Floresti-Calinesti	5	Depleted	Prahova
19	Berca-Arbanasi	5		Buzau
20	Calacea	5	Producing	Timis
21	Satchinez	5	Producing	Timis
22	Malu Mare	2.44	Depleted	Dolj
-	**TOTAL**	**246.78**		

Source: European CO2 storage database: CO2 Storage Potential in Europe

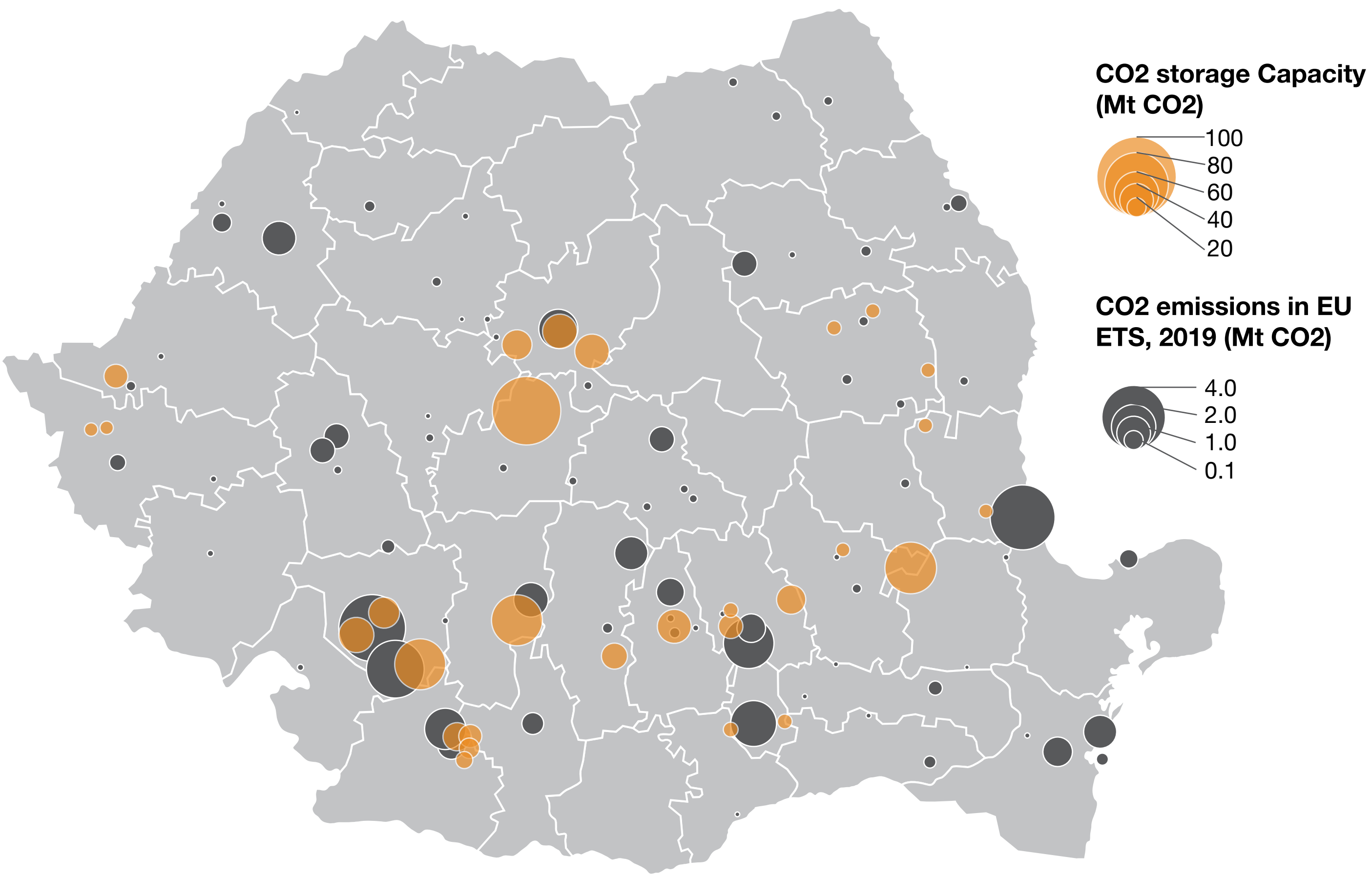
When mapping both the largest CO2 emitters and CO2 storage capacity, we observe six main areas of interest for potential CCS development: (1) Gorj, (2) Dolj, (3) Galati – Buzau, (4) Mures, (5) Valcea, (6) Prahova, as presented in Figure 18.

