The Building momentum for the long-term CCS deployment in the CEE region project is funded by Iceland, Liechtenstein and Norway through the EEA and Norway Grants Fund for Regional Cooperation.

Iceland Liechtenstein Norway grants
Norway grants

BUILDING MOMENTUM
FOR THE LONG-TERM CCS DEPLOYMENT
IN THE CEE REGION

Regional cooperation for CCS/CCU deployment

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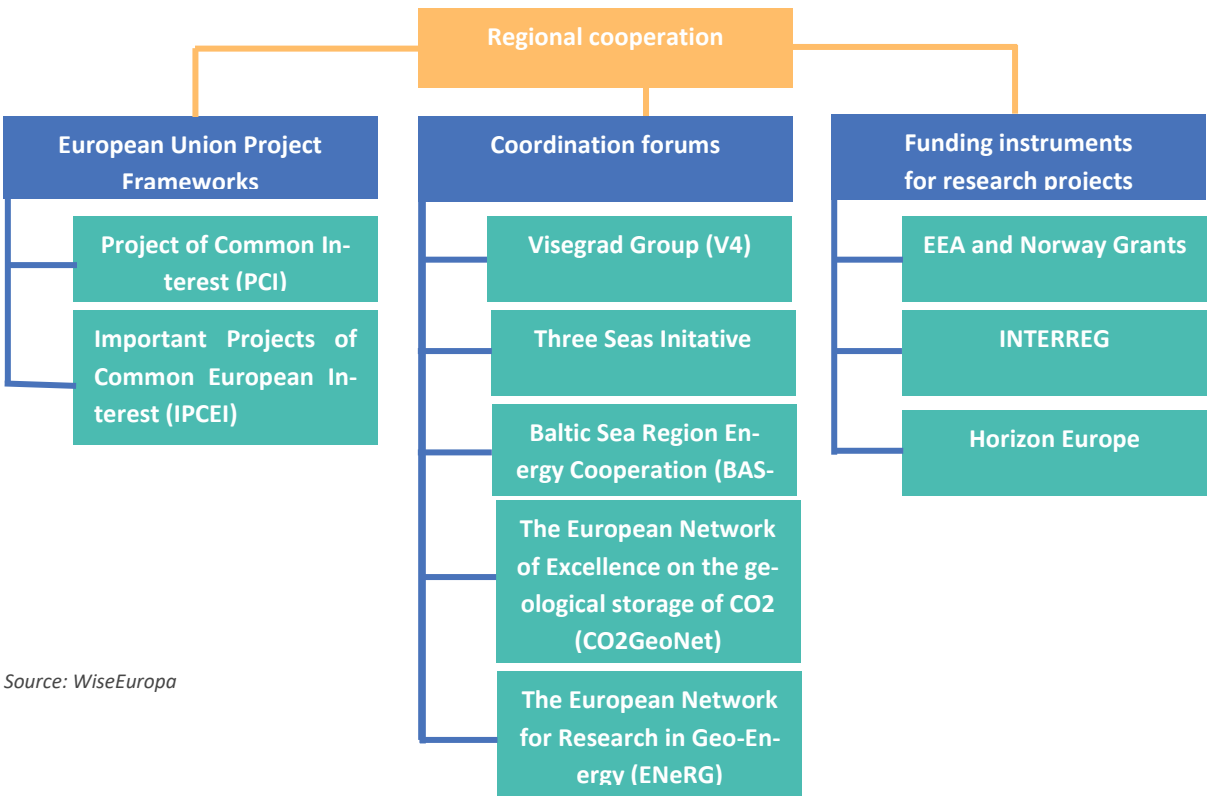
1. Framework for regional cooperation

As the climate and ecological crises do not recognize national borders, regional cooperation in the context of climate protection is in the interest of all countries in the Central and Eastern European (CEE) region. By using the synergy effect provided by partnerships in terms of knowledge, know-how, technology transfer, cross-border projects, market integration, geopolitics and geological potential, the countries of the region can jointly address similar challenges in decarbonisation, filling the gaps emerging in individual countries and accelerating the process. This is to be particularly important in the case of emerging technologies, which need an appropriate knowledge base and new infrastructure to be built.

The regional analysis gives a general overview of the cooperation of specific CEE countries (namely Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia and Ukraine referred to as partner countries/CEE region for the purposes of the report) to date in carbon capture and storage (CCS) as well as carbon capture and utilization (CCU) deployment and outlines the opportunities and the barriers for regional cooperation. The structure of the available regional cooperation options has been described according to the Figure 1.

FIGURE 1. SUMMARY OF COOPERATION OPPORTUNITIES



Source: WiseEuropa

1.1. European Union project frameworks

The European Union provides special frameworks to facilitate the development and investment processes of projects for regional projects of particular importance for the objectives of the European Union and the internal market.

1.1.1. Projects of common interest (PCI)

Projects of common interest (PCIs) are the main mechanism for regional cooperation investments in EU, covering cross-border energy infrastructure projects that link the energy systems of EU countries.[1] PCIs are coordinated by regional groups divided by type of energy infrastructure: electricity, gas, oil, smart grids and CO_2 networks. The members of the groups are representatives of EU countries, the European Commission, European Transmission System Operators (TSOs), European Network of Transmission System Operators for Electricity and for Gas (ENTSO-E and ENTSO-G respectively), project promoters, regulatory authorities, as well as the Agency for the Cooperation of Energy Regulators (depending on the group).

To obtain the PCI status, a project must have a significant impact on energy markets and market integration in at least two EU countries, boost competition on energy markets, increase the EU's energy security by diversifying energy sources and contribute to the EU's climate and energy goals by integrating renewable energy sources.[2]

To apply for PCI status, the project promoters (i.e. TSO, distribution system operator, other operator or investor developing the project etc.) shall submit an application for selection to the relevant group. The projects are then assessed in terms of compliance with the criteria and requirements set out in the EU Regulation 347/2013 on guidelines for trans-European energy infrastructure (TEN-E) as amended and consulted with the public and other authorities. Every two years, European Commission adopts the PCI list with selected projects.[3] The project with PCI status benefits from number of advantages, such as simplified and accelerated planning and permit procedures, more favourable regulatory treatment or the possibility of financial support under the Connecting Europe Facility.[4]

One of the thematic priorities of PCIs is **cross-border CO_2 networks**. A project which falls into this category must contribute significantly to all of the following specific criteria: (i) the avoidance of CO_2 emissions while maintaining security of energy supply; (ii) increasing the resilience and security of CO_2 transport; (iii) the efficient use of resources, by enabling the connection of multiple CO_2 sources and storage sites via common infrastructure and minimising environmental burden and risks.[5]

So far, PCIs have proved to be a valuable platform for cooperation in cross-border infrastructure projects. There are no CO_2 pipeline projects under PCI between countries of Central and Eastern Europe, however, there are number of other projects such as gas infrastructure projects, which share some common features with CO_2 transport pipelines with regard to the technology. One of the successful examples of the PCI project execution is Poland and Slovakia gas cross-border interconnector described in Box 1.

