Note:

This is a preliminary version of the deliverable entitled "Stakeholders' views on CCUS developments in the studied regions". This version is still under approval by the European Commission.

Date: August 13th, 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 837754

Stakeholders' views on CCUS developments in the studied regions

Release Status: FINAL

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Date: 20 July 2020

Filename and version: D3.2_STRATEGY CCUS_ Stakeholders' views on CCUS developments in the studied regions.docx

Project ID NUMBER 837754

STRATEGY CCUS (H2020-LC-SC3-2018-2019-2020/H2020-LC-SC3-2018-NZE-CC)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 837754

Document History

Location

This document is stored in the following location:

Filename	D3.2_STRATEGY CCUS_ Stakeholders' views on CCUS developments in the studied regions.docx
Location	

Revision History

This document has been through the following revisions:

Version No.	Revision Date	Filename/Location stored:	Brief Summary of Changes

Authorisation

This document requires the following approvals:

AUTHORISATION	Name	Signature	Date
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Distribution

This document has been distributed to:

Name	Title	Version Issued	Date of Issue
			00/00/0000

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Executive summary

The diffusion of CCUS technologies takes place in socio-technical systems and requires the acceptance and support of several stakeholder groups. To reflect the importance of societal actors in the CCUS innovation system development, the STRATEGY CCUS project has a work package (WP3) dedicated to understand stakeholder and public attitudes towards CCUS applications.

This deliverable has the aim to map stakeholders' views on CCUS technologies in eight European regions: Paris Basin (France); Rhône Valley (France); Ebro Basin (Spain); Lusitanian Basin (Portugal); Northern Croatia (Croatia); Galați Region (Romania); West Macedonia (Greece) and Upper Silesia (Poland) regarding to CCUS technologies. This has involved: i) identifying relevant actors for a societal discussion around CCUS; ii) conducting interviews with selected representatives of the stakeholder groups in the study regions as well as on the national and EU-level.

Method

Semi-structured interviews with selected members of the stakeholder groups were conducted in each of the study regions to identify stakeholders' overall evaluation of CCUS technologies, their level of acceptance of CCUS developments in their regions, sources of concern, perceived benefits and costs of the development of CCUS to the region, conditions for acceptance, perceived barriers and enablers to the development of CCUS in the study regions and preferences and expectations for energy futures.

Results

Most of the stakeholders consulted in the regions considered that the implementation of CCUS technologies would help in climate change mitigation and decarbonisation by significantly reducing emissions in the industry. In countries such as Spain and Portugal, interviewees emphasized the potential role of CCUS in reducing CO2 emissions from the process industries (cement, steel and glass). In France as well as in other countries, interviewees emphasized that CCUS should be considered as one among the many options to reduce CO2 emissions. Overall, we found a more favourable attitude towards CCU relative to CCS, although some interviewees perceived CCU as promising in the long term but currently insufficient to result in significant reductions in CO2 emissions

Stakeholders in the eight regions outlined the environmental global benefits (climate change mitigation) as well as the potential regional benefits of developing CCUS projects. The socio-economic benefits of implementing CCUS technologies were a key topic of discussion in the eight regions. Overall, there was the perception, not shared by all the stakeholders, that CCUS technologies would bring potential regional benefits in terms of job creation and the generation of new industries in the region. As for the potential costs and risks of implementing CCUS in the regions, economic considerations as well as the potential risks for the environmental were raised by stakeholders in all the studied regions. The societal impacts of carbon capture and storage were also considered by the stakeholders.

Overall, most of the interviewees in the eight regions were rather positive about the development of CCUS technologies. Support for the deployment of CCUS in the regions was based on a favourable attitude towards CCUS technologies as well as on a recognition of the potential socioeconomic benefits of CCUS projects for the region. Only a minority of stakeholder representatives were

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opposed or sceptical about the introduction of CCUS projects in their region. These interviewees reported a negative attitude towards CCS, preferred alternative technologies to reduce CO2 emissions and were sceptical about the potential regional benefits of CCUS projects. As conditions for acceptance, interviewees regions mentioned the need to consider the costs (financial viability), acceptance issues (adequate information and engagement), and support from the government (new and adequate legislation).

Regarding the barriers for CCUS deployment in the various studied region, most of the interviewees referred to financial and economic barriers (economic feasibility of CCUS projects), lack of socio-political acceptance and technical feasibility. In Spain, Croatia and Romania, lack of support and interest from authorities, political actors, and administration was considered a critical barrier. Lack of technological know-how as well as limited CO2 storage possibilities were also barriers mentioned in countries such as Romania and Poland.

Regarding the enablers for the development of CCUS projects, interviewees in the various regions generally pointed out to the existence of process and petrochemical industries potentially interested in implementing CCUS technologies as well as to the onshore geological storage capacity.

Conclusions

This report gives a comprehensive overview about the stakeholders' perceptions, attitudes and interest in the selected regions. We hope this report contributes to discussion of the policy and social issues arising from CCUS developments.

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Stakeholders' views on CCUS developments in the studied regions

1 Introduction

The main objective of STRATEGY CCUS is to conduct a feasibility study of applying CCUS to a set of clusters of major industrial and other CO_2 sources in various European regions by 2025-2030. The goal is to identify the need, desirability and opportunity to apply CCUS technologies to fossil fuel power plants and/or energy and carbon intensive industries in eight European regions: Paris Basin (France); Rhône Valley (France); Ebro Basin (Spain); Lusitanian Basin (Portugal); Northern Croatia (Croatia); Galați Region (Romania); West Macedonia (Greece) and Upper Silesia (Poland). Since the diffusion of a technology is not only a technological but also a social challenge, work package 3 of STRATEGY CCUS looks specifically at stakeholders and the public and their acceptance and support for CCUS applications.

The goal of task 3.2 is to map stakeholders' perceptions, attitudes and interest in the studied regions leading to a scoping of relevant issues and needs. This has involved: i) identifying relevant actors for a societal discussion around CCUS; ii) conducting **semi-structured interviews** with selected representatives of the stakeholder groups in the study regions as well as on the national and EU-level. This task is based on work carried out in task 3.1, namely, the social characterization of the study regions and the identification of potential stakeholders to be interviewed in the study. The focus of task 3.2 was on stakeholders' views on new developments to capture, storage (CCS) and reuse of CO2 (CCU).

As reported in deliverable 3.1, both the innovation system of CCUS as well as its social acceptance have been under researched (Jones et al. 2017; Karimi and Komendantova 2017). Thus, in this task, we extend the perspective on stakeholders and their acceptance concerning CCUS. Hereby we will define **stakeholders** as a *representative of a group that might influence or that might be affected by CCUS developments* and therefore has demands and/or responsibilities towards it.

In the following pages, we provide the main details and results of this consultation exercise.

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2 Design of the task

This report is based on semi-structured interviews with selected members of the stakeholder groups regarding their general attitude towards CCUS developments in the studied region. We aim to identify stakeholders' overall evaluation of CCUS, their level of acceptance of CCUS developments in their region, sources of concern among the stakeholders, perceived benefits and costs of the development of CCUS to the region, conditions for acceptance and perceived barriers to the development of CCUS in the study regions and preferences and expectations for energy futures.

2.1 Recruitment of participants

Between 10 and 12 representatives of the stakeholder groups and additionally around three key informants at the national level were interviewed in each of the study regions. The first criteria for selection of the interviewees was the maximization of the diversity of stakeholder groups included in the study (see deliverable 3.1 for a stakeholder categorization).

Another relevant criterion was the maximization of the information obtained. Participants should be potentially influential in CCUS developments in the study region or be potentially affected by CCUS developments and should have some level of understanding of CCUS technologies (alternatively, information can be provided to participants before the interview). Finally, when recruiting participants for the study, it is important to consider their motivations for participation. This is partly coupled with ethical considerations and how to incentivize people to participate. Participants may be inherently interested in the project or perceive some personal benefit from the project.

In Table 1 we have provided an overview of stakeholders that were included in the study. In addition to these stakeholder interviews on the regional and national level, we conducted four interviews with stakeholders on the EU-level. Thus, even though Portugal and the Rhône Valley in France did not reach the planned number of 10-15 interviews, we conducted a total of 102 interviews on the perception of CCUS.

Table 1. Types of regional stakeholder representatives that were interviewed

Stakeholder type	France (Paris Basin)	France (Rhône Valley)	Spain	Portugal	Croatia	Romania	Greece	Poland
Politics and policies	5	2	2	-	3	2	5	2
Research and Education	3	-	5	3	2	2	5	4
Industry: Demand side (adoption and use)	2	1	2	1	3	5	3	3
Industry: Supply system	-	-	1	1	3	1	-	-
Support organizations	2	4	1	-	2	2	1	3
Influencer (NGO's, experts, etc.)	1	1	3	1	2	3	-	1
Total	**13**	**8**	**14**	**6**	**15**	**15**	**14**	**13**

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2.2 Invitation to participate in the interview

Potential stakeholder representatives should have been personally contacted via email or telephone by a member of the regional team. See a potential template for the email in the box below. The email could also include a link to the STRATEGY CCUS website and/or a brochure in pdf about the project and/or a formal letter of invitation. It should have been translated into the local language.

Dear [include name],

In the context of the European project STRATEGY CCUS, aimed at studying the potential for CCUS developments in eight selected European regions, we are interviewing a number of key representatives of the stakeholder groups in each region.

Given your experience as [include], we are very interested in collecting your views and feedback on the potential development of CCUS technologies in [include selected region]

The interview would just take around 30 minutes and responses can be made anonymous. We can call you this or the next week or arrange a personal or Skype meeting whenever it suits you best.

Thanks in advance,

[add name of researcher]

2.3 Conducting the interviews

The interviews were conducted via telephone, skype or in person. Preferably the interviews were audio-recorded as this strongly increases the quality of interview documentation. In case this was not possible, the interviewer took extensive notes of the main opinions expressed by the interviewee during and after the interview. The approximate duration of the interviews was between 20 and 30 minutes.

2.4 Interview protocol

An initial list of topics to be covered in the interview were:

- Personal overall evaluation of CCS and CCUS
- Perceived benefits and costs of CCS and CCUS developments in the region
- General attitude and conditions for acceptance of CCUS developments in the region
- Perceived barriers and strengths for the development of CCUS in the region
- Trust in promoters
- Preference for alternative options
- Expectations about the future of CCUS in the region

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A relevant issue when conducting the interviews was to address both CCS and CCU[1]. We tried to cover both aspects of the technology but focused on the issues that the interviewee was more familiar with. Possibly attitudes differed towards CCUS in general and towards potential CCUS developments in the region. The focus was set on the latter, if possible.

2.5 Interview protocol

This section lists the interview questions that were provided to the interviewer to briefly illustrate the process of each interview.

For presentation or for the contact letter/email:

My name is _____ and we are conducting this interview as a part of the STRATEGY-CCUS project. The goal of the project is to understand the views of the different stakeholders on the adoption of Carbon Capture, Utilization and Storage (CCUS) technologies in the ____region. As a [type of stakeholder] we value your opinions and insights. We want to know how you personally or your organization feel about CCUS technologies, how do you perceive their potential benefits and risks for the region and whether you think CCUS projects should be supported in your region.

The information collected will be analysed by the researchers in the project only. We will respect participants' anonymity. In order not to lose parts of the information you will be providing, we would like to do an audio recording of this interview, use this recording as a basis to write a summary of this interview and afterwards delete it.

To inform you about the implications regarding data protection, we prepared this form on informed consent and if you are fine with it, we ask you to sign it

Introduction

To get started, just please let me know about [add an introductory topic about the interviewee] (e.g. history of CCUS in the region, experience with CCUS and the region)

[provide a brief explanation about CCUS to participants not familiarized with the technology]

Carbon capture, **utilization** and **storage** (CCUS), also referred to as **carbon capture**, **utilization** and **sequestration**, is a process that captures **carbon dioxide** emissions from sources like coal-fired power plants and either reuses or stores it so it will not enter the atmosphere. See https://www.energy.gov/carbon-capture-utilization-storage

[1] As stated by the Madrid Forum CCUS Taskforce in the document *The potential for CCS and CCU in Europe*[1]: "The taskforce agreed on the importance of separating out the CCS and CCU value chains into their component parts, in order to identify the barriers, incentives and public financial support that could apply to individual segments of the chain (capture, transportation, and utilization or storage). When the CCS and CCU value chain is disaggregated, it becomes easier to design targeted incentives which facilitate the deployment of capture, transport, use and storage as individual business cases, thereby creating an overall CCS and CCU system, which in turn encourages scale".

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General evaluation of CCS and CCUS

- Thinking about climate change mitigation in general, what do you think about Carbon Capture, Utilization and Storage (CCUS) technologies?
- Do you think these technologies can play an important role in mitigation efforts? In your region and in Europe?

Perception of benefits and costs (focus on the region of the interviewee)

Now, thinking about the potential benefits and risks of the adoption of Carbon Capture Utilization (CCU) and Carbon Capture and Storage (CCS) technologies in the region…

[If the interviewee has mentioned any benefits or costs for the region]

- You have mentioned that CCUS technologies would benefit/have this cost…please explain a little more.
- What other benefits do you think this project would have for the region?
- What other negative impacts do you think this project would have for the region?

[If the interviewee has not mentioned any benefits or costs]

- What do you think would be the main (direct and indirect) benefits for the region? Why?
- What do you think would be the main negative impacts for the region? Why?

What other benefits and risks do you think CCUS technologies could have for the region? Elicit potential direct and indirect impacts if not mentioned such as:

Differentiate between *storage* and *use* of CO_2

- Socio-economic impacts
- Technology development
- Creation of high value products (food preservation, horticulture)

General attitude and conditions of acceptance

- Thinking overall, what is your general position towards the development of Carbon Capture, Utilization and Storage (CCUS) projects in the region? Are you in favour, ambivalent or against? Do you think the adoption of Carbon Capture, Utilization and Storage (CCUS) technologies in the region is acceptable?
- Under what conditions would you accept/reject a project like this? [Explore potential conditions for acceptance or rejection]

Perceived barriers and enablers

- What are, from your perspective, the main barriers to the adoption of CCUS technologies in the region?
- What are, from your perspective, the main strengths of the region for the adoption of CCUS technologies?

Trust in promoters

- Do you think project developers/the industry in the region is capable of handling the technical and coordination challenges of adopting Carbon Capture, Utilization and Storage (CCUS) technologies?
- Do you think regional policy makers and the regional administration are capable of handling the coordination challenges of adopting Carbon Capture, Utilization and Storage (CCUS) technologies?

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- What about support organizations?
- What about universities and research centres?
- Are there other actors that you consider critical in the adoption of Carbon Capture, Utilization and Storage (CCUS) in the region?

Preference for alternative options

- Do you think there are alternative options to CCUS that you consider better suited to the region in order to substantially reduce CO_2 emissions?

Expectations about the future

- Do you think in the future (5 to 10 years) we will see the development of CCUS projects in the region?

2.6 Analysis

Each of the interviews was coded according to a pre-determined conceptual framework. The frame mirrored the basic structure of the interview guideline, but the analytic design also allowed for open coding – i.e. for new codes arising from the data to be added. In the analyses, numerical incidence is partly used as an indicator of relative salience and hence thematic prominence, helping to structure the presentation of results below. However, the focus is on a thematic analysis that tries to capture and to describe lines of arguments and networks of topics from the point of view of the study participants and thereby trying to identify patterns that lead to overarching conclusions.

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3 Findings

In this section, we provide the main findings from the interviews for each of the studied regions. The findings are structured similar to the interview guideline and start with the overall perception of CCUS technologies. We cover the various dimensions underlying the acceptance of the technology: general evaluation, perceived benefits and costs, perceived barriers and enablers, general attitude, trust in promoters, preference for alternative options and future expectations about CCUS. We finally provide the results from the interviews at the European level.

3.1 France (Paris Basin)

Role of CCUS technologies in climate change mitigation and general evaluation

When we asked interviewees about their perception of the role of CCUS technologies, they generally referred to the potential contribution of CCUS in reducing CO2 emissions in the industry and energy sectors and discussed and compared the potential contribution of CCS and CCU.

We found three key ideas in the interviews in the Paris Basin:

CCUS technologies will help reducing carbon dioxide emissions. Most of the interviewees in Paris Basin considered that the implementation of CCUS technologies would help in climate change mitigation. For some interviewees, CCUS is a critical technology to achieve carbon neutrality. As one interviewee commented: “Certainly, CCUS has an important role in emissions mitigation. In particular, on the short term...” As another interviewee from the industry commented: “CCUS is an interesting solution from an industrial point of view. And it is necessary.”

CCUS is one among the various options for climate change mitigation. Interviewees commented that CCUS should be considered as one option among many options to reduce carbon dioxide emissions. Some interviewees were more positive about CCUS technologies and considered that CCUS should play a relevant role in the solution. As two interviewees stated: “For the CO2 emission’s reduction, there is not one solution. It is a set of technologies, but I think yes, CCUS will be one of them. CCUS might be more encouraged in the future and it is still a challenge for decarbonisation of the industries.” However, other interviewees generally considered that other options should be prioritized against CCUS. An interviewee commented: “So, before putting in place the CCUS, we need to put in place other solutions. I am working for industries. I think it is important for the industries to reduce any amount of CO2, actually it is here where I think CCUS is important but still a complex technology and also expensive”. Generally, interviewees referred to the need to reduce energy consumption as well as to use resources that emit less CO2.

CCU has more potential than CCS. But the use of CO2 is limited. While some interviewees emphasized that CCU has more potential than CCS, given the perceived limitations of carbon capture and storage (technical complexity, cost, lack of societal acceptance), other interviewees commented that the use of CO2 to produce new products and materials is currently very limited. As one interviewee stated: “The use of CO2 is rather limited. Unless we find new technologies which use CO2”. One interviewee summarized this idea: “For the CCUS, the risk is weaker so in terms of acceptability I think it is way better and easier (than CCS), but the utilization is still limited who knows probably later the use will be more developed and important.” Generally, there was some hope among the interviewees in Paris Basin that more uses of CO2 will be developed in the future.

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Benefits and costs of deploying CCUS technologies in the region

Interviewees commented on several benefits associated to the development of CCUS technologies in the studied region:

- Environmental benefits. Interviewees consistently referred to the potential benefits of implementing CCUS technologies in terms of reductions of CO2 emissions. This would allow achieving carbon neutrality targets for the country and the region, in combination with other options, as well as to reduce the local impact of CO2 emissions. However, although most interviewees refer to the environmental benefits of implementing CCUS solutions, some questioned whether these benefits would be global and not local. One interviewee, for instance, commented: "The benefit is environmental as it allows emissions reduction. But this is a global benefit, not local. This can also be inconvenient [*for local acceptance*]"
- Economic development. The potential positive effect of CCUS technologies in terms of economic development was also a key benefit for some interviewees. Benefits in terms of (1) employment generation, (2) attraction of new actors, (3) generation of a new industry, (4) potential attraction of investments to the region and (5) regional leadership in the technology were mentioned by some interviewees.
  However, other interviewees commented that CCS projects would not necessarily increase job opportunities in the region: "Regarding CCUS, people will considerate it as a pollution. A pollution with no employment vacancies. The storage won't bring important employment opportunities to the region neither an economic interest. So, we may not have the approval of the region or the department". Another interviewee also mentioned that: "CCS will surely create some economic activities but it will not offer much employment. Regarding CCS, all of this is a risk on their territory"
- Other benefits. Other perceived benefits of CCUS technologies were related to (1) the potential financial benefits for companies (if the price of CO2 increases), (2) the potential benefits for companies' activities, and (3) the contribution to a circular economy around CO2.

Table 2. List of perceived benefits and costs, from more to less mentioned in Paris Basin.

Benefits	Risks
Environmental benefits (climate change mitigation, carbon neutrality in the industries in the region, pollution reduction in the region)	Economic viability (increase in cost, decrease in competitiveness for industries)
Economic development in the region (new industries, employment, investments, allow power plants to keep working)	Environmental risks (risk of underground storage)
Other (financial benefits for companies; beneficial for company image; promotion of circular economy)	Social impacts (public opposition)

Regarding the potential costs and risks of deploying CCUS technologies in the region, interviewees in Paris Basin referred to several issues:

- Economic viability. For some interviewees, adopting CCUS technologies is considered an expensive option that can reduce economic competitiveness of the local industry. One interviewee stated: "One needs to ask the following question: If this is a costly process, is it worth to put it in place?" Generally, interviewees considered that the price of capturing CO2

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would need to be reduced for the technology to become competitive. Another interviewee mentioned: "If we are able to have projects where they capture the CO2 for 30-50 Euros/t... well, it is an extra cost for the productive system. This extra cost might be a gain if you later on have to exchange the production system. If we talk about more than 100 euros/t then it is no longer a deal. Also the international market plays a role here."

- Environmental risks. Some interviewees were concerned about the potential impacts of CCS on the local environment. The risk of leakages impacting the local environment and public health was mentioned by some interviewees. One interviewee commented: "We all fear the leakage for sure. The main challenge is the geological concept. The really hard part is to find the storage site". Another interviewee also referred to the impacts on the underground and its consequences: impact on water resource etc. The interviewee was in particular concerned with the impurities that can be present in the CO2 injected underground: SOx, NOx which are far more harmful than CO2.
- Social impact. The potential social impacts were also a concerned for some interviewees. Public opposition in the region to CCS projects was mentioned by several interviewees. But also, there were references to other societal impacts such as the risks for the identity of the region. One interviewee commented: "CCS can cause a problem if it is installed under vineyard because it is a matter of identity of the region. There is very low social acceptability".

Acceptance of CCUS technologies and general attitude toward CCUS in the region

Most of the interviewees in the region accepted the implementation of CCUS technologies in the Paris Basin. Interviewees were, in general, positive about the use of CCS along with other low carbon technologies. The interviewees were positive about the potential benefits of CO2 use applications. As displayed in Table 3, we found significant levels of conditional acceptance of CCS.

Table 3. General position towards CCUS development in the Paris Basin region

Interviewee	Stakeholder group	Position	Description of position
PB3	Politics and policies	Acceptance	Positive opinion on CCUS but under conditions. Negative opinion about CCS. CCUS has more potential than the CCS
PB8	Politics and policies	Acceptance	Trust in CCUS to reduce the CO2 emissions in the atmosphere.
PB10	Politics and policies	Acceptance	Carbon capture and storage is part of the solution. It is indispensable to achieve the objectives of carbon neutrality
PB11	Politics and policies	Acceptance	Considers CCUS as one of the various solutions for climate change mitigation (a transition solution). She has a clear perception of the various potential benefits for the region: development of the territory, possibility of circular economy around CO2, CCUS deployment could constitute a differentiating element for the territory, driving force for local development, possibility for the region to develop a leadership on CCUS.
PB12	Politics and policies	Acceptance	Based on the idea that we need to multiply the number of solutions we can have for reducing

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			the emissions. “CCS can participate, especially since renewable energy has started only slowly”
PB1	Research and Education	Support	Totally in favour of CCS because of the environmental impact of this technology. Do not believe that CCU can have as much impact as CCS because of the smaller volumes that can be valorised compared to storage capacity.
PB2	Research and Education	Acceptance	More positive about CCU than of CCS. But she considers that the use of CO2 in new product is very limited. She considers that CCS will be more efficient for the important emitters.
PB5	Research and Education	Acceptance	CCUS will be one among the various options to reduce CO2 emissions in the industry.
PB4	Industry: demand	Acceptance	CCUS can reduce the CO2 emissions in the industry. CCUS should be one technology among a panel of solutions that will be required. CCUS can help in the transition to decarbonization.
PB6	Industry: demand	Support	He considers that CO2 storage could give a second life to power plants.
PB9	Industry: demand	Ambivalence	CCUS, and specially CCU, are important technologies to mitigate emissions, but investments in CCUS should not prevent other solutions, in particular the priority is limiting the emissions.
PB7	Support organisation	Acceptance	CCUS and specially CCU is perceive to have a positive impact on the region. “If we can make an energy from the CO2 and prevent pollution than it is a positive point for us”
PB13	Influencer	Acceptance	Trust in CCUS to have the ability to reduce the CO2 emissions in the atmosphere.

Regarding the conditions of acceptance of the implementation of CCUS technologies in the region, interviewees referred to four main conditions:

- Local acceptance. One interviewee, for instance, commented: “The social acceptability comes in the first place. Taking the example of the CCS project in Dunkirk, it was easier to go store CO2 offshore than to convince locals which means that technically we can prove our efficiency, we can go for more costly projects but not have the social acceptability”.
- Transparency and involvement of the civil society. As one interviewee mentioned: “The acceptance would depend on the communication, inform them before any actual act. Get them involved in the project, well explain the impacts and the benefits of the use of this technology”. Another interviewee commented on related issues: “There is still a long way to go for people to understand CCUS. Conditions for acceptance would be: pedagogy, undeniable scientific approval, and a project follow-up open to the civil society, transparency over the project duration.” Referring to potential CCS projects, another interviewee referred to the need to make the project a regional project: “They must show that it is a territorial project, not from a multinational industry. The local community must

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be involved…they need to show that the benefits are going to be territorial, for the region. There is a need to involve the citizens from the beginning…Involve the association and explain more points". This interviewee, for instance, recommended establishing scientific committees for the projects and to conduct more socioeconomic studies.