The distance from the emitter's location to potential storage sites was computed with the help of GIS software. Having in mind that some of the storage sites are small and setting up a transport infrastructure between the emitter and the storage site requires a significant investment, for each emitter the software selected the nearest storage site that has a capacity of at least ten times higher than the CO2 emissions in 2019. For example, the closest storage site to Galati is Independenta which has a capacity of 5Mt. That is almost the yearly amount of CO2 emissions from Galati (4.24Mt). Thus, the emissions from Galati would fill in the deposit in Independenta in less than two years. Therefore, the Ghergheasa deposit (capacity of 50Mt) represents a more suitable location for potential CCS development. Although it is located at a greater distance (73 km) from Galati, it can store more than ten times the yearly CO2 emissions from Galati. The distances are expressed as km of straight line between the emitter location and the storage location.

Moreover, the proximity to the gas transport pipeline represents a major advantage for potential CCS projects, because a CCS transport pipeline could be developed next to the existing gas network. Such a strategy might facilitate the building permit procedures and tackle current challenges related to the poor public evidence of ownership - local public authorities do not always have accurate information as to the ownership of the plots of land in their jurisdiction.

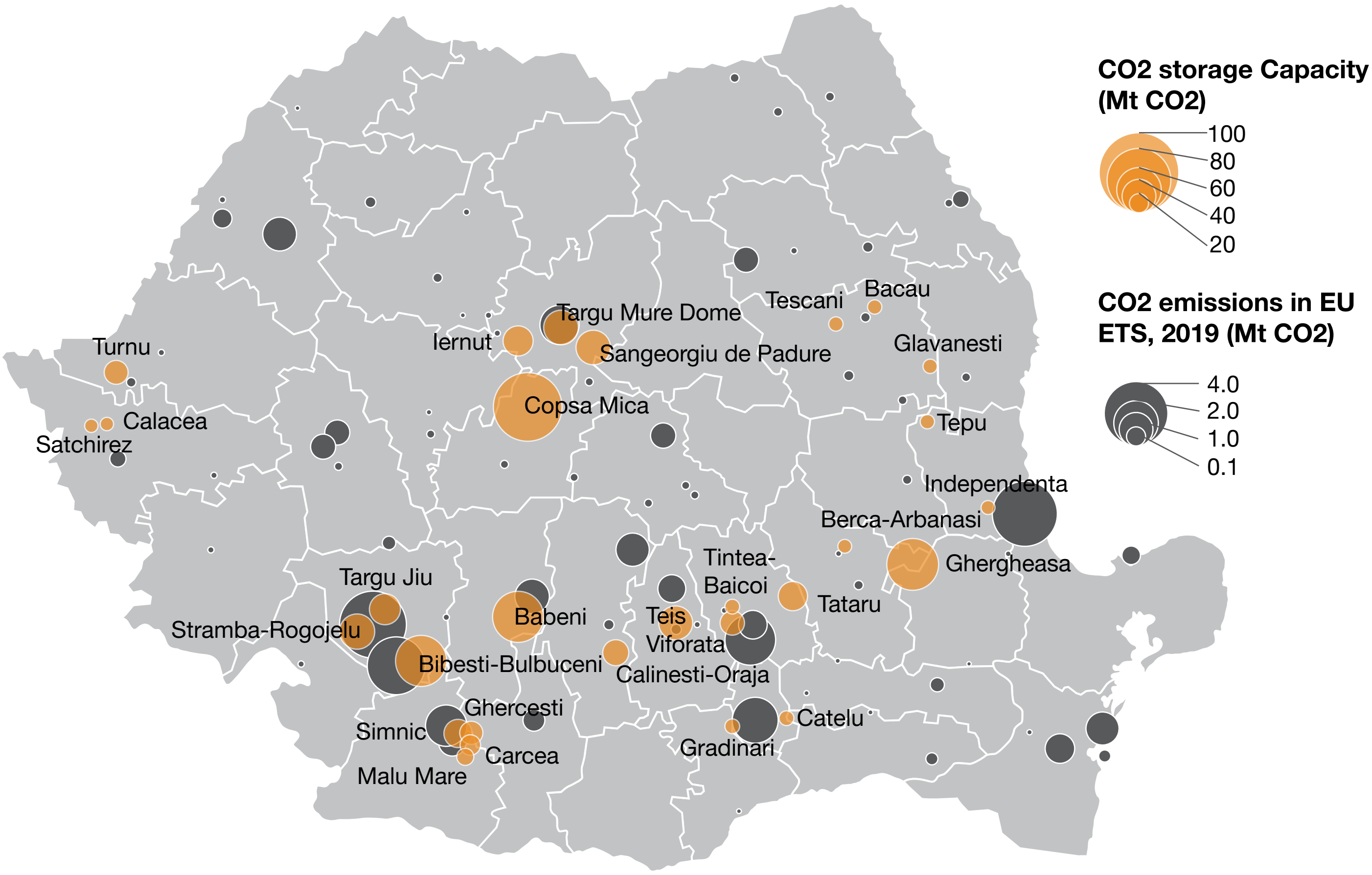
There were several cases in which the nearest deposits had a lower capacity than the 10 years threshold. In order to solve this problem, several deposits were listed as alternatives (please see Table 14 in Appendix).