[1] https://ec.europa.eu/energy/topics/infrastructure/projects-common-interest_en
[2] https://ec.europa.eu/energy/topics/infrastructure/projects-common-interest/key-cross-border-infrastructure-projects_en
[3] Regulation TEN-E is currently under revision.
[4] ibidem
[5] ibidem

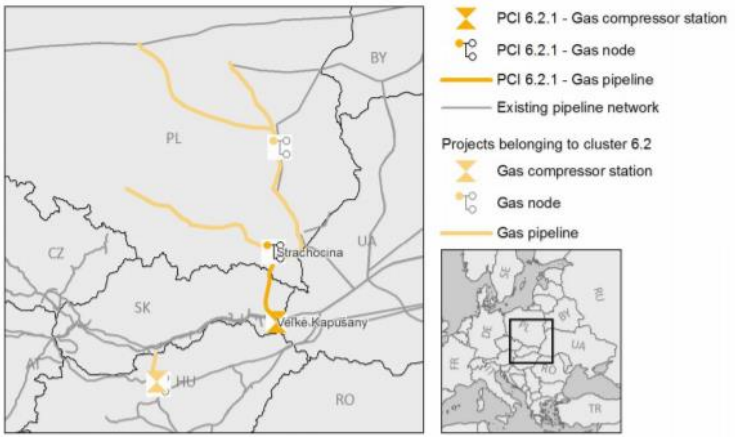
Box 1. Example of PCI – Project of Common Interest 6.2.1 – Poland and Slovakia gas interconnection[6]

The project aims in connecting Polish and Slovakian natural gas transmission networks by constructing approximately 165 km long gas crossborder pipeline with auxiliary infrastructure on both sides. The promoters of the project are TSOs of both countries: Eustream a.s. (Slovakia) and GAZ-SYSTEM S.A. (Poland).

The project was granted funding from Connecting Europe Facility (CEF) in the amount of €97 mln, which is 40% of total eligible cost of the investment (€243 mln).

The construction is still ongoing and the commissioning of the project is expected in early 2022.

Figure 2. Poland – Slovakia interconnection scheme



Source: European Commission[7]

1.1.2. Important Projects of Common European Interest (IPCEI)

The status of Important Project of Common European Interest can be applied to the project that falls within Article 107(3)(b) of the Treaty.[8] This framework is dedicated to disruptive research and innovation projects with significant benefits to EU economy and competitiveness. The eligibility criteria for obtaining this status are set out in so called "IPCEI Communication" and among others, includes following provisions:[9]

- must contribute to one or more EU objectives and have a significant impact on Union's competitiveness, sustainable growth, societal challenges or value creation in the EU,
- must involve more than one Member State and the project must be beneficial for other Member States,
- the benefits must not be limited to one sector and must be of wider relevance.

Projects that obtained IPCEI status can benefit from special state-aid rules:[10]

- The existence of the market failure affecting the project can be presumed (for normal R&D&I projects this needs to be clearly demonstrated for larger projects to get state aid),
- Up to 100% of the funding gap on the basis of large set of eligible costs can be supported (in contrast to normal regional and R&D&I aid rules when upper limits and lower caps exists),

[6] https://ec.europa.eu/inea/en/connecting-europe-facility/cef-energy/6.2.1-0019-SKPL-W-M-16
[7] https://ec.europa.eu/energy/maps/pci_fiches/PciFiche_6.2.1.pdf
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:C:2008:115:FULL&from=EN
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XC0620(01)&from=EN
[10] https://industria.gob.es/es-es/participacion_publica/Documents/proyecto-PIICE/Presentacion-PIICE-Comision-Europea.pdf

- Costs of first industrial deployment (i.e. between pilot/demo line and before start of mass production) are considered eligible (not possible under normal R&D&I rules).

Since adopting communication, there are three approved IPCEI projects (two in battery value chainand one for microelectronics. [11,12] Other IPCEI proposals are in developments such as: Hydrogen IPCEI, and IPCEI for Cloud Infrastructure and Services (IPCEI-CIS). [13,14]

While there is no carbon capture related IPCEI yet, it has a potential to be crucial framework for regional cooperation for carbon capture projects, as they may fall into one of strategic value chains (low-carbon industry) recommended by the Commission, which strengthen position of these technologies to obtain IPCEI status.

The European Commission is currently preparing revision for IPCEI Communication, as the current framework of rules expires on 31 December 2021.[15]

1.2. Coordination forums

Activities related to CCS/CCU technology can be promoted and intensified at the international level thanks to the existence of coordination forums, gathering selected European countries around specific topics. Examples of coordination forums are described below.

1.2.1. Visegrad Group (V4)

The V4 is an alliance of four Central and Eastern European countries: the Czech Republic, Hungary, Poland and Slovakia. Member states cooperate in the fields of politics, economy, culture, education, science and information exchange.[16]

Recently, Visegrad Group announced it will strengthen cooperation and take a common position on the EU's energy and climate policy. V4 will seek to further develop integration of the group's energy infrastructure.

1.2.2. Three Seas Initiative

Three Seas Initative is a forum of twelve countries: Austria, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. The initiative is focused on strengthening cooperation in economic growth, security, and stronger and more cohesive Europe. One of the listed cooperation priorities includes energy security and achieving climate goals.[17]

[11] https://ec.europa.eu/commission/presscorner/detail/en/IP_21_226
[12] https://www.ipcei-me.eu/
[13] https://ec.europa.eu/growth/industry/policy/supporting-clean-hydrogen/ipceis-hydrogen_en

[14] https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/07/20210709-cloud-ipcei-entering-next-phase.html

[15] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12661-Revision-of-Communication-on-important-projects-of-common-European-interest_en
[16] https://www.visegradgroup.eu/
[17] https://3seas.eu/

1.2.3. Baltic Sea Region Energy Cooperation (BASREC)

Baltic Sea Region Energy Cooperation was created in 1998 by the ministers of energy of the Baltic region and the European Commission. In 2015 the format of BASREC was revised so that meetings are not held on a regular basis; however, any group member can take the initiative and propose a meeting on energy issues of common interest.[18]

One of the BASREC's initiatives focuses on CCS: BASRECCS.[19] The objective of BASRECCS is primarily to facilitate regional collaboration and joint research, pilot and demonstration projects. Currently, in 2020-2022, a project is being realized within this format by, among others, Tallinn University of Technology and Polish Geological Institute. The project's overall aim is to strengthen networking on tackling climate change through technology such as CCU/CCS in the Baltic Sea Region between authorities, companies, universities and experts in order to facilitate deployment of a large-scale CCUS project.