- Interest from the industry and especially, interest from the users of CO2. It is perceived that the industry, especially the potential users of CO2, need to be aware of the benefits of implementing CCUS technologies.
- Investments in CCUS do not compromise investments in other technologies. One interviewee, for instance, stated that: "A condition is the ranking, the prioritisation, the articulation of CCUS with respect to the other solutions. It has to remain proportionate: companies should invest x% on CCUS and x% on low-carbon solutions"

Perceived barriers and enablers/strengths

Regarding barriers for CCUS deployment in the region of Paris Basin, most of the interviewees referred to financial and economic issues, both affecting CCS and CCU, as well as to safety considerations and a lack of societal acceptance (mainly regarding CCS). The following barriers were considered as more relevant by the interviewees:

- Financial and economic barriers. Interviewees mentioned the economic feasibility of CCUS projects as one critical barrier to the deployment of the technology. Participants referred to lack of funding, high costs relative to the cost of emitting CO2, low return of investment, etc. One interviewee commented: "CCUS will be hard to develop as long as we don't have sufficient taxes on carbon…It will be complicated as long as there is no economic relevance…We need to attract private companies to make CCS, because the public will not be able to hold the whole cost."
- Safety. Safety issues and potential threats to human health were mentioned by several interviewees as a potential barrier for CCS projects. A political stakeholder from the Paris basin argued: "An important issue is the potential danger of this kind of project. I think it is not very well known. Is there a risk for the population (leakage, explosion, overconcentration of CO2)? I think there are real fears. (…) Most people are not aware of these elements [CO_2 is not flammable, not explosive, not toxic]. If people ask to a local politician if risks have been evaluated, if the project does not endanger them, he will probably not have the capacity to answer these questions."
- Local opposition. A number of interviewees referred to the lack of societal acceptance of CCS projects in the region. One interviewee from the industry commented on this: "The difficulty of explaining CCS safety and its evolution with time makes it hard to see CCS well accepted. In fact, we already have many difficulties to put through projects that are less complicated than CCS. For example, for a project of off-shore wind turbines, we had contestation, in spite of upstream consultation, accompanying measures, etc."
- Technical feasibility. For some interviewees, the technology is still not well developed and known.
- Other barriers:
    - Lack of a mature sector for uses of CO2,
    - Lack of industries: "In the Reims region, there are few outcomes for CO2: there are no greenhouses, no chemical industries",
    - Lack of political support,
    - Lack of trust in project leaders (perceived as not environmentally friendly).

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Regarding the enablers for the development of CCUS projects in the region, interviewees mainly referred to two main issues:

- Existence of favourable geological formations for CO2 underground storage. This was mentioned by several stakeholders in the Paris region. As one regional politician commented: “I think that the Paris basin is an interesting region to consider, since it is a favourable region for geothermal. So, there may be some potential to look at for the geological storage of carbon”. Another researcher also mentioned that: “I am not a geologist, but I know that what attracts geologists the most to the region and to CO2 storage is the end of the Paris basin. We have the suitable conditions for storage.”
- Interest in sustainable energy in the region. It is considered by some of the interviewees that the Centre-Val de Loire region is active in the fight against climate change. One interviewee, for instance, commented: “The Centre-Val de Loire region is largely invested in the fight against climate change, in an open and participative way. There is a will for commitment and an opening to innovation. Also, the region has a lot of space.”

Trust in promoters

Regarding the industry, there is the general perception that the industry is technically skilled to develop and implement CCUS projects. As one interviewee commented: “I am working with industrials and scientific community and I will say there are experts in the domain proved by the projects already done with success, so I always refer to the acceptability and the cost as the main barriers”. Some interviewees were, however, more critical about the existing capabilities for underground storage: “I trust them for the utilization of CO2 but for the storage it is a little tricky because there is a lack of knowledge”.

On the other hand, some interviewees were sceptical about the intentions of the fossil fuel industry in adopting CCUS technologies. As one interviewee commented: “I have no doubt on the technical actors. However, I have doubts on the environmental integrity of CCUS and I fear a rushing ahead of the industrials, which could consider CCUS as a growth opportunity. Just like companies which develop renewable energy without reducing its fossil fuel consumption.” Another interviewee also mentioned that: “What I have noticed, since almost 10 years, since I started having an interest in the idea of CCS, is that unfortunately the petroleum industries use to show their fake interest in this technology in the future, but in reality they continue on the same business. Even the regulated capture is not that serious, based on my knowledge there is no efficient elaborated study. I will say I am a little pessimistic about it. I would say there is a potential, but I do not believe the announced looseness. Apart from that, the roadmap of the international agency of energy was not at all respected for example”.

Interviewees also referred to the important role of politicians. One interviewee commented on the lack of interest from policy makers: “At a local scale, I don’t think there is support from politicians since they are not aware of this technology; we are talking about a lack of knowledge…Same for the national level, they will say why would we go for CCS or CCUS if we have simpler technologies like collecting heat with a less price? The policy of the government is to start with which is simpler”. Another interviewee mentioned: “It is a question of political priorities…There is a need to improve the skills of politicians also…they need an expert pool to rely on”. Another interviewee referred also to the need of involvement from national policy makers: “A region cannot implement alone this kind of project. It requires a national plan that defines the need for this technology”.

Some interviewees also discussed the important role of research centres, the local community, environmental organizations, regulators, inspectors in the development of CCUS projects in the region.

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Preference for alternative options

Overall, most of the interviewees consider that CCUS should be part of a broader strategy to reduce emissions by reducing consumption, improving energy efficiency and transitioning to renewable energies. Here, CCUS technologies were perceived as part of the solution to climate and energy problems, potentially to be introduced in the medium term. One of the interviewed policymakers commented: "There are many alternatives. But what we need is a mix of all the solutions. We have no choice to make, but priorities to define. Which are, I think, consumption reduction and renewables. Then, at medium term, CCUS". Another interviewee from the academia commented: "There is no single alternative or technology, it is a set of options that we need to work on if we want to reduce the carbon footprint by: using biomass; renewable energy; control of the consumption; use the hydrogen for the transport". One interviewee from the industry stated: "The ambition of the company is to reduce the carbon footprint of its installations by: using resources that emit less CO2 (biomass, geothermal…); reducing the energy consumption; and capturing the CO2. But we are less mature on these issues and the applicability on small-size installations is not proven yet".

Expectations about the future

Most of the interviewees were somehow positive about the future prospects of CCUS. One interviewee, for instance, considered that there will be CCUS projects in the coming five to ten years as industries are interested and there will be future taxes on carbon. Not all interviewees were so positive about the future of CCUS, but somehow believed that CCUS projects will proliferate in the long term. This positive expectation was usually based on:

- The existence of pilot projects. As one interviewee commented: "I think in 10 years there will be already demonstrator pilots (especially in the South of France). I easily see a pilot in the 5-10 years but not an outstanding industrial development…The hydrogen is a subject discussed right now and it seems to be accepted. I know that it will be easier though for the CCUS and not the CCS". Another interviewee saw a pilot in the next 5-10 years to prove the technical and economic feasibility of CCUS. He considered that a working pilot would allow CCUS to develop (first demonstrators, then large-scale). Another interviewee also mentioned: "Let's hope to see installations of the CCUS and if we get the case of Dunkirk done, it is already an achievement and it will be a proof and a step towards on-shore projects…By 2030, we estimate a CO2 storage field of 10 millions of tonnes."
- The region and industries are very active. As some interviewees stated, CCUS could develop faster than expected as the region is very active on sustainability issues and already has a dense network of actors involved.

Other interviewees were more ambivalent about the future of CCS in the region. One interviewee, for instance, commented: "From now until 10 years we should be in projects that exceeded the stage of demonstrators. At the same time, I wrote papers five years ago but we still come back to them so it makes me wonder if we are progressing that much".

Finally, some interviewees were more negative about the future of CCUS in the Paris Basin, based on the potential existence of public opposition to CCS projects and the expectation that the market for CO2 use is going to remain relatively small in the medium term.

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3.2 France (Rhône Valley)

Role of CCUS technologies in climate change mitigation and general evaluation

When we asked interviewees in the Rhône Valley region about their perception of the role of CCUS technologies, they generally referred two key ideas:

- CCUS technologies will foster climate change mitigation. Some of the interviewees considered that the implementation of CCUS technologies would help in climate change mitigation. For some interviewees, CCUS is a critical technology to achieve carbon neutrality. As one interviewee commented: "Absolutely yes! In my opinion it takes part of the different technologies essential for the objective of limiting greenhouse effect and global warming…There are some projects of CCUS in the region, especially from the biomass…"
- CCUS is just one among the various options for climate change mitigation. Interviewees commented that CCUS should be considered one option among the many options to reduce carbon dioxide emissions, given the perceived limitations of the technology or the simply preference for investments in alternative options. As one interviewed from the policy arena commented: "If in a few years the technology is more efficient, yes, for me, it might be a key. For the moment, is the multiplicity of projects that will allow us to play a small role at this level, otherwise we are still weak in term of effectiveness". Some interviewees were more negative about CCUS technologies and considered that CCUS should play a limited role in the solution given the specific characteristics of the French energy system, the costs of CCUS, the limited public acceptance of storage sites or the limited technological advances in the last years in CCS technologies.

Benefits and costs of deploying CCUS technologies in the region

Interviewees commented on several benefits associated to the development of CCUS technologies in the studied region:

Environmental benefits. Interviewees consistently referred to the potential benefits of implementing CCUS technologies in terms of reductions of CO2 emissions. This would allow achieving carbon neutrality targets for the country and the region, in combination with other options, as well as to reduce the local impact of CO2 emissions. In this sense, some interviewees mentioned the potential benefits in terms of improved air quality and reduced local impacts of plants. One interviewee, for instance, mentioned that the Auvergne-Rhone-Alpes (AURA) region comprises a large industrial pole which are high CO2 emitters so they region would benefit from less emissions. Other interviewee referred to the potential benefits of CCUS in terms of local emissions: "CCS has an integrated dimension: it provides a local solution for reducing the local emissions."

Economic development. The potential positive effect of CCUS technologies in terms of economic development in the region was also a key benefit for some interviewees. Benefits in terms of employment generation, attraction of new actors, potential attraction of investments to the region and regional leadership in the technology were mentioned by some interviewees. One interviewee commented on this: "At a local level, CCUS development could generate investments, create jobs, etc. It can be complementary to classical existing industries, and can be seen as an additional link we would add." Another interviewee mentions the potential benefits of CCS in terms of local investments, and of CCU in terms of adaptation of the industry: "CCS deployment can create activity, at least for the building phase. But less for the exploitation…CCU can consolidate some economic sectors. We can work on process adaptation so that they last longer. And it is good for the resilience of already established industries". Another interviewee in the region emphasized the potential

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benefits of the introduction of CCUS technologies for the survival of the local industries: “CCU can consolidate some economic sectors. We can work on process adaptation so that they last longer. And it is good for the resilience of already established industries”. More specifically, one interviewee in the region refers to potential benefit of CCUS technologies to the continuation of the energy industry (a coal power plant) in the region: “The idea of CCUS in the region is issued from the case of the coal-fired power plant. They are trying to keep it open. Therefore, and to not shut down the power-plant this project aims to cultivate micro algae in open basins from industrial fumes without treatment.”

Other benefits. Other perceived benefits of CCUS technologies were related to the hydrogen sector (combination of CO2 with H2 to produce methane with high potential for this use in the region AURA), the potential financial benefits for companies (if the price of CO2 increases), the potential benefits for companies’ activities, the contribution to a circular economy around CO2.

Table 4. List of perceived benefits and costs, from more to less mentioned in Rhône Valley.

Benefits	Risks
Environmental benefits (climate change mitigation, carbon neutrality in the industries in the region, pollution reduction in the region)	Economic viability (increase in cost, decrease in competitiveness for industries)
Economic development in the region (new industries, employment, investments, allow power plants to keep working)	Environmental risks (risk of underground storage)
Other (new possibilities for the hydrogen sector; financial benefits for companies; beneficial for company image; promotion of circular economy)	Social impacts (public opposition)

Regarding the potential *risks and costs* of deploying CCUS technologies in the region, interviewees referred to several issues:

Economic cost. For some interviewees, adopting CCUS technologies is considered an expensive option that can reduce economic competitiveness of the local industry. One interviewee states: “From an economic point of view, the issue is the competition at the global scale. Indeed, CCUS has a substantial cost that would raise the cost of the manufactured products.” Generally, interviewees considered that the price of capturing CO2 would need to be reduced for the technology to become competitive. Another interviewee mentioned: “If we are able to have projects where the capture the CO2 for 30-50 Euros/t well it is an extra cost for the productive system. This extra cost might be a gain if you later on have to exchange the production system. If we talk more than 100 euros/t then it is no longer a deal. Here, comes also the international market.” Another interviewee also referred to the costs: “I had some reservations about the economic viability of these projects because we know how expensive this type of infrastructure, construction and pipeline is, but the case of the Norwegian project proves an economic reality”.

Environmental risks. Some interviewees were concerned about the potential impacts of CCS on the local environment. The risk of leakages impacting the local environment and public health was mentioned by some interviewees. One interviewee commented: “I am not an expert but I can talk about leakage that will decline any interest of CCS. There is no interest if the CO2 will finally end up in the atmosphere even if it is only in 20 – 30 years”. Another interviewee referred to the impacts on the underground and its consequences: impact on water resource, leakage risk etc. Another interviewee referred to the environmental performance of CCUS technologies: “As far as the

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benefits on the environment are concerned, I really wonder about the energetic balance of all the chain (energy, solvents, etc.) in a Life Cycle Analysis perspective. This is an issue for acceptance".

Social impact. Public opposition in the region to CCS projects was mentioned by several interviewees. As one interviewee from the industry commented: "People do not accept CCS, there is contestation". Another interviewee commented: "In term of acceptability, I will say that effectively it is an easier technology to put in place because we don't treat the question 'not in my backyard'. It depends eventually where we are going to do the storage! In several countries, we risk to capture the CO2 but store it in other country that has the geological potential or offshore"

Acceptance of CCUS technologies and general attitude toward CCUS in the region

Interviewees were, in general, positive about the implementation of CCUS in the region along with other low carbon technologies. The interviewees were positive about the potential benefits of CCUS applications in terms of climate change mitigation and technological and socioeconomic development. We found significant levels of conditional acceptance of CCS.

Table 5. General position towards CCUS development in the Rhône Valley region

Interviewee	Stakeholder group	Position	Description of position
RV3	Politics & Policies	Support	Positive opinion on CCUS. CCUS has to be deployed together with other solutions: the first one should be sobriety, then renewable energies, carbon capture by biodiversity, building energy efficiency
RV8	Politics & Policies	Acceptance	CCUS could play a role in the region. She thinks the technology could play a role in the future but thinks that is not currently efficient enough.
RV6	Industry / Demand	Ambivalence	He considers that CCUS is not the solution to climate change. He acknowledges that it can contribute to emissions reduction.
RV1	Support organisations	Acceptance	Trust in CCUS to reduce CO2 emissions in the atmosphere, especially on the storage part, as the uses of CO2 will not be able to significantly reduce emissions
RV2	Support organisations	Support	Totally in favour of CCU, due to her involvement in hydrogen development. Unsure about CCS.
RV5	Support organisation	Acceptance	CCUS is necessary but insufficient to mitigate climate change. CCUS projects can have important benefits for the region. However, for the French case, motivation for developing CCUS may be lower due to its low-carbon power
RV7	Support organisations	Acceptance	In favour of a mix of solutions, prioritizing the reduction at the source and the valorisation of the CO2 to different products.
RV4	Influencer	Acceptance	CCUS is perceived as one among the different technologies that can contribute to climate change mitigation

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Regarding the conditions of acceptance of the implementation of CCUS technologies in the region, interviewees referred to three main conditions:

- Public acceptance. Acceptance by the local population and the civil society was considered a critical issue for acceptance. As one interviewee commented: “We have to involve the NGOs and to do so, to involve the local agencies of energy and climate, who can relay to the NGOs”.
- Favourable regulation and policy interest. Two interviewees referred to the need of favourable regulation (“It is regulation that make things happen”) and interest and understanding from local national and regional policy makers.
- Limited environmental impacts. A reduction of the risks from storage was considered a critical element for acceptance for some of the interviewees. As one interviewee commented: “Public opinion is also waiting for environmental protection at the storage site”. Another interviewed referred to the environmental and economic dimensions as preconditions for acceptance: “Both economic and environmental aspects must be taken into account when sizing the project since the beginning. We have to see for example in CO2 storage project if we can transport in a hydrogen-powered boat. It seems more profitable if we transport and store rather than use it.”

Perceived barriers and enablers/strengths

Regarding the barriers for CCUS deployment in the region, most of the interviewees referred to economic and financial issues, both affecting CCS and CCU, as well as to safety considerations and lack of societal acceptance (mainly regarding CCS). The following barriers were considered as more relevant by the interviewees:

- Financial and economic barriers. Interviewees mentioned the economic feasibility of CCUS projects as one critical barrier to the deployment of the technology. Participants referred to lack of funding, high costs relative to the cost of emitting CO2, low return of investment, etc. One interviewee commented: “There are big questions that remain on, are we really sure of our cost? Is it a reliable technical and economic model?”
- Lack of socio-political acceptance. A number of interviewees referred to the potential lack of societal acceptance of CCS projects in the region. One interviewee from the industry commented on this: "For CCU, I do not see more barrier than other projects. It will be well perceived…Locally, there is an opposition, especially from local associations for environment protection, biodiversity… These associations are competent and are well armed, legally speaking"
- Technical feasibility. For some interviewees, the technology is still not well developed and known.
- Other barriers:
    - Regulatory acceptance,
    - Lack of knowledge about the technology
    - Lack of a full value chain for CCUS. One interviewee commented on the need to make the actors of the sector cooperate on this.
    - Transport issues,
    - Technology not adapted to small emitters in the region,
    - Geological conditions,
    - Nuclear tradition,

Regarding the enablers for the development of CCUS projects in the region, interviewees mainly referred to the existence of industry in the region interested in CCUS technologies. This was mentioned by several interviewees. One interviewee commented: “The region is highly emitting so

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we have to find solutions for these emissions." Another interviewee also perceived a significant interest in these solutions: "There is a demand for CCUS from the industries of the region: there are a lot of emitting industries that need to reduce the emissions, there are also industries that require CO2 (chemical…). So there is a clear interest to federate the actors around a CO2 hub".

Trust in promoters

Generally, the interviewees trusted the technical capabilities of the local industry to implement CCUS projects in the region. Some interviewees commented on the different capabilities of the various industrial actors in the region: "It really depends on the type of the technology if we are talking about a new matter, like biogas I will be hard to judge their maturity and I will say they (Industries and project managers) are not mature enough but after all it depends on the industry, there are ones that have engineering capacities and can ensure. Because also we are the first region in France in biogas production with big ambition." But, overall, the stakeholders expressed a high level of trust in the industry. As one interviewee commented: "In France, we are totally able to lead these projects. We have enough capacities, knowledge. But France is waiting, and this is not a bad idea."

Some interviewees also discussed the important role of research centres, the local community, environmental organizations, regulators, inspectors in the development of CCUS projects in the region. As one interviewee commented: "About universities and research centres there are experts in this domain and also we have people that have interest to prompt this subject since it their field. For promoting for CCUS, I will support more the academics and the national public institution".

Preference for alternative options

Overall, most of the interviewees consider that CCUS should be part of a broader strategy to reduce emissions by reducing consumption, improving energy efficiency and transitioning to renewable energies. Here, CCUS technologies are perceived as part of the solution to climate and energy problems, potentially to be introduced in the medium term.

Other less dominant ideas were:

- CCUS technologies are not really considered as part of the solution to energy and climate issues. "CCUS is a downstream palliative. The major issue is reducing the emissions basically, limiting the emissions. We need a more sober world, an economic model more sober. This lever is far more important than CCUS (downstream)". In this sense.
- CCS is the only solution that enables large emission reductions. One interviewee commented: "I do not see alternative options to CCUS. Indeed we are large emitter, so we need "large" solutions… Or… maybe EOR could be an alternative."

Expectations about the future

Most of the interviewees were somehow positive about the prospects of CCUS. One interviewee, for instance, considers that there will be CCUS projects in the coming five to ten years as industries are interested and there will be future taxes on carbon. Of course, not all interviewees are so positive about the future of CCUS, but somehow believe that CCUS projects will proliferate in the long term. This positive expectation is usually based on the perception that the region and industries are very active. As some interviewees state, CCUS could develop faster than expected as the region is very active on sustainability issues and already has a dense network of actors involved. Other interviewees were more ambivalent about the future of CCS in the region. One interviewee commented that: "I don't know when we can expect a CCUS project. But we should already start to talk about it from now, for the idea to get in the people's mind".

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3.3 Spain (Ebro Basin)

Role of CCUS technologies in climate change mitigation and general evaluation

In Spain, interviewees' attitudes regarding CCUS technologies and its role in climate change mitigation varied from enthusiasm and support to scepticism and rejection. Some interviewees emphasized the important role of CCUS technologies in the decarbonization of the European economy in the medium and the long term. Other interviewees, on the contrary, considered that CCUS will have a less relevant role in reducing CO2 emissions and discussed its limitations as a mitigation option.

We find several key ideas in the interviews:

- CCUS technologies will be needed to speed up decarbonization. For most interviewees, CCUS technologies will play a relevant role in decarbonization of the energy and industrial sectors in Europe. CCUS is perceived as an intermediate technology to accelerate climate change mitigation and to complement the deployment of renewable energy technologies in the medium and the long term. Both storage and use of CO2 will contribute in this reduction.
- CCUS will be critical in the long term for the process industries (cement, steel, etc.). The reduction of CO2 emissions from the cement and steel industries is perceived as a critical area for the development of CCUS technologies. These industries -emitting high quantities of CO2- will have very few options to reduce their CO2 emissions in the medium term so they will need to implement CO2 capture technologies.
- Options for CCUS in the energy sector will be limited. While some interviewees consider that CCUS will contribute to emission reduction in the energy sector, others consider that CCUS will not be relevant in the energy sector. Interviewees emphasize that the use of coal for electricity generation- where CCUS could play a role in reducing emissions- will not be relevant in Spain, making CCUS non relevant in the energy sector. Retrofitting carbon capture and storage technologies to existing natural gas-fired power plants is considered, by some interviewees, as economically unviable so it is not considered a relevant area for the development of CCUS.
- The use of carbon dioxide in the development of products and services is promising in the long term but currently insufficient to result in significant reductions in CO2 emissions. Most of the interviewees agree on the potential of using CO2 in new products for climate change mitigation and economic development. Some interviewees state that the reutilization of CO2 for the generation of methane, synthetic gas and related products will be economically viable in ten years. The reutilization of CO2, linked to the broader idea of a circular economy, is generally perceived as a good idea. But some interviewees state that the potential contribution in terms of climate change mitigation is still very limited.
- The storage of CO2 is potentially problematic. While some interviewees consider that the storage of CO2 is needed for a fast and short-term reduction of CO2 emissions, the interviewees tend to view the on-shore storage of CO2 as more problematic than the use of carbon dioxide in new products and services (costs, availability of suitable geological storages, public opposition, and lack of regulatory acceptance).

Benefits and costs of deploying CCUS technologies in the region

Regarding the potential benefits of developing CCUS technologies in the studied region, the interviewees refer to three main benefits: preservation of the local industry, new socio-economic opportunities for the region and technological development:

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- The preservation of the local industry is the key benefit of deploying CCUS technologies for some of the interviewees. The interviewees consider that the petrochemical and the process industries would benefit from implementing CCUS technologies as this would allow the continuation of their activity in the future. Most interviewees agree that industries should reduce their carbon emissions and CCUS is perceived as a key tool here.
- Another benefit of deploying CCUS technologies in the region, according to the interviewees, is the potential socio-economic positive impact (in terms of industry, job and wealth creation). CCUS technologies could promote the development of new industries in the region, according to these interviewees. This is linked to the use carbon dioxide (CO2) in the development of products and services and the generation of a circular economy.
- Finally, investing in CCUS technologies could promote technological development. Interviewees refer to the potential benefits of becoming a leader in these technologies, which is associated to potential socio-economic gains. Table 6 shows extracts from the interviews summarizing these ideas.

Table 6. Perceived benefits in Ebro Basin

Benefits	Extracts
Preservation of the local industry	"If this technology is implemented in the medium term, these industries will be able to continue developing its activity. Companies would be able to maintain their activity by reducing CO2 emissions." (ES6) "These industries (cement, paper, steel) have no other way to reduce their CO2 emissions." (ES13) "The survival of petrochemical companies in Tarragona will only be possible if they are carbon neutral and one of the ways to achieve this is by capturing CO2." (ES14)
New socio-economic opportunities for the region	"These technologies may lead to development of the region from the point of view of population." (ES7) "It is going to be a new industry. It will be generated the formation of hubs where different industries and sectors will be associated. This will generate new job opportunities, new direct and indirect jobs… it could attract investment and industries to the region." (ES11) "These are very large investments of money that do have a positive effect: it creates jobs, it creates associated local industry ..." (ES13)
Technological development	"The main benefit is the possibility to explore a new technology and, if you are able to lead this technology globally, make a profit." (ES2)

As for the costs of deploying CCUS technologies in the region, the interviewees focused, mainly, on cost-effectiveness considerations. Some interviewees consider that the implementation of CCUS solutions is not cost-effective, relative to the price of carbon dioxide and of alternative technologies. The high price of capturing a ton of CO2 is the main perceived cost of CCUS technologies. One interviewee, for instance, refers to the increase in cost that this can result for a cement factory, when cement factories in other countries are not reducing their emissions. The need for important

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investments in infrastructure (for capture and for storage) is also related to this lack of cost-effectiveness.

Other costs mentioned by the interviewees were related to the potential environmental and societal impacts of on-shore storage of carbon dioxide. In this sense, some interviewees mentioned the potential effects of CO2 storage on the local environment and its consequent potential local opposition.

Table 7. Perceived costs in Ebro Basin

Costs	Extracts
Cost-effectiveness	"At the present time, these technologies have an unacceptable cost because, first, the technologies are not mature and second, because you are not alone in the world, there are many competitors around you who have no obligation to reduce CO2 emissions. It is very difficult to compete with this." (ES8) "There is no doubt that the initial investment is very high. This investment has a very high risk because they are technologies that cannot be considered closed yet." (ES11) "This technology is still relatively expensive. It will be linked to the price of CO2 ton and to environmental requirements. Or companies are given a solution to capture CO2 at a reasonable price or they will leave. In fact, some cement companies have already gone to Morocco or to Turkey to produce cement." (ES13)
Environmental and societal impacts	"In the case of underground storage structures, we would have to see what negative territorial impacts it can have in terms of the environment." (ES3)

Acceptance of CCUS technologies and general attitude toward CCUS in the region

Interviewees' were mostly favourable towards the development of CCUS technologies in the studied region. Support for the deployment of CCUS in the region was based on a favourable attitude towards CCUS technologies in general as well as on a recognition of the potential benefits of CCUS projects for the region. Several conditions for acceptance as well as potential barriers for the deployment of CCUS were mentioned by the interviewees. A minority of interviewees rejected or were sceptical about the deployment of CCUS projects in the region.

The following table characterizes interviewees' general position regarding the development of CCUS technologies in the studied region.

Table 8. General position towards CCUS development in the Ebro Basin region

Interviewee	Stakeholder group	Position	Description of position
ES3	Politics and policies	Support	The region should promote the deployment of CCUS projects given its potential socio-economic benefits.