Fig. 18 CO2 emitters and CO2 storage capacity



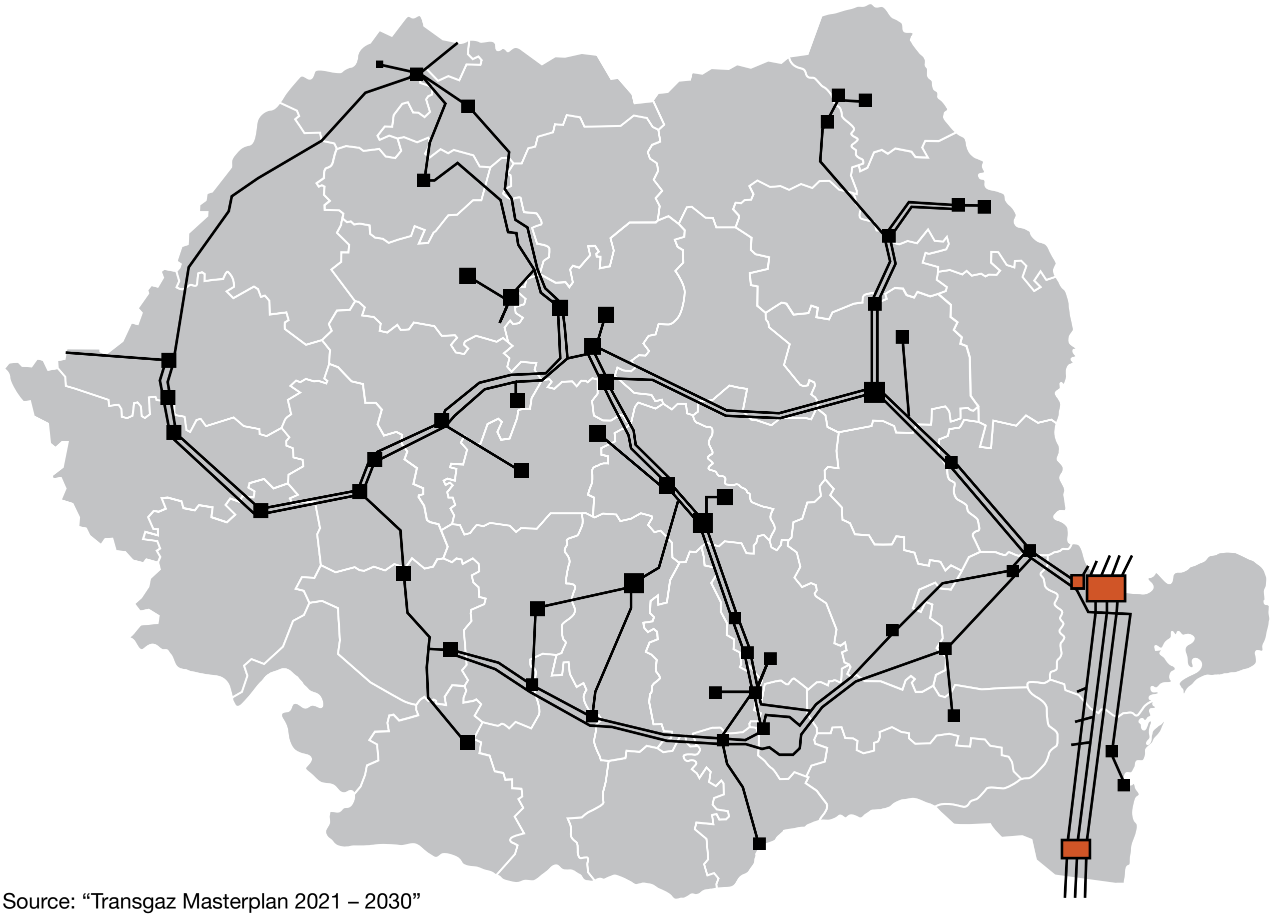
Source: EPG mapping based on European CO2 storage database: CO2 Storage Potential in Europe and EU ETS.

Fig. 19 Largest CO2 emitters & storage capacity (Mt)



Source: EPG mapping based on European CO2 storage database: CO2 Storage Potential in Europe and EU ETS.

Fig. 20 Gas Transport Network



Source: "Transgaz Masterplan 2021 – 2030"

Assessment of potential short- and medium-term investments in CCS projects

CCS is one of the most expensive and technically challenging carbon emissions abatement options so the full life-cycle cost of CCS must be considered in the context of the overall social, environmental and economic benefits which it creates, and the costs associated with environmental and social risks it presents. Stationary fossil-fuel powered energy and large-scale petroleum industry operations are two examples of industries which could benefit from CCS.

Recently, the willingness of some of the largest local CO2 emitters in becoming carbon neutral and the skyrocketing prices of the EU ETS (Figure 21) increased the investors' interest in CCS projects.

