Stakeholder mapping report

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Executive summary

This deliverable has the aim to provide a first identification of the actor structure in the innovation system for carbon capture use and storage (CCUS), with a focus the European level, the national level, and the regional level. This stakeholder mapping will serve as a basis to prepare the social acceptance studies that follow in the Strategy CCUS project (tasks 2, 3, and 4 in WP 3) but also to inform consortium partners and further deliverables.

Since the diffusion of a technology is not only a technological but also a social challenge, the Strategy CCUS project has a dedicated work package that looks specifically at actors and their social acceptance of CCUS applications. This deliverable lays the ground for this work package. Therefore, it outlines the conceptual framework, reviews the current state of knowledge on social acceptance for CCUS and takes a first look at the relevant actors. These CCUS related actors will be differentiated in this report along three levels: The European level, the national level, and the regional level.

The literature review showed for instance, that the awareness of CCS and CCU technologies in the broader public continues to be rather limited and that acceptance levels are found to be moderate on average. Regarding the local acceptance, the review showed that social acceptance is also influenced by the CO_2 source. Specifically, combining coal-fired power plants with CCUS is less embraced by the public than e.g. integration in heavy industries (Dütschke et al. 2016). CCU is evaluated more positively than CCS (Whitmarsh et al. 2019; Linzenich et al. 2019; Arning et al. 2019a). On a national level, some variety in social acceptance was found. While in the past community acceptance for CCS was found to be lower than on the national level e.g. for Germany, more recent research in the UK detected also more positive evaluations on the local level (Whitmarsh et al. 2019). While a few studies have looked into different groups of stakeholders and experts, the majority of social acceptance research focuses on the broader or the local public. Regarding stakeholders, most approaches involve only very small samples and a differentiation between stakeholder categories is therefore difficult to draw. A more detailed analysis of stakeholder perceptions is therefore part of the second task of this WP.

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1. Introduction

CCUS has been acknowledged as a possible reduction instrument for carbon dioxide emissions. In times of accelerated global warming, the diffusion of CCUS applications becomes crucial. For instance in their most recent report on Global Warming of 1,5°C, the IPCC does not only look at CO_2 capture from industrial plants or fossil fuel fired power plants but also includes bioenergy with carbon capture and storage (BECCS) and even direct air capture with CCS (DACCS) {IPCC 2018 #453D}.

The technical literature on CCUS applications is vast. Also in the social sciences, the literature has been growing over the past years. However, both the innovation system of CCUS as well as its social acceptance has been underresearched (Jones et al. 2017; Karimi and Komendantova 2017). Thus, in this deliverable we extend the perspective on acceptance and stakeholders concerning CCUS and thereby extend the existing literature. Hereby we will define stakeholders as a person such as an employee, customer, or citizen who is involved with CCS technology or a CCS project and therefore has demands and or responsibilities towards it.

The focus of this report from a technological point of view is, in line with the project scope, on the capture of CO_2 at industrial point sources. Point sources include energy intensive industries, mainly heavy industries, and energy generation, mainly fossil fuel power plants. Heavy industry include iron and steel production, cement production, chemicals, pulp and paper, non-ferrous metals, food processing, textiles and leather, mining. Fossil fuel power plants include coal power plants as well as gas-fired power plants. The CO_2 that is captured at these plants can be either sequestrated and stored (CCS) or reused (CCU). Sequestration options include injections in geological formations like saline aquifers or (nearly) depleted gas and oil fields. Use scenarios include many industrial processes for instance in the chemical industry. For instance, CO_2 can be used to produce synthetic fuels. However, potential uses in the Oil & Gas, cement cluster and other process industries, geothermal development, pharmaceutical industry, welding and refrigeration systems, water treatment processes, carbonated beverages and food industry are also possible. Today, most CCS applications are available, while "CCU technologies will need to overcome still a number of challenges related to conversion efficiencies, costs and developing of markets as well as customer persuasion." [1]