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ES4	Politics and policies	Scepticism	The role of CCUS technologies in climate change mitigation is questionable. The benefits of CCUS projects in the region would be limited (perhaps only to the cement industry). There is no need for these projects in the region. A lot of conditions should be satisfied in the region (industrial concentration, social acceptance, high storage capacity, easy transport of CO2) to promote CCUS projects.
ES2	Research and Education	Acceptance/ tolerance	CCUS technologies are potentially useful in mitigation efforts. The potential of CCUS technologies should be explored in the region as it could foster technological development.
ES5	Research and Education	Support	Perceives new opportunities to use carbon dioxide (CO2) in the development of products and services in the petrochemical industry.
ES6	Research and Education	Support	Support for CCUS technologies in general and for the deployment of CCUS projects in the region linked to significant benefits for the local industry and for technology development.
ES7	Research and Education	Support.	The deployment of CCUS projects would benefit the region (socio-economic development).
ES12	Research and Education	Acceptance	Linked to a potential but perceived as limited use of carbon dioxide for agriculture.
ES11	Industry: demand	Psychological identification	Linked to new opportunities to use carbon dioxide (CO2) in the development of products and services to mitigate climate change, promote technology leadership and support a circular economy.
ES13	Industry: demand	Support	Very positive about the potential use of carbon dioxide in the process industry and the gas sector. More political support is needed for the deployment of CCUS projects in the region.
ES14	Industry: supply	Support	CCUS is a relevant option in climate change mitigation. CCUS technologies could be very beneficial for the survival of the local petrochemical industry.
ES8	Support organisation	Psychological identification	CCUS technologies are critical for mitigation efforts in the process industries. Sceptical about the needed conditions in the region.
ES1	Influencer	Psychological identification	The deployment of CCUS projects in the region will be very positive for the technology and for the region.
ES9	Influencer	Acceptance	The deployment by the industry of CCUS projects

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			would reduce pollution in the area and contribute to a circular economy.
ES10	Influencer	Rejection	CCUS technologies are not needed for climate change mitigation. The conditions for the deployment of these projects in the region are not met (existence of coal power plants and opportunities for underground storage close to large emitters). Development of CCUS linked to the promotion of gas power plants.

Perceived barriers and enablers/strengths

The interviewees identified several strengths and enablers to the development of CCUS technologies in the region: existence of process and petrochemical industry potentially interested in implementing CCUS technologies, underground storage capacity in the region, and existence of research centres focused on these technologies.

- The existence of process and petrochemical industry with an interest in CCUS technologies was considered a key strength of the region. Although some interviewees refer to the lack of coal power plants in Aragón and Cataluña, it is generally perceived that the process industry in Aragón and the petrochemical industry in Cataluña are relevant industries in the region and interested in the implementation of CCUS technologies to reduce carbon emissions. See specific comments by the interviewees in Table 9.
- The existence of onshore storage capacity was perceived as a key strength of the region. Previous studies have identified the Ebro region as potentially suitable for onshore storage of CO2. Although not all the interviewees refer to the storage capacity of the region, some of the interviewees consider that the existence of specific areas in the region with high storage capacity is a key strength of the region.
- Finally, some interviewees referred to the existence in the region of research centres focused on CCUS technologies. This is considered a strength of the region, given the potential collaboration between the local industry and the local research centres in the development of CCUS technologies.

Table 9. Perceived enablers and strengths in Ebro Basin

Enablers	Extracts
Underground storage capacity	"From the point of view of geological conditions, there are stable structures with good storage potentials." (ES7) "We have geologically suitable areas for deep geological storage of CO2." (ES8)
Interest from the industry	"In the Ebro basin region, we have a powerful industry interested in the use of these technologies. We have paper industries, combined cycle power plants…" (ES3) "All CO2 emitting industries (energy, glass, petrochemical) are very interested" (ES14) "The cement industries are very interested in these technologies." (ES13)
Existence of research centres	"We have been working from this region for a long time. Capture

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focused on CCUS	technologies have been analysed a lot, storage areas have been analysed ... we have institutions that are very powerful in capture, it is something that in technological development I believe that Aragon is well positioned." (ES6)

Regarding the perceived barriers, the interviewees referred to several issues related to CCUS technologies in general and to its potential deployment in the studied region.

- Low demand for utilization of CO2. Although interviewees tended to refer to the potential benefits of reusing carbon dioxide in new products, the idea that there is not enough demand to reuse all the CO2 that is emitted was mentioned by several interviewees. As some interviewees mentioned, there is not enough market demand for all the CO2 that is produced.
- Public and stakeholder opposition to underground storage of CO2 was considered as a relevant barrier to the deployment of CCUS technologies. Interviewees referred to the existence of opposition by some regional governments and local communities to on-shore long-term storage of CO2.
- Lack of political and regulatory support was also considered a critical barrier. Some interviewees perceive that the national government, contrary to other countries, is not committed to developing CCUS technologies in Spain. And this is considered critical for CO2 storage projects.
- The economic costs of CCUS technologies, in terms of investment and operation, and technological immaturity were also considered relevant barriers by some of the interviewees.
- Other perceived barriers more specifically related to the region were related to the distance of potential storage sites from large emitters, and the inexistence of large emitters inexistence (specially, coal and gas power plants) in the region.

Table 10. Perceived barriers in Ebro Basin

Barriers	Extracts
Low demand for utilization of CO2	"Right now, what use does CO2 have? It has a relative utilization. There is no demand for uses." (ES1) "The problem is that nobody can see a stable use solution in the medium term (…) There are no utilization technologies that guarantee that CO2 will be fixed and will not be emitted in a short time." (ES2) "There are not enough uses for the existing volume of CO2." (ES8) "Nowadays, not all of the CO2 can be reused with the uses that exist. We have to create new uses, new materials that need CO2." (ES14)
Public opposition	"When you talk about storage, people generally don't want to hear about it. There is an important rejection towards storage. People do not finish trusting in it." (ES2) "To store CO2 in my backyard it is always a problematic issue. I think rejection could be generated." (ES6) "The problem is that people can associate it with the Castor

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	experience or with the fracking that are precedents that have nothing to do with it." (ES13) "General public may oppose to this type of projects because they think it is not safe to store CO2. A very good job of raising awareness of the project should be done." (ES14)
Lack of political and regulatory support	"When I compare what Germany, France, Denmark, Holland, England do ... the big difference is that companies in those countries have economic guidelines with their respective governments. In Spain this does not exist and stops companies from launching to other alternatives." (ES5) "There are legislative barriers, barriers of political support and political uncertainty. There is no legal certainty in this country. Do you think that companies, if there really were legal certainty and support on this issue, would not be investing? " (ES8) "At present, there is no clear regulation or a position of the government of our country about the CCUS. Companies need security over time, a framework that ensures that there will be a return on investment." (ES11)
Location of storage sites relative to emitters	"The difficulty of the Ebro basin is in its situation, a little far from the emitters." (ES1) "CO2 storage should be near to where the CO2 is generated. In Tarragona the facilities that they can emit are minimal. I do not see it feasible, economically viable, because this would mean having to transport the CO2 from one place to another." (ES10)
Inexistence of high emitters	"Right now, there is no generation in Aragon. There are no thermal power plants because all of them have closed." (ES6) "There are no coal power stations in Tarragona. Therefore, it cannot be applied here. It could be applied to combined cycle gas power plants but, in Tarragona, we have only one and it is operating at very low efficiency." (ES10)

Trust in promoters

Trust in the industry and the government to take good decisions regarding CCUS technologies appeared in some of the interviews. Some of the interviewees supporting or accepting the development of CCUS technologies in Spain tended to report a significant level of trust in the willingness of the energy and the process industries to implement CCUS technologies in the coming future. There is the generalized perception that the process and petrochemical industry is highly interested in reducing its carbon dioxide emissions in the long term (specially the cement industry and steel industry) as well as in exploring new commercial uses of carbon dioxide (specially the petrochemical and the energy industries). Generally, interviewees agree that the industry is also technically able to develop and implement CCUS technologies. Doubts are expressed by some interviewees about ability of the industry to collaborate in the search for alternative uses of CO2 (one interviewee refers to the lack of proactivity from the large carbon dioxide emitters).

These same interviewees tend to report a low level of trust in the government to promote CCUS technologies. This is especially critical regarding carbon capture and storage. As two of the interviewees state, industrial carbon capture and storage projects will only be possible with the

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active support from the national and regional governments. Some regional governments are perceived as more supportive of CCUS technologies compared to the national government.

Preference for alternative options

CCUS would compete with alternative options to decarbonization. We find two clear positions in our interviews. For some interviewees, there is the perception that CCUS technologies would complement existing and future renewable technologies. Interviewees consider that even if governments should prioritize decarbonization efforts via renewable technologies, carbon capture and storage would help accelerating the decarbonization of the energy and the industrial sectors. As some interviewees state, the urgency for reducing CO2 emissions from the energy sector and the process industry makes CCUS and, specially, carbon capture and storage, a critical tool. One interviewee, for instance, states that the underground storage of carbon dioxide is the most promising method to achieve short term significant reductions of emissions.

From a different perspective, other interviewees consider that the existence of alternatives for decarbonization make CCUS technologies useless. Two interviewees, for instance, consider that, regarding the energy sector, governments and companies should prioritize investments in renewable energies and forget about CCUS. CCUS could have a potential but limited use the process industry. Another interviewee considers that there is no a clear role for CCUS in the energy sector, first because there are many renewable alternatives, second because CCUS technologies cannot capture all the required CO2 and, third, because if CCUS is used for small reductions of carbon dioxide, carbon capture is not price competitive.

Expectations about the future

Some interviewees are relatively optimist about the future development of CCUS technologies in Spain. For these interviewees, the existence of pilot projects proves that the technology is almost ready. With the proper incentives (supportive regulation and taxation, etc.), the technology could play a significant role in reducing CO2 from the process industry in Spain. Interviewees are usually more optimistic about the development, in the medium term, of small scale projects to use of CO2, relative to big capture and storage projects, perceived as more complex and dependent on an active political support.

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3.4 Portugal (Lusitanian Basin)

Role of CCUS technologies in climate change mitigation and general evaluation

In Portugal, interviewees emphasized the potential role of CCUS technologies in decarbonization and climate change mitigation as well as the potential important role of CCUS in the cement industries and large consumers of natural gas specifically in Lusitanian Basin and the chemical sector in Portugal in general. At the same time, some interviewees expressed some doubts about the implementation of CCUS in Portugal and perceived that CCUS was not regarded as a key technology in the national energy policy plans.

We find several key ideas in the interviews:

CCUS technologies may be essential for climate change mitigation and decarbonization. As one interviewee from a research centre commented: "I think that CCS is absolutely essential for reaching the climate targets. There is no way that we can reach the Paris Agreement levels without resorting to CCS at a planetary scale, most countries will rely on fossil fuels for a long time and they have no other realistic technical option". Interviewees, overall, considered that the technology is a mature and viable technology option. However, this position was partly questioned by other interviewees who agreed on the potential role of CCUS technologies in climate change mitigation but emphasized the need of investing in other options first and questioned the technical viability of the technology. As one interviewee commented: "According to 3 of the scenarios in the IPPC 1.5 report, the CCUS may play an important role. However, CCUS is a second option compared to other mitigation options, more structured and relevant…CCUS may play a role in decarbonisation, especially if we delay our [mitigation] action but with strong uncertainties regarding the real gains of this technology to mitigation."

CCUS is a critical technology for the process industries (e.g., cement) in Portugal. The reduction of CO2 emissions from the cement industry is perceived as a critical area for the development of CCUS technologies. This industry -emitting high quantities of CO2- will have very few options to reduce their CO2 emissions in the medium term so it will need to implement CO2 capture technologies. An interviewee from the industry clearly emphasized this position: "Around two thirds of cement emissions are process emissions, and currently there are few solutions to reduce them. The players in the cement sector have been doing research and several lines of research say that CO2 capture is promising. A portion may be captured in existing factories with auxiliary equipment. At the limit, the studies carried out indicate that capture technologies can reduce 90 percent of CO2 emissions. Today there is a consortium that proposes a new cement factory with a new oxyfuel technology in which the air is replaced by oxygen and allow a greater capture of CO2. Thus, CCUS makes sense".

Benefits and costs of deploying CCUS technologies in the region

The interviewees in the Lusitanian Basin region mentioned the following benefits of CCUS technologies:

- Decarbonization of specific industries. Some interviewees emphasized the important role CCUS technologies can play for the cement and chemical industry in Portugal. As one interviewee commented: "Medium-sized industries at the area, like ceramics and glass, face challenges not just from the emission constraints imposed by the European Union Emissions Trading System, but from their clients themselves, who request products with a low carbon footprint… the situation is desperate for some companies, their clients turn to paper, metal or even plastic packages".

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- Socio-economic benefits. The potential socio-economic benefits of deploying CCUS technologies were clearly emphasized by some of the interviewees. Two main benefits were associated to CCUS technologies: job creation and the generation of new industries in the region. Regarding job creation, one interviewee commented: "There could be big benefits in terms of employment. These are new technologies that will generate qualified employment and the fact that it is local, creates national employment avoiding the exodus of the most qualified people. The problem is getting companies to hire these qualified people".
  Regarding the creation of new industries, some interviewees perceived that CCUS may increase the competitiveness of some industries as they have access to technology to reduce, transport and store their emissions. Moreover, CO2 use could lead to the development of new business models such as alternative fuels. Two interviewees commented on this: "[CCUS] leads to the development of a new sector, it is an industry that generates jobs, thus leading to prosperity at the regional level and passing it to the national level"
  "Transport and storage will be transversal to several sectors (…). The industries that exist around [the cement industry] can also capture and if they find an easy solution to transport over short distances, and if storage is regulated and safe, this sectors can also use these infra-structures, increasing their competitiveness and the country…Eventually, if we have a large reservoir, it can even be used by other countries. The use of CO2 can also have these benefits because it will encourage research for methane production or for use in the cement itself to treat inert materials with CO2 injection. It can also promote the development of algae and they may be used as alternative fuels. With all these dynamics and a structure regulation, it is possible to carry out a series of investments with a certain sense that today it is difficult"
  Not all the interviewees agreed on this. As one representative of an NGO commented: "I am not sure if the CCUS benefits will be significant. The CCUS can stimulate greater technological development with positive socio-economic aspects. However, these impacts must always be compared with other, perhaps more sustainable, mitigation alternatives. CCUS may have short and very specific benefits, compared to other alternatives"
- CO2 emissions reduction targets. Two interviewees considered the implementation of CCUS technologies as indispensable to reach national mitigation targets in the long term given the need to reduce CO2 emissions in process industries. As one interviewee commented: "There is no other way to mitigate the emissions from large industrial facilities like cement production and gas-based power stations"

Regarding the potential *costs* of deploying CCUS technologies in the region, interviewees referred to several issues:

- Economic cost. The cost of implementing CCUS technologies was considered a key drawback of the technology by some interviewees. The following excerpts represent this view:
  "Cost is always an obstacle when talking to industry. The main concern is always what is the profit, when will be the recovery of investment. To be attractive, the payback period has to be around 4-5 years."
  "The injection of CO2 for storage is very expensive, that is why it has not yet appeared on a large scale in Europe. Storage exists together with oil exploration, which helps to mitigate the costs. But CCS alone may not be advantageous."
  "The main barrier has an economic nature due to the cost of the technologies. I don't know if there will be environmental barriers."
  However, other interviewees emphasized the reductions in costs that have been achieved in the last years. Two interviewees commented in this sense: "The CCUS costs [at salt caverns]

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are similar to Natural Gas storage costs, provided there is utilization and not merely CCS… and CO2 can be transported with the same, or superior, ease than Natural Gas."
"Our technology provides low capture costs, and there are available sites onshore in the study area…although in the medium to long term we would need to store the CO2 at pre-salt geological formations… and even at the ocean floor as hydrates, as many natural occurrences exist"

- Technological maturity. The fact that CCUS imply new processes for the industry and it is a technology without the necessary maturity and reliability was mentioned by two interviewees: "The main obstacle, which is not a real negative impact, is that technologically we still do not see that CCUS is the best technique available, perhaps it is emerging but in practical terms we still do not see it"…"The CCU implies a new approach on these matters [price of CO2, climate change mitigation], implies a new technology to be incorporated in companies and all of this is a barrier."
- Need for new infrastructures. Two interviewees reflected on the need of new infrastructures for CCUS implementation. On their view, this is not a major issue for CCUS deployment in the region: "This region is already crossed by many infrastructures, but CO2 transport requires very low space and visual impact…caves and buried pipelines"
"The industries are already scattered, dispersed at the region, and as it is of the interest of the economy of the region there should be no problems with additional CCS needs"
- Environmental impacts and safety. Two interviewees mentioned the potential environmental risks associated to carbon capture and storage relative to carbon capture and utilization: "There are still environmental impacts that are not known. We are creating kind of bomb. If CO2 release occurs, a very large environmental disaster will occur."
"I don't see any negative impacts on the use of CO2 [CCU]. CO2 storage [CCS] has many negative impacts, or rather, the risk associated with injection and storage is very large in a seismic country."

Acceptance of CCUS technologies and general attitude toward CCUS in the region

The interviewees in Portugal were divided between support and ambivalence. Support for CCUS was linked to a positive position regarding the potential role of the technology in climate change mitigation particularly for process emissions from industry, linked to potential socio-economic benefits. Ambivalence was linked to the perceived costs and barriers in the implementation of CCUS, a preference for alternative options and a rejection of carbon capture and storage.

Table 11. General position towards CCUS development in the Lusitanian basin region

	Stakeholder group	Position	Description of position
PT1	Research and education	Ambivalent	S/he is ambivalent about the actual implementation of CCUS technologies. S/he considers that alternative measures such as the increase of energy efficiency and use of more clean fuels in ceramic and glass industries can reduce/eliminate the need of CCUS technologies for these sectors
PT2	Research and education	Support for CCU	S/he is very positive about the potential contribution of CCU in terms of climate change mitigation and socio-economic regional development.

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PT6	Research and education	Support	S/he considers that that CCS is essential for reaching the climate targets.
PT4	Industry	Support	S/he supports the development of CCUS technologies as he considers that it is the only option currently available to reduce significantly cement sector emissions
PT5	Industry	Ambivalent/neutral	S/he considers that if the Government decides in that direction, and there is a business case, the industry would be ready to implement CCS transport and storage in Portugal.
PT3	Influencer	Ambivalent about CCU. Opposed to CCS	S/he thinks there are some potential options for CCU in specific industries based on a case by case life cycle analysis. S/he considers CCS a dead option.

Regarding the conditions for the acceptance of CCUS technologies, the interviewees raised several key issues that were of importance for acceptance from their point of view:

- Cost effectiveness. Several interviewees commented on the need to make CCUS investments cost-effective as a precondition for its development. One interviewee commented on this: "CO2 capture technology has very substantial costs which means that large investments will have to be made. Almost or more than 50% of the price of a new production line [cement] and this will contribute to increased cost for production. All these aspects are feasible considering 2 fundamental aspects: 1. what we know the destiny of CO2; 2. that exists a comparable framework in terms of mitigation goals in Europe and beyond. This is because if the sector is competing with other industries that are not subject to CO2 emissions reduction, obviously it is a disadvantage."
- One interviewee was positive about this precondition: "Our economic analysis show that the technology is nearly ready, and with emission permits in the region of 100 €/ton the medium-size companies would take the step". Another interviewee raised some concerns about the potential profitability of the technology: "What will command the capture and use of CO2 is profitability. While the use is not profitable, in a transition phase, there may be an intermediate step in which there is capture and the CO2 is stored but not geologically [CO2 tanks like in liquid air]. However, I doubt that only the carbon price will make this option profitable. In the case of storage, I think it will never be profitable for Portugal due to our small dimension."
- Reduced environmental impacts. One interviewee mentioned the need of careful life cycle analysis of CCUS developments: "An analysis of the impacts of the technology must be made. This technology only makes sense if it turns out to be better than the alternatives. It is important to see case by case, in some situations the CCUS may have advantages, but we must do a careful assessment."
- Government leadership. A representative from the industry commented on the need of a clear leadership from the government: "If the Government decides in that direction, and there is a business case, we would be ready to implement CCS transport and storage there."
- Urgency of climate change mitigation. For some interviewees, as the urgency to mitigate CO2 emissions increase (i.e., because we delay our action), CCUS can be the easier, faster, cost-effective or even the only option to reduce CO2 emissions (linked also with biomass

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negative emissions). As one interviewee commented: “As there are delays in mitigation, CCUS technology begins to become inevitable. It can be economically advantageous compared to other alternatives, or a more competitive option or easier to implement.”

Perceived barriers and enablers/strengths

Interviewees in Portugal discussed three types of potential barriers to the deployment of CCUS technologies in the region.

- Economic cost. Considered by some interviewees as a potential barrier to technological development (as one interviewee commented: “The main barrier has an economic nature due to the cost of the technologies. I don't know if there will be environmental barriers.”), this barrier was considered by other interviewees as a minor obstacle, given their perception that costs are dropping for capture and will drop for storage.
- Social acceptance. Social perception and acceptance were discussed as potential barriers to CCUS deployment. Interviewees emphasized that the reaction of the local population has been traditionally positive. Three interviewees commented on this: “It is likely that social barriers to CO2 storage exist in Portugal. However, there is already storage of natural gas [in Portugal] and there have never been major controversies.”; “We do not think that there would be significant opposition. Many infrastructures are already present, in fact it is one of the zones of the country with the most burden of infrastructures, roads, railways, pipelines, power cables… the municipality is used to that, should not oppose” ; “Our perception when talking with local industry is that there would be no fights about land use…not even from environmental NGOs”
- Need for new infrastructures. Two interviewees discussed the potential effects of deploying CCUS infrastructures on the territory. In their view, this should not be a main barrier for CCUS in Portugal: “This region is already crossed by many infrastructures, but CO2 transport requires very low space and visual impact…caves and buried pipelines”; “The industries are already scattered, dispersed at the region, and as it is of the interest of the economy of the region there should be no problems with additional CCS needs”

One main enablers was discussed in the interviews:

- Interested industry. The existence of cement, glass, ceramic and chemistry industry interested in reducing CO2 emissions was mentioned by various interviewees. There is the idea, mentioned by several interviewees, that some industries do not have alternative solutions do reduce the sector process emissions and that, therefore, CCUS will always be necessary. As one interviewee commented: “There is a very strong concentration of glass and ceramics in the region (...) and with other industries in the region synergies can be created.” However, the interviewees mentioned several difficulties. First, that the heterogeneity of the ceramics and glass sectors can lead some sub-sectors to have the capacity to go ahead in CCUS projects, while others will not be able to do so. Second, that due to its small dimension, chemical industry will probably not have the conditions to lead CCUS projects in Portugal, that is, some industries will be able to develop CCUS projects, while others need additional support. Three interviewees commented on this:
  “The use of CO2 is not a very complex technology, it is a chemical engineering technology. However, as Portugal has a poor business fabric of chemical industry, there may be some difficulties in the knowledge. That is why it is important the link with the universities and research centres to support the industry”
  “If there is an associated cluster and the advantage of the technology is demonstrated in principle the industries will be able to implement it. But for industry to trust in CCUS, it is necessary to exist for example, case studies that promote the confidence in the technology.”

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"Each sector is at a different level. (...) Smaller or less technical industries will need to be sensitized. I believe that they will not be at the same level in terms of information and there is the need for training."

Trust in promoters

We found the following ideas regarding the various societal actors:

- Industry:
  - The heterogeneity of the ceramics and glass sectors lead some sub-sectors to have the capacity to go ahead in CCUS projects, while others will not be able to do so.
  - Due to its small dimension, chemical industry will probably not have the conditions to lead CCUS projects in Portugal. Additional support may be needed.
  - Some industries will be able to develop CCUS projects, while others need additional support.
- Government:
  - Central government are aware of the relevance of decarbonisation and consequently they will have openness to CCUS, particularly for CO2 utilization due to circular economy issues. However, local authorities may need training, particularly to deal with population acceptance.
  - Policy makers will have a major regulatory role and should reduce the bureaucratic issues and developed adequate legislation otherwise this can be a barrier to CCUS.
- Universities and research centres:
  - Universities and research centres have the knowledge and thus can support industries and policy makers on their decisions.
- Financing:
  - Economic funds can be relevant in an earlier phase for CCUS financing demonstration projects.
  - They must be accessible to industry and be distributed in a "fair" way.

Preference for alternative options

We found three main ideas regarding the alternative options for decarbonization:

- CCUS will always be necessary in industries with high process emissions (e.g., cement). Some interviewees think that there are no alternatives for the cement industry to reduce the sector process emissions. As one interviewee commented: "There is no other way to mitigate the emissions from large industrial facilities like cement production and gas-based power stations… the medium-sized industries at the zone are under pressure… their only other option is to delocalize to North Africa or some other region."
- Alternative measures as the increase of energy efficiency and use of more clean fuels in ceramic and glass industries can reduce/eliminate the need of CCUS technologies for the process industry. As one interviewee commented: "More primary measures: combustion efficiency, combustion at lower temperatures with lower energy consumption. In the case of brick production, they can also use biomass with zero emissions. For the other sectors, the introduction of hydrogen, natural gas blended with hydrogen (despite the danger of hydrogen) or the introduction of other cleaner fuels will always be very welcome measures."
- CCUS will be an end-of-pipe alternative to reduce the national CO2 emissions. For some interviewees, CCUS may be a solution but just after the deployment of other measures (e.g., reduction of energy services demand, increase of energy efficiency, use of low carbon fuels such as electricity produced by renewables).

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Expectations about the future

We found three main positions regarding the future of CCS in the region:

Positive. Two interviewees stated that CCUS projects will be developed in the region in the next ten years. As one interviewed commented: “Yes, we believe carbon capture pilots first and then full scale systems will appear at the region in the next few years, and this will require storage also… although not sure in what kind of geological formation, and if onshore or offshore.”

Neutral. Several interviewees considered that it was likely that some projects would be developed in Portugal but they were more optimistic about the development of CCUS in other Europe countries. As two interviewees commented: “Yes, absolutely in Europe. In Portugal maybe. It is necessary to study how to integrate different stages (capture, use) so that the projects are profitable”; “10 years from now in Portugal I don't know but at the European level with the projects that are being developed (...) there is already a solid knowledge of what can be done. In this decade I think that there will be solutions.”