To estimate the initial investment needed to develop a CCS project, we used various research papers and studies published by international institutions. According to such studies, the cost range for new CCS projects outside clusters or hubs is higher as there are no previous spill-over effects. This scenario applies to Romania, as there are no clusters either locally, or in the region, therefore, we used as benchmarks the figures presented in Table 9.

Fig. 21 – EU ETS carbon prices (EUR/t)

Source: Analysis based on Ember Climate Data

Table 9. Estimated cost range for CCS projects

Cost range for CCS projects (EUR/tCO2)		
Capture	258	343
Compression/Dehydration	26	43
Transport	26	43
Storage	17	26
CCS - Total	326	455

Note: Usually CCS cost range is estimated in USD/tCO2, but we used the European Central Bank exchange rate (2021 average and 2022 Jan – May average), in order to approximate the figures in EUR.
Source: Estimations based on Global CCS Institute, major CCS investments in Northern Europe, Kearney/Energy Transition Institute: CC(U)S Towards net zero.

The initial investment needed for the development of a CCS project with a capacity of 1Mt of CO_2 per year in Romania ranges between EUR 326m and EUR 455m. The lifetime of such a project is approximated at 20-25 years.

Out of the total cost, the capture process represents almost 80% of the total cost for a CCS project, being more complex.

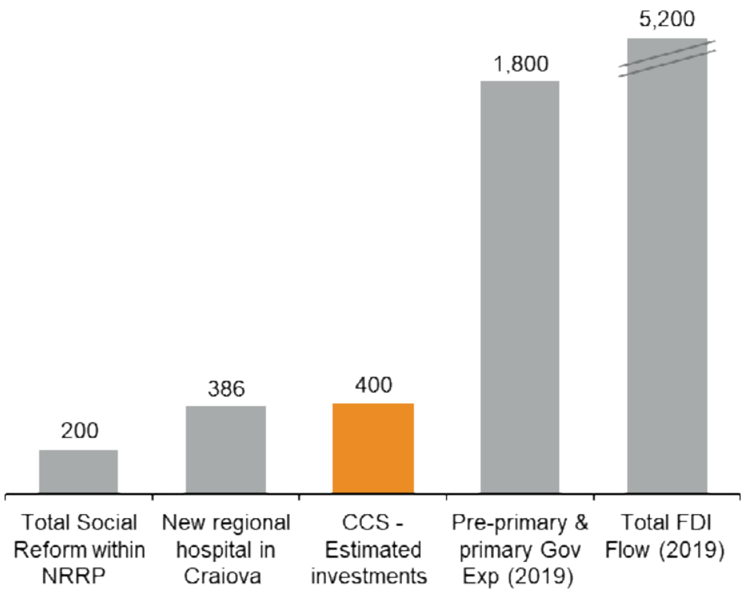
Table 10. Estimated initial investments for a CCS project

Mt CO_2 storage per year	Investment range (EURm)	
1	326	455
4	1,304	1,819

Source: PwC and EPG estimations

High investments are needed to develop a CCS project (average at EUR 400m) and for a better understanding of this amount, we used some references as highlighted in Figure 22. For instance, the investment needed for a CCS project is similar to the development of a regional hospital with 807 beds. Moreover, the amount represents 22% of the pre-primary and primary government expenditures for education, or 7.6% out of the total Foreign Direct Investment flow from 2019.

Fig. 22 CCS projects require high level of investments (EURm)



Source: Analysis based on public available data: NRRP, EIB website – Craiova hospital, Eurostat, NBR Report on FDI evolution in Romania.

In the medium term, to reach for example a 4Mt of CO_2 storage, representing approximately 10% of the total ETS CO_2 emissions, the needed investments are up to EUR 1.3 – 1.8bn.

Large-scale infrastructure projects, such as CCS, are capital intensive. Companies are most likely to invest where there is support from the government, through direct grant funding or to support private sector equity investments. Above high costs, there are also high risks associated with these types of projects, notably:

- Revenue risk due to an insufficient value on CO_2, while the sale of CO_2 for EOR has generated revenue for some CCS projects, large-scale deployment requires stronger climate policies.
- In most jurisdictions, the cost of capture, transportation and storage of CO_2 is greater than the value currently placed on it.
- Value chain risk, as CCS facilities may involve one source, one sink, and one pipeline. These disaggregated business models are expensive and there is an interdependency risk. For example, if the industrial source of CO_2 closes, the pipeline and storage operators both have no customers and no revenue.

Moreover, in Romania, it currently seems to be a lack of Government support for such projects.

Socio-economic impact of CCS investments in Romania

CCS should prove sustainable to be effectively an option in the efforts to mitigate climate change, by delivering consistent environmental and social benefits which exceeds its costs of capital, energy and operation; namely, it should prove to protect the environment and human health in the long run and be suitable for deployment on a significant scale.