1.2.4. The European Network of Excellence on the geological storage of CO_2 (CO_2GeoNet)

The European Network of Excellence on the geological storage of CO_2 (CO_2GeoNet) is the European scientific body on CO_2 geological storage, currently comprising 26 research institutes from 20 European countries, including 5 geological institutes and universities from Czech Republic, Estonia, Croatia, Romania and Slovenia. It offers an expert perspective on CO_2 geological storage, provides an open forum for exchange and discussion with all interested parties and supports the capacity-building required for the full-scale deployment of CO_2 geological storage, for example by holding webinars; joint research is also encompassed by the activities of CO_2GeoNet. Therefore, this organisation might have a valuable role to play in enabling the efficient and safe geological storage of CO_2 in the region.[20]

1.2.5. The European Network for Research in Geo-Energy (ENeRG)

ENeRG promotes the cooperation between European research and development (R&D) organisations whose main interest is to conduct basic or applied research or technological development in the field of sustainable use of the underground for the energy transition. Recently, the focus of the Network is therefore also on CO_2 geological storage. ENeRG comprises 26 members from 19 countries, including 12 research institutes and universities from Croatia, Czech Republic, Estonia, Lithuania, Poland, Romania, Slovenia and Ukraine. The organisation might serve as a platform for matching opportunities and requirements for new R&D projects and disseminating geo-energy research results in the region.[21]

1.3. Funding instruments for research projects

1.3.1. EEA and Norway Grants

EEA and Norway Grants consist of two schemes: EEA Grants, funded by Iceland, Liechtenstein and Norway, and Norway Grants, supported solely by Norway.[22] Both grants are dedicated to diminishing social and economic disparities and enhancing cooperation between funding countries and the 15 beneficiary countries in Europe (for EEA Grants: Bulgaria, Croatia, Czech Republic, Cyprus, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia; for Norway Grants - the same, excluding Greece and Portugal). During the 2014-2021 funding period, the

[18] http://basrec.net/
[19] BASRECCS. https://bcforum.net/index.php
[20] http://www.co2geonet.com/home/
[21] https://energnet.eu/about-energnet/
[22] https://eeagrants.org/about-us

EEA Grants amount to €1.5 billion and Norway Grants to €1.3 billion.[23] One of the areas covered by EEA and Norway Grants is CCS, under which R&D and implementation activities are supported. Some examples are the POLNOR CCS 2019 call for projects (Poland), where six applications were selected for a total co-financing amount of over €11.7 million.[24] Another example is research projects on phase behaviour in CCS systems in the Czech Republic, with €526,302 support from Norway Grants.

1.3.2. INTERREG

INTERREG, with a budget of €10.1 billion funded by the European Regional Development Fund, offers a number of programmes supporting cross-borderand interregional cooperation both within and beyond the European Union in several areas such as health, environment, research, sustainable energy or transport.[25] Under the low-carbon economy topic, several projects related to CCS/CCU technologies are being conducted, such as 'Supporting the clean energy transition of coal-intensive regions' (covering Bulgaria, Romania, Greece, Slovakia, Austria, Poland, Portugal, Germany and Denmark) with a study visit in Lusatia and Cottbus coal-mining regions in Germany on the potential of 'cleaner coal' and CCS technologies.[26]

1.3.3. Horizon Europe (predecessor: Horizon 2020)

Horizon Europe is the Research and Innovation programme within EU's long-term Multiannual Financial Framework (MFF), with a budget of €95.5 billion for 2021-2027 to be spent on projects conducted by all types of organizations from EU member states.[27] The main aim of Horizon Europe is to tackle climate change by facilitating green and digital transition, strengthening resilience and crisis preparedness as well as increase the competitiveness of Europe.[28] In 2014-2020 funding period, the predecessor of Horizon Europe (Horizon 2020), supported 17 projects in the "Carbon Capture & Storage, Power Plants area", of which in 8 projects involved at least one country from the CEE region.[29]

2. Regional cooperation overview

2.1. International research projects

Cooperation between partner countries in terms of CCU/CCS projects has been limited to international research projects so far. Summary of selected international research projects realized in cooperation of partners from the region has been presented in Table 1.

[23] EEA Grants. https://eeagrants.org/about-us
[24] Politechnika Wrocławska, *Międzynarodowe projekty naszych naukowców z dofinansowaniem NCBR*. https://pwr.edu.pl/uczelnia/aktualnosci/miedzynarodowe-projekty-naszych-naukowcow-z-dofinansowaniem-ncbr-11557.html
[25] https://interreg.eu/
[26] https://www.interregeurope.eu/decarb/
[27] https://www.horizon-eu.eu/
[28] Horizon Europe. https://www.horizon-eu.eu/
[29] European Commission, *H2020 projects in the "Carbon Capture & Storage, Power Plants" field*. https://ec.europa.eu/inea/en/horizon-2020/h2020-energy/projects-by-field/875?page=1

TABLE 1. SUMMARY OF SELECTED INTERNATIONAL RESEARCH PROJECTS REALIZED IN COOPERATION OF PARTNERS FROM THE REGION (SOURCE: CORDIS AND RFCS – RESEARCH FUND FOR COAL AND STEEL DATABASES, NORWAY GRANTS)