Sceptic. Finally, some interviewees were more negative about the future of CCUS in Portugal. One interviewee argued that maybe there will be some demonstration case studies but nothing at a relevant scale. Another interviewee focused on the important role of the government and commented: “We wait to see what the strategy of the Government is, regarding hydrogen and synthetic fuels… so far we had no signal that the Government is interested in CCS.” Importantly, this statement is true for CCS but not for CCU (which is currently discussed as a medium-term solution in Portugal).

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3.5 Croatia (Northern Croatia)

Role of CCUS technologies in climate change mitigation and general evaluation

In Croatia, fifteen persons from different stakeholder categories were interviewed. In general, the interviewees' attitudes regarding CCUS technologies and its role in climate change mitigation was positive and most interviewees supported a CCUS project in the region of Northern Croatia.

As main benefits of CCUS, they mentioned the reduction of CO2 emissions and related health benefits as well as economic benefits due to the development of new technologies and the creation of new jobs. As main barriers to CCUS technologies, the interviewees mentioned the high costs for implementation, the lack of knowledge and expertise - in citizens and companies - regarding CO2 reduction as well as regarding the specific CCUS technology, and the lack of support from politics and companies. The majority of the interviewees in Croatia did not perceive the risk of CO2-leakages as a barrier.

As conditions for a possible CCUS project in Northern Croatia, the interviewees expressed that a feasibility study and economic analysis would be necessary to estimate the financial costs. Moreover, the general public should be involved and informed about the processes, the benefits as well as the risks and consequences to avoid potential public resistance. Additionally, a legislative framework that supports CCUS (and nudges companies to invest) was perceived as a condition for a successful implementation of CCUS technologies in Northern Croatia.

Regarding CCUS-relevant actors, most interviewees stated that a collaboration of researchers, policy-makers, and industry would be desirable. Whereas industry and project coordinators were perceived as being capable of handling CCUS implementation processes, the interviewees saw a need to nudge and educate policy-makers.

Regarding the future of CCUS and alternative options, the majority of interviewees mentioned renewable energy sources or energy efficiency as possible other option. However, most Croatian interviewees were positive and hoped that CCUS will be implemented in the future in Croatia to use all option that lead to decarbonisation.

The following table characterizes interviewees' general position regarding the development of CCUS technologies (independent from the region in Northern Croatia).

Table 12. General position towards CCUS of the stakeholders in Northern Croatia

Interviewee	Stakeholder group	Position	Description of position
C1	Politics and policy (pol1)	Support	Mitigating the effects of climate change is necessary and CCUS technologies are innovative solutions that aim to reduce greenhouse gas emissions in the atmosphere. "CCUS is emerging as perhaps the most attractive innovative solution for reducing greenhouse gas emissions and reaching the low carbon energy sector."
C6	Politics and policy (Pol2)	Support	"CCUS technologies are a proven way to dispose of CO2 as one of the most significant greenhouse gases. The advantage of this technology is that it can be used to increase oil and gas production, thus significantly improving the economics of

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			projects, given that, in addition to climate, financial benefits are also achieved."
C8	Politics and policy (Pol3)	Support / Neutral	"These technologies can play an important role in mitigation efforts in our region and in Europe."
C4	Research and education (R+E1)	Support	"These technologies certainly can and should play an important role in reducing emissions, both in our region and in the rest of Europe."
C10	Research and education (R+E2)	Support	"Of course, these technologies can play an important role in emissions mitigation. [...] Considering that Croatia gets 70% of its total energy from fossil fuels, switching to technologies that allow the storage and consumption of CO2 would make a significant contribution to reducing emissions."
C2	Industry: demand (demand1)	Support	"Absolutely the most important topic today, there is consensus. Still, it is not implemented [...] CCUS technologies can play an important role, but technologies must be available and developed."
C9	Industry: demand (Demand2)	Support	"Climate change is one of the greatest challenges of the modern age. CCUS is certainly one of the key technologies leading to decarbonization and contribute to fulfilling the goals of the low carbon strategy."
C11	Industry: demand (Demand3)	Neutral	"CCUS technologies in theory have potential. [...] CCUS technologies can play an important role in reducing CO2 emissions, but other issues need to be addressed."
C5	Industry: supply (Supply1)	Support / not sure	"If we focus on the Republic of Croatia and greenhouse gas emissions, we can see that they are lower than the emissions of economically and industrially developed EU countries. Considering the cost of CCSU technologies, it is necessary to determine the cost-effectiveness of such projects in the Republic of Croatia, but they certainly should not be rejected without analysis."
C12	Industry: supply (Supply2)	Support	"We believe that such technologies should have an important impact on emission reductions, especially in our region."
C14	Industry: supply (Supply3)	Neutral	"CCUS technologies have been recognized as one of the mitigation measures."
C7	Support organisation (Support1)	Support / Neutral	"We will positively promote any technology supported by the Intergovernmental Panel on Climate Change (IPCC) and each technology that

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			expert teams have shown as necessary in mitigating greenhouse gas emissions."
C15	Support organisation (Support2)	Neutral / rather negative	"CCUS technologies are one of the potential ways to reduce CO2 emissions. Using CCUS as an EOR or EGR is only partially positive for climate impact."
C3	Influencer (Infl1)	Neutral	"CCUS technologies can provide a transitional solution for those technologies for which there is currently no alternative without an emission facility. However, these technologies cannot play an important role at this time (because of the cost-effectiveness of the technology and the ability to use it)."
C13	Influencer (Infl2)	Support	"CCUS technologies can certainly be a significant factor in reducing carbon footprint [...] Given a large number of point sources of carbon dioxide in the region and Europe, there is certainly great potential for mitigating emissions through the use of these technologies."

Benefits and costs of deploying CCUS technologies in the region

Perceived benefits

The interviewed stakeholders in Northern Croatia mentioned the following benefits of CCUS:

(1) Reduction of CO2 and related health benefits for humans as well as the eco-system.
(2) Economic growth due to the development of new technologies (incl. less costs for CO2 emissions).
(3) Potential use for Enhanced Oil Recovery.
(4) Creating new jobs.
(5) Raising awareness of climate change and the need to reduce CO2.
(6) New collaborations and structures (between research, industry and investors).
(7) Reputational benefits for companies and Croatia.

These benefits can be clustered in (a) climate benefits, (b) economic benefits, (c) reputational benefits and (d) societal benefits and are explained in the following.

Mainly *climate benefits related to health benefits* were mentioned, such as reducing greenhouse gas emissions (pol1, support1, pol3, demand2, infl2, supply3, support2), improving the air quality (pol1, R+E1, supply1, infl2), improving human health in the area (pol1, supply1, R+E2) and positive effect for " the conservation of flora and fauna [... as well as] aquatic ecosystems" (R+E2). One stakeholder also mentioned the increased use of renewables "which must be the low carbon basis for CCUS" (infl2) as a climate benefit.

In addition, *economic benefits* of the implementation of CCUS were stated: There could be economic growth in Croatia due to the development of new technologies (demand1, R+E1, support1, demand2, R+E2, infl1, supply2, infl2, support2). In addition, companies can reduce their costs for CO2 emissions (pol1, support2) and it could be connected to Enhanced Oil Recovery (EOR; (R+E1, pol2, pol3, demand2, infl2).

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Furthermore, the political stakeholder interviews contained *reputational benefits* for companies as well as for Croatia in general (without describing details): Companies whose facilities use CCUS technology would improve their image in the general public (pol1) and Croatia could help neighbouring countries (pol2).

Moreover, *societal benefits* were mentioned such as the creation of new jobs (R+E1, demand2, R+E2, demand3, infl2) as well as raising awareness of CO2 effects and why citizens and stakeholders should reduce CO2 (demand1, supply2) - "sensitizing the community to global environmental topics and trends" (demand1). Additionally, CCUS can lead to new collaborations between industry, research and potential investors (supply3, support2) including the exchange of ideas and opinions, the engagement with experts (demand1, supply1), and the development of knowledge centres (demand2).

Perceived costs

Regarding the potential costs and negative impacts of developing CCUS technologies in Northern Croatia, interestingly, some interviewees mentioned that they do not see any costs or negative impacts (pol2, support1, pol3, supply3), demonstrating the rather positive attitude towards CCUS. However, others expressed the following concerns:

(1) Public scepticism and potential public resistance (the public is not sufficiently familiar with this technology; pol1, demand2) and interlinked "possible misunderstandings in the communication of the project results to the public" (support2).
(2) The high cost of implementing CCUS (pol1, demand1, R+E1) "These are expensive projects that can only be executed by large capital" (demand1).
(3) The potential leakage of CO2 and the security of CCUS (pol1, demand2, infl2, supply3) in capture, transport as well as underground storage that was partly perceived as uncontrollable (pol1).
(4) Poor application or inappropriate use of the CCUS technology leading to a lack of the desired positive effects for the environment (pol1, infl1, supply1, demand3, infl2). According to the interviewees this could occur due to a focus on solely financial gains (supply2) and/or due to a lack of sufficient analyses and expertise (demand2, infl2).
(5) Other connected negative effects of the CCUS technology on the environment such as a high energy consumption that is required for capturing and compressing CO2 (demand2, supply2). Moreover, CCUS could "slow down the transition from fossil fuels to renewables" (R+E2) and/or could be used for EOR (support2).

However, our empirical analysis shows that "the benefits of such projects (=CCUS) far outweigh its negative impacts." (supply2)

Acceptance of CCUS technologies and general attitude toward CCUS in the region

The "interviewees" were rather positive about the development of CCUS technologies in the region. Only four of the fifteen interviewees expressed rather neutral attitudes toward the implementation of CCUS in Northern Croatia. Support for the use of CCUS in the region was based on the above presented benefits of CCUS technologies. No interviewee mentioned a sceptical or opposing view regarding the introduction of CCUS projects in the region.

The following table characterizes interviewees' general position regarding the development of CCUS technologies in the studied region.

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Table 13. Position towards CCUS development, specifically in Northern Croatia

Interviewee	Stakeholder group	Position	Description of position
C1	Politics and policies (pol1)	In favour/positive	"Given the growing problem of climate change, i.e., the trend of global warming, the development of these projects is of crucial importance."
C6	Politics and policies (Pol2)	In favour/positive	"My attitude towards CCUS technologies is positive, and the benefits of their development can be extended to the wider region."
C8	Politics and policies (Pol3)	In favour/positive	"I'm in favour of project development and the adoption of carbon capture, utilization and storage (CCUS) technologies in the region."
C4	Research and education (R+E1)	In favour/positive	"I am absolutely in favour of developing CCUS projects."
C10	Research and education (R+E2)	In favour/positive	"I fully support the implementation of new CCUS technologies and the related investments in the region. I am personally interested in any form of a technological shift towards reducing greenhouse gas emissions and combating climate change."
C2	Industry: demand (demand1)	In favour/positive	"My attitude towards CCUS technologies is positive
C9	Industry: demand (Demand2)	In favour/positive	"We believe that the adoption of such technologies in the region is acceptable."
C11	Industry: demand (Demand3)	In favour/positive, but has some doubts	"I support the development of such projects, but I doubt that the current economic situation in the country and the region can support and facilitate the development of new technologies."
C5	Industry: supply (Supply1)	In favour/positive	"Any project that includes clear objectives, technical and economical implementation options while meeting environmental criteria for climate change mitigation is useful and meaningful to support."
C12	Industry: supply (Supply2)	In favour/positive	"Our attitude on the development of the CCUS project is very affirmative and we believe that this option is an acceptable benefit for the region in terms of reducing CO2 emissions."
C14	Industry: supply (Supply3)	Neutral	"Carbon capture, storage and utilization projects and technologies are good solutions to climate change mitigation, but they should follow eventually or at least in parallel with other priority measures such as energy efficiency and renewable energy."
C7	Support organisation (Support1)	Neutral	"As noted earlier, we support technologies that have been proven and advocated in the application of our members. We have not conducted any research on the overall acceptability of the technology by the industry,

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			and we will certainly evaluate the need to develop it when these technologies are put into use by members who can use the technology."
C15	Support organisation (Support2)	Neutral	"It is acceptable if used as pure CCS, not as EOR / EGR."
C3	Influencer (Infl1)	Neutral / undecided	"As I said before, this is a transitional solution when there is no alternative."
C13	Influencer (Infl2)	In favour/positive	"We support the development of regional CCUS projects as one of the elements of the transition towards a carbon-neutral society."

Interviewees identified several conditions that should be met for the successful implementation of CCUS in Northern Croatia; these are outlined in the following.

(1) Detailed assessment of the suitable storage capacity, the technical implementation as well as an economic analysis
(2) Favourable legislations and regulations
(3) Including the public and local communities - transparency and good communication of the project's implementation
(4) Safety and constant monitoring
(5) Being in line with environmental criteria for climate change mitigation
(6) Education for all stakeholders to understand the technology

Interviewees suggested an accurate and detailed assessment of the suitable storage capacity (pol1, support2), the technical implementation (supply1) as well as an economic analysis whether CCUS technologies are financially feasible for companies (pol1, supply1, pol2, support1, pol3, demand2, R+E2, demand3, supply2, infl2, supply3, support2). Only if the analyses show a positive financial, "favourable long-term and widely observed economic impact" (infl2) or the projects were co-financed (demand2) CCUS could be implemented in Norther Croatia: "We would reject in case of need for intensive financial investments" (pol3)

Moreover, a favourable legislation and adequate regulations were seen as a condition for implementing CCUS in Northern Croatia (demand2) in order to convince companies to implement CCUS.

Other stated that jobs for local people (R+E2) are required to accept CCUS projects in the regions. In general, including the public and local communities was mentioned as a condition for CCUS projects: The interviewees asked for transparency about all future implications of CCUS (for citizens and businesses) as well as a good communication (demand1, support1, R+E2, supply1). Also, safety and a constant monitoring of the storage sites were mentioned (R+E1, infl2).

On a more general perspective, several interviewees mentioned that they would be in favour of implementing CCUS in Norther Croatia under the condition that CCUS technologies meet the environmental criteria for climate change mitigation and is environmentally sustainable (supply1, support1, R+E2, infl2).

Additionally, two interviewees mentioned that a further education of all relevant stakeholders would be a basic condition for CCUS technologies in Northern Croatia (supply3): "It is undoubtedly important to involve civil society organizations in early-stage project activities in order to make the

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information on new technologies accessible to them and to increase the overall understanding of the technology itself." (support1).

Perceived barriers and enablers/strengths

Perceived barriers

Respondents perceived the following aspects as barriers of the implementation of CCUS:

(1) High cost of CCUS technology and/or the lack of funding (pol1, demand1, infl1, R+E1, supply1, pol3, demand2, demand3, supply3, support2)

(2) Insufficient awareness of the benefit of CCUS implementation and of climate change issues related to CO2 (pol1, demand3, supply2, infl2)

- "First of all, it seems to us that the level of public awareness about CCUS technologies, as well as the awareness of the importance of including their application, is very low." (infl2)

(3) Lack of expertise and knowledge about CCUS technologies (demand3, supply2)

- “As a region, we have a lot of economic problems, and we have a hard time keeping up with the existing industry. We have problems with modernization, even when technologies are already well known and widely accepted. I doubt we can successfully cope with the adoption of new technologies.” (demand3)

(4) No support from the legislative framework (support1, demand2, supply3) and/or too little action from (local) policy makers (demand1, support1, R+E2) - maybe due to insufficient knowledge (R+E2). Respondents also mentioned the insufficient interest and activity from companies (pol2) which is interlinked with the legislative framework and support.

- “If EU makes policies that give security to industry and decision makers that CCS is a valuable technology worth investing in, and states set mandatory targets for the installation of CCUS facilities, then the above barriers would be removed.” (supply3)

(5) Possible public acceptance issues (infl1, support2, pol3, infl2) such as "resistance from the local community due to lack of information” (pol3) and the fear of the potential insecurity of CCUS technologies (infl1, support2)

- "We need to guarantee that storage is successful and will last long enough" (infl1)

(6) Also, one interviewee mentioned that the access to the underground reservoirs could be difficult presenting a potential, geographical barrier (R+E1)

Perceived enablers/strengths

One enabler of a CCUS project in Norther Croatia could be the “use of the existing database of geological, geochemical, geophysical and well data when estimating storage capacities suitable for geological storage of CO2." (pol1). Also "existing mining facilities and technological resources" (Infl2) can facilitate the implementation of CCUS technologies in the studied region. The existing conditions in Northern Croatia are perceived as a good fit for CCUS, for instance it was mentioned that there are greenhouses with plants and algae within the region, that could use the captured CO2 (for CCU; pol1)

Trust in promoters

Trust in project developers and the industry

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Regarding CCUS-relevant actors, most interviewees stated that they believe that project developers and the industry are capable of handling the necessary developments for CCUS technologies (pol1, demand1, infl1, R+E1, supply1, support1, pol3, demand2, R+E2, supply2, infl2, support2).

- "Given the years of experience in the petroleum industry, as well as the chemical industry (which seems to be the most important for the use of CO2), we believe that the region has all the necessary competences" (infl2)

Some of these interviewees mentioned conditions for their trust such as project developers and industries are capable "with adequate education, enthusiasm, [...] and sufficient funding" (demand1) or - if needed - "with assistance of professionals" (supply1). Only a minority of interviewees was not sure of the capability of project developers and industries (pol2, demand3, supply3) because "currently, they are not active enough and present in the media" (pol2, demand3) or because "additional education is needed" (supply3). This demonstrates that project developers and the industry are perceived as relevant actors for the implementation of CCUS.

Trust in regional policy makers and administration

The views of the Croatian interviewees on the CCUS-required capability of regional policy makers and administration differed. Some interviewees stated that regional policy makers and administration are capable of handling the coordination challenges of adopting CCUS (pol3, pol1, R+E1, demand2, supply2, supply3); under the condition that related laws, strategies and measures will be developed (pol1, R+E1) or "they may still need a little incentive, but they are capable" (R+E1). Whereas others do not believe in the capability of regional policy makers and administration (demand1, supply1, pol2, support1, R+E2, demand3, support2): further education is required (supply1, pol2, support1, similar demand2, R+E2, infl2, supply3) or they are too bureaucratic (R+E2). Only few were not sure about the capability of regional policy makers and administration (infl1, infl2).

Trust in support organisations

A similarly diverse picture occurred regarding the trust in support organisations. However, the opinions were slightly more extreme: Some interviewees mentioned that support organisations are extremely important (pol1, support1, pol3, supply2, infl2, support2), for instance: "Support is very important, and it needs to be built with the synergies of many stakeholders. They play a key role in informing and educating the media and the public" (infl2). Others did not believe in the capability of support organisations (demand1, pol2, demand2, R+E2, demand3) because they are "redundant or bureaucratic" (demand1, similar R+E2) or "not sufficiently familiar with CCUS technologies" (pol2, demand2, R+E2). Only few were undecided regarding the role of support organisations for CCUS (Infl1, R+E1).

Trust in universities and research centres

Regarding the universities and research centres and their relevance for CCUS technologies, most interviewees did not express a simple "yes"- or "no"-answers but elaborated more on the situation. A majority stated that universities and research centres are important for CCUS implementation (supply1, pol2, pol3, demand2, R+E2, supply2, infl2, supply3). Others were not sure (pol1, infl1, R+E1, support2) and explained that scientists' capability of handling CCUS-relevant processes depends on politics that determine financial and human resources (demand1): "They do not have sufficient financial support, although they have the knowledge and will to promote such projects." (R+E1, similar supply2).

Again, others mentioned that universities and research centres should actively work on a better network to connect with the industry (support1, pol3, infl2, supply1, demand3): "There is certainly room for improving targeted cooperation with the economy in terms of exchanging needs and ideas

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for particular projects." (supply1) Or that they should be involved in educating national policy makers and administrations (pol3).

Two interviewees saw an issue in the scientific community's perception of climate change research in general: “Environmental protection is still perceived as a less valuable branch of science. [...] innovative technologies in the field of reducing greenhouse gas emissions are very often perceived with considerable scepticism.” (R+E2; similar support2).

Trust in other actors

When asked for other CCUS-relevant actors, the interviewees in Croatia mentioned the following organisations: investment banks (pol1), NGOs (demand1, supply1, support2), independent experts and scientists (demand1, supply1), local communities (demand1, support2), industry (R+E1, supply1, demand2, R+E2), schools (R+E1) , state authorities (supply1, pol2), energy buyers (pol2), the EU (infl2) and transnational cooperation of decision-makers (supply3). This highlights that the collaboration of different actors appears very relevant for CCUS in Northern Croatia (pol1, support1, demand2, supply2, infl2) - as was already mentioned in a previous section.

The following statement summarizes why a collaboration (e.g., between the scientific community and industry) seems important, for instance to educate the public: "It is very important to educate and sensitize the public on this subject, and this could most effectively be achieved through the cooperation of state energy authorities with companies and other actors (universities, research centres, and support organizations). Co-operation should include the organization of lectures and conferences and public panels, where the causes and consequences of global warming caused by human actions are explained and understood, followed by measures and ways to mitigate the effects, e.g., what is exactly CCUS, what are the benefits and risks of this technology and the impacts on the energy sector." (pol1)

Preference for alternative options

Regarding their preference for alternative options, the interviewees mentioned

(1) Renewable energy sources (pol1, demand1, infl1, supply1, support1, pol3, demand2, R+E2, demand3, infl2, supply3, support2)
(2) An increase in energy efficiency (infl1, supply1, pol3, demand3, supply3) - preferably "across sectors" (infl1)
(3) Forest conservation and planting new forests (demand1, pol2, infl2)
(4) Use of alternative fuels (such as hydrogen; infl2, pol2, pol3)
(5) Recycling and better waste management (R+E2, demand3)

Only two out of fifteen interviewees stated that they currently do not see any other alternative to CCUS in order to decrease CO2 emissions substantially (R+E1, supply2). This shows that the following statement summarizes the view of the Croatian interviewees well: "There is so little time that no set of technologies or activities should be seen as alternatives to each other but as welcome complementary efforts." (infl2)

Expectations about the future

Concerning the future development of CCUS in the region of Northern Croatia, the interviewees' opinions differed. A majority of interviewees was (very) positive and hopeful that CCUS will be implemented in the studied region within the next five to 10 years (pol1, demand1, R+E1, pol2, pol3, demand2, supply2, infl2). Few interviewees expected the CCUS infrastructure to be implemented, but not within the next 10 years, for instance because "in the Republic of Croatia, all processes that depend on public governing bodies and administration are extremely slow." (R+E2) or because "our

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region must address some preconditions before engaging in further projects" (demand3, similar supply3)

Several interviewees were not sure about the future of CCUS in Northern Croatia (infl1, supply1, support1). They stated that it “depends on the speed of commercialization of such projects, technical feasibility, economic feasibility, and meeting environmental goals.” (supply1) or it "depends on the legislative framework and the financing conditions for the application of this technology" (support1)

Only one interviewee held a pessimistic opinion regarding CCUS technologies in Norther Croatia by stating that - if it will be implemented at all - it will only be used for EOR and then "reducing CO2 emissions is a secondary effect" (support2)

The following statement summarizes the general view of the interviewees on the implementation of CCUS in Northern Croatia nicely. "We believe that the potential certainly exists and that, with all of the assumptions mentioned earlier and intensive cooperation of all stakeholders, several pilot projects can be prepared and implemented [...] that will be important for the practical demonstration of the achievement of CCUS goals." (infl2)

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3.6 Romania (Galati region)

Even though all Romanian interviewees shared a similar opinion and expressed a positive general attitude toward CCUS, differences between different stakeholder groups can be perceived. For instance, policy makers and people involved in politics focused more on the environmental and health benefits of CCUS than demand and support stakeholders. Also, the level of knowledge regarding CCUS differed largely depending on their past expertise with CCUS (the interviewed stakeholders from the research and education sector as well as the supply stakeholders had high knowledge and a lot of experience with CCUS). Interestingly, the social perception of CCUS in Romania might be influenced by an unsuccessful CCS project in the past: The Getica project was mentioned several times during the interviews. It has started but was stopped due to (financial) issues: “The government even backed a project named Getica. It was a project intended to be funded via the state budget and Norwegian grants” (pol1). The incomplete outcome of this project seems to affect the perception of CCUS in Romania like a shadow: "We had also the Getica project in 2013, which would have been a success and would have represented a motivation for others" (supply1).

Next to the large environmental and health benefits, a main benefit that was mentioned was the possibility to keep jobs (mostly within the fossil fuel industry). As main barrier, the high costs and lack of funding for the implementation of CCUS as well as the lack of experts and/or training were mentioned. Moreover, awareness regarding environmental issues was perceived as low or even missing within the Romanian population. Thus, especially more information and a good communication regarding CCUS projects as well as the political support could have a positive impact on the social acceptance of CCUS. Only few interviewees saw an alternative to CCUS and most Romanian stakeholder representatives were hopeful to see CCUS in Romania in the future.

Benefits and costs of deploying CCUS technologies in the region

Perceived benefits

As benefits regarding CCUS, the Romanian interviewees mentioned

(1) Environmental benefits,
(2) Health benefits,
(3) Economic benefits,
(4) Social benefits,
(5) The maintenance of using fossil resources
(6) Reputational benefits.

Mainly *environmental and health benefits* were mentioned, such as reducing CO2 emissions and reducing the pollution locally and globally (demand1, support1, R+E1, demand2, infl1, demand3, R+E2, demand4, pol1, infl2, pol2, support2, infl3), helping the environment (demand1, demand2, support2, infl3) and decreasing pollution-related diseases (demand1, infl1, pol2, support2, infl3). Some interviews stressed that although they benefit from the reduction of CO2 emission, they would still continue using fossil resources like oil, coal, or gas (e.g., R+E2, infl3).