Although the CCS market is not that mature, there are studies presenting the socio-economic impact of such projects. The main conclusions identified include the following:

- CCS have an important role in reducing CO2 emissions and contributing to the net-zero target.
- CCS could achieve deep decarbonisation in hard-to-abate industry: The cement, iron and steel, and chemical sectors are amongst the hardest to abate due to their inherent process emissions and high-temperature heat requirements.
- CCS could create new jobs - Once construction is complete, job generation tends to decline, with typical plant estimates of 200–300 jobs in operation and maintenance and the associated supply chain, of which 50–100 jobs are at the plant itself.
- CCS could enable the production of low-carbon hydrogen at scale: Hydrogen is likely to play a major role in the decarbonisation of hard-to-abate sectors and may also be an important source of energy for residential heat demand and flexible power generation.
- CCS could provide low-carbon dispatchable power: The rapid decarbonisation of power generation is crucial to achieving net-zero emissions. CCS-equipped power plants play an important role as they help ensure that the low-carbon grid of the future is resilient and reliable.
- CCS could support economic growth through new net zero industries and innovation spill-overs: The widespread deployment of CCS will create new opportunities in the supply of infrastructure and technology, the provision of services and finance, and the production of low-carbon products.

- CCS could enable infrastructure re-use and deferral of decommissioning costs: Where oil or gas production fields are at the end of their lives, there may be opportunities to re-use existing oil and gas infrastructure by repurposing it for CO2 transport and storage. This could provide a range of benefits, including reducing the cost of building transport and storage infrastructure and potentially reducing permitting time.

- CCS could facilitate a just transition by alleviating geographic and timing mismatches: One of the key challenges of achieving a just transition is the disconnect between the geographic spread of job losses and gains, and the timing of these changes. Jobs created in low-carbon industries may not occur at the same time as job losses in high-emission industries. This will reduce the long-term employment prospects of workers in declining industries over time.

Following a thorough literature review on the public perception regarding CCS projects, we acknowledge that it is highly important to present the impact at the local level rather than aggregated figures. Moreover, Section 4.4 on the storage capacity identifies potential clusters for CCS (i.e. regional/county level) based on supply and demand.

The first step of the socio-economic analysis consists of a high-level analysis of identified potential counties/locations for CCS projects followed by a deep dive at the local level.

Table 11. High-level analysis of identified potential clusters/locations for CCS projects

#	Location	Emissions by large CO2 emmitter/s (Mt CO2)	Storage capacity by largest deposit (Mt CO2)	Linear distance from emitter (km) to storage capacity	Transport Gas Network in proximity (Yes/No)	Observations
1	Gorj (Rovinari & Turceni)	8.0	50 (Bibesti Bulbuceni)	12--35	Yes	Draft GEO on coal phase out. Expected reduction of CO2 emissions from the 2 largest emitters in the following years.
2	Dolj (Isalnita & Craiova)	3.1	15 (Simnic)	16 --48	Yes	Craiova I and II are due to be shut down by 2026 and Isalnita 8 by the end of curret year. Thus, emissions in DJ will go down. Potential for CCS
3	Galati (Liberty) - Buzau	4.2	55 (Ghergheasa - Buzau)	73	Yes	Long distance - higher investments in CCS transport infrastructure. However, there is a strong potential for CCS. For instance, Liberty declared its intentions to reduce its carbon footprint.
4	Mures (Azomures)	1.6	25 (Targu Mures Dome)	2	Yes	Strong potential for CCS. Moreover, as a location with history in the hydrocarbons. However, recent geopolitical events led to increased storage capacity for natural gas. Thus, this field might be used for this purpose.
5	Prahova (Brazi)	2.7	15 (Tataru)	36	Yes	Strong potential for CCS. Favourable variables: including access to research (Petroleum and Gas Univ) and history within the sector
6	Bucuresti (CET)	2.3	55 (Ghergheasa - Buzau)	130	Yes	Long distance and more difficult to develop the needed infrastructure (i.e. transport) due to Bucharest density and activity

Source: PwC and EPG analysis

Following the high-level analysis, we identified 2 potential locations for a CCS development, respectively: Galati-Buzau and Prahova.

For a deep dive assessment, we selected Galati – Buzau locations based on: (i) cross-counties economic impact, (ii) Liberty Galati announced objective to become carbon neutral and (iii) lower GDP per capita and Foreign Direct Investments compared to Prahova. Thus, the socio-economic impact is expected to be higher.