So far, several CCUS pilot plants have been introduced across Europe. However, large CCUS clusters have not been implemented. To level the way to such broader implementation, the Strategy CCUS project facilitates the development of CCUS clusters in eight regions across seven southern and eastern European countries. Since the diffusion of a technology is not only a technological but also a social challenge, the Strategy CCUS project has a dedicated work package that looks specifically at actors and their social acceptance of CCUS applications. This deliverable lays the ground for this work package. Therefore, it outlines the conceptual

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[1] https://ec.europa.eu/clima/sites/clima/.../summary_report_en.pdf

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framework, reviews the current state of knowledge on social acceptance for CCUS and takes a first look at the relevant actors. These CCUS related actors will be differentiated in this report along three levels: The European level, the national level, and the regional level. The collection and analysis of CCUS related actors will be informed by the literature on socio-technical transitions as well as the technological innovation system (TIS) (Bergek et al. 2008). The analysis on the European Level is mainly based on a desk research, while the national and regional stakeholders have been found with support from partners from the consortium in the eight dedicated focus regions.

This deliverable is structured as follows: In second section, we give an overview on the concept of social acceptance and differentiate between different layers of acceptance. This is followed by a short introduction to the actor system according to the TIS concept. The third chapter will summarise relevant research into CCUS acceptance. The fourth chapter contains the mapping of CCUS related actors. Here, also the eight regions will be presented. We will finish with conclusions.

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2. Social acceptance and actors

2.1. Social acceptance of new technologies[2]

A definition from Upham et al. (2015) describes (social) acceptance as "a favourable or positive response (including attitude, intention, behaviour and – where appropriate – use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organisation)". It draws on the regularly cited definition by Wüstenhagen (2007) who differentiates socio-political, local and market acceptance as facets of acceptance.

Socio-political acceptance refers to the general societal climate towards a technology or innovation within a society, i.e. it relates to typical discussions about a topic or social desirable opinion. For example, opinion polls on CCS throughout Europe have indicated in the past that a large share of people (36 %) does not have an opinion whether or not CCS is effective in fighting climate change while the rest is divided with a majority being convinced of its effectiveness (39 % vs. 25 %) (Special Eurobaromenter 2011). Socio-political acceptance is shaped and mirrored by opinion leaders, poll data, media and alike.

In contrast to socio-political acceptance, *community acceptance* is a concept that is most relevant for siting decisions and refers to the attitudes and behaviours exhibited by neighbours of installations or others somehow affected by an innovation or technology without actually using it. In case of CCUS this includes the full chain, i.e. the CO_2-Source, the transport by pipelines, trucks or ships etc., and the installations for CO_2 use or storage. As will be outlined in more detail below (chapter 3) most discussions around social acceptance of CCUS have come up around storage sites (Dütschke et al. 2016).

Market acceptance finally refers to the acceptance of a technology that is manifested by market actors, i.e. supply and demand side as well as intermediate actors like installers, consultants etc. It is important to note that acceptance may be a challenge with all of these actors, e.g. as new developments might change their business models or impact their daily behaviours; at the same time, all of them are needed to some extent for the emergence of a functioning system. Relevant actors include for example energy intensive industries as CO_2-sources, operators of CO_2-transport systems as well as on the demand side those potentially using CO_2 for further processes or running storage sites.

As already implied into the examples given above, acceptance has an attitudinal and a behavioural level. The attitudinal level includes the cognitive and emotional response, i.e. how individuals evaluate a technology and how they feel about it. These are often related, but not

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[2] This chapter strongly draws on a similar repot section from another EU-project which focuses on concentrated solar power and cooperation mechanisms, cf. Dütschke et al. 2018.

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necessarily identical and both are open for ambiguity. I.e. one might feel positively excited about a technology, which does not necessarily mean that the person is no longer able to weigh pros and cons of this technology. Additionally, while – amongst other – emotions and attitudes influence behavioural intentions, these are also shaped by additional factors e.g. by control beliefs or personal and social norms. Finally, while behavioural intentions are valid predictors of behaviour, they are not fully determining it e.g. due to situational constraints or conflicting motives. For example, while an investor may be willing to implement a carbon capture application, this behavioural intention may be impeded by a lack of space in an existing industrial installation and therefore imply extremely high costs. Furthermore, the literature also differentiates between decision making ('adopting') and maintaining and implementing this decision over time ('using') (Hameed et al. 2012). In case of CCUS, this could mean that a national or regional government decide to support the diffusion of CCUS related technologies, but later this decision is overthrown for instance by financial restraints.