Other often mentioned benefits were *economic benefits*, such as maintaining and/or creating new jobs which was partly perceived as one of the largest benefit (mentioned by R+E1, demand3, support1, R+E2, demand4, pol2, support2). Also, the Romanian interviewees perceived CCUS as an economic benefit because it leads to new products when CO2 is used in construction materials (demand2), to the development of new technologies (pol1) and new types of competences

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(demand3) as well as to the development of new business models (demand3) and industry lines (infl1, R+E2). Moreover, a benefit of CCUS can be the positioning of the Galati region as a research site which will ultimately lead to local infrastructural benefits: "There is also the possibility for research. A sort of research tourism. Because the region could be promoted, bringing other investments. If a CO2 capture and storage project were to be implemented, the local infrastructure would benefit." (R+E1)

Further, the *maintaining of using fossil resources* like coal and enhanced oil recovery (EOR) was mentioned as benefit (R+E2, supply1, demand5): In EOR, "the CO2 injection increases productivity, so it brings real benefits in this activity. And of course, it combines the two directions that are partly opposite: on the one side, the need to reduce global warming, on the other side, to increase economic efficiency of the activity in the area." (R+E2). Further, it can be an economic benefit because inactive drillings can be reactivated to recover the oil completely (demand5). However, one interviewee stated that "In Europe this solution is not considered acceptable, because CO2 is used to produce a fuel that at its turn releases CO2 in the environment. Thus, the EU does not finance projects based on EOR. Otherwise EOR would have been an option, in Romania we have many depleted oil fields." (supply1)

Moreover, one interviewee mentioned a *social benefit* of CCUS, namely, the potential change in mentality: The promotion of CCUS could lead to more awareness of environmental issues in the next generation and thus could be seen as a long-term sustainability solution (demand2). Also, keeping the social balance between coal exploitation and energy production was perceived as a benefit of CCUS: "A large part of the population is involved either in coal exploitation and in electric energy production...Of course, in that area social balance can be maintained and this is a big benefit, to keep it." (R+E2)

A few interviewees also uncovered *reputational benefits* of Romania within the EU when implementing CCUS: They mentioned that Romania has a large storage capacity and could store CO2 for other countries: "Our country does not have large emissions, but we have a big storage capability. So we could store CO2 emissions for other countries. This could have a positive impact for our country." (support1). They emphasized that this could result in a better reputation being closer to other European countries: "We would reach the target of becoming carbon neutral ... so we would join the European trend. This would be a benefit." (demand3)

The following statement of an interviewee summarizes a few of the mentioned benefits: "It is very important, and at the present it is the only option for mitigating climate changes and for reducing CO2 emissions. [...] In Romania, this technology would be good because it would be implemented at a rural level, where people need jobs. Then the environment would be cleaner." (support1)

Perceived costs

The Romania interviewees mentioned the following costs of CCUS:

(1) High financial costs (including an unfair process due to the missing CO2-price),
(2) Lack of expertise,
(3) The potential risk of leakages (with related impacts on the biodiversity and life),
(4) That it will slow down or hinder the development of other options and renewable technologies,
(5) That people could lose their jobs, and
(6) Public acceptance.

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Regarding costs, the Romania stakeholders mentioned the *high financial costs* of the implementation of CCUS, specifically for capture installations, transport, drilling installation and injection of CO2, geological research evidence for the deposits which is costly due to the lack of data, for the maintenance of all installations, the pipelines, and the sites (R+E1, support1, infl1, demand2, demand3, demand4, supply1). “This technology is interesting for investors only from the perspective of usage. Yes, we`re thinking about the environment, we store CO2, but profit is important." (support1_RO). “Initial investment is high, but then it pays off in the next 5 years. So they have a profit.” (Infl1). “Costs are high, not only in the capture part. As I was saying the costs for implementing the technologies for capture, monitoring, site storage… the risk after this type of effort. You can end up with a site that is not good for its role and all the financial effort is useless." (demand3) This statement highlights a cost of CCUS especially for business owners of small to medium companies. If CCUS could be used for Enhanced Oil Recovery, this would reduce the costs but CCUS-related EOR can also be perceived as negatively because "through EOR, hydrocarbons as an energy source will still be present. People perceive it as a solution identified by hydrocarbons operators for extending their use“. (R+E1)

Related to financial costs, it was mentioned that the process of CCUS implementation will *not be fair* because for instance, in the construction industry, there is a black market that only cares about money and would not implement it (demand2). Moreover, it would not be fair if it is implemented only by some companies because CCUS is an additional financial cost but in Romania, there is no CO2 price (yet) presenting a "wrong" advantage for those who do not implement CCUS (supply1).

Also, many interviewees mentioned the *lack of expertise* to implement this complex technology as a cost (demand1, demand3, demand5, support2). They stated that the technology is not developed enough and/or too complex and that technical specialists are needed: “It is not a technology that is well established. In order to have the chance of efficient capture – as CO2 is a gas, you need to have a technology well established. Other types of technologies, such as in the automotive industry, are simpler (...) One needs to have liquifying installations for CO2, then storage installations, then special transport installations, so the risk is generated, in my opinion, by lack of technology. Then specialists are needed." (demand1)

Another cost that was mentioned was the potential risk of *storage or pipeline leakages* (support1, demand3, demand4, supply1, pol1, infl2, demand5). However, this was mainly perceived as a theoretical risk or as (very) low; only few interviewees perceived this risk as medium and were concerned with the risks related to leakages such as affecting local communities, their land and related biodiversity, vegetation and animals (infl2): "Everything has a risk. Drillings explosions? Yes, there were such explosions here as well. But people have been living near hydrocarbon deposits for tens of years. Of course accidents are possible.“ (R+E1) "Risks, theoretic risks, CO2 leakages from the storage site, but this did not happen from what I know." (support1). Other interviewees (support2, infl3) described it more carefully by addressing the unknown long-term effects: "The greatest risk is the lack of experience. Probably over the next 50 years, we will know what the consequences are." (support2)

Moreover, one interviewee strongly stated that CCUS is *still not a clean way* to reduce emissions because it is not a long-term solution for CO2 reduction; instead replacing the use of fossil resources would be important (infl2). Others agreed because CO2 remains in the ground (Infl1) and CCU is not really a reduction of CO2 (supply1). Additionally, the implementation of CCUS may *slow down the development of other renewable energy sources* (supply1, infl1), so that no other options are going to be explored and developed (pol2): “Ok, we capture the carbon, and then? What we will do next? Then, there is another problem: we will continue to produce more carbon, and then what? We will

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have to make more room for more even carbon [...] The only thing negative I am thinking about is what will do with all that captured carbon." (pol2). Thus, CCUS is not perceived as a perfect or long-term solution.

One interviewee also saw a cost in CCUS because people might *lose their jobs*: "If you shut down a site which uses coal and where you need around 50 people…50 people working there…and you show up with a new technology where you need 15 people to generate the same amount of energy…" (infl1)

Other interviews considered the *public acceptance* of CCUS as problematic (pol1, demand3, R+E1). Earthquakes in Romania caused by schist gases can be associated with CO2 storage (demand3). However, some interviewees disagreed (demand5) and/or stated that people are used to these earthquakes (R+E2). Another interviewee mentioned that *companies* are not necessarily interested in CCUS: "I do not see many problems in implementing the technology, only that people do not want to do it." (demand5) Moreover, the correct communication of CCUS to a general population was perceived as challenging: "There are several technologies that were not well received by society – the wind power and wind power plants, the shale gas. [...] communicating science to lay citizens is a thing that must not be neglected." (pol1).

One interviewee stated that CCUS should be implemented regardless of any potential risks: "Anything presents some risks, but if we think in this way, we don't implement anything any more." (infl3)

Acceptance of CCUS technologies and general attitude toward CCUS in the region

Most Romanian stakeholders were positive about the implementation of CCUS technologies in the Galati region. Support for CCUS projects in the region was based on the above mentioned benefits. Four interviewees mentioned to prefer CCS over CCU. Only two interviewees were neutral or more sceptical about the introduction of CCUS projects in the region.

The following table characterizes interviewees' general position regarding the development of CCUS technologies in the studied region.

Table 14. General position towards CCUS development in the Galati region

Interviewee	Stakeholder group	Position/ evaluation/ opinion	Description of position
R10	Politics and policies	In favour / positive	"I personally favour all that is new technology. Those rejecting CCUS are referring to the potential risk of this technology and to the security of the respective sites."
R14	Politics and policies	In favour / positive (mainly for people's health; to decarbonise fossil fuel)	"It would be good for us, humans. If my understanding is right, there are lots of persons having asthma, due to high level of pollution by carbon dioxide. This seems to be the most important thing – the health issue. [...] I am for the construction of such a site for capturing carbon. With a condition – that we should gradually give up to using fossil fuels "
R3	Research and	In favour /	"It is necessary. [...] Yes, for sure. Even if we

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	Education	positive	were to use only renewable sources of energy (…) there are still other industries remaining (cement, steel etc.), which need CO2 emissions depletion. And they are still needed for the economy of the region, for producing energy. Plus, we cannot get that fast to renewable energy production."
R7	Research and Education	In favour / positive (mainly to decarbonise fossil fuel)	"As long as fossil fuels will still be used in the energetic mix of countries and in the world in general, these technologies are mandatory. As long as we want to reduce global warming gas emissions. [...] There are two directions different from everything we have discussed so far and CO2 can play a positive role compared to the negative role it is playing at the moment."
R1	Industry: demand	In favour / positive	CCUS is seen as a solution for CO2 emissions, but these technologies still need to be proven at large scale. "I support these technologies (CCUS). The education that I received in the past 20 years of research activity taught me something important: if you don`t start adopting new technologies, you cannot evolve.(…) As long as we have so many manufactures of automotive components like those in Arad, Timisoara, it is impossible not to identify benefits."
R5	Industry: demand	In favour / positive	"We believe that we need to reduce carbon footprint- we as producers, and the industry in general and right now we have a company target to reduce this footprint. In Romania, we do different activities in our market to build awareness and to inform opinion leaders about the importance of reducing carbon emissions and capturing them. We are directly interested in this."
R6	Industry: demand	Confused/neutral	The interviewee is not sure whether focusing on CO2 is the right way to go or whether other gases should be captured and stored: "Storage refers to a potential gas that contributes to global warming. On the Kyoto list there are another 5types of emissions. So the question is whether we are working in the right direction. [...] I am neutral in a waiting phase because I`ve told you…I have this perception that this has not been decided yet. The EU does not have a project that can be given as example, that can be used from the beginning to the end, that can be seen as a representative model."

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R8	Industry: demand	In favour / positive (preference of CCU over CCS)	"It is a good idea to capture CO2 [...] A CCS project has to be done as fast as possible [...] I would use in the food conservation only the CO2 resulted from capture in the food industry. I would choose the transformation in calcium carbonate, to use it as a fertilizer. This way, the carbon is tied, introduced in the earth, this would be the best use. [...] It is better to distribute it on a larger area instead of concentrating it in holes."
R12	Industry: demand	In favour / positive	"I would not say there are any reasons for not doing it. When we chose those deposits, I mean I chose them, we made sure that they are 100% safe."
R9	Industry: supply	In favour / positive (to decarbonise fossil fuel; prefers CCS over CCU)	"Of course that I am in favour of these projects, but they are not known. [...] If the product releases also CO2, then it is not satisfactory."
R2	Support organisation	In favour / positive	"I am totally pro this solution and I think that for our country this could have a positive impact. We could be perceived positively by other countries from the EU."
R13	Support organisation	In favour / positive	"These technologies are the only tangible solution to mitigate global warming effects. I don`t think that we are advanced enough for other solutions. [...] In our case, for CET plants, besides the implementation of a CO2 storage system, there is no other solution and no other solution will exist in the next 20 years."
R4	Influencer	In favour / positive	“Yes, I believe that it has an important role not only in Romania and Europe, but also globally."
R11	Influencer	Neutral (against storage, but in favour of usage)	"I am open to investments in research and innovation in this domain, and I would like to see as many solutions as possible, but which don`t imply only storage. I don`t have the arguments for the sustainability of storage, durable throughout time. If I would know that this storage could bring carbon neutrality or even usage so, from something bad, we end us with something good – then I could pay more attention. [...] At one point, that carbon needs to be given back, so we put the responsibility on the next generation. [...]I think that the right solution is replacing fossil fuel. Not accepting and encouraging it because we found the solution to capture and deposit carbon."
R15	Influencer	In favour /	"I would be in favour of CCUS. [...]The use

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		positive (prefers CCU over CCS)	seems better to me than storage, the winning variant. [...] why don't use it if it is possible?"

Regarding the social acceptance, the Romanian interviewees stated that acceptance and awareness of the required CO2 reduction is rather low in Romania: (1) more information and (2) a favourable communication is required to achieve (3) a proper understanding. Also, (4) policies and regulations as well as (5) involvement and (6) training of relevant stakeholders is needed to create social acceptance. Moreover, (7) risks should be explained to distinguish CCUS from past accidents with other gases and (8) more research and studies regarding the social acceptance of CCUS would be desirable within Romania. Additionally, (9) high costs as well as (10) required support from the EU in terms of funding and successful projects were seen to potentially impact the acceptance of CCUS.

Many interviewees mentioned that social acceptance of CCUS technologies and of sustainable technologies in general is rather low in Romania. Some interviewees said that there is no acceptance because people are not aware of the urgency to reduce CO2 (Infl1, Infl2) and a lack of a proper understanding (demand2). Others agreed by stating that (1) more information is required (infl2, infl3) and that it depends on (2) how the project is presented to the public (demand1, infl3): If this information is presented in favour of CCUS, then it will most likely be perceived as a positive technology. "It seems that in this area we are more reluctant [...] I mean that, before studying a fact, we believe on the neighbour's word that it is not good. [...] it depends how fine the channel is and how well the information is conveyed, so publics would not be reluctant. And communication should be done on different levels of perception and understanding." (infl3) "It can become acceptable. It depends on communication campaigns, environment policies… until this; everything is at a declarative level." (demand1). These statements highlight that also (3) policies and regulation could help to raise awareness of the importance of CO2 reduction and the implementation of CCUS: CCUS could be possible if Romania will be constrained by the EU to implement it, so legislative pressure is needed (infl1, support2). One interviewee also mentioned that the owners of the EOR are non-Romanian, thus "Romanians are not interested, if we are doing this, we are working and they are winning. So when we get rid of them, then we will do it." (demand5). This shows that considering the interconnection with other partner countries can help to raise awareness and acceptance.

Furthermore, the *involvement and support from stakeholders* as well as (specialized) *training of stakeholders* (mainly of industry operators and politicians) is required to make CCUS socially acceptable (demand2, R+E2, infl2, demand5). "For a couple of years, when discussing public acceptance, I was suggesting my colleagues to introduce a new direction called industrial manager and administration acceptance. So determining those decision makers from the industry and the politicians who can support this. This is the key – if these forces shake hands, I see no other barriers because it all depends on the willingness of these factors." (R+E2)

The public acceptance of CCUS could also be connected to the *storage of other gases and related accidents* that happened in the past in Romania: "In Galati, there were some issues with gas leakages and some earthquakes, so maybe people are more reluctant." (R+E1) In this context, the Getica project was also mentioned (R+E1, infl3): "I would like to work in this type of project, but I would like to see a long term vision. Based on my experience with Getica, it was quite bad. Things suddenly stopped. So I would like to see more support. From authorities, from emitters, hydrocarbons operator and long term contracts." (R+E1) Also, one interviewee mentioned other projects that could influence the social acceptance of the implementation of CCUS because it requires pipelines: "It shouldn't be as they have done to villages, introduce pipelines for water and gas and no one wants to connect, because they don't want to pay the branching." (Infl3)

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Other interviewees stated that CCUS is perceived as positive at a local level, but that *more research and studies are required* (also on a national level) to receive a full picture of the social acceptance of CCUS in Romania (support1): “I did a study with 300 people and perceptions were positive. I do not know however how it could be perceived at a national level. Not many studies are available. [...] I would like to be part of the project, of the communication team. Be part of surveys and interviews. I would like it to be successful.” (support1)

Also it was mentioned that the *high costs* could lead to less public acceptance (demand3, infl2) however, " I think we are in a phase in which we should consider it." (demand3). Another interviewee (demand4) stated that *support needs to come from the EU*, in terms of funding and successful projects. His/her statements summarizes some aspects regarding social acceptance: “I believe that things have to be explained, presented in the media. People should receive explanations about risks and safety. [...] If the money would not come from the EU, this would not be acceptable, because we have many other priorities. The project is “a nice to have.” (demand4)

Perceived barriers and enablers/strengths

The barriers and enablers partly resembled the above described costs and benefits. Thus, only additional aspects will be described in this section. The empirical analyses showed that interviewees anticipate a substantially larger number of barriers than of enablers/strengths. No new enablers and strengths were expressed other than the aspects mentioned in the section "Benefits". As barriers, the following aspects were mentioned which will be illustrated in more detail:

(1) Lack of funding / money
(2) Lack of knowledge, information and awareness regarding environmental issues and the effects of CO2 - in the general population as well as in many companies
(3) Consequences and/or regulations are required to convince the industry and operators to implement CCUS
(4) Lack of support and interest from authorities, political actors, and administration
(5) Difficulties to obtain permits from the National Agency of Mineral Resouces and difficulties to obtain data from operators and similar projects in Romania
(6) Lack of cooperation / collaboration of relevant actors.

Moreover, the following barriers were mentioned by one interviewee each:

(7) Political instability (because it influences developments and investments; R+E1)
(8) Romania being conservative (demand1)
(9) Lack of business plans (supply1).

Several Romanian stakeholders (demand1, infl1, R + E2, demand4, pol1) mentioned the *lack of funding / money*. Economic agents might be reluctant to implement CCUS technologies because of the large investments/financial resources: Specialized training is required which is cost-intensive (demand1) - "the need to teach people...we are not talking about specialists that could develop the technologies. However, about the employees working for sites generating CO2 emissions. They should get specialized training for capture and so on.(...) and this means money and investments from the business environment.“ (demand1). Moreover, a continuous flow of (human and financial) resources is needed once the projects have started (pol1). One interviewee also stated that it is important to spend the funding/money effectively - without corruption (Infl3).

Another barrier in the general population is the *lack of knowledge and information about environmental issues* (demand1, infl1, demand3, pol2, infl3). Some interviewees perceive it as a barrier to involve the public in a subject (=CCUS) that is not developed and/or known enough. Others add that more awareness of the environmental effects of CO2 is required and too little

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information about the last CCUS project is provided. The same applies for industrial companies: In many companies, there is a *lack of awareness of environmental issues and of the large CO2 emissions in the industry* (demand2, infl2): "Besides the cement industry in Romania, I do not know any other industry that made massive investments in technology, in environment friendly technologies in an organized and efficient manner." (infl2)

Several interviewees (supply1, demand2, and support2, R + E2) stated that (financial) *consequences and/or regulations are required to convince the industry and operators to implement CCUS*:

- "It is hard for me to believe that a polluter will want to efficiently coordinate this aspect as long as it does not have consequences." (support2);
- "Locally, probably without an external regulation, no one will do anything voluntarily or few will do this." (demand2);
- "CCUS should not be optional, in this way nothing will be done. This solution is available for 15 years and nothing happened. "(supply1).

This leads to the next barrier that was mentioned: *lack of support and interest from authorities, political actors, and administration* (support1, demand3, demand4, infl1, infl3 demand5, support2, R+E2). This also includes the *difficulties to obtain environmental and storage permits* from the National Agency of Mineral resources (that handles these permits) as well as *difficulties to obtain data from operators and similar projects in Romania*:

- "Authorities are the main barrier. I am referring to storage permits, that should be given by the National Agency of Mineral Resources and by the government that has the most important role. IF political actors get involved, then the pilot project could be possible. In 2010 it was almost successful." (support1)
- "Obtaining authorizations: environment authorization, construction, these take time. [...] Bureaucracy is eating time and efforts. " (demand4);
- Power plants are mostly owned by the state and "in these types of institutions, weak, problematic and political management leads to the incapability of these large polluting companies to implement a technological solution" to reduce emissions. (support2)
- "It depends very much on people - who is in the top and decides, who is the manager." (infl3)

Closely related to this barrier is the *lack of cooperation / collaboration of relevant actors* (pol1, pol2, supply1), as illustrated in the following statements:

- "The main barriers are economic, financial and legal – because they have to impose legally the use of these technologies by the CO2 emitters. And the managers should make a business plan to see that in time they will recover their investment." (supply1)
- "A CCUS project should be a joint effort: public-private partnership." (pol1)
- "I think we are quite far from implementing such a technology. First of all this is a political decision, therefore, they should be the ones involved in making such a choice. [...] Then there are the companies, interested in the development of such a project. Than the environment activists – they should also be involved. And of course the people, because they are the "end users" of the air that we are all breathing." (pol2)

To summarize, the barriers for implementing CCUS in Romania are highlighted in the following quote: "Poor information of people regarding the impact they have on the environment. [...] Politically wise, no one cares. Industrially, [...] there is a big, very big cost. So help is needed." (infl1)

Trust in promoters

Trust in universities and research centres

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Regarding *universities and research centres*, interviewees had diverse opinions: Some stated that universities have a major role (infl1, demand2, demand3, pol1) and should be involved more (demand1, support2), for instance because they understand the relevant processes due to their involvement in previous CCUS projects (pol1, R+E1) and develop the projects in a safe way without risks (demand3). Also, they could help "identifying the products in which CO2 can be used." (demand1). Other interviewees stated that universities and research centres can participate and support CCUS implementation but that they are not very important (demand4, supply1, pol2, infl2) because their research is not visible enough and thus will not be considered appropriately (infl2). Interestingly, both sides mentioned the university's role in communication: "They need to inform future adults about what is happening and what can happen." (Inf1), they play a critical role for the implementation of CCUS and the awareness that it is necessary for the environment (demand2), they could contribute to communication campaigns (pol2). Financial issues were mentioned in regard to the university's impact as well: For instance, they should not focus on getting paid (support2); or "Research is so underfunded that I am surprised that it exists anymore." (inf3). One interviewee also stressed the required collaboration between researchers, project coordinators, and operators and the need of sharing existing data: "In other states, for instance, after 5 years of drilling, there are public data bases. Here, in Romania, this information is confidential."

Trust in NGOs and support organisations

Regarding NGOs and support organisations, only some interviewees had a clear opinion and if they had, they saw NGOs as an important support for CCUS that should be involved from the beginning (demand4, R+E2, supply1) and that should be strengthened (support1). Especially more Romanian NGOs (instead of international ones) are required and they should address public resistance (R+E1). Only one interviewee (interestingly a stakeholder from the category "Influencer") stated that NGOs will not have a large impact on the development of CCUS (infl2).

Trust in administrative, policy and political actors

Regarding the capability and support of administrative, policy and political actors, the Romanian interviewees were rather sceptical. The following reasons were mentioned for their view:

(1) They are too slow due to a lot of bureaucracy (infl3)

(2) They lack information, expertise, and interest (infl2, demand1, demand3, demand4; "Administration officers are appointed on political criteria and they lack specialization and competence. [...] They were not capable of building two roads. Can they implement a million euros industrial project? I don’t think so." demand4)

(3) The current system does allow it. A different system would have to be in place: The ministry of environment should be more involved because regional policy makers lack the capability (demand2) or a new national administrative authority/body for coordinating CCUS projects should be installed (pol2).

The relevance of collaborations was highlighted by several interviewees (support1, infl1, pol1, support2, R+E2): The political environment in Romania is problematic and currently very fragmented, so political actors will only be capable to implement CCUS with the help from other actors (R+E2); “as long as they work with specialists in this domain.” (infl1); "get everyone to the same table" (support2); also from experiences in previous research and data projects, collaborations with other actors appeared relevant: "The cooperation with administrative structures was very good. In such projects, we speak about mixed teams: people from local administrative structures teamed up with technical experts. Such a team works best and this was already proven." (pol1)

Moreover, the role of policy authorities and political actors was perceived as providing more support (supply1, inf2). One interviewee (R+E1) stated that the support of policy makers depends on the

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popularity of the technology: "If the technology is perceived as something positive, then there won`t be an issue in implementing the technology."

Trust in project developers and the industry

Most Romanian interviewees mentioned trust in project developers, (technical) specialists, and industry to handle the technical and coordination challenges when implementing CCUS (demand1, infl3, support1, pol1, R+E1, infl1, demand2, R+E2). The interviewees mentioned several examples for their trust in this regard, for instance successful global Romanian projects (support1, infl1), projects in large companies (demand2), in the car industry (demand1) or the oil and geological sector (R+E2): "We have the capacity, but it needs to be explored." (demand1). "Our country has a known history in the oil industry, geological knowledge of the underground sites – which is in a very advanced state. The experience we`ve earned is top in the geological domain and in the oil industry the managers – if supported by political factors – have all the capacity to coordinate these activities." (R+E2)

Others believe that the capability of industry and project developers can be enhanced by the following aspects:

- additional exchange with other specialists working on CCUS projects or specialized training (pol1, demamd4, infl2),
- more information and maybe counselling (demand2),
- more support from political factors (R+E2, supply1),
- more funding especially for small to medium companies (demand2, R+E1),
- successful projects that show how it works (demand3, demand4).

Only few Romanian interviewees did not trust the industry to be able to handle a possible CCUS implementation due to the lack of vision and administrative capacity to work with European funds (pol2) and/or lack of experts and motivated people (demand5).

Trust in other actors

As other CCUS-relevant actors, the Romanian interviewees mentioned

- industrial clusters/groups/companies (demand1),
- government actors/decision makers (demand1),
- business owners because "they need to accept the challenge" (demand3), and
- social and mass media ("Mass-media still can move things, they remain a power as well as social media." inf3)

Especially the media was mentioned several times (demand3, demand4, demand5, supply1, infl2, infl3) as crucial to communicate the environmental necessity and to raise awareness of CCUS projects as well as to push the government (demand4) and "the authorities to the faster adoption of these technologies." (supply1) "As long as there is will and one starts doing this, and the press writes about it, then many more will want it." (demand5)

Preference for alternative options

Nine of fifteen Romanian interviewees did not know of or currently, do not see a comparable alternative of CCUS (R+E1, demand1, demand2, demand3, demand5, pol1, pol2, support1, support2) -- "I think that this is the only option that can help for carbon neutral objectives on the short term. " (demand3); "the only other solution is not to produce CO2." (pol1); "well, the solution will be to give up entirely to use fossil energy. But it is impossible to do this form one day to the next." (pol2); "the renewable energy part has fluctuations, whilst the electric energy coming from steam power plants

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does not have fluctuations and this maintains balance in the entire national electric system. [...] So from the energy perspective, only carbon sequestration is a solution." (support2).

Some stated that renewable energy sources could be an alternative for CCUS (R+E2, demand4, supply1, inf2, inf3) – "The alternatives must be used altogether. You cannot use only one- for example, solar energy." (demand4). However, some interviewees perceive renewables to be promoted and further developed ("Of course there are alternative technologies that use these renewable resources: wind, water, sun ... they are extremely important. Of course, they are promoted in our country at the highest level." R+E2), whereas others do not see this change in Romania (supply1) or are insecure "On the other hand, I heard that the plan for these coal-powered plants is to close them – and that is making this CCS politics unclear to me. I don't know to what extent they are necessary any more if they wish to pass to the energy from renewable sources" (infl3). Only one interviewee was certain that "there will be alternatives in the future, if we support the research at institutes and universities" (infl1).