Therefore, a potential CCS project developed with a 1Mt CO2 storage capacity between Galati & Buzau might lead to:

- EUR 400m capital inflow for the initial development of the project. If the share will be 80% in Galati and 20% in Buzau (and across the transport pipeline). This means approximately EUR 320m in Galati for the capture technologies and EUR 80m in Buzau (and across). The amount in Galati accounts for 45% of total FDI stock in the county (EUR 708m) and the one in Buzau accounts for 18% of total FDI stock in the county (EUR 451m).
- Enabling the decarbonization of the industry: CO2 emissions reduction by about 1Mt per year, representing about 24% of the county's emissions, with a positive impact on the environment and people.
- Between 200-300 new jobs, out of which 50-100 in the plant and the additional for the maintenance process and along the value chain.
- High-paying new jobs, as most of them will involve the need for technical/specific skills.
- Safeguard existing jobs both in Galati (i.e. Liberty Galati has around 5,600 employees, being the largest employer in the county) and in Buzau.
- Increased local fiscal revenues through taxes and contributions.
- Significant contribution to the Romanian objectives on GHG emissions reduction.
- Development of a competitive advantage in terms of know-how and technology within the Region. Romania could acquire, before other countries, the technical know-how, which would allow the development of a CCS base that will also serve the countries in the region.
- The setting up of a national flagship project.
- Attract new business which will provide benefits through knowledge sharing and other spill-over impacts, but also research opportunities.

Public perception

Romania's experience (results of public perception on energy projects)

Romania has a relevant track record in terms of negative public perception of big energy projects which led to long-term echoes of failure. Rosia Montana is the most famous in light of a huge conflict among opponents, initiators of the mining project and supporters. With the efforts of the company Rosia Montana Gold Corporation to conduct surface exploitation of several mountains, environmental activists and NGOs actively promoted the touristic potential of the area highlighting environmental risks and barriers against the touristic development of the region.

A few years after, in a context in which Europe was seen as having good potential for shale gas exploitation with the aim of contributing to the much-debated energy security and independence from the Russian gas, the business plans of the American company Chevron were doomed to failure in several countries, Romania included, which led to the exit of the company from Europe, motivated as "economic decision" against the lowering of the oil price. Although highly experienced in shale gas technologies and procedures, Chevron came to Romania, after steps taken to discover shale gas in Bulgaria, at a time when social media had developed a huge campaign against the American company, attracting supporters, NGOs and local communities in opposition to any operations by Chevron, advertised as causing huge environmental risks and inevitable earthquakes. Although actively engaged in a well-tailored CSR strategy in the relation with the local communities in the locality of Pungesti, the benefits brought by Chevron's presence on the ground - translated into building schools and other facilities, promoting programs in support of the local children and communities overall and investing significant amounts of money to raise the living standards of people in Pungesti -, the company could not finalize its business plan. Efforts had also been made by organizing special conferences with foreign specialists from Europe and US to explain to relevant stakeholders the technology, the procedures used, the exact impact, the real level of potential risks and the benefits. Nevertheless, the approval of the shale gas exploration licenses was a governmental step highly criticized by the public and stirred in big public protests and local barriers which in end contributed to Chevron's exit from Romania and from the other countries in Europe.

Lack of knowledge on modern technologies and the environmental impact – perceived as negative - derived from their use and seen as affecting peoples' life, are major triggers of critical public perception. Public support for the implementation of any such modern projects is of utmost relevance and should be thoroughly considered by any company prior to taking steps for developing large-scale operations. In many respects, it can be far more beneficial to understand public reactions and influences on public attitudes/support before projects commence. Otherwise, industrial and policy actors are usually left cleaning up the mess of a project implementation gone wrong. Without public acceptance, technologically robust and economically viable development will fail.

In order to develop a CCS project in Romania, a stakeholder' engagement process should be developed as highlighted in Table 12.

Table 12. Stakeholders' engagement process for CCS development

Stakeholders	Key expectations and interests	Potential contribution to the project
Policymakers (state level)	Safety of CCS technologies, reducing the negative impact on the environment, fulfilling responsibility to reduce CO2 emissions, modernizing equipment of industrial enterprises, technological and socio-economic development, improving the country's positions in the global area, budget revenues of the project	Financial support of the projects, opportunities for lobbying, additional measures to stimulate emission reduction and development of CCS technologies based on cooperation with research centres, promoting projects implementation for socio-economic development
Policymakers (municipality level)	Safety of CCS technologies, reducing the negative impact on the environment, increasing attractiveness of the region, socio-economic development, budget revenues	Implementing PPP mechanisms, opportunities for lobbying
Investors and financial institutions	Sustainable development and socially responsible investment, the creation and strengthening of partnerships with companies participating in the projects, diversification of the projects portfolio, the accumulation of experience in participating in CCS projects	Providing financial and other resources for the project implementation
Large emitters and participants	Achieving the goals of the projects, projects implementation in accordance with the terms and budgets, the technological development of the companies, increasing the investment attractiveness of the business	Full responsibility for implementation of projects, promoting the popularization of CCS in the industry
Technology suppliers	Buoyant demand for CCS technology	Key impact on project costs (capital and operating)
Local public	Safety of CCS technologies, employment opportunities, socio-economic development of the region	Staffing, the ability to purchase local goods and services, social license to operate
NGOs	Safety and evidence-based feasibility of CCS technologies, environmental compliance during the project implementation, minimizing the negative impact on ecosystems	Opportunities for lobbying due to the authority of a number of NGOs among the public
Research/ Academia	Research on all aspects of CCS in support of basic science and Romanian government efforts on energy and climate change.	Full support on research and pilot project development
Media	Transparency and availability of information on projects, open dialogue with project participants	A communication tool, promoting a positive opinion about CCS technology in society, as well as a positive reputation of operating companies
Controlling organizations: ANRM, ANRE, ANPM and local authorities	Reliability and regularity of provided data on projects, implementation of projects in the framework of current legislation	Favourable institutional conditions for conducting work on the project
Project teams	Social responsibility of operating companies, high wages, decent working conditions, opportunities for professional development	The main influence on the achievement of project objectives and indicators of their effectiveness
Suppliers and contractors	Long-term contracts and stability of interaction	The main impact on the performance of projects in terms of cost, time and quality