Project name	Project focus	Timeframe	Countries from the region involved in the project										
			CZ	EE	HR	HU	LT	LV	PL	RO	SI	SK	UA
Assessing European capacity for geological storage of carbon dioxide (**EU GEOCAPACITY**)	Storage	2006-2008	+	+	+	+	+	+	+	+	+	+	
Monitoring and verification of CO_2 storage and ECBM in Poland (**MOVECBM**)	Storage	2006-2008							+		+		
Towards a transport infrastructure for large-scale CCS in Europe (**CO2EUROPIPE**)	Transport	2009-2011	+						+				
Pan-European coordination action on CO_2 Geological Storage (**CGS EUROPE**)	Storage	2010-2013	+	+	+	+	+	+	+	+	+	+	
Novel algae-based solution for CO_2 capture and biomass production (**ALGADISK**)	Capture	2012-2014				+					+		
Technology Options for Coupled Underground Coal Gasification and CO_2 Capture and Storage (**TOPS**)	Capture and utilization	2013-2017							+		+		
Enabling Onshore CO_2 Storage in Europe (**ENOS**)	Storage	2016-2020	+									+	
From residual steel gasses to methanol (**FReSMe**)	Utilization	2016-2021								+	+		
Innovative management of Coal by-Products leading also to CO_2 emissions reduction (**COALBYPRO)**	Capture and storage	2017-2020	+						+				
Unconventional MEthane Production from Deep European Coal Seams through combined Coal Bed Methane (CBM) and Underground Coal GAsification (UCG) technologies (**MEGAPlus**)	Storage	2018-2021	+						+				
Strategic planning of regions and territories in Europe for low-carbon energy and industry through CCUS (**STRATEGY CCUS**)	Multiple	2019-2022			+				+	+			
Biomass gasification with negative carbon emission through innovative CO_2 capture and utilisation and integration with energy storage (**BIOMASS-CCU**)	Capture and utilization	2019-2022				+			+				
Building momentum for the long-term CCS deployment in the CEE region (**CCS4CEE)**	Multiple	2020-2023	+	+	+	+	+	+	+	+	+	+	+

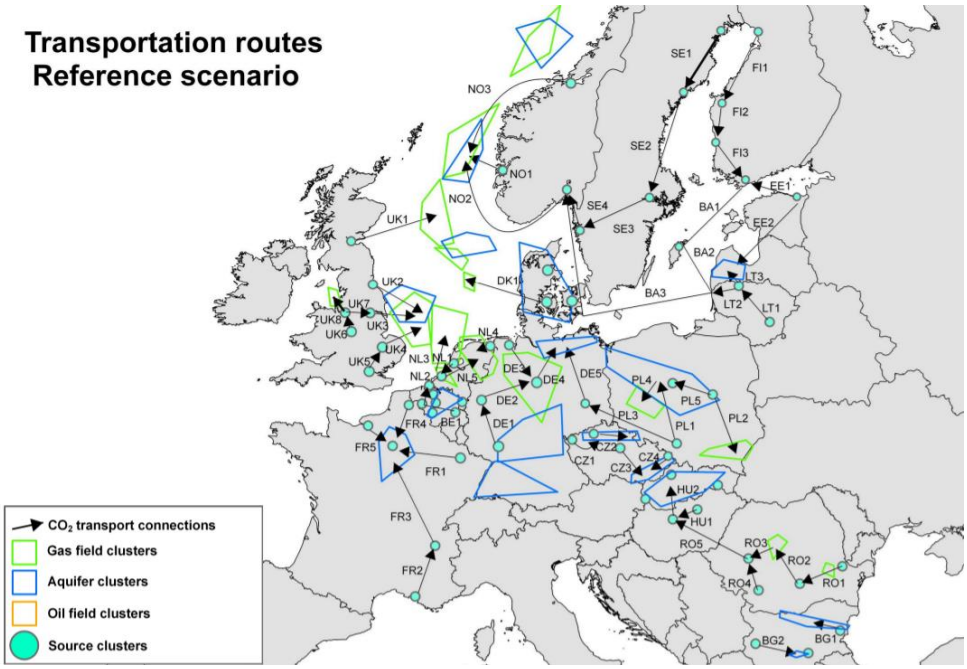
CZ – Czech Republic, EE – Estonia, HR – Croatia, HU – Hungary, LT – Lithuania, LV – Latvia, RO – Romania, SI – Slovenia, SK – Slovakia, UA – Ukraine; "+" – at least one entity from a given country took/takes part in the project; blank space – no entity from a given country took/takes part in the project

In all of the projects listed above CEE countries were part of bigger, international consortia, usually involving many partners (both European and non-European), whose cooperation is not necessarily very close, and where the contribution of the involved entities from the CEE region is not always significant: none of the projects realized within the Community Research and Development Information Service (CORDIS) was coordinated by a CEE country. Moreover, some projects, like EU GEOCAPACITY, required partners to submit only a self-prepared report on the country's potential for CO_2 storage. Therefore, in most cases the cooperation between CEE countries is a result of the EU or European coverage of the international projects, rather than a specific focus on joint research work in the CEE region.

However, the overall impact of these research projects for building regional potential for cooperation is significant. For example, the projects like EU GEOCAPACITY and CGS EUROPE to some extent established the cooperation of geological institutes from CEE. Three projects, however, are of particular importance: ENOS, CGS EUROPE and CO_2EUROPIPE. When it comes to CGS Europe, the project aimed to create a durable network of research capacity on CO_2 storage in Europe and involved, among others, 8 geological research institutes and 2 universities from Czech Republic, Estonia, Croatia, Hungary, Poland, Lithuania, Latvia, Romania, Slovenia, Slovakia and Ukraine. Within the ENOS project, the Vienna Basin has been investigated as a potential transborder underground carbon storage site for Czech Republic, Slovakia and Austria; it was concluded that oil fields located in the basin could be considered for CO_2-driven enhanced oil recovery (CO_2-EOR), combined with subsequent CO_2 geological storage.[30] The last project, CO_2EUROPIPE, resulted in a study on a potential regional CO_2 pipeline network encompassing Central and Eastern Europe.[31] In Figure 2, the potential transportation routes are presented for the reference scenario, where storage takes place both onshore and offshore. Overall, the study indicates that onshore CO_2 storage as well as international cooperation is essential to ensure efficient CCS transport infrastructure thorough Europe.[32]

[30] Mikunda T. et al., *Report: Towards a strategic development plan for CO2-EOR in the Vienna Basin* (https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cdb30e62&appId=PPGMS).
[31] EU CO_2Europipe Consortium 2009-2011. *Report: Development of a large-scale CO_2 transport infrastructure in Europe: matching captured volumes and storage availability* (Microsoft Word - D2 2 1 - CO2Europipe Report CCS infrastructure_20110415.doc).
[32] Ibidem.