To summarize the Romanian view on CCUS and alternatives: "It (=CCUS) is considered a transitional technology, an alternative for the problems we are facing today in terms of pollution and climate change, until we find something better" (pol1)

Expectations about the future

Only a few interviewees were pessimistic regarding the future of CCUS in Romania (infl2, infl3, demand3), for instance due to experiences in solar panel projects. Most Romanian interviewees were hopeful or optimistic about the future of CCUS in Romania (demand1, demand2, demand4, demand5, support1, support2, R+E1, R+E2, pol1, infl1). However, regarding the timeframe of CCUS implementation the views of the Romanian interviewees differed, ranging from "In the next few years, I see it implemented in the cement industry (...and) in the steel industry" (R+E2) and assuming a fast development and implementation in approximately 5 years (demand4) through "maybe in 10 years yes, but in 5 years I don't think so" (supply1) to "at least 20 years. It can be shorter with a very significant help from the EU." (infl1). To sum up, the Romanian stakeholders think implementing CCUS could be difficult but it is necessary: "It will be hard, but I think that this will be possible. I think, in the end, people will realise that we need a healthier earth, that their children will inhabit it and therefore we need the earth to … exist." (pol2)

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3.7 Greece (Western Macedonia)

Role of CCUS technologies in climate change mitigation and general evaluation

In Western Macedonia, interviewees' attitudes regarding CCUS technologies and their role in climate change mitigation varied from general support to scepticism. The majority of interviewees supported the diffusion of CCUS. Most of these people stated that the diffusion of CCUS applications could help to cut CO2 emissions. Second, they hoped to extend the life of Western Macedonian lignite mines and power plants. Other interviewees, on the contrary, rejected the idea that CCUS should be widely rolled out in Western Macedonia due to the following two reasons: (1) CCUS does not have the potential to reduce as much CO2 as it would be sufficient. (2) The technology has not been ready so far and it is unlikely that it is ready now.

The following table characterizes interviewees' general position regarding the development of CCUS technologies in Western Macedonia.

Table 15. General position towards CCUS of stakeholders in Western Macedonia

Interviewee	Stakeholder group	Position	Description of position
G1	Politics and policies	Modest support	Thinks that CCUS will certainly help the region and Europe, and will lead to mitigating climate change.
G3	Politics and policies	Support	Believes that carbon capture, recovery and storage technologies can play an important role in reducing climate change and enhancing environmental protection.
G6	Politics and policies	Supportive	Thinks that CCUS is important. However, this is only the case if CCUS is deployed at scale and not only in pilot applications.
G8	Politics and policies	Rather supportive	Thinks that CCUS can play a very important role in reducing emissions.
G9	Politics and policies	Sees potential, rather supportive	"Clearly, they can help exploit carbon dioxide without damaging the climate." "Yes, they can play an important role both in the region and in Europe."
G5	Research and Education	Supportive	Believes that CCUS can play an important role in limiting climate change.
G10	Research and Education	Supportive	Is convinced that CCUS is an important climate change mitigation tool that should be used in combination with other technologies and strategies.
G11	Research and Education	Supportive	Believes that CCUS technologies can obviously make a significant contribution to reducing climate change and enhancing environmental protection.
G12	Research and Education	Rather supportive	Thinks that CCUS is a key-technology to limit CO2 emissions in the atmosphere, though not the only one. These technologies can play an important role in mitigation efforts both in

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			Greece and in Europe, but they are very expensive and the CO2/ton fines should not be so increased to support the installation and pipeline cost.
G14	Research and Education	Supportive	Thinks that CCUS can play an important role both in Europe and in the West Macedonian region.
G4	Industry: demand	Sceptical	Does not think that CCUS can reduce emissions by a large extent. In his/her opinion, CCUS has been around for quite some years and did not yet enter the diffusion phase. The interviewee doubts that this will be different now.
G7	Industry: demand	Undecided	Is well aware that CCUS applications can help mitigate climate change.
G13	Industry: demand	Supportive	Thinks that carbon capture and use is important.
G2	Support organisation	Support	Puts forward that CCUS technologies play an important role in climate change mitigation efforts. Thinks that these are well established technologies and can be easily retrofitted onto existing plants.

Benefits and costs of deploying CCUS technologies in the region

Perceived benefits

The benefits that were mentioned and are connected with the implementation of CCUS-related technologies in the Western Macedonian region dealt mainly with (1) economic development, (2) the creation of jobs and (3) environmental protection. Also, (4) less air pollution was mentioned as a benefit (G10, G12), even though reduced pollution is not necessarily an outcome of newly implemented CCUS applications, since these do not by default deal with the emission of particular matter (e.g., nitrogen oxide or ammonia).

- Economic development. Concerning economic development, the interviewees hoped that the implementation of CCUS can help to avoid the CO2 related penalties. Then, this would relieve coal related industry and respective companies (G2). Hereby, these companies could continue to operate lignite mines and lignite power plants and consequently safe their business model for some more time (G4, G5). Especially CCU may have merits since it may lead to the local development of "high value-added products" in the region of Western Macedonia (G4); this could ultimately lead to overall economic growth (G8).
- Jobs. Deeply intertwined with economic development is the hope for more jobs that was envisioned because of CCUS implementation in the Western Macedonia region (G1, G3, G10, G11, G13, G14). CCUS-related investments are also believed to eventually bring know how (G3) and build expertise in the region (G12), again creating more jobs in the region.
- Environmental protection. On a supra-regional scale, the key benefit of CCUS implementation is the reduced CO2 emissions (G2). However, the number of interviewees referring to these benefits was substantially smaller than the number of interviewees that referred to economic development and the creation of jobs.

Perceived costs

Regarding the potential costs and negative impacts of developing CCUS technologies in Western Macedonia, three interviewees referred to the potential risk of storage failure. Explicitly, leakage

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due to an unpredicted event such as earthquakes (G2, G12), aquifer contamination and micro-seismicity were mentioned (G12). On the other side, nine interviewees did not see any risks with CCUS related infrastructure implementation, whereas three interviewees did not answer the question on CCUS-related risks at all.

Acceptance of CCUS technologies and general attitude toward CCUS in the region

The interviewees were rather positive about the development of CCUS technologies in the Wester Macedonia region. Support for the use of CCUS in the region was based on the already mentioned advantages of CCUS technologies such as economic development and securing jobs. However, it was mentioned that there is currently no comprehensive strategy in place to drive the implementation of CCU infrastructure. Furthermore the interviewees stated that the focus should be on CCU instead of CCS.

The following table characterizes the interviewees' general position regarding the development of CCUS technologies in the studied region in Greece.

Table 16. Position towards CCUS development specifically in the Western Macedonia region

Interviewee	Stakeholder group	Position	Description of position
G1	Politics and policies	Supportive	"Yes, I am in favour and I believe that their adoption will be acceptable."
G6	Politics and policies	Supportive	"In favour, of course. And I believe that it would be acceptable 100%."
G8	Politics and policies	Supportive	"I am in favour. If we don't do it there will be job losses with [name of large energy supplier] that leads to economical loss for the region."
G9	Politics and policies	Supportive	"Yes, I am in favour and I believe with a thorough analysis of all aspects of the project it will be approved."
G3	Politics and policies	Supportive	"I am in favour." "Of course, especially in our region, which is particularly burdensome on the environment, but also in Europe."
G5	Research and Education	Supportive	"I am in favour."
G10	Research and Education	Rather sceptical	"In Greece, such projects, especially storage, are far from being implemented as there is no strategy to address the issue, especially as long as emission allowances price remain low."
G11	Research and Education	Supportive	"I am very much in favour and I believe that the adoption of CCUS technologies in the area will be

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			acceptable because there is sufficient maturity around this issue."
G12	Research and Education	Supportive	"Positive. We are in favour of it."
G14	Research and Education	Supportive	"I am in favour. I do not think there are any barriers. I believe it would be acceptable, the region is particularly sensitive with the lignite and mineral wealth of the region. If people were aware of such technologies, which extend the life of the lignite, they would certainly be in favour."
G4	Industry: demand	Supportive	"Probably in favour and I think that under the current circumstances, it would look like a one-way street for the Region of Western Macedonia."
G7	Industry: demand	Supportive	"I am in favour and I believe it will be acceptable."
G13	Industry: demand	Rather supportive with a focus on utilization	"Always in favour. However, I am not aware of the technology needed for CCUS. We could capture CO_2, but I wouldn't want Western Macedonia to become landfill if we proceed in storage. I only agree to capture and utilization."
G2	Support organisation	Supportive	"I am truly in favour of CCUS project."

Interviewees suggested a number of conditions that need to be met for the successful implementation of CCUS applications in Western Macedonia. These conditions roughly referred to (1) costs, (2) acceptance issues, (3) state initiatives and (4) more research.

- Concerning cost, the interviewees stressed that CCUS-related projects need to be financially viable (G1, G10, G14) and it was mentioned that the required resources should or can come from the local government (G7). In contrast, it was suggested that it would come from the national level, the Greek state (G7).
- Concerning social acceptance the interviewees stated on the one hand that CCUS will be accepted if adequate information is provided (G8) and if the carbon is transported away from West Macedonia region, for instance to the port of Thessaloniki (G4). However, further information was not given what to do with the transported carbon. Apart from that another actor stated, that captured carbon should not be stored at all, but it should only be captured to the extent to which it can be used of with utilization (CCU; G13).

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- Concerning state initiatives, it was stated that new and adequate legislation needs to be implemented (G9) that includes strict control mechanisms (G12).
- Furthermore was questioned whether the current state of knowledge about the region is sufficient and whether the potential CCUS applications were sufficiently explored. Thus, it was suggested that further high quality geological studies should be conducted in the run-up to concrete CCUS project developments.

Perceived barriers and enablers/strengths

It was mentioned that the region of Western Macedonia hosts a number of coal fired power plants and lignite mines. Most of them are run by the public power cooperation - a mainly state-owned electricity company. The region depends substantially on the jobs offered by the public power cooperation.

Since coal-burning processes emit substantial volumes of CO_2, the operators of such power plants are requested to buy CO2 emission allowance that are traded in the European emission trading systems. Hence, one interviewee suggested that the anticipated investment costs for CCUS over time should be smaller than the additional expected cost for the emissions trading allowances (G1). Another interviewee doubted that the knowhow of CCUS related infrastructure in Greece is sufficiently available (G4). Furthermore, it was mentioned that local resistance can be expected by "environmental organizations and misinformed citizens, who may consider these technologies unsafe" (G5). However, yet another actor doubted that there will be any barriers, "as long as everything is within the prescribed legal framework" (G11).

Trust in promoters

The trust in developers/industry was generally prevalent during the interviews with the Greek stakeholders, however scarce knowledge was often brought up as a limiting factor. For instance, one interviewee stated that s/he considered the Public Power Cooperation (see above) as being "capable of handling the technical and coordinating challenges of adopting carbon capture, recovery and storage technologies (CCUS)" (G3, similarly G11, G14). Concerning other and smaller industrial stakeholders in the region, the doubt of scarce knowledge (G1) and right approaches was quite strong (G12). In accordance, it was stated that regional industrial actors are believed to operate on extremely short time horizon (G9) and "will need to be educated" (G5).

Generally, the interviewees believed that regional policy makers and administration are generally open to help implementing CCUS projects (G1). Furthermore, they are believed to engage if they are legally obligated to do so (G6). Concerning trust in the capabilities of regional policy makers and administration, the opinions deviated. Some interviewees were certain that policy makers and administration have sufficient knowledge (G9) and that regional administrations are capable to "coordinated such projects" (G8). However, other interviewees were not as certain about the capabilities of CCUS-relevant actors. For instance, one interviewee stated that "in Greece, policy makers and regional administration appear to be struggling to cope with the challenges of coordinating CCUS technologies" (G10). Another interviewee stated, that "they are not capable of facing such challenges" (G11, G13). Due to the lack of expertise to cope with large infrastructural projects, one interview suggested that "they also need to be educated" (G5).

An interesting finding of the interview series is that no interviewee was aware of any support organization (such as NGOs) in Western Macedonia. Quotes from the interviewees were "they do not exist in the region" (G5), or "We do not know if they exist in Greece" (G14).

Among the interviewees, stakeholders from the university are generally believed to play an important role (G1, G8, G10) and including university stakeholders "in such projects is essential" (G3). Furthermore, one interviewee believed that "they are at a good level and it would be beneficial

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for the region to involved them" (G6), while a another actor affirmed that "they have great expertise on the subject" (G13). However, there was also some doubt that "probably they can handle (CCUS projects), but I am not quite sure about it" (G11). Another interviewee thought that the stakeholder from the research and education sector should not be praised since they have not yet completed their mission and need to carry out some more research of large-scale investigations and field trials before really engaging in CCUS infrastructure implementation.

Trust in other actors

A crucial role in the process of decarbonizing the Western Macedonian energy sector was attributed by the interviewees to the Western Macedonian Environmental Centre, the Technical Chamber of Greece (section of Western Macedonia) and the Geotechnical Chamber of Greece (G5). Furthermore, it was hoped that some other "universities outside the region and perhaps some foreign companies that know these technologies in depth" could help in the CCUS implementation process (G11).

Preference for alternative options

Three out of fourteen interviewees perceived the use of other renewable technologies as another viable option that should be taken into account (G1, G13, G14). Apart from that, one interviewee suggested to use mud to produce hydrogen. However, no evidence was given if this is a viable solution for a large-scale implementation and CO2 reductions. One interviewee believed that CCUS is the only viable large-scale option to decarbonize the coal industry (G4). Another interviewee did not see the future as being set in stone, but depending on the policies of the central government.

Expectations about the future

Concerning the future developments of CCUS in Western Macedonia, the opinions differed. Out of 14 interviewees, four expected to have CCUS infrastructure in Western Macedonia in the near future (G1, G3, G5, G6). However, four were not sure about the future developments of CCUS in the region and another two were quite sceptical. As reasons for a soon and successful implementation the interviewees mentioned, for instance, that "the country's decarbonization policy creates a fertile climate for the development of such projects" (G12). However, this was countered by the looming exit out of coal power over the next years (G9, G14) and the "economic problems [that Greece] is facing" (G8).

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3.8 Poland (Upper Silesia)

Role of CCUS technologies in climate change mitigation and general evaluation

In Poland, interviewees' attitudes regarding CCUS technologies and its role in climate change mitigation varied from enthusiasm and support to scepticism. Some interviewees emphasized the important role of CCUS technologies in the decarbonisation of the highly industrialized Upper Silesia region. These interviewees expected greenhouse gas emissions to decrease due to the implementation of CCUS. Also, they hoped for keeping jobs in Upper Silesia, the region is currently highly reliant on coal incinerating power plants and mining.

On the contrary, other interviewees rejected the idea that CCUS should be widely rolled out in Poland due the reasons displayed in the following list:

- CCUS applications may not be the right path altogether, since investment into renewable energy sources may be a cheaper path to CO2 emissions reductions.
- The potential of CCUS applications in Poland is not large enough.
- CCUS technology is not mature enough and therefore implementation would be expensive.
- Anticipation of lacking social acceptance, which then leads to lengthy or unsuccessful implementation processes.
- Insecurity if anthropogenic activity is the clear source of climate change.
- Even if climate change is due to anthropogenic activity, other countries should do their contributions first. Countries named were China, the US, India, and Russia.
- Fear that some geological layers may not be sufficiently sealed and greenhouse gases may escape.

The following table characterizes interviewees' general position regarding the development of CCUS technologies (detached from the Upper Silesia region).

Table 17. General position towards CCUS by stakeholders in the Upper Silesia region

Interviewee	Stakeholder group	Position	Description of position
P8	Politics and policies	Support	CCUS technologies can certainly play an important role in mitigating climate change, so it is worth investing in them.
P10	Politics and policies	Rather supportive	Technologies that reduce greenhouse gas emissions should be supported. CCU and CCS technologies can play an important role, especially in regions with high CO_2 emissions, such as Upper Silesia. However, the focus should be on CCU and on eliminating the burning of fossil fuels.
P1	Research and Education	Sceptical / undecided	Not completely convinced that current climate change takes place due to anthropogenic activity. The potential for CCUS is questioned. Nevertheless, if CCUS applications are to be installed, it seems important to increase public awareness of CO2 emissions and its impact on climate change. The contribution of CO2 emissions to climate change is still down played

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			in Poland. Others should start cutting emissions at the same time.
P2	Research and Education	Support	Favours CCU over CCS, since CCU is believed to create more jobs. But also sees advantages in CCS, because then coal fired power plants can continue to operate.
P3	Research and Education	Support	Accepts anthropogenic climate change as a scientific fact and strongly supports CCUS even though it may "significantly reduce the efficiency of power plants". Favours CCU over CCS.
P6	Research and Education	Sceptical/ undecided	Thinks that CCUS is a generally good idea to curb CO2 emissions, but is convinced that the goal should be to actually stop the extraction of fossil fuels immediately. All measures and intellectual effort should be directed towards renewable energy sources, not CCUS, which only extends the time of abandoning the burning of fossil fuels.
P4	Industry: demand	Support	In favour of CCU. Not so much in favour of CCS. Thinks that CCU technologies are not yet sufficiently mature and thus economically not interesting. Is unsure if storage capacities and safety are sufficient. Calls for stronger regulation to implement CCUS projects.
P9	Industry: demand	Support	Sure that climate change is a fact. One of the basic causes of climate change are CO2 emissions. Any action taken to eliminate CO2 from the atmosphere is definitely positive and will play an important role.
P12	Industry: demand	Rather supportive	If it is financially viable, CCUS applications should be implemented.
P5	Support organisation	Support	Supports the implementation of CCUS but thinks that this technology "will not play a revolutionary role".
P11	Support organisation	Rather supportive	Sees CCU and CCS viable options, but doubts that the technology is already mature enough. Furthermore, is in favour of other CO2 reductions measures.
P13	Support organisation	Intermediate	Thinks that CCUS can help, but the amount that CCUS will be able to prevent from going to the atmosphere is rather limited, since storing CO2 is expensive and CO2 can only be used in a limited amount in the fuel and food industry and in the production of fertilizers.
P7	Influencer	Intermediate	Believes that CCUS can be helpful but efforts should mainly be made to stop extraction and burning of fossil fuels. Sequestration is also likely to have negative results that cannot all be

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			foreseen so far.

Benefits and costs of deploying CCUS technologies in the region

Perceived benefits

Regarding the potential benefits of developing CCUS technologies in Upper Silesia, the interviewees referred to four main benefits:

- Reduction of CO_2 emissions. Almost half of the interviewees were strongly aware that CO_2 emissions need to be curbed, and see decreased CO_2 emissions as a benefit in itself.
- The coal industry decline in Upper Silesia could be slowed down and jobs could be saved in the coal extraction and power plant sector. Prices for CO_2 allowances have recently increased by five times (spring 2017 until spring 2020). This has put a lot of pressure on electricity generation from coal, and could likely accelerate the decline of the coal sector in Upper Silesia. The implementation of CCS and CCU applications is perceived as an opportunity to alleviate these pressures, to keep the coal industry alive, and to preserve the job opportunities in the region.
- Increased employment opportunities in the CCS and CCU related industries. The Polish interviewees mainly believed that CCUS applications were likely to create new research and technology development in the region as well as support the development of new competences in the regional work force (P2, P8, P9, P10). Since CCU has a larger variety of applications, it is expected that CCU could contribute at a larger scale to such a development of new competences.
- Increased health benefits to the region's residents. Due to its strong industry base and despite installed filtration applications, the Upper Silesia region is one of the more contaminated regions in Poland. Part of the interviewees hoped for cleaner air in Upper Silesia as a result of a wide implementation of carbon capture applications (P13). However, it is important to note that the local air quality is not solely linked to climate change and CO2 emissions.

Perceived costs

Regarding the potential costs and negative impacts of developing CCUS technologies in Upper Silesia, the interviewees refer to five main themes:

- Uncertainties about environmental effects. Interviewees perceived it as a problem that it is not known what the long term environmental effect of CCU and CCS technologies are and whether large-scale CCUS applications are completely safe for the environment (P6). Especially the risk of methane leaks, which may be a result of injecting CO2 into deep coal seams, was discussed (P13). In this context, interviewees referred to methane leaks related mining disasters that took place in the past in Upper Silesia (P2, P4). These past methane leaks may also undermine acceptance for future CCS projects. Furthermore, it was mentioned that new infrastructures will also cause new CO2 emissions, which again will need to be recovered.
- Uncertainties about sufficient market potential of CCU based products in the region and in Poland in general. CCU is a new field, and interviewees were not sure how large the potential of CCU related products is in Poland.
- High upfront costs. CCU and CCS related infrastructure come with high upfront costs. Interviewees perceived these as risks to the already struggling power sector companies in Poland. Hence, CCUS related investments might need to be co-financed by the government. Also, some interviewees raised concerns if these investments will ever be recovered (P1).

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- Large costs for the transport infrastructure. Since Upper Silesia is believed to have very limited geological formations that may hold the CO2 (P1), CO2 will need to be transported over longer geographic distances. This will again increase the CCUS infrastructure related costs.
- Higher energy costs due to reduction of power plant energy efficiency. Carbon capture is an end-of-pipe technology that requires substantial energy to function. This energy is likely to come directly from the electricity plant where the carbon capture technology is implemented. Therefore, the implementation of carbon capture technology further decreases the energetic as well as financial efficiency of fossil based power plants which either decreases the marginal revenue per sold energy unit or the sales price needs to be increased which then has repercussions on the industrial players further downstream (P2, P3).

Acceptance of CCUS technologies and general attitude toward CCUS in the region

The interviewees were rather positive about the development of CCUS technologies in the Upper Silesia region. Support for the use of CCUS in the region was based on the already mentioned advantages of CCUS technologies. Respondents identified several conditions for acceptance as well as potential obstacles to the use of CCUS. A minority of respondents was opposed or sceptical about the introduction of CCUS projects in the Polish region.

The following table characterizes interviewees' position regarding the development of CCUS technologies in the studied region.

Table 18. General position towards CCUS development in the Upper Silesia region

Interviewee	Stakeholder group	Position	Description of position
P8	Politics and policies	Support of CCU	In favour of CCU, but not of CCS in Upper Silesia region, due to the limited storage capacity.
P10	Politics and policies	Support	Supports both CCU and CCS in the region.
P1	Research and Education	Sceptical	Capture is extremely expensive and storage of large quantities seems to be ineffective in Upper Silesia. Furthermore, the additional cost for CCUS implementation is likely to be high.
P2	Research and Education	Support	Support to implement CCUS infrastructure in the Upper Silesia region if the approach is "sensible".
P3	Research and Education	---	No direct comment to the CCUS implementation in the Upper Silesia region.
P6	Research and Education	Sceptical	Sceptical due to not sufficiently mature and too expensive technology.
P4	Industry: demand	Undecided	Generally supports CCUS in the region but is not sure that Upper Silesia is the right place to implement it due to low local storage capacity.
P9	Industry: demand	Support	The benefits that CCUS technologies can bring to the region are so large that they are worth implementing and promoting, as long as there is reliable economic analysis of these activities prior to the investment. Furthermore sees

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			opportunities for the region's development related to the emergence of technologically advanced innovative companies, creation of new jobs, and new products.
P12	Industry: demand	Support	Generally supportive, but expects substantial social resistance due to previous malicious events involving underground storage.
P5	Support organisation	Support	In favour of CCU for the region, but not CCS.
P11	Support organisation	Support of CCU	More support for CCU than for CCS, due to its potential for a circular economy.
P13	Support organisation	Support	General support for CCUS
P7	Influencer	Undecided	Not against CCUS, but says that rather the causes of climate change should be tackled directly by investing more into renewable energy technologies.

Interviewees suggested a number of conditions that need to be met for the successful implementation of CCUS applications in Upper Silesia. These conditions roughly refer to costs, infrastructure, and acceptance issues.

- Concerning cost, the interviewees stressed that either costs for CCUS applications need to be substantially reduced or they would need to be covered by the government, since industry actors are not perceived as being able to make the additional investment costs available (P1, P2).
- One condition for a successful implementation of CCUS is that the implemented infrastructure to use storage potentials in the region is secure (P4, P8). However, since the storage capacity for gases in the Upper Silesia region is rather limited, it is likely that the carbon would need to be transported to other areas. This would require additional infrastructure such a pipelines, which again increase the cost of the CCUS related projects (P3).
- Several interviewees were wary about social acceptance issues as fundamental condition for successful implementation of CCUS applications. On one hand, it was stated that "storage of CO2 in coal seams in Upper Silesia would cause great social resistance" (P8, similar P12), as well as "storage is a ticking bomb and society would not be up for it." (P8). On the other hand, some interviewees stated contradictory suggestions, for instance that "the implementation of CCU technology is acceptable, given that it is properly tested, prepared and completely secure" (P5). as well as "CCUS would be acceptable if it guaranteed the security of such storage, and would not exceed economic and social costs" (P8). Independent of the general attitude of the local population, some interviewees anticipated that "construction of a new ground installation and interference in the landscape, or the expropriation of inhabitants from installation areas " would be counterproductive to acceptance. Therefore, one suggested way to prevent social resistance is, that pipelines should "run underground and there is no interference with the landscape" (P8).

Perceived barriers and enablers/strengths

The coal industry in Upper Silesia is very strong. Since coal-burning processes emit substantial volumes of CO2, the operators of such power plants are requested to buy CO2 emission allowance

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that are traded in the European emission trading systems. Interviewees suspected that a large increase of the prices for these allowances may likely be a key driver for any CO2 emission reduction technology - hence also for CCUS related applications (P2, P4). Furthermore, substantial financial support schemes could be a driver for the implementation of CCUS related technologies. As already pointed out before, CCUS is likely to be socially contested. Therefore, it is "important to make people aware that new technologies are not an attack on their future, but a necessary alternative".

The empirical analyses shows that interviewees anticipated a substantially larger number of barriers than of drivers. Barriers included the limited CO2 storage possibilities in Upper Silesia (P4, P8) as well as the high upfront cost of CCUS related infrastructure investments (P1, P2, P5, P6, P7, P8, P9, P13). Furthermore, Upper Silesia is seemingly a rather densely populated area, thus additional large infrastructures may require land that is not easily available (P8). Apart from that social acceptance is not perceived as given in Upper Silesia (P2, P12). Specifically regarding CCU applications, some interviewees doubted that there is currently sufficient industrial players that could make use of captured carbon and process it further to other value creating products (P3). For the implementation of CCUS related infrastructure, some regulations would need to be adapted or new laws would need to be passed. If these policy processes make only slow progress, they could also turn out to be a barrier for a fast adoption of CCUS in the Upper Silesia Region.