Source: Analysis based on the Report Stakeholder Management: An approach in CCS Projects, SP Mining University, 2018

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Appendices

Table 13. List of companies with CO2 emissions over 100.000 tonnes in 2019

#	Installation Name	Verified emissions (tonnes)	NACE code	Location
1	SC C.E. Oltenia SA - SUC. Electrocentrale Rovinari	4,628,600	Production of electricity (35.11)	Oraș Rovinari
2	Liberty Galați SA	4,193,464	Manufacture of basic iron and steel and of ferro-alloys (24.10)	Municipiul Galați
3	S Complexul Energetic Oltenia SA - SE Turceni	3,296,552	Production of electricity (35.11)	Oraș Turceni
4	S Complexul Energetic Oltenia SA - SE Isalnita	1,818,205	Production of electricity (35.11)	Ișalnița
6	SC Azomureș SA	1,578,627	Manufacture of fertilisers and nitrogen compounds (20.15)	Municipiul Tîrgu Mureș
7	SC Complexul Energetic Oltenia S.A. - SE Craiova II	1,268,134	Production of electricity (35.11)	Municipiul Craiova
8	Centrala de Cogenerare cu Ciclu Combinat - Brazi	1,256,180	Extraction of crude petroleum (06.10)	Brazi
9	Petrobrazi	1,062,993	Extraction of crude petroleum (06.10)	Brazi
10	SC Holcim (Romania) SA - Ciment Alesd	1,048,635	Manufacture of cement (23.51)	Aștileu
11	SC Holcim (Romania) SA - Ciment Câmpulung	1,039,764	Manufacture of cement (23.51)	Valea Mare Pravăț
12	SC CET Govora SA	1,028,701	Steam and air conditioning supply (35.30)	Municipiul Râmnicu Vâlcea
13	SC Rompetrol Rafinare SA	963,953	Manufacture of refined petro-leum products (19.20)	Oraș Năvodari
14	CRH Ciment (RO) SA - Punct de lucru Medgidia	942,568	Manufacture of cement (23.51)	Municipiul Medgidia
15	SC Electrocentrale București - CET București Sud	792,976	Production of electricity (35.11)	București
16	CRH Ciment (RO) SA - Punct de lucru Hoghiz	758,387	Manufacture of cement (23.51)	Hoghiz
17	Electrocentrale Deva	733,306	Production of electricity (35.11)	Vețel
18	Heidelbergcement Romania SA - fabrica de ciment Tașca	731,001	Manufacture of cement (23.51)	Tașca
19	Heidelbergcement Romania SA - fabrica de ciment Fieni	715,632	Manufacture of cement (23.51)	Oraș Fieni
20	Heidelbergcement Roma-nia SA - fabrica de ciment Chișcădaga	664,484	Manufacture of cement (23.51)	Șoimuș
21	SC Petrotel -Lukoil SA	645,532	Manufacture of refined petro-leum products (19.20)	Municipiul Ploiești
22	CTE București Vest	561,533	Production of electricity (35.11)	București