Already implicit in the differentiations outlined so far, is the notion that acceptance for an innovation or technology is manifested on the individual and the collective level and that these two levels influence each other. For example, socio-political acceptance is shared among a bigger group of citizens within a wider region or country; however, it may be rooted in prominently voiced opinions of relevant societal members. At the same time, literature has also pointed out that perceived social norms of a technology influence individual decision making on technology adoption (Dütschke et al. 2017).

Another question on acceptance refers to the timing and to which type of acceptance is relevant in which stage of innovation development. It is important to note, that what mainly refers to market acceptance already has significant influence on the further development of an idea in early stages where research funds are directed towards certain projects etc.

The concept of social acceptance, as approached in this report allows for a broader perspective on the roles of different actors, their expectations and interactions, and the diverse materialization of technologies at different scales (Devine-Wright and Batel 2017). The figure (see Figure 1) developed by Upham et al. (2015) summarises the notions introduced so far.

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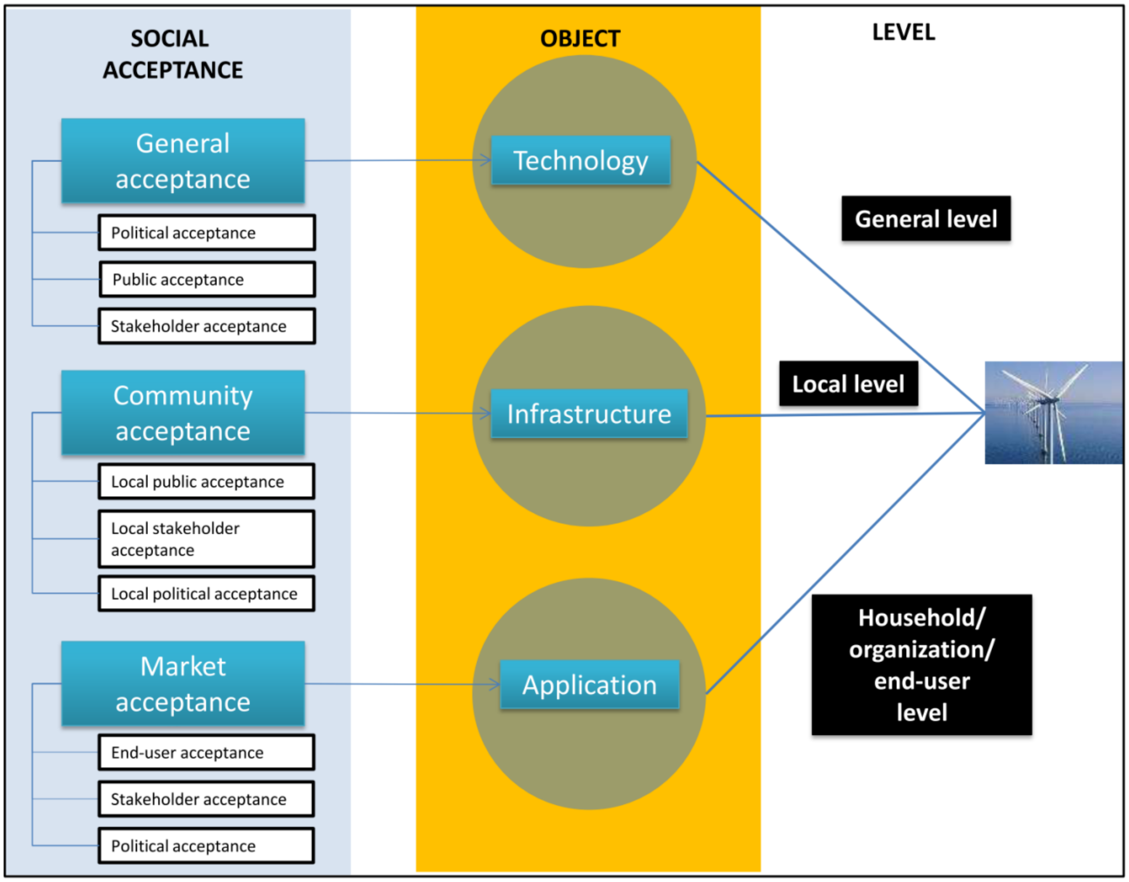