Trust in promoters

Many interviewees did not have specific opinions on the role, tasks, or capabilities of many regional actors. This may also be because CCUS has not been a central topic in the regional discourse yet.

Regional administration was believed to be able to support the implementation, although for many members of the administration this is anticipated to not be an easy task (P10).

The future role of support organizations was seemingly debated among the interviewed stakeholders. On the one hand, some believed that organization such as NGOs are not sufficiently educated yet (P5) and are rather believed to oppose large CCUS related infrastructure developments (P6). Other interviewees attribute them a major role in the process of CCUS development and implementation (P10).

The university system was perceived as well developed in the Upper Silesian region in comparison to other areas in Poland. Hence, universities such as the Silesian University of Technology as well as the Central Mining Institute may have sufficient know-how to assess for instance ecological effects of CCUS implementation (P3). However, among the interviewees, there was also some uncertainty if actors from these research organizations are willing to support CCUS and may not favour other "simple and natural solutions" such as renewable energies development (P6).

A crucial role in the process of decarbonizing the Polish energy sector was attributed to the coal miners' trade union. They "could have a significant opinion-forming character" (P8) and therefore the interviewees stated that they need to be integrated into the industrial transition process of the Upper Silesian region.

Preference for alternative options

Two out of thirteen interviewees perceived CCUS as the only option for substantially decreasing the CO2 emissions in the Upper Silesia region and Poland altogether: "To sum up, there seems to be no alternative to CCUS and sooner or later these technologies will appear" (P2, similarly P13).

However, preferences for alternative options among the other interviewees were broad and many stakeholders thought "the energy sector should be completely remodelled" (P7) in other ways than by solely focusing on CCUS technologies. These alternative options include implementing renewable energies such as wind offshore or solar PV (P1, P8, P9, P12), but also nuclear as well as larger use of

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natural gas is being discussed (P3). Sporadically also the use of green hydrogen (P3) as well as better use of energy efficiency measures and other decentralized solutions were noted (P5, P6, P10).

Expectations about the future

Concerning the future development of CCUS in the Upper Silesia region, the opinions differed. A majority of interviewees anticipated that CCUS will eventually be implemented in the Upper Silesia region (P2, P3, P4, P8 P9, P10, P12, P13). However, the expected time horizon differed. Most of these interviewees expected that CCUS infrastructure will start to be implemented within the next five to 10 years. However, for instance P13 expected 20-30 years as a more likely time horizon "due to the high complexity of CCUS related issues" (P13).

In contrast, for instance P6 was not very convinced that CCUS infrastructure will be part of the future energy related technology mix in the Upper Silesia region. S/he argued that "CCUS technologies will prove to be too expensive, too risky, and socially unacceptable" (P6).

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3.9 Stakeholders' views at the EU level

This section presents the results of four interviews that were conducted on the European level with actors dealing with CCUS. They were selected based on their assumed knowledge and engagement in CCUS to present a European perspective on CCUS. The interviewees were mostly representatives from NGOs (being part of the "Influencer"-category) or from politics and policies. These EU-level interviews were not analysed in the same depth as the interviews from the eight regions because the view from an EU-level is more on a meta-level and cannot consider the regional conditions as detailed as the regional interviewees. Overall, we did *not* find a diversity of positions: Generally, the representatives on the EU-level shared similar views and expressed a positive attitude toward CCUS. In the following, we present a summary of the results and then describe each interview in detail. Regarding the structure of each description, we start with CCUS-relevant sectors as well as drivers/benefits and barriers that were mentioned by the interviewee, before covering the social acceptance of CCUS and CCUS-related actors. The description of each interview closes with the interviewee's perspective on the future of CCUS.

All interviewed representatives stated that - although other options exist - CCUS is a required solution to meet the climate goals, to reach net-zero, and to reduce emissions. Moreover, all interviewees on the European level expressed that the implementation of CCUS projects is missing: They agreed that successful CCUS projects need to be implemented now to provide a good model for future CCUS projects ("Nothing successes like success.", Interviewee 4). Projects in the Netherlands, the UK, and Norway were mentioned as promising examples which could determine the future of CCUS in Europe. The interviewees on the European level mentioned that CCUS should be used to reduce carbon emissions within the industry sector and not in the power sector (as earlier narratives have suggested) because renewables are further developing and become less expensive; thus, they seem better suited to reduce emissions in the power sector than CCUS. Since CCUS is especially relevant for the industry sector and the investment circles in heavy industries are long, following the interviewees, CCUS-related framework conditions need to be adjusted now in order to substantially help to reach the climate goals.

As main barriers, the EU-representatives mentioned the missing infrastructure and related liabilities, the high costs connected to the low CO_2 price as well as the complexities of CO_2 capture units. Regarding acceptance, the interviewees uniformly stated that the social acceptance of CCUS differs between countries, for instance, from a historical point of view, it was mentioned that the UK and Norway were rather accepting of CCUS whereas Germany (and France) were seen as rather on the negative end of social acceptance of CCUS. In these countries, changing the narrative was mentioned as a possible solution to increase social acceptance as well as implementing more ambitious national climate goals from politics. Regarding relevant actors, politicians, the public, NGOs, as well as industrial players were mentioned. The interviewees shared the view that there is no lack of technologies, science, and research regarding CCUS and that also policy makers are aware of CCUS. However, the latter may require some nudging (and successful CCUS projects) to provide the necessary infrastructure, regulations, and oversight. The interviewees agreed that the future of CCUS will depend on the success of current or planned CCUS projects and that it is important to act as soon as possible to reduce carbon emissions.

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Interviewee 1: "CCS for power is still a No-Go in Europe [... but CCS is] the only maybe mature enough technology for the industry sectors that significantly can cut emissions as off now."

The first interview on the European level was conducted with a representative of a network focusing on climate change. The representative highlighted that the results of their analyses demonstrate that CCUS will play a role for climate change and carbon neutrality.

Sectors

Regarding different *sectors*, in interviewee's view, CCS is not a solution for the power sector (because other renewables are more effective). However, CCS is "the only maybe mature enough technology for the industry sectors that significantly can cut emissions as off now". According to the interviewee, using CCU in the transport sector is not a good idea because "the cost of it does not make sense" (compared to other more effective fuels). Nonetheless, CCU can be used as fuel for aviation "since there are a few options there". Consequently, "for industry, especially for steel and cement, these [=CCUS technologies], yes, will probably have to play a role."

Drivers and barriers

Regarding *drivers and barriers*, s/he mentioned technical issues and CCUS-related costs by stating "there are still technical issues to solve but in principal these are issues that - as the experts at least say - are solvable if you just deploy. [...] You can also not reduce costs by not actually investing in a technology to figure out where I can cut costs". As a benefit, s/he perceives that CCUS can help to keep current jobs: "Because CCS is an end-of-pipe solution, it would not change current industry clustering that much, meaning you could also preserve current job structures." However, s/he explained that there are many other factors influencing the job structure and that his/her statement is not backed-up by data. As a barrier, s/he underlined that it is important to ensure a real cut in CO_2 emissions when implementing CCU: For instance, for aviation fuels, "the source of CO_2 for these fuels needs to come from direct air capture if you want to be really talking about not only postponing CO_2 emissions but actually taking them out from the air and that is currently not what is under discussion". S/he described further that CCU often raises the question of who gets the benefit from this CO_2 cut (industry or transport/aviation), "whereas in reality no CO_2 has been cut, you are just postponing it. That is for us a real concern and that is not something where we should spend our time if we are talking about carbon neutrality. [...] If we are talking about net-zero, we are talking about net-zero."

Social acceptance

Regarding *social acceptance*, s/he highlighted that s/he does not like the term "social acceptance" because it presents a dichotomous view (whether one accepts a technology or does not): "I think it's a much more of a nuanced debate around it. It's scepticism whether this could then hinder [...] the development of other technologies, other processes". In his/her opinion, social acceptance can be improved by "better understanding of what is required for heavy industry" but also by realizing planned CCUS projects (for instance in Rotterdam and Norway) to show what actually works. According to the interviewee, successful projects lead to social acceptance and, in addition, can help to increase political acceptance: "There have been a lot of projects that have been started but that have for various reasons not worked. So this perception that CCS is difficult and expensive is very much in many politicians' but also other stakeholders' minds, so making sure that it actually works so you can disprove this narrative still needs to happen."

Actors

Regarding *CCUS-related actors*, s/he mentioned that CCUS seems relevant for several actors, however, they encounter different barriers: "Things are moving but not fast enough". In the interviewee's view, this is probably the case because relevant actors are very fragmented but

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currently his/her organization aims to build a coalition that focuses on industry decarbonization in general - including CCUS. S/he presented an issue by stating "industrial players that we think actually could have benefits from this [=CCUS] see that there is no business case. NGOs are not vocal about it, there is no infrastructure, why should they be vocal about it then? They know under current conditions they are only going to lose money if they would invest in this". Thus, in his/her view, all actors are important: NGOs, industrial players, the public and especially politics because they often decide about the finances and infrastructures.

Future of CCUS

Regarding the *future of CCUS*, s/he thinks that it depends on future CCUS projects: "I'm optimistic that it actually steps up but it depends also a bit on making sure that certain projects are realized". To conclude, the interviewee stated that CCUS is needed to reach the 2030 goals (especially for the industry sector) because there is no other option that can replace CCUS (without requiring a lot of renewable energy).

Interviewee 2: "CCS is kind of the conversation changer and an innovation driver for us at the same time. [... Thus,] CCUS is a low-regrets option if not a no-regrets option."

In the second interview on the EU-level, a representative of a European NGO was interviewed. In his/her general view, CCS is prominent when talking about net-zero, but only very few NGOs deal with it and push CCS as a climate solution: "For us, it was always about getting emissions down as fast and as much as possible." Regarding their view on CCU, s/he mentioned that "we are definitely not fans of the CCUS wording because it confuses a lot - two very distinct technology parts [...] For us, CCU is less of a climate technology and more of a sustainability technology [...] because it has very little climate effect in most of the applications. [...] If it is about emissions, you need CCS". S/he also sees the high energy intensity that is needed for CCU products for instance for fuels (here electric vehicles seem more efficient, in his/her view). However, s/he stated that both technologies present an important combination for the future: "It is definitely not either or [...]. It definitely is CCS AND CCU".

Sectors

Regarding *sectors*, the interviewee stated that s/he does not perceive CCS as a solution in the power sector: "For us, the focus is really to deploy the most efficient and effective mechanisms wherever they can be applied. So for electricity and power, I think renewables have proven to be the way for that." In his/her view, the oil and gas industries are very present in discussions on CCS, however, when it gets to concrete plans, s/he does not perceive them as very active.

Drivers and barriers

Regarding *drivers and barriers,* as a key benefit of CCS, s/he mentioned to reduce emissions from a huge industry to have a chance to get to net-zero. As a main barrier, s/he explained that "CCS is always an additional cost." In his/her view, the biggest challenge to get the emitters on board of CCUS projects is the question "what will be the price tag for the transport and the storage". Due to the infrastructure, the price for CCS is often too high (45-60€/t vs. < 10€/t). As another possible barrier, s/he underlined the diversity of the regional and industrial conditions: "Not every region is the same, not everyone has the same potentials and the same geographic that allow for you to make the best use of the one technology".

As a further benefit, the interviewee from the European NGO perceives CCS as the conversation changer and innovation driver at the same time: "We always see CCS as the conversation changer. As I said, currently everyone goes around and says 'Oh, we can't do it. It's too difficult [...], it costs so

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much. Let's just retain this kind of notion of unavoidable CO_2.' But once you have CCS in place, once you have your zero-carbon cement, your zero-carbon ammoniac production suddenly you have changed the conversation". Consequently, in the interviewee's view, other companies then need to follow this example and cannot hide anymore behind the excuse of unavoidable emissions. Moreover, having CCS implemented can lead other companies to think "I need to drive my innovations fast and better and I need to be more competitive, I need to find new ways." presenting CCUS as an innovation driver.

As a main barrier, s/he mentioned the installation of the infrastructure and of the CO_2-capture units. S/he experiences a need for political regulations: "It is down to government to set the boundaries so clearly that the companies know what they are dealing with." Because s/he perceives a big trust issue between different *CCUS-relevant actors*, namely between NGOs and emitters on one side and the oil and gas industry on the other side. In his/her view, the oil and gas industry try to get the infrastructure in place and try to get as much as possible out of the CCS process: "Once we have made our investments into the capture units and we are hooked up to the system (=infrastructure for transport), what stops them (=oil and gas industry) to renegotiate the deal." Furthermore, s/he mentioned that projects in Norway, the UK, and the Netherlands show that "we do not actually need the oil and gas players to be part of CCS. All we need is technical expertise to implement the infrastructure. [...] So, what we would like to see is [...] governments providing CO_2 infrastructure and options to access these infrastructures fairly across different industry sites across Europe. So companies can actually make the decision."

Actors

To summarize, regarding *CCUS-relevant actors*, s/he mentioned that it is important to sort out the best role of government and operators (1) to prevent monopolization, (2) to provide fair access to infrastructure, and (3) to protect domestic industry. S/he sees the initial infrastructure to have the highest risk (who is liable for it) and the highest costs (who pays for it; single-pay at the beginning or spreading of costs over the lifetime): "Each part of industry is only capable of taking care of the one thing they know how to do. [...] There is too many complexities, too many counter-party risks in this chain, too many cost issues, too many regulatory issues. [...] There will need to be a governmental oversight and a very clear and central oversight and to have regulations - at least for the start".

Social acceptance

In his/her view, the *social acceptance* of CCS varies largely depending on regions and countries as well as various other factors. However, s/he experienced that social acceptance can increase immensely, once a net-zero plan is in action; as the project in the Netherlands has shown: "Once the government decided the new ambitious targets for emissions and CCS needed to be back on the table, the conversation that you were having with people about the value that is attached to CCS, (1) the retaining of industry, (2) a clean industry, (3) being a pioneer showing the world how it is done, and (4) being able to keep the jobs in a new clean industry was very appealing. So there was a public acceptance of the technology that came from the idea of the economic value and the jobs value of the technology." Thus, according to the interviewee, national targets (and NDCs) with more ambitious climate target goals could help to trigger more public acceptance of CCS. In other countries, like Norway and the UK, s/he perceived that implementing CCS was relatively easy because there was a trust in and social acceptance of the engineering work that is well known and established in these countries. "In Scotland, for example, kids said 'my father got the oil and gas out for the UK and I'm going to put the CO_2 for the UK back in.' " Since this cultural association with CCS is rare, s/he sees a loss in support of CCUS by the UK leaving the EU. In his/her view, on the EU-level, social acceptance issues are solvable. S/he believes it will depend on France and Germany. S/he stated that Germany is the country in which the resistance is perceived to be the largest, however,

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there were many misperceptions, for instance "the connection with coal, having an extension of fossil exploration is generally a bad idea" and the misperception of German politicians of the public acceptance. In the interviewee's view, the apparent resistance in Germany is created by small activist groups and the media because in fact most people in Germany do not even know about CCUS. To increase social acceptance of CCUS, s/he mentioned (1) a shift of the narrative and the associated danger with CCS (linked to fracking and the pollution of ground water) and (2) a strategic plan of the government how to implement CCS in the existing industry. "The more difficult one is of course the emotional side of this and that is the fear of a fossil lock-in, that is the fear of paying money to oil and gas industries who keep polluting and now we are paying them to put their waste back basically. The double paying issue". For this, the interviewee did not see an easy solution.

Future of CCUS

Regarding the *future of CCUS*, although s/he believes that alternatives to CCUS will evolve, s/he highlights that it is important to start CCS now (and not in the next 10-15 years): "In the long-term, there will be alternatives, there have to be, simply because CCS will always be an added cost to your production. [...] But that is not to say that we shouldn't do CCUS now and wait for those magical unicorns to appear at some point in the future. [...] That is the next big issue, that you are basically missing the crucial time of industry right now to make the investment decisions that they need to make. [...] So, from my perspective, the risk of delaying actions is only decreasing. So, developing CCS now is - if it is not a no-regrets-option - it's a low regrets option." Further, s/he believes that the industries are ready to deploy CCS, they only need the certainty that they will stay in business once they have implemented CCS and that social acceptance will increase: "I think they are waiting to have access to these storage networks and they are waiting for the people to then also recognize this is running, this is working, this is safe, we can do it". In his/her view, this requires political leadership regarding the infrastructure and regulations, and the current CCUS projects to be successful.

Interviewee 3: "Nothing successes like success"

Interviewee 3 at the EU-level was a representative of an international think tank stating that "we are not a lobbying organization or a trade association. [...] We try to be policy-relevant but not policy-prescriptive." Consequently, s/he was in favour of CCUS: "It is going to be extremely difficult - if not impossible - to get to net-zero unless CCUS is one of the options, one of the tools that we have in our efforts, to tackle climate change." Thus, his/her organization aims to accelerate the deployment of CCUS - "it's not a silver bullet but - together with renewables, efficiency etc. - we think that it needs to be one of the key components".

Sectors

Regarding *sectors*, similar to the other interviewees, s/he described a change: "CCUS was seen as a way of cleaning up coal-power. [...] Particularly in Europe, coal is now out of the agenda. CCS is not going to be applied to coal-fired power plants. [...] I think I can say that with certainty." - especially with the decreasing price for renewables. According to the interviewee, "the role of CCS, CCUS, in Europe will be heavy industry. For decarbonizing steel and cement in particular." S/he mentioned that there are some options to decarbonize these industries but these options require electricity, which does not really cut the CO_2 emissions; thus, CCUS appears to be an essential option.

Drivers and barriers

Regarding *drivers and barriers*, s/he mentioned financial aspects as a barrier: "It is perceived as an expensive technology and at the moment and in the absence of having a robust business case particularly for heavy industries like cement and steel, it adds to the cost of the final product". Also,

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following the interviewee, border taxes that are currently discussed by the EU commission in light of the Green New Deal could play an important role for CCUS because cement that is produced with a low-carbon footprint by using CCUS is twice as expensive as the cement with the usual production. Consequently, it would be cheaper to buy cement from countries that do not use CCUS. Here, a regulation seems necessary. As a benefit of CCUS, s/he explained that CCUS can keep people employed in the same or similar positions, it can keep industries intact and clean up their emissions at the same time. Thus, "I think there is an industrial and economic transition benefit for the EU." As further barriers, s/he mentioned, firstly, the need of a robust business case for CCUS: "There is social responsibility and climate targets etc. so there is movement in terms of wanting to deploy it but it still remains expensive." Following his/her description, companies will not invest unless they are obligated to do so or unless there are some revenue benefits. Secondly, according to the EU-representative, the low carbon price represents one component of a barrier but a smaller one since it is starting to pick up. Thirdly, s/he highlighted the need of initial projects and the understanding how CCUS could work. Fourth, s/he mentioned the relevance of political support for companies that deploy CUS: "Will there be demand for it? Could they have things like clean cement certificates? Could the governments regulate that a certain amount of cements that has been bought will be low carbon cement etc. etc." However, generally, the interviewee sees "strong developments", for instance the EU innovation fund for early deployment of technologies, therefore s/he thinks "the challenges of CCUS in that sense are well understood at the EU-level and I think they are being addressed. Mostly."

Social acceptance

Regarding *social acceptance*, s/he stated: "I would argue that social acceptance is not a uniform issue across Europe." She experienced in Norway (with two projects) and in the UK more social acceptance for CCUS than in other countries as, for instance, in Germany: "In certain countries, perhaps social acceptance may be something that needs to be addressed and worked on together with various different stakeholders." As a tool to increase the social acceptance of CCUS, she sees a change of the narrative: Using CCUS for cleaning up coal-power "was clearly kind of a big part of the perception in Germany, I think unfortunately, it still remains one part. [...] I think there is still - if I may say - the fear of coal. [...] I think particularly from the environmental NGO community [...], I think there is still a bit of a worry about the fact that this may be about coal. I think that's the biggest reason."

Actors

Regarding *CCUS-relevant actors*, s/he thinks that "more research is always good" - especially promoting the science and making it more easily understandable is quite important. "I think there should be something said about actually communicating science in a better way to people." However, the representative mentioned CCUS projects as a key component: "Nothing successes like success. I think what we need is actual projects up and running." In his/her view, we need projects like the ones in Norway to create support for CCUS, to show that it works, and that it is safe. "Therefore, getting projects actually off the ground is almost more important than doing more R&D necessarily because the sciences - I think - is fairly advanced." Regarding policy makers, s/he stated "I think there is always a bit of nudging that can be done." S/he thinks policy makers are aware and sensitive for CCUS but - since policy makers are often elected - they have to balance different group interests, views, and concerns. In his/her view, NGOs also play a major role and an increasing number of NGOs is looking at CCUS: "I think they obviously know the science, they read the ICCP report" but in his/her opinion, NGOs are afraid that people only talk about CCUS but do not act (which has been validated by Interviewee 3). According to him/her, a reason could be that "things take a lot of time, even with CCUS to plan, to build etc. etc. [...] I think there is a worry that basically it [=CCUS] may deter or slow down other emission reduction opportunities." Moreover, s/he

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underlined that direct air capture needs more research funds because it is expensive and still at the pilot stage. S/he also sees other options for a reduction of emissions like the decreasing price of renewables or planting trees: "I think we should do both, plant more trees, because there are challenges with planting trees and there are challenges with doing direct air capture, in terms of that for planting trees - can you get the number of trees? Do you have the land space? But that's not a reason to say let's not plant trees, let's put all our dreams in direct air capture or vice versa. We got such a massive challenge in front of us that we need to do everything that we can do."

Future of CCUS

Regarding the *future of CCUS*, s/he said "CCUS is not a magical answer" but it will certainly play a role in the next five years or even earlier. S/he stated that if we want to change something in heavy industry, "we should get started with CCUS. I think it is kind of a robust answer in a lot of ways." S/he is looking forward to getting green light for a number of projects in Europe (for instance, the off-shore storage in Norway and the project in Rotterdam). As a conclusion, s/he mentioned: "We need to do it and we need to do it now!"

Interviewee 4: "We are going too slow - way too slow"

The forth interview on the EU-level was conducted with a representative of a European Commission's Directorate-General (DG). In general, s/he thinks that CCUS is essential to reach the climate goals: S/he stated that CCS is one of the "building blocks for climate neutrality". Regarding their view on CCU, "our position is much more clear on the CCS part and the U-part is a very cautious position because we also look from the climate perspective."

Sectors

Regarding *sectors*, similar to the first interview, the EU-representative mentioned a change regarding the use of CCS: "We were much more optimistic in the past with CCS [...] because that time the focus was on CCS on power [...]. Now this has changed entirely because with the renewable energy getting much cheaper, we actually see much less needs to have CCS on power [...]. So now the focus is more on CCS on industry and industrial installations - especially those who do not have an alternative." S/he explained that especially for cement and steel CCS appears promising: "For cement, there are some process emissions you cannot do anything with. For steel, there are some process emissions. There are some technologies though that may remove even these process emissions, for instance, if you use hydrogen - but they are expensive. CCS is expensive and they are even more expensive." Thus, even though the role of CCS became smaller due to other developments, in his/her view, CCS is an indispensable solution for climate change, and "therefore, we really need to continue the development throughout Europe". In his/her view, the benefits of CCU for climate neutrality are less clear and need to be determined for each product and projects separately: "We are taking a more cautious approach with CCU generally because it is also not very energy-efficient. Well, it's hard to generalize". Moreover, s/he explains that "quite often the people do not realize that utilization is actually limited to the market of this product [...]. Nowadays with emissions, you can use 10%. So with the other 90% you have to do something else - maybe you have to avoid them or you have to use CCS."

Drivers and barriers

Regarding *barriers* of CCS, s/he explains that the infrastructure is often missing, even though the industrial conditions are given: "Quite often there are clusters, there are all these industrial clusters so it is possible to have, to develop regional infrastructure for collecting the CO_2." Another barrier for CCS might be a potential leakage: "For CCS, the problem of course people raise often, is how secure the storage of CO_2 is." In his/her opinion, a leakage is very unlikely because the directive is very strict regarding the selection of a suitable storage site; there are many regulations also

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regarding monitoring: "There will be a lot of preventive measures and corrective measures, the selection of a corrective measures plan that has to be adopted in advance of any permit being given". Here s/he highlighted another problem: The storage site managers are liable for the unlikely case of CO_2 leakage. However, one cannot calculate the potential costs for CO_2 in the future, thus you cannot insure against the risk of a CO_2 leakage - according to the interviewee, this is a barrier because it makes CCS really expensive. Moreover, this problem is intertwined with another barrier. S/he mentioned that there is a lack of knowledge - not regarding the technologies but regarding the legislation and the steps that have to happen before CCS: "It is really a lot of preparatory work and a lot of insurances which have to be given to the state before actually CO_2 injection takes place." A fifth barrier for CCS, that s/he mentioned, is the low CO_2 price because the CO_2 price is cheaper than CCS so from an economic point of view it does not make sense to develop a CCS site.

Social acceptance

Regarding *social acceptance*, s/he referred to the strict regulations and the lack of current CCUS projects: "From the public side, we want to prevent this [= CO_2 leakage] ever happening, so we do not really want to relax the very restrictive requirements of the directive - especially in the lack of any projects in Europe. I mean, when we see how it works, when we have 10-20 projects then we can think of perhaps relaxing the very strict requirements of the directive." Furthermore, in his/her view the social acceptance of CCUS, "is very cultural-specific. Some countries are much more aversed to new technologies like Germany or Austria for example. In other countries, people are not so concerned", however, she explained that it is difficult to generalize because it also depends whether the storage is on-shore or off-shore: "If it is away from population there is much less public resistance" (but of course only a few countries in Europe do have off-shore access). Moreover, s/he underlined the importance of projects across European countries: "It does not make sense to have CCS country by country [...] Germany has to team up with neighbouring countries. They realize it but there is still very little going on in concrete steps to get us somewhere."