FIGURE 2. CO_2 TRANSPORTATION ROUTES FOR THE REFERENCE SCENARIO – CO_2EUROPIPE PROJECT



Source: EU CO_2Europipe Consortium 2009-2011, *Report: Development of a large-scale CO_2 transport infrastructure in Europe: matching captured volumes and storage availability*

For projects realized within CORDIS[33] and Research Fund for Coal and Steel (RFCS)[34] (see Table 1), leading partner countries from the region are Poland and Czech Republic. Entities from these countries are experienced in joint, specific research on technologies of CCS (e.g. COALBYPRO and MEGAplus projects). For this reason, their future cooperation in this field is promising. A node of this cooperation could be the Central Mining Institute (GIG - Główny Instytut Górnictwa), who took part in 5 out 13 projects listed in the Table 1 and even coordinated one project (MEGAPlus). There are also examples of less formal scientific cooperation between Baltic states conducted. Researchers from Lithuania, Latvia and Estonia have been collaborating on several papers on geological storage potential, economic feasibility and the operation of the CCS system as a whole in the Baltic region.[35,36]

[33] European Commission's primary source of results from the projects funded by the EU's framework programmes for research and innovation (FP1 to Horizon 2020). https://cordis.europa.eu/en

[34] EU funding programme supporting research projects in the coal and steel sectors. The RFCS has its own legal basis and stands outside the Multiannual Financial Framework. https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/research-fund-coal-and-steel-rfcs_en

[35] Shogenova A. et al. (2014), *Implementation of the EU CCS Directive in Europe: Results and Development in 2013,* Energy Procedia, Volume 63, p. 6662-6670.

[36] Gusca J. and Blumberga D. (2011), *Simplified dynamic life cycle assessment model of CO_2 compression, transportation and injection phase within carbon capture and storage,* Energy Procedia, Volume 4, p. 2526–2532.

2.2. Intergovernmental agreements

No intergovernmental CCU/CCS agreement between any of partner countries has been identified. However, there are intergovernmental agreements in other sectors that may apply to CCU/CCS. Several examples of intergovernmental agreements have been described in Box 2.

Box 2. Examples of intergovernmental agreements in other sectors

Offshore wind energy

On the 30th of September 2020, governments of eight Baltic Sea countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden) signed an agreement to jointly support the development of offshore wind energy in the region. The focus of this agreement is on intensifying regional integration in terms of economics, policies, technological advancements and availability.[37]

Energy cooperation in the gas sector

Within the Baltic Energy Market Interconnection Plan Initiative, governments of V4 countries (Poland, Hungary, Slovakia, Czech Republic) and other CEE states (Lithuania, Latvia, Estonia, Romania, Slovenia, Croatia) agreed to cooperate in the gas sector. The collaboration is aimed at improving energy security and expanding gas connections and infrastructure in the region.[38]

Both initiatives can serve as a source of good practice for future agreements on CCS, if any will be concluded.

2.3. Transborder pilot projects

So far, no CCU/CCS transborder pilot project has been realized in the region. However, there are examples of promising transborder cooperation in the field of CCS, such as the ENOS research project which resulted in the identification of the transborder carbon storage site in the Vienna Basin on the Czech Republic-Slovakia-Austria border (for details see: International research projects). Moreover, the most significant Croatian CCS projects (i.e.: enhanced oil recovery (EOR) with the use of CO_2 in the Ivanić and Žutica oil fields and the planned biorefinery in Sisak (60 km from Zagreb) and iCORD CCS projects) are implemented by INA, an important oil company whose major stakeholder is MOL, another oil company from Hungary, which borders Croatia to the east. There may be closer cooperation of this entities in the future, as bioethanol produced in the biorefinery is to be distributed on the market through the commercial channels of INA and MOL Group.

[37] https://www.offshorewind.biz/2020/10/01/eight-baltic-sea-countries-ink-offshore-wind-pact/ (retrieved on September 7, 2021).
[38] European Energy Hub (n.d.). *Energy cooperation in gas sector within central and eastern Europe.* http://www.energy-hub.expert/energy-cooperation-in-gas-sector-within-central-and-eastern-europe. Retrieved on September 2, 2021.

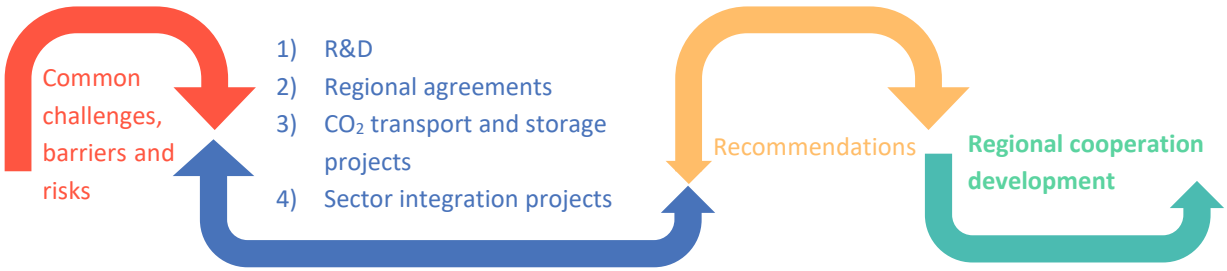
Chapter 2. Future regional cooperation outlook

1. Common challenges, barriers and risks

In order to facilitate the deployment of CCS/CCU technologies in CEE countries, several common challenges can be addressed thanks to the synergies driven by regional cooperation. Partner countries face similar economic and emissions-related challenges, which are further explored in the summary report. Other challenges, according to many CEE experts, are: **insufficient public awareness of CCS/CCU technology, lack of CO_2 transport infrastructure, insufficient political will and lack of interest from the representatives of public administration**. Moreover, cross-border cooperation on CCS/CCU pilot projects, research initiatives and sectoral collaboration is low. There are no regional industrial clusters and, according to the experts, in some cases regional cooperation is dependent on the capture readiness as well as location and size of these sources.

The potential for cooperation between CEE countries in the field of CCS/CCU may be enhanced through the dissemination of research results and cross-border educational campaigns, which would increase knowledge of CCS/CCU technologies and benefits arising from their deployment. As a consequence, the topic of CCS/CCU could enter broader public debate. Currently, it seems that the most challenging problem to be addressed for CEE region will be financial and regulatory issues. Moreover, from the technical point of view, preparation of the effective CO_2 transport infrastructure may be a challange, as countries have varied infrastructure and storage capabilities. Nevertheless, building transborder CO_2 transport infrastructure and its common use could reduce both the risks and the costs of projects, which could attract new investments to the CEE region.

FIGURE 3. FUTURE REGIONAL COOPERATION OUTLOOK



The future regional cooperation development outlook, presented in this chapter, has been divided into three parts (see Figure 3). The first one (section 1) describes common challenges, barriers and risks (red arrow) that hinder specific aspects of future regional cooperation such as R&D or sector integration projects (blue arrow, section 2). In turn, in order to address these challenges and facilitate regional cooperation, several recommendations have been formulated in section 3 (orange arrow).