Table 13. List of companies with CO2 emissions over 100.000 tonnes in 2019

23	Blue Air Aviation S.A.	483,240	Passenger air transport (51.10)	București
24	CTE Progresu	435,267	Production of electricity (35.11)	București
25	SC ALRO SA - Sediul Social	383,641	Aluminium production (24.42)	Municipiul Slatina
26	S.N.G.N. Romgaz S.A. - SPEE Iernut - CTE Iernut	333,688	Production of electricity (35.11)	Oraș Iernut
27	S.C. Tarom S.A.	311,340	Passenger air transport (51.10)	Oraș Otopeni
28	CET Iasi II	292,532	Steam and air conditioning supply (35.30)	Holboca
29	Veolia Energie Prahova SRL-Punct de lucru Brazi	288,076	Steam and air conditioning supply (35.30)	Brazi
30	Termoficare Oradea S.A.	265,943	Steam and air conditioning supply (35.30)	Municipiul Oradea
31	Sectia CET; Instalația CALCINAREA Al(OH)3	257,313	Aluminium production (24.42)	Municipiul Tulcea
32	CTE Grozăvești	236,102	Production of electricity (35.11)	București
33	S.C. CHEMGAS HOLDING CORPORATION S.R.L.	223,021	Manufacture of fertilisers and nitrogen compounds (20.15)	Municipiul Slobozia
34	SC Carm. Hold. SRL Brasov - Pdl Valea Mare Pravat	186,639	Manufacture of lime and plaster (23.52)	Valea Mare Pravăț
35	SC Carm. Hold. SRL Brasov - Pdl Fieni	162,116	Manufacture of lime and plaster (23.52)	Oraș Fieni
36	Centrala Termică Palas	161,295	Production of electricity (35.11)	Municipiul Constanța
37	CT Timișoara Sud	159,612	Steam and air conditioning supply (35.30)	Municipiul Timișoara
38	S.C. P.E.E.T. Electrocentrala Paroșeni S.A.	153,808	Production of electricity (35.11)	Municipiul Vulcan
39	SC Uzina Termoelectrică Midia SA	123,223	Trade of electricity (35.14)	Oraș Năvodari
40	Ciech Soda România SA - Instalație obținere sodă calcinată	120,339	Manufacture of other inorganic basic chemicals (20.13)	Municipiul Râmnicu Vâlcea
	Heidelbergcement Romania SA - fabrica de ciment Fieni	715,632	Manufacture of cement (23.51)	Oraș Fieni
41	S.C. Celco S.A.	106,429	Manufacture of concrete products for construction purposes (23.61)	Corbu

Source: EPG analysis

Table 14. Distance from largest emitters to closest deposits (km)

Emitters LAU code (SIRUTA)	Emitter's location	Emissions in 2019 (Mt CO2)	Distance to closest deposits (km)	Closest deposit name	Closest deposit capacity (Mt CO2)
82895	ROVINARI	4.63	35	Bibesti-Bulbuceni	50
82895	ROVINARI	-	10	Stramba-Rogojelu	25
82895	ROVINARI	-	12	Targu Jiu	15
75098	GALAȚI	4.24	73	Ghergheasa	50
82617	TURCENI	3.32	15	Bibesti-Bulbuceni	50
130712	BRAZI	2.65	106	Ghergheasa	50
130712	BRAZI	-	36	Tataru	15
179196	BUCUREŞTI	2.27	19	Catelu	5
179196	BUCUREŞTI	-	13	Gradinari	5
179196	BUCUREŞTI	-	91	Calinesti-Oarja	10
179196	BUCUREŞTI	-	130	Ghergheasa	50
70094	IŞALNIȚA	1.82	42	Bibesti-Bulbuceni	50
70094	IŞALNIȚA	-	8	Simnic	15
70094	IŞALNIȚA	-	16	Ghercesti	9.59
114319	TÂRGU MUREŞ	1.58	2	Targu Mures Dome	25
69900	CRAIOVA	1.27	4	Simnic	15
69900	CRAIOVA	-	11	Ghercesti	9.59
69900	CRAIOVA	-	10	Carcea	8.75
167473	RÂMNICU VÂLCEA	1.23	13	Babeni	50
13524	VALEA MARE PRAVĂȚ	1.23	50	Teis-Viforata	20
60507	NĂVODARI	1.16	149	Ghergheasa	50
26742	AŞTILEU	1.06	155	Iernut	15
60847	MEDGIDIA	0.94	140	Ghergheasa	50
65609	FIENI	0.88	21	Teis-Viforata	20
130534	PLOIEŞTI	0.81	12	Aricesti	10
41177	HOGHIZ	0.76	66	Sangeorgiu de Padure	25
91330	ŞOIMUŞ	0.75	109	Targu Jiu	15
91330	ŞOIMUŞ	-	113	Copsa Mica	100
91982	VEȚEL	0.73	104	Targu Jiu	15
91982	VEȚEL	-	124	Copsa Mica	100
124563	TAŞCA	0.73	104	Sangeorgiu de Padure	25
125347	SLATINA	0.52	38	Ghercesti	9.59
117827	IERNUT	0.33	2	Iernut	15
95159	HOLBOCA	0.29	82	Bacau	5
155243	TIMIŞOARA	0.27	21	Calacea	5
159614	TULCEA	0.27	89	Independenta	5
26564	ORADEA	0.27	110	Turnu	10
92658	SLOBOZIA	0.22	73	Ghergheasa	50
60419	CONSTANȚA	0.16	161	Ghergheasa	50
87175	VULCAN	0.15	40	Targu Jiu	15
92569	CĂLĂRAŞI	0.14	89	Catelu	5
61513	CORBU	0.11	141	Independenta	5

Source: EPG analysis based on European CO2 storage database: CO2 Storage Potential in Europe

Important notification

It is recommended to read this notification

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