Actors

Regarding *CCUS-relevant actors*, s/he stated that "we still need an overall EU-plan for CCS. ... There is a lot going on in the West of Europe, it is still very dispersed and it does not touch the right actors or the right actors are not fully involved. Perhaps they are not given green light in their ministries to develop further, to do more - most probably this is the reason". As important actors, s/he sees not only the national government but also involving the responsible persons for planning CCS sites on the local and regional level. In his/her opinion, companies need a business case, an obligation, or no other alternative, to deploy CCUS. "The other problem is: If you are industry or power installation, you do not have the knowledge or you do not even want to develop the knowledge to start building pipelines or starting a storage site - it's a completely different business. [...] But somebody has to start it in some ways." According to the interviewee, starting to plan a storage site is the first step which leads to dealing with the next problem: CO_2 capture. S/he underlined the importance of the government to support the cost of the difficult CO_2 capture: "The only benefit of all this complication is that you do not have CO_2 in the air, I mean you do not have any other benefits. So, the only benefit, potential benefit, is that you do not pay the CO_2 price. There is no other benefit, unless the government provides any other." S/he thinks that support organizations such as NGOs are well connected and build a small CCUS community which s/he evaluates as good but in his/her view their actions could be more efficient because s/he has often experienced overlaps. Regarding research and education, s/he thinks that there is enough funding, referring to the innovations funds for large demo-projects. However, s/he mentioned that there is still a gap of what can be provided and what is needed for a pilot installation.

Future of CCUS

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Regarding the *future of CCUS*, s/he highlighted the need of projects that implement CCUS to see how it works: Other than in the Netherlands, the UK, and Norway, "you just do not see any proper planning in any other country". In his/her view, the project of Rotterdam is a good model which has only one operator to ensure that one company (the harbor of Rotterdam) provides the infrastructure. According to the interviewee, the project in Rotterdam can be replicated in other industrial clusters: "So in the future this is the model which is likely to prevail and it's good that they are starting in this way. [...] The risk is 'Will there be enough installations?' I mean they have a lot of industries with potential interest but how many of these will indeed sign contracts?" In this line, the financial aspect seems to be an important factor: "All the industries are in fact looking into other solutions. [...] So if there are other technologies which are cheaper but they are doing the same, they will be taken by the market. [...] Our modelling shows that it will be overall cheaper to have this option [=CCUS] rather than not to have it - in the long-run." Following the interviewee, starting to build CCUS infrastructure now seems to be crucial for a future of CCUS: "The trouble is that all this CCS infrastructure needs a lot of time to be developed. If you are starting from scratch, you need 10 years to develop a CO_2 storage site ready for injection. [...] The biggest concern is that we are going too slow - way too slow". As a closing remark, the EU-representative states that "CCUS is necessary" so it will be hopefully deployed in the future.

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4 Summary of results

France (Paris Basin)

- Most of the interviewees considered that the implementation of CCUS technologies will have a relevant role to reduce CO2 emissions in the industry and energy sectors. The interviewees mentioned that CCU has more potential than CCS although the use of CO2 is limited.
- Interviewees outlined some benefits associated to the development of CCUS technologies in the region: environmental benefits (reduction of CO2 emissions), economic benefits (employment generation, attraction of new actors, generation of a new industry, potential attraction of investments to the region and regional leadership in the technology) and other benefits related to the benefits for companies and the promotion of a circular economy.
- Regarding the potential costs of deploying CCUS technologies in the region, interviewees referred to several issues: the economic viability, environmental risks (risk of leakages impacting the local environment and public health) and social impacts (public opposition and the risks for the identity of the region).
- Most of the interviewees accepted the implementation of CCUS technologies. Interviewees were, in general, positive about the use of CCS along with other low carbon technologies. The interviewees were positive about the potential benefits of CO2 use applications.
- Regarding the conditions of acceptance of the implementation of CCUS technologies in the region, interviewees referred to four main conditions: local acceptance, transparency and involvement of the civil society, interest from the industry (specially the users of CO2) and investments in CCUS that do not compromise investments in other technologies.
- As for the barriers for CCUS deployment in the region, most of the interviewees referred to financial and economic issues (lack of funding, high costs relative to the cost of emitting CO2 and low return to investments), safety considerations (potential threats to human health) and local opposition (mainly regarding CCS).
- Regarding the enablers for the development of CCUS projects in the region, interviewees mainly referred to two main issues: Existence of favourable geological formations for CO2 underground storage and interest in sustainable energy in the region.
- There was the general perception that the industry is technically skilled to develop and implement CCUS projects. However, some interviewees were sceptical about the intentions of the fossil fuel industry in adopting CCUS technologies. The lack of interest from policy makers was also mentioned by the interviewees.
- Overall, most of the interviewees considered that CCUS should be part of a broader strategy. CCUS technologies were perceived as part of the solution to climate and energy problems to introduce in the medium term.
- Most of the interviewees were positive about the prospects of CCUS in the region. Some of them considered that there will be CCUS projects in the coming 5-10 years while other interviewees believed that CCUS projects will proliferate in the long term. This positive expectation was usually based on the existence of pilot projects and the existence of active industries in the region. On the contrary, some interviewees were more negative about the future of CCUS, based on the existence of public opposition and the expectation that the market for CO2 use is going to remain small in the medium term.

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France (Rhône Valley)

- Most of the interviewees in the Rhône Valley region considered that the implementation of CCUS technologies would help in climate change mitigation. They commented that CCUS should be considered as one option among many options to reduce CO2 emissions. Some interviewees, however, were more negative about CCUS technologies and considered that CCUS should play a limited role in the solution.
- The main benefits of developing CCUS technologies mentioned by the interviewees were: environmental benefits (climate change mitigation, carbon neutrality in the industries, pollution reduction), economic development (new industries, employment, investments, allow power plants to keep working) and other benefits (new possibilities for the hydrogen sector, benefits for companies and the promotion of circular economy).
- Regarding the potential costs of the development of CCUS technologies in the region, interviewees referred to several issues: economic viability (high cost and local industry competitiveness), environmental risks (risks of leakages) and social impacts (public opposition).
- Interviewees were, in general, positive about the implementation of CCUS in the region along with other low carbon technologies. The interviewees were positive about the potential benefits of CCUS applications in terms of climate change mitigation and technological and socioeconomic development.
- Regarding the conditions of acceptance of the implementation of CCUS technologies in the region, interviewees referred to three main conditions: public acceptance, a favourable regulation and interest from policy makers and a reduction of environmental impacts.
- As barriers for CCUS deployment in the region, most of the interviewees referred to financial and economic barriers (economic feasibility of CCUS projects), lack of socio-political acceptance and technical feasibility.
- Regarding the enablers for the development of CCUS projects in the region, interviewees mainly referred to the existence of industry in the region interested in CCUS technologies.
- Generally, the interviewees trusted the technical capabilities of the local industry to implement CCUS projects in the region. Some interviewees also discussed the important role of research centres, the local community, environmental organizations, regulators, and inspectors in the development of CCUS projects in the region.
- Overall, most of the interviewees considered that CCUS should be part of a broader strategy to reduce emissions by reducing consumption, improving energy efficiency and transitioning to renewable energies. CCUS technologies were perceived as part of the solution to climate and energy problems, potentially to be introduced in the medium term.
- Most of the interviewees were somehow positive about the prospects of CCUS. Some of them considered that there will be CCUS projects in the coming five to ten years. Other interviewees believed that CCUS projects will proliferate in the long term. This positive expectation was usually based on the perception that the region and industries are very active. As some interviewees stated, CCUS could develop faster than expected as the region is very active on sustainability issues and already has a dense network of actors involved.

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Spain (Ebro Basin)

- Most of the stakeholders considered that CCUS technologies will play a relevant role in decarbonisation of the energy and industrial sectors. While these technologies will be critical in the long term for the process industries, options for CCUS in the energy sector will be limited. The use of CO2 in the development of products and services was perceived as promising in the long term but currently insufficient to result in significant reductions in CO2 emissions. The storage of CO2 was perceived more problematic than the use of CO2.
- Regarding the benefits of developing CCUS technologies in the Ebro Basin, the preservation of the local industry, new socio-economic opportunities (development of new industries, job opportunities and wealth creation) and technological development are the key benefits perceived by stakeholders.
- As for the costs of deploying CCUS technologies in the region, the interviewees focused on cost-effectiveness considerations. The high price of capturing a ton of CO2 and the need for important investments in infrastructure (for capture and for storage) were the main highlighted costs. Interviewees also mentioned other costs related to the potential environmental and social impacts related to CO2 storage.
- Interviewees were mostly favourable towards the development of CCUS technologies in the Ebro Basin region. Support for the deployment of CCUS in the region was based on a favourable attitude towards CCUS technologies in general as well as on a recognition of the potential benefits of CCUS projects for the region. A minority of interviewees rejected or were sceptical about the deployment of CCUS projects in the region.
- Several enablers and strengths to the development of CCUS technologies in the region were identified by the interviewees: the existence of process and petrochemical industries potentially interested in implementing CCUS technologies, the onshore storage capacity in the region and the existence of research centres which focused on these technologies.
- The main barriers mentioned by the interviewees were: low demand for utilization of CO2, public opposition, lack of political and regulatory support, the distance of potential storage sites from large emitters and the lack of high emitters in the region.
- There is a significant level of trust in the industrial sector to implement CCUS technologies in the coming future. However, interviewees tend to report a low level of trust in the government to promote CCUS technologies. Regional government was perceived as more supportive of CCUS technologies than the national government.
- CCUS would compete with alternative options to decarbonisation. For some interviewees, CCUS technologies would complement existing and future renewable technologies. For other interviewees, the existence of alternatives for decarbonisation limits the value of implementing CCUS technologies.
- Interviewees tend to be more optimistic in the development, in the medium-term, of small scale projects of CO2 than with big capture and storage projects (perceived as more complex and dependent on active political support).

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Portugal (Lusitanian Basin)

- In Portugal, stakeholders generally perceived CCUS technologies as an important component for climate change mitigation and decarbonisation. More importantly, the reduction of CO2 emissions from the cement industries and large consumers of natural gas industries (e.g., glass industry) was perceived as a critical area for the development of CCUS technologies.
- The potential benefits of CCUS technologies were discussed in terms of the decarbonisation of the process industry in the region, the potential socio-economic impacts (job creation and the generation of new industries in the region) and the achievement of the CO2 emissions national reduction targets.
- The economic cost of implementing CCUS technologies, the fact that CCUS imply new processes for the industry and it is a technology without the necessary maturity and reliability and the potential environmental impacts and safety issues were regarded as potential drawbacks of deploying CCUS projects in the region. The need for new infrastructures was discussed but generally it was not considered a key cost of CCUS technologies for the region.
- The interviewees were divided between support and ambivalence regarding the implementation of CCUS within the Lusitanian Basin. Support for CCUS was linked to a positive position regarding the potential role of the technology in climate change mitigation and to decarbonisation of the process industry, linked to potential socio-economic benefits. Ambivalence was linked to the perceived costs and barriers in the implementation of CCUS, a preference for alternative options and a rejection of carbon capture and storage.
- As important conditions for acceptance, the interviewees considered cost effectiveness of CCUS projects, reduced environmental impacts, government leadership and the sense of urgency of climate change mitigation.
- As potential barriers for CCUS developments, the interviewees discussed the economic cost of implementing CCUS technologies in some industries, the problems linked to social and public acceptance and the need for new infrastructures. Generally, these aspects were not perceived as major barriers.
- The existence of cement, glass, ceramic industry interested in reducing CO2 emissions as well as the existence of good geological storage sites were considered key enablers in the region.
- Doubts were expressed by the stakeholders regarding the capacity of the process industry in the region to lead CCUS projects. Also, doubts were expressed about the intentions of the national government and the capacities of the local authorities to foster CCUS developments. Universities and research centres were perceived as having the knowledge to support industries and policy makers on their decisions
- Regarding the alternatives to CCUS, some interviewees considered that there are no alternatives for some industries (e.g. cement) to reduce their process emissions. Other interviewees commented that there are alternative measures as the increase of energy efficiency and use of more clean fuels (e.g., in ceramic and glass industries) that can reduce/eliminate the need of CCUS technologies. Generally, stakeholders considered that CCUS may be a solution but just after the deployment of other measures.
- We found positive, neutral and negative expectations about the future of CCUS developments in the region.

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Croatia (Northern Croatia)

- In general, the interviewees' attitudes regarding CCUS technologies and its role in climate change mitigation was positive and most interviewees supported a CCUS project in the region of Northern Croatia.
- Regarding the benefits of developing CCUS technologies in the region, the interviewees mentioned environmental benefits (reduction of CO2 emissions and improvement in air quality), economic growth, reputational benefits for companies and social benefits (the creation of new jobs and new collaborations between research, industry and investors).
- As for the costs and negative impacts of the development of CCUS technologies in the region some interviewees mentioned the following: public scepticism and public resistance, high cost of implementing CCUS, potential leakage of CO2 and security of CCUS, poor application or inappropriate use of the CCUS technology.
- Most of interviewees were rather positive about the development of CCUS technologies in Northern Croatia. Support for the use of CCUS in the region was based on the benefits of these technologies. No interviewee mentioned a sceptical or opposing view regarding the introduction of CCUS projects in the region.
- As conditions for a possible CCUS project in Northern Croatia, the interviewees expressed that a feasibility study and economic analysis would be necessary to estimate the financial costs. Moreover, the general public should be involved and informed about the processes, the benefits as well as the risks and consequences to avoid potential public resistance. Additionally, a legislative framework that supports CCUS (and nudges companies to invest) was seen as a condition for a successful implementation of CCUS technologies in this region.
- The main barriers to CCUS technologies identified by interviewees were the high cost of implementing these technologies and the lack of funding; the insufficient awareness of the benefit of CCUS implementation and of climate change issues related to CO2; the lack of expertise and knowledge about CCUS technologies and the lack of support from politics and companies.
- Some enablers to the development of CCUS technologies in the region were identified by the interviewees: the use of the existing database of geological, geochemical, geophysical and well data when estimating storage capacities suitable for geological storage of CO2 and the existing mining facilities and technological resources. The existing conditions in Northern Croatia were perceived as a good fit for CCUS. They also mentioned that there are greenhouses with plants and algae in the region that could use the captured CO2.
- Most interviewees stated that a collaboration of researchers, policy-makers, and industry is desirable. Whereas industry and project coordinators were perceived as being capable of handling CCUS implementation processes, the interviewees saw a need to nudge policy makers.
- Regarding the future of CCUS and alternative options, most interviewees mentioned renewable energy sources or energy efficiency as possible other options.
- Most Croatian interviewees were positive and hoped that CCUS will be implemented in the future in Croatia to use all option that lead to decarbonisation.

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Romania (Galati region)

- In general, interviewees in Romania shared a similar opinion and expressed a positive general attitude toward CCUS technologies.
- The main benefits of developing CCUS technologies mentioned by the interviewees were: environmental benefits (reducing CO2 emissions and the pollution), health benefits (decreasing pollution-related diseases), economic benefits (maintaining and/or creating new jobs, new products and new business models, promotion of the region) and the maintaining of using fossil resources.
- As costs of deploying CCUS technologies in the Galati region, the following aspects were perceived as key costs by the interviewees: lack of expertise, high financial costs including an unfair process due to the missing CO2 price, the potential risk of leakages (with related impacts on the biodiversity and life), that it will slow down or hinder the development of other options and renewable technologies, that people could lose their jobs, and the public acceptance.
- Most stakeholders were positive about the implementation of CCUS technologies in the Galati region. Support for CCUS projects in the region was based on the benefits. Some interviewees mentioned to prefer CCS over CCU. Only two interviewees were neutral or more sceptical about the introduction of CCUS projects in the region.
- Regarding the conditions of acceptance, the interviewees stated that awareness of the required CO2 reduction is rather low in Romania. For this reason, more information and a favourable communication is required to achieve a proper understanding. Also, policies and regulations as well as involvement and training of relevant stakeholders are needed to create social acceptance.
- As barriers, the aspects mentioned, among others, were: lack of funding / money; lack of knowledge, information and awareness regarding environmental issues and the effects of CO2 in the general population as well as in many companies; consequences and/or regulations are required to convince the industry and operators to implement CCUS; lack of support and interest from authorities, political actors, and administration; difficulties to obtain permits and difficulties to obtain data from operators and similar projects in Romania and lack of cooperation and collaboration of relevant actors.
- Interviewees considered that universities and research centres should play an important role. They also mentioned NGOs and support organisations as an important support for CCUS. They were rather sceptical regarding the capability and support of political decision makers. Most interviewees trust in project developers, technical specialists and the industry to handle the technical and coordination challenges when implementing CCUS.
- Regarding the future of CCUS and alternative options, interviewees do not currently see a comparable alternative to CCUS to help for carbon neutral objectives on the short term and stated that CCUS technologies must be used together with renewable energy sources. CCUS is considered a transitional technology, an alternative for the problems we are facing today in terms of pollution and climate change, until we find something better.
- Most of the interviewees were hopeful or optimistic about the future of CCUS in Romania. Regarding the timeframe of CCUS implementation, the views of the interviewees differed (from in the next few years to 20 years at least). Importantly, even the most optimistic

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interviewees expected that the implementation of CCUS will take longer than 5-10 years. However, only a few interviewees were pessimistic regarding the future of CCUS in Romania.

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Greece (West Macedonia)

- Most of the interviewees supported CCUS technologies. They stated that the diffusion of CCUS applications could help to cut CO2 emissions and hoped to extend the life of Western Macedonian lignite mines and power plants. However, other interviewees rejected the idea that CCUS should be widely rolled out in this region. They stated that CCUS does not have the potential to reduce as much CO2 as it would be sufficient and that the technology is not ready now.
- The benefits that interviewees mentioned were mainly related to the economic development, the creation of jobs and the environmental protection (reduction CO2 emissions and air pollution).
- Regarding the potential costs and negative impacts of developing CCUS technologies in Western Macedonia, some interviewees referred to the potential risk of storage failure. Explicitly, leakage due to an unpredicted event such as earthquakes, aquifer contamination and micro-seismicity were mentioned.
- The interviewees were rather positive about the development of CCUS technologies in the Western Macedonia region. Support for the use of CCUS in the region was based on the already mentioned advantages of CCUS technologies such as economic development and securing jobs. However, it was also mentioned that there is currently no comprehensive strategy in place to drive the implementation of CCU infrastructure, and furthermore that the focus should be on CCU instead of CCS.
- Interviewees suggested a number of conditions that need to be met for the successful implementation of CCUS applications in Western Macedonia. These conditions refer to costs (financial viability), acceptance issues (adequate information), state initiatives (new and adequate legislation) and more research (further high quality geological studies).
- The main barriers to the implementation of CCUS technologies in the region mentioned by the interviewees were related to investment costs, know-how of CCUS related infrastructure and resistance of the local population.
- Trust in project developers and industry was generally prevalent although scarce knowledge was often brought up as a limiting factor. Interviewees considered that regional policy maker and administration are generally open to help implementing CCUS projects. Among the interviewees, universities were generally believed to play an important role.
- As for the preference of alternative options, some interviewees perceived the use of other renewable technologies as a viable option that should be taken into account. Apart from that, one interviewee suggested to produce hydrogen. One interviewee believed that CCUS is the only viable large-scale option to decarbonize the coal industry.
- Concerning the future developments of CCUS in the Western Macedonia, the opinions differed. Some interviewees expected to have CCUS infrastructure in the near future. Others were not sure about the future developments of CCUS in the region and other few interviewees were quite sceptical. The reasons given for a soon successful implementation were that the country's decarbonisation policy creates a climate for the development of projects. However, this was countered by the looming exit out of coal power over the next years and the economic problems that Greece is facing.

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Poland (Upper Silesia)

- Some interviewees emphasized the important role of CCUS technologies in the decrease of CO2 emissions and in the decarbonisation of the studied region in Poland. Other interviewees rejected the idea that CCUS should be widely rolled out in Poland. The main reasons, among others, were related to the potential and utility of CCUS technologies, the maturity and the cost of these technologies, problems with geological sites and a lack of social acceptance.
- Regarding the benefits of developing CCUS technologies in Upper Silesia, the reduction of CO2 emissions, preserving the coal industry, the increase of employment opportunities, and the health benefits to the residents were mentioned as key benefits by the interviewees.
- As costs and negative impacts of deploying CCUS technologies in the region, the interviewees mentioned uncertainties about environmental effects (it is not known what are the long term environmental effects of CCUS technologies), uncertainties about sufficient market potential of CCU based products in the region, high initial costs, large costs for the transport infrastructure and higher energy costs due to reduction of power plant energy efficiency.
- Interviewees were rather positive about the development of CCUS technologies in the Upper Silesia region. Only a minority of respondents were opposed or sceptical about the introduction of CCUS projects in the region. They suggested some conditions (related to costs, infrastructure, public acceptance and the need to further research and development), that have to be met for the successful implementation of CCUS technologies.
- The main barriers mentioned by the interviewees were: lack of financial support and social opposition. Other barriers, such as limited CO2 storage possibilities, high initial costs of CCUS related to infrastructure investments, doubts about if there is sufficient industrial players to make use of CO2 and the need to adapt some regulation or to pass new laws, were also mentioned by few interviewees.
- Interviewees believed that regional administration could support the implementation of CCUS technologies. They attributed to NGOs an important role in the process of CCUS development. Universities and research centres were perceived as well developed in the region having experience and sufficient know-how to assess the effects of CCUS implementation. A crucial role in the decarbonisation process was attributed to the coal miners' trade union by the interviewees.
- Preference for alternative options among the interviewees was broad in Upper Silesia. Many stakeholders thought that the energy sector should be completely remodelled in other ways than by solely focusing on CCUS technologies. These alternative options included renewable energies, nuclear energy, and natural gas. The use of green hydrogen and the better use of energy efficiency measures were other alternative options. Only few interviewees perceived CCUS as the only option for substantially decreasing the CO2 emissions in the region.
- Concerning the future development of CCUS, a majority of interviewees thought that CCUS will be implemented in the region. However, the time horizon differed. While some interviewees expected that CCUS infrastructure will be starting to be implemented within the next 5 to 10 years, other interviewees expect 20-30 years as a more likely time horizon. In contrast, other interviewees were not very convinced that CCUS infrastructure will be part of the energy related technology mix in the region.

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5 CONCLUSIONS

Based on semi-structured interviews with selected members of the stakeholder groups in eight regions, we identified stakeholders' overall evaluation of CCUS, their level of acceptance of CCUS developments, sources of concern, perceived benefits and costs, conditions for acceptance, perceived barriers to the development of CCUS in the regions and preferences and expectations for energy futures.

Role of CCUS technologies

Generally, we found that most of the stakeholders consulted in the studied regions considered that the implementation of CCUS technologies would help in climate change mitigation and decarbonisation by significantly reducing emissions in the industry. In countries such as Spain and Portugal, interviewees emphasized the potential role of CCUS in reducing CO2 emissions from the process industries (cement, steel and glass). In France, as well as in other countries, several interviewees emphasized that CCUS should be considered as one among the many options to reduce CO2 emissions. Overall, we found a more favourable attitude towards CCU relative to CCS, although some interviewees perceived CCU as promising in the long term but currently insufficient to result in significant reductions in CO2 emissions

Benefits and costs of CCUS

Stakeholders in the eight regions outlined the environmental global benefits (climate change mitigation) as well as the potential regional benefits of developing CCUS projects. The socio-economic benefits of implementing CCUS technologies were a key topic of discussion in the eight regions. Overall, there was the perception, not shared by all the stakeholders, that CCUS technologies would bring potential regional benefits in terms of job creation and the generation of new industries in the region. The generation of new industries and markets was emphasized by stakeholders in France and Romania. In Spain and Portugal, the preservation of the local industry was considered a key potential benefit of implementing CCUS technologies in the region. The reduction of local air pollution was also considered a relevant topic in Romania, Greece and Poland. As for the potential costs and risks of implementing CCUS in the regions, economic considerations as well as the potential risks for the environmental were raised by stakeholders in all the studied regions. The societal impacts of carbon capture and storage were also considered by the stakeholders.

Acceptance

Overall, most of the interviewees in the eight regions were rather positive about the development of CCUS technologies (this was especially true in Croatia). Support for the deployment of CCUS in the region was based on a favourable attitude towards CCUS technologies as well as on a recognition of the potential socioeconomic benefits of CCUS projects for the region. Only a minority of respondents were opposed or sceptical about the introduction of CCUS projects in their region. These interviewees reported a negative attitude towards CCS, preferred alternative technologies to reduce CO2 emissions and were sceptical about the potential regional benefits of CCUS projects. As conditions for acceptance, interviewees in all the studied regions mentioned the need to consider the costs (financial viability), acceptance issues (adequate information and engagement), and support from the government (new and adequate legislation).

Barriers and enablers

Regarding the barriers for CCUS deployment in the various studied region, most of the interviewees referred to financial and economic barriers (economic feasibility of CCUS projects), lack of socio-political acceptance and technical feasibility. In Spain, Croatia and Romania, lack of support and

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interest from authorities, political actors, and administration was considered a critical barrier. Lack of technological know-how as well as limited CO2 storage possibilities were also barriers mentioned in countries such as Romania and Poland.

Regarding the enablers for the development of CCUS projects, interviewees in the various regions generally pointed out to the existence of process and petrochemical industries potentially interested in implementing CCUS technologies as well as to the onshore geological storage capacity.

Trust in actors

Generally, the interviewees discussed the important role of local industries, national and regional policy makers, research centres, the local community, environmental organizations and regulators in the development of CCUS projects in the regions. Generally, there was the general perception that the industry is technically skilled to develop and implement CCUS projects. Regional governments were perceived as more supportive of CCUS technologies than the national governments in most of the study regions. Universities and research centres were perceived, generally, as having the knowledge to support industries and policy makers on their decisions.

Preference for alternative options

Overall, most of the interviewees in the eight regions considered that CCUS should be part of a broader strategy to reduce emissions together with improving energy efficiency and transitioning to renewable energies. Some interviewees in Spain and Portugal emphasized that there are no alternatives for the process industry (e.g. cement, petrochemical, glass) to reduce the sector process emissions. On the contrary, a minority of interviewees in the various regions saw no role for CCUS technologies given the amount of alternative options for climate change mitigation.

Future expectations

In general, and concerning the future development of CCUS, a majority of interviewees in the eight studied regions thought that CCUS technologies would be implemented in the region. However, the level of optimism, the basis of the expectations and the time horizon differed among stakeholders. While some interviewees expected that CCUS infrastructure would be starting to be implemented within the next 5 to 10 years, other interviewees expect 20-30 years as a more likely time horizon. Other interviewees were not very convinced that CCUS projects would be part of the energy mix in the regions.

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