Source: WiseEuropa

Regional cooperation in terms of CCS/CCU technology may be hindered by several barriers and risks resulting from bottlenecks in the individual countries. The main barriers, identified by stakeholders from partner countries and based on available sources are:

	***Legal constraints, i.e. lack of specific regulations allowing for CO_2 transport and storage in some countries and insufficient coherence between national documents and EU legislation in terms of CCS/CCU technology***
	Regional cooperation will not be effective if in some countries activities related to CO_2 transport and/or storage are illegal. For example, the storage of CO_2 is prohibited in Estonia and Latvia, whereas in Slovakia the regulation implementing the Act on the Permanent Storage of Carbon Dioxide is missing. These bottlenecks are also enhanced by low interest in CCS in some states and different priorities given to the deployment of CCS/CCU technology (some countries do not plan to introduce CCS until around 2040).
	***Focus on national activities***
	Due to the low popularity and slow pace of development of the CCS/CCU technology, activities carried out by countries are mainly focused on adjustments to internal conditions and capabilities rather than cross-border cooperation. Furthermore, as the cost of CCS/CCU technology is high, companies are not able to deploy this kind of technology alone.
	***Limited/lack of cross-border infrastructure for CO_2 transportation***
	Some countries face obstacles when it comes to providing CO_2 infrastructure both for the storage and transportation of CO_2. A new pipeline system is costly and requires detailed planning that includes geological patterns of the countries.
	***Insufficient storage capacity***
	Some countries possess no or limited CO_2 storage capacities. Moreover, in some cases, small storage sites are distant to each other, hence the aggregation into bigger storage capacities is hindered. Therefore, regional cooperation in terms of CO_2 transportation may be an only opportunity for them to deploy CCS/CCU infrastructure.
	***Low public acceptance of CCS/CCU technology***
	The sceptical attitude of some countries towards storage may be a bottleneck to any complex regional project of capturing CO_2 from surrounding countries and storing it in in one of the countries (e.g.

	Romania). Moreover, low social awareness of CCS/CCU technology leads to fears of CO_2 leakage , which is unlikely.[39]
	***Financial constraints - high cost of CCS/CCU technology***
	One of the main obstacles for CCS/CCU technology deployment in CEE region is high cost of the technology together with insufficient financial incentives. Experts in some countries indicate that emission allowance price above 100 EUR/tCO_2 would be a turning point to trigger the development of the CCS/CCU technology.[40]
	***Different level of experience in CCUS technology***
	Partner countries are characterised by different levels of experience in CCUS technology. For example, Poland has already realized pilot projects and there is strong support for the development of CCS from universities and research institutes whereas Ukraine lacks this know-how and seems unprepared to implement a full-scale CCS installation.

Although CEE countries face similar barriers and risks, there are key differences between states that should also be highlighted. **Poland** has a potential to become a leader in the deployment of CCS/CCU technology in the CEE region because of its geological conditions (i.e. significant storage capacity) and extensive past research experience related to its coal sector. **Estonia**, as a country near the Baltic Sea, expects significant costs of potential transportation of CO_2 since land transportation is considered unfeasible. **Slovakia** is characterised by many areas of the protected landscape where the deployment of CCS/CCU technology will be impossible for social and legal reasons. In **Ukraine**, despite no legislation regarding CCS/CCU, there is some potential for sectoral cross-border cooperation of gas, chemical and agricultural sectors. **Hungary** is ready to introduce CCS pilot projects, however, based on already known technologies as the R&D sector is lagging behind. For **Latvia and Lithuania**, one of the main risks is prohibition on the geological CO_2 storage, therefore the bigger potential seems to be in CCU technology. Nevertheless, the urgent need of establishing cross-national CCS infrastructure can be identified throughout most CEE countries. From the perspective of **Romania**, it seems that lack of government and industry involvement is the main hurdle that may influence CEE regional cooperation.[41]

2. Future regional cooperation

The subchapter explores the possibilities of continuing already-established or starting new cooperation. It evaluates topics of **regional agreements, CO_2 transport and storage, R&D and sector integration projects**. It also highlights

[39] https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_summaryforpolicymakers-1.pdf and https://theicct.org/blog/staff/carbon-capture-storage-and-leakage
[40] CCS4CEE country report: Czech Republic; CCS4CEE country report: Estonia
[41] CCS4CEE country report: Poland, Estonia, Slovakia, Ukraine, Hungary, Latvia, Lithuania, Romania

possible solutions regarding cross-border cooperation such as geological storage of CO_2 in the Vienna Basin, Upper Silesian Basin or Upper Paleozoic Basin, which offer suitable characteristics for future international collaboration, particularly in terms of the creation of industrial clusters. This would facilitate CCS deployment and provide better coverage, reduced costs through economies of scale, and enhanced resilience.

2.1. Research and development

Research and development projects are crucial for the CCS deployment in the CEE countries, as they facilitate regional cooperation helping to achieve scientific and technological leadership. Hence, R&D projects can provide information on CCS technologies and its role in reducing greenhouse gas (GHG) emissions from the use of fossil fuels, and to achieve longer-term technological breakthroughs. So far, the regional collaboration regarding R&D projects for CCS exists, but its full potential is not completely achieved and some of the CCS researchers see the need to improve regulatory framework and solve technology issues such as to develop specific CO_2 capture devices, CO_2 cleaning technologies.[42]

It is crucial to faciliate R&D projects with a focus on CEE countries in line with enhancing the quality of scientific outputs, establishing new public-private partnerships, boosting innovation and finally facilitating CCS deployment in the region.

2.2. Regional agreements

As currently there are no regional agreements for CCS technologies, it is recommended to establish new cross-border cooperation and to set mutual agreements supporting CCS investments. Regional international agreements could define the methods and means by which national regulations should be changed, in order to harmonize regulations in each CEE country (if there are any legal obstacles to transborder CCS projects) and to fine-tune the details regarding CO_2 transport and storage on a regional scale.[43] It is also beneficial to follow good practices from other sectors, such as regional agreements regarding offshore wind energy or gas infrastructure (for details see chapter 1, subchapter 2.2).