Figure 1: A context-based classification of types of energy technology acceptance (from Upham et al. (2015), p. 12)

2.2. Actors in the innovation system

Particularly in transition research, the importance of actors and actor systems has repeatedly been emphasized (Bögel and Upham 2018; Geels 2014). Here, the addition of findings from innovation research, in particular innovation system research, which has put a stronger focus on the actor system, is helpful. Innovation systems research focuses on the description of innovation systems at national, regional or sector level (Warnke et al. 2016) and concentrates on the nature and rate of technological change (Hekkert et al. 2011). In earlier conceptualizations of innovation systems (Kuhlmann and Arnold 2001) various subsystems (e.g. demand, industrial system, education and research) and the relationships between these subsystems are described. The subsystems correspond to specific groups of actors or institutions which Hekkert et al. (2011) outline more specifically. Their conceptualisation focuses on the supply side which is framed on the one hand by research and education, which can be understood as input factors, and on the other hand by the demand side. Politics and institutions set the wider framework. Finally, supporting organisations are identified as actors

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with influence, which include capital providers such as banks and investors as well as specific networks such as industry associations. This system was further extended in recent works by Dütschke et al. (2019; 2018) to make it useful for an innovation or technology specific actor analysis (see Figure 2).

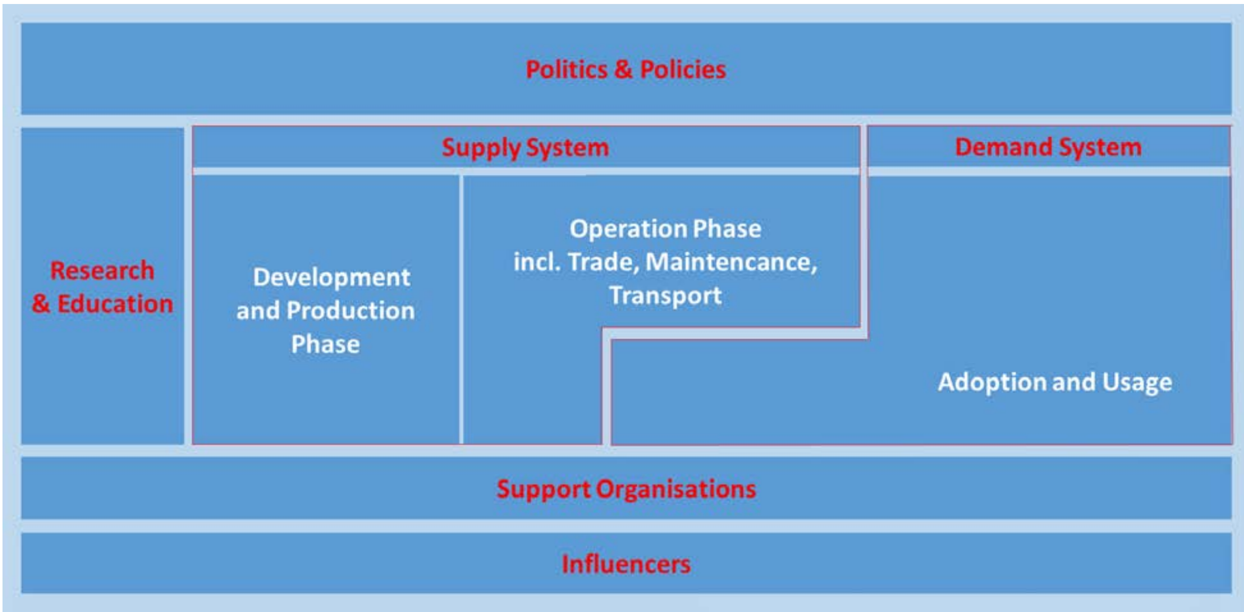

Figure 2: Actors in the energy innovation system

The core of this actor system are the "Supply" and "Demand" side of the innovation system differentiating groups of actors within these categories. To apply this to CCUS we take the perspective that the supply side provides the possibility for CCUS while the demand side produces uses and stores CO_2 drawing on the technology and service provision of the supply side. The supply side thus includes technology providers for CCUS systems along the supply chain for providing capture technology, installations for transporting CO_2 by different means (trucks, pipelines, ships), installations for CO_2 use and storage including injection. The demand side in this is case is more complex than for other technologies as it encompasses (i) CO_2 emitters, e.g. CO_2-intensive energy generation from fossil fuels and other energy intensive industry like cement or steel; ii) storage operators; iii) the CO_2 use industry, e.g. the fuel industry or chemical processes demanding CO_2 (cf. Figure 3). Thus, between these demand side parties also several relationships exist along supply chains.

This core of supply-demand is framed by 'Politics and Policies' which provide the relevant legislative and regulatory framework, thereby also influencing the market design. However, this category also includes the actual administrative procedures which for example influence lead times of projects and organise processes around the issuing of permits which have been subject to acceptance discussions in the past. In interaction with Demand-Supply-core is the category of 'Research & Education' defining input and constant improvement and refinement as well as

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providing specific education and professional training. Additionally, 'Support Organisations' form the basis as they fuel the innovation system by providing financial resources, additional knowledge and advice from the non-state sector. Furthermore, the stakeholder system also includes the 'Influencer' category which is closely related to the concept of social acceptance as it summarises stakeholders that are not part of the other categories in a narrow sense but play an important role for the decision making of other actors, e.g. voters on the decision making of policy makers. This actor system is relevant on the different political and geographical levels, i.e. the European, national as well as regional and local level which is illustrated by the different layers in the extended version in Figure 3. Earlier experience with CCUS development has already pointed to low levels of acceptance with citizens and neighbors as well as policy makers for CCUS. The relevant literature will be reviewed in the next section.