2.3. CO_2 transport and storage projects

In CEE there is some potential for transborder carbon transport and storage clusters. The most promising location for them could be the Vienna Basin on the Czech Republic-Slovakia-Austria border (see Figure 4 and for details section 2.1.). However, the development of these clusters may be challenging, because, for example, the area close to the Czech LBr-1 oil field, a potential CO_2 storage site in Vienna Basin (located in an oil field cluster CZ III. on the map (Figure 5) below),

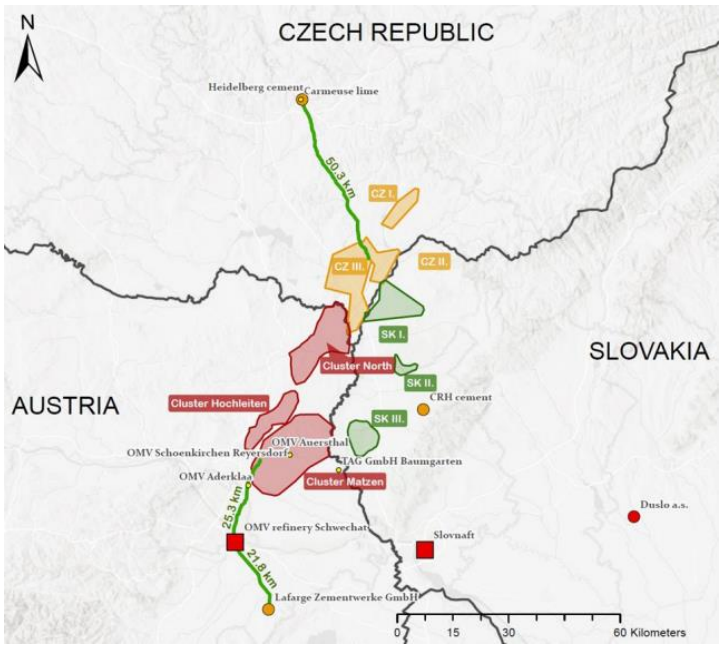
[42] CCS4CEE country report: Estonia

[43] 1) Ukraine, a non-EU country, has not transposed the directive; moreover, there is no framework legislation on carbon capture and storage, carbon trading, technological and geological qualities of carbon capture equipment, carbon well safety etc. at all. 2) Harmonization might be needed in the Vienna Basin, since underground CO_2 storage is, in principle, forbidden in Austria (the Directive doesn't force member states to allow for geological storage). 3) Directive sets out general provisions on CCS, regulations in particular countries can be different in details. 4) It is not clear who is responsible for the monitoring of transborder carbon storage sites, the entity from which of the neighbouring countries grants consession for carbon storage in a transboundary storage site, etc. 5) The Directive states that: "In cases of transboundary transport of CO_2, transboundary storage sites or transboundary storage complexes, the competent authorities of the Member States concerned shall jointly meet the requirements of this Directive and of other relevant Community legislation" (article 24)

is "excluded from the areas where carbon storage is permitted" according to Slovakian legislation.[44] This may affect the exploitation potential of a transborder storage site in LBr-1 by Slovakia.

Given the geological potential of the coalfields in the Upper Silesian Basin(limited, but still up to ca. 150 million tonnes of estimated capacity for CO_2 storage)[45] on the Poland-Czech Republic border, they may also become carbon storage sites for industrial and power plants located in Třinec (Czech Republic), e.g. a Třinec Iron and Steel Works, which produces about half of all the steel produced in the Czech Republic (roughly 2.5 million tons annually[46]).[47] Moreover, initial studies on the transborder pipeline connecting these and other Czech Republic plants with Lutomiersk/Budziszewice/Kutno saline aquifers in central Poland have been already conducted.[48]

FIGURE 4. LOCATIONS OF THE SELECTED CO_2 SOURCES (THE CZECH HEIDELBERGCEMENT PLANT, THE OMV REFINERY AND THE LAFARGE CEMENT PLANT IN AUSTRIA), AS WELL AS THE OIL FIELDS CLUSTERS IN THE VIENNA BASIN. GREEN LINES DEPICT THE POTENTIAL INDICATIVE PIPELINES

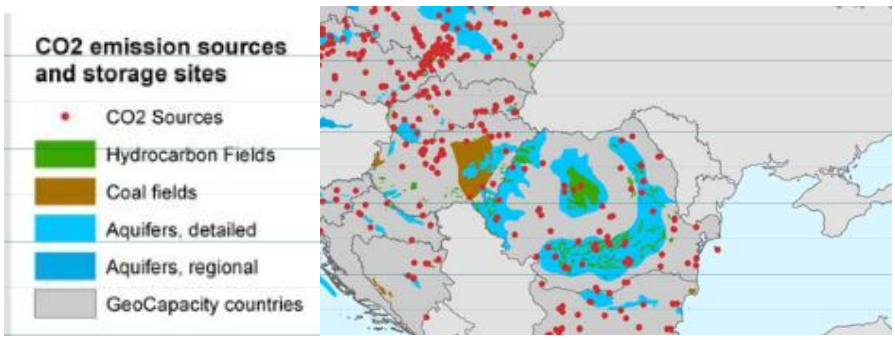


Source: Mikunda T. et al., *Report: Towards a strategic development plan for CO_2-EOR in the Vienna Basin*

[44] CCS4CEE country report: Slovakia. The Czechian assessment does not elaborate on the legal possibility of carbon storage in LBr-1 site.
[45] CCS4CEE country report: Poland; CCS4CEE country report: Czech Republic.
[46] Třinecké železárny. 2020 annual report (https://www.trz.cz/upload/1/files/TZ_AR_2020.pdf).
[47] Based on the report on steel production in Chechia in 2019: https://www.ocelarskaunie.cz/vyroba-oceli-v-cesku-loni-klesla-o-8-vyhled-pro-eu-je-letos-jeste-horsi/.
[48] *Towards a transport infrastructure for large-scale CCS in Europe. CEZ CO_2 transport test case* (http://www.co2europipe.eu/Publications/D4.4.3%20-%20CEZ%20CO2%20transport%20test%20case.pdf).

There are also hydrocarbon fields on the Poland-Ukraine border which are eligible for CO_2 storage and might be a trigger for Polish-Ukrainian collaboration in the field of CCS, but no analyses and studies on this case have been identified. Another transborder cooperation could be established between Hungary and Romania, since potential carbon storage sites (aquifers) were identified on the Hungary-Romania border (a major part of these sites are located on the Romanian side of the border, see: Figure 5).

FIGURE 5. SOURCES OF CO_2 AND POSSIBLE STORAGE SITES IN ROMANIA AND HUNGARY



Source: A Response to Climate Change. An EU Infrastructure to Store Carbon Dioxide (https://petrolog.typepad.com/climate_change/2009/08/eu-infrastructure-to-store-carbon-dioxide.html; retrieved on September 6, 2021).

Moreover, a regional hub of transborder transport and storage projects could be located in Romania. With its 22.6 Gt[49] of storage capacity, Romania emerges as a significant CO_2 storage site, compared to the 2 neighbouring countries: Hungary (maximum storage potential of 0,85 Gt[50]) and Bulgaria (maximum storage potential of ca. 2,7 Gt).[51] Therefore, the project of an interstate CO_2 pipeline transporting Hungarian and Bulgarian CO_2 to Romania might be considered in the future. However, stakeholder perceptions of Romania's role as a storage hub for neighbouring may not all be positive, as found in the CCS4CEE project activities in Romania so far.[52]

2.4. Sector integration projects

No CCS/CCU transborder projects facilitating sector integration have been identified. There have been some strategies and plans for sector integration in some CEE countries, however none of them has a cross-border range. For example, in 2021 Polish Ministry of Economic Development, Labour and Technology joined a consortium to implement a strategy for the development of technologies for capture, transport, utilization and storage of CO_2 in Poland and the piloting of a Polish CCUS Cluster (CCUS.pl). The project is at an early stage and aims to develop a strategy for the development of CCU/CCS technology in Poland, facilitating the preparation of drafts of adequate legal regulations stimulating this

[49] See: a subchapter *Assessment of geological potential for CCS* of the *Assessment of current state, past experiences and potential for CCS deployment in the CEE region* for Romania.
[50] *Ibidem*.
[51] Rütters, H. and the CGS Europe partners (2013), *State of play on CO_2 geological storage in 28 European* countries (http://www.cgseurope.net/NewsData.aspx?IdNews=87&ViewType=Actual&IdType=478).
[52] CCS4CEE country report: Romania

development in an economically, socially and environmentally sustainable manner, as well as preparing the pilot of the first Polish industrial cluster, which will constitute the research and advisory base for further development of this technology in the country. Also in Romania, within the 2011 Getica project, a consortium was created aimed at applying a large-scale integrated CCS installation to an existing coal-fired power plant in Romania's South West Development Region, with a great focus on sector integration.[53]

There is a need for the establishment of regional inter-sectoral cooperation regarding CCS projects. **CEE countries have the potential to integrate different industries that could be a part of international holdings with common strategies and goals.** Hence, industrial clusters should be introduced. Favourable areas for cross-border CCS clusters in the CEE region include the Vienna Basin, Upper Silesian Basin or Central Bohemian Upper Paleozoic Basin. There is potential for cost reduction of CO_2 storage and transportation, which would attract smaller emitters.

3. Recommendations for regional cooperation development

3.1. Best practices and lessons learned

Due to the fact that the cooperation between CEE countries in terms of the deployment of CCS/CCU technology is not advanced, best practices can be formulated based on the collaboration of these countries in past research projects. The best example of such collaboration is the examination of CO_2 storage potential in Vienna Basin, covering Austria, the Czech Republic, and Slovakia, and the identification of challenges regarding regulatory, technical and potential conflicts in this area.[54] This study serves as a foundation for formulating the strategic development plan for this region. Another good practice results from characteristic features and specific challenges of individual countries, i.e. taking into account the diversity of CEE countries and various potential for CO_2 storage or transport infrastructure.

In the process of preparation and implementation of potential CCS/CCU projects, it is necessary to consider the diverse know-how of individual countries, for example, Romania requires intensified support in knowledge sharing with authorities and key stakeholders, especially from other CEE countries that have similar problems but which have managed to introduce appropriate solutions in terms of enhanced sector integration or the countries that implemented a large-scale integrated CCS installations. Some other recommendations for regional cooperation can be derived from existing examples of other sectors (for details see Box 2).

Looking at Western countries, activities related to the establishment of infrastructure for cross-border transportation of CO_2 for storage purposes are to be widely implemented around the mid-2020s. The best example is the Northern Lights (Norway) project. The project aims to import and store CO_2 emissions from European industries in Belgium, France, Germany, Ireland, the Netherlands, Sweden and the UK, and the extension of CO_2 transport infrastructure capabilities.[55] Taking into account the potentially growing cooperation network in Western Europe, the involvement of CEE countries may be crucial for the future development of CCS/CCU technologies in Europe.

[53] CCS4CEE country report: Romania

[54] *Report: Towards a strategic development plan for CO_2-EOR in the Vienna Basin* (https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5cdb30e62&appId=PPGMS).

[55] *The potential for CCS and CCU in Europe. Report to the thirty second meeting of the European Gas Regulatory Forum 5-6 June 2019,* https://ec.europa.eu/info/sites/default/files/iogp_-_report_-_ccs_ccu.pdf

3.2. Recommendations for future cooperation

As it is commonly agreed that regional cooperation is necessary for the facilitation of CCS/CCU deployment, there are several possible actions that can be undertaken, indicated by representatives of CEE countries as shown in the CCS4CEE country reports. Some examples are:

- Activities focused on inter-sectoral collaboration: establishing industrial clusters that may decrease the cost of the CCS/CCU technology and reduce risks linked with the implementation of the project, maintaining consistency with development of the hydrogen market and Power to Gas storage technology, and the cooperation of major emitters especially within steel, cement and chemical sectors. For example, stakeholders interviewed in the CCS4CEE project reinforced the potential for regional clusters in the Vienna Basin, in the Central Bohemian Upper Paleozoic Basins, and in the Upper Silesian Basin;

- Developing business models of cooperation based on prior economic analyses and monitoring plans, considering the necessary changes in national regulations that would enable introducing pilot projects;

- Facilitating knowledge exchange, developing an interactive map of CO_2 storage potential locations within the CEE region, the dissemination of results of the scientific projects and the utilisation of cross-border storage potential;

- Conducting R&D activities with the involvement of major stakeholders within the CEE region, including partnerships with research institutes, industry, public representatives such as ministries and local authorities, academia, as well as establishing international collaboration between CEE region and countries experienced in CCS deployment such as Norway;

- Clarifying regulations regarding the possibility of CO_2 storage in individual CEE countries; the regional regulations pertaining to transport and storage of CO_2 should be also harmonized or even made uniform in order to allow for transborder projects;

- Intensifying cooperation regarding CO_2 transport and storage infrastructure together with integration of the existing infrastructure;

- Given the geological potential for CO_2 storage, the number and advancement of implemented CCS projects and the individual needs to reduce greenhouse gas emissions, Poland and Romania emerge as countries which should be considered as regional CCS hubs and whose potential should be exploited for the benefit of the region;

- Increasing public acceptance by joint effort in conducting education campaigns regarding CCS/CCU technology in CEE countries, focused not only on the public but also on CO_2 emitters and governmental bodies.