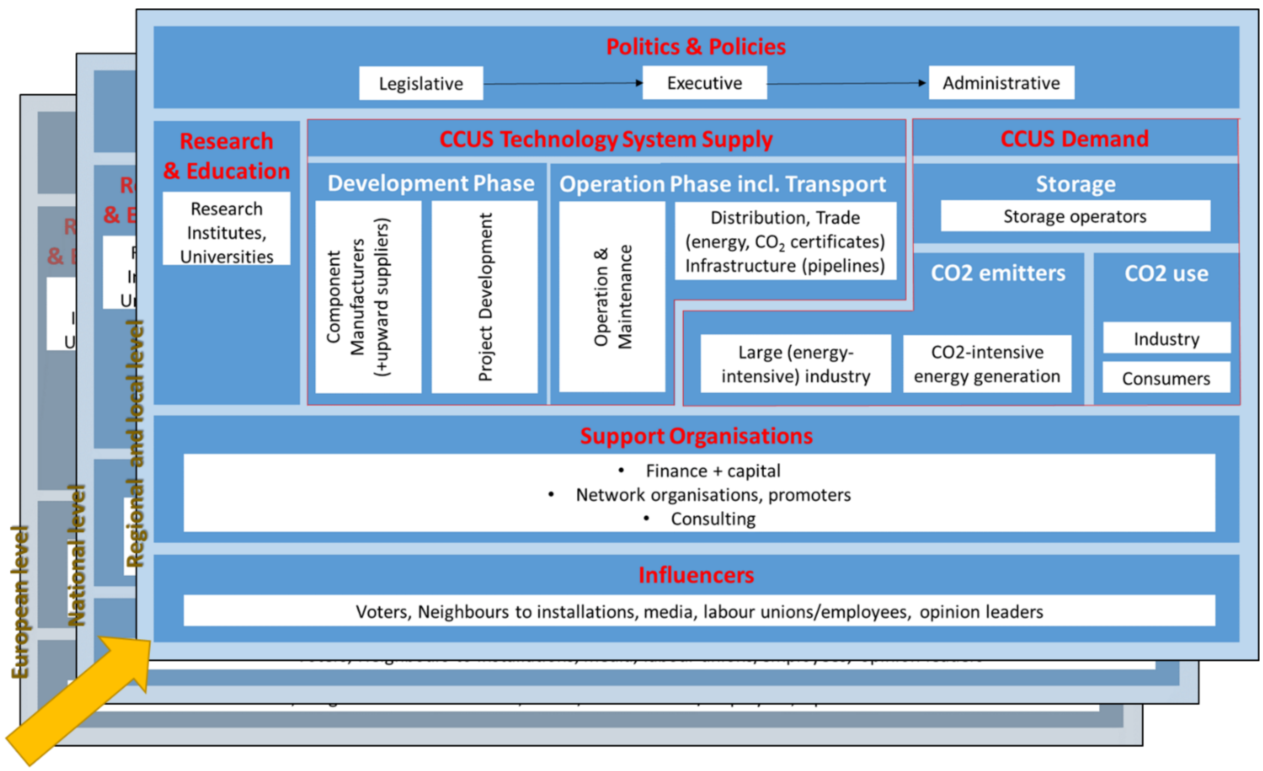

Figure 3: Actors in the CCUS system

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3. Social acceptance of CCUS

Two relatively recent reviews summarize the existing research on the perceptions of CCS (L'Orange Seigo et al. 2014) and CCU (Jones et al. 2017). The two applications are to some extent discussed in separate streams of literature and it is also argued that it is important not to neglect the differences between them (Jones et al. 2017); however, some empirical work also combines scenarios of both types. In the following, the studies will be outlined according to their focus.

3.1. Social acceptance of CCS

L'Orange Seigo et al. (2014) summarise the earlier literature on CCS perceptions and acceptance drawing on 42 papers. With the exception of four studies which include Japan or China the large majority draws on empirical work in Western democracies, mostly from Europe. The research mainly focuses on *socio-political* and *community acceptance*, without explicitly differentiating between these types of acceptance in the review paper, and the public as actors. At that point of time when the review was written (*socio-political*) acceptance levels for the technology were often moderate, neither specifically positive nor negative. However, exposure rates and levels of knowledge were low. Perceived risks and benefits were the main predictors of variation in acceptance. Potential risks include leakages or blowouts of CO_2 incl. induced seismicity, local impacts e.g. on property value or tourism as well as CCS as an unsustainable solution for keeping up harmful industries. On the positive side, the main perceived benefit is the contribution to climate change mitigation, but sometimes also that CCS might enable a smoother transition and bring local economic benefits. The basic rationale for CCS is usually that the precondition that climate change is a recent problem that needs to be tackled is understood and accepted; this is the case for large majorities in different societies as underpinned by the studies reviewed. For actual projects, i.e. for *community acceptance*, the review outlines - based on Oltra et al. (2012) - that "trust in the developer, the quality of public engagement activities, and the public's and stakeholders' perceptions of the need for the facility" (p. 852) are most relevant. Furthermore, this analysis gives some hints that earlier local experience with similar industries might be important.

Recent works on public awareness and socio-political acceptance

To deal with the challenge that survey participants have little knowledge concerning CCS the approach of information-based questionnaires emerged in the CCS-related literature to study socio-political acceptance in broad household surveys (L'Orange Seigo et al. 2014). Providing respondents with information on the technology tended to lead to more stable opinions; depending on the type of information given as well as the indication of the source of this information, perceptions of CCS were more or less positive. Similarly, other studies find varying degrees of trust for different actors with industry being least trusted and higher levels of trust towards researchers and NGOs (L'Orange Seigo et al. 2014). Additionally, as supported by

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experimental research, trust emerges also from a congruence of ascribed motives and messages, e.g. industry is expected to act on their own interests and specifically mistrusted if communicating the opposite.

Boyd et al. (2017) confirmed earlier findings that knowledge levels on CCS are low in the public and not very enthusiastic for Canada. A multi-country-study (Whitmarsh et al. 2019) also replicated the finding that awareness of CCS is low in five countries (Canada, USA, UK, Netherlands, Norway). They drew representative national samples in addition to local ones, i.e. living in proximity to current or potential CCS sites, and found local residents being more supportive on CCS. Overall, they found participants to be slightly positive on CCS with lower levels in the Netherlands and higher levels in the UK and Norway. CCS is seen more positively in combination with bioenergy than with shale gas, underground coal gasification or heavy industry; scenarios combining carbon capture with use, i.e. CCU, are seen more positive than without.

These last findings are in line with a more in-depth analysis of public perceptions of the CCS chain brought forward by Dütschke et al. (2016). Their study examines the public perception of different options within the CCS chain, i.e. for the three elements capture (comparing industry vs. biomass vs. coal as a CO_2 source), transport (pipeline vs. no pipeline) and storage (saline aquifer vs. depleted gas field vs. enhanced gas recovery (EGR)[3]. They use an experimental approach in an online survey of 1830 German citizens. Overall, they find neutral evaluations on average. However, if the CO_2 is produced by a biomass power plant or industry, CCS is rated more positively than in case of a coal-fired power plant. Exploratory regression analyses show that the perception of the respective CO_2 source is most important for the overall evaluation and that the perception of the CO_2 source depends on its perceived relevance for the Germany.

A recent paper by Nuortimo (2018) avoids the issue of low knowledge levels by applying machine learning to analyse publications (edited and from social media) from the internet published between 2014-2016. First, while they find a large number of relevant items, the number is much lower than for other energy technologies. Second, looking into the tone of the publications, shows that positive presentations are a majority (45 %), however, negative sentiments are also strong (around a third). Much more publications are editorial, i.e. signifying a low level of societal discussion around this theme. Similarly, Mander et al. (2017) analyse the discourse around CCS in the UK focusing on who is involved in the discussion and differentiating between online twitter and regional offline streams of discussion. In both cases, they find that CCS communications happen in niches. In the offline world, information mainly stems from the national level and is shared regionally where it is mainly limited to industry, academia and local government. Similarly, in the twitter outlets, the national plays the major role in sharing information, which then also remains within a limited community. Thus, both studies underline

[3] This type of storage is sometimes also considered as a CCU-application.

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the finding that awareness is low and no broad debate around CCS taking place in (Western) societies.

Broader factors influencing socio-political acceptance

A first study tries to incorporate cultural factors to explain variation in acceptance levels (Karimi and Toikka 2018). They use data from Euro-Barometer on CCS and relate it to Hofstede's cultural dimension on the national level. They find relationships with uncertainty avoidance, long-term orientation and power distance as well as some support that in countries with a higher need for risk avoidance perceived risks of CCS are stronger. Similarly, a higher long-term orientation is associated with lower perceived benefits. While the authors provide an interesting approach and also plausible lines of argumentation for their findings, contrary expectations also seem to be plausible, e.g. countries with a higher long-term orientation are more prone to support CCS as it contributes to fight climate change especially on the long run.

Broecks et al. (2016) assume that the lack of public acceptance "discourages stakeholders, such as energy or industrial firms, policy makers and NGOs, from moving toward large-scale implementation" (p. 58). They study in detail how arguments for and against CO_2-storage are perceived by the public by letting respondents judge the persuasiveness, the importance and the novelty of arguments presenting in pairwise comparisons. While more persuasive arguments tend to be perceived as more important and vice versa, novel arguments tend to be perceived as less convincing and relevant. The most persuasive pro-arguments are that "CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions" and "A waste product such as CO_2 should be disposed of properly" while reference to clean coal and enhanced oil recovery are not seen as convincing issues. On the negative side avoidance of CO_2 is the main counter argument together with the challenge that risks are not fully understood and that CO_2-storage is not necessary to fight climate change. Interestingly, the argument that CO_2-storage might promote the use of coal-fired power plants is seen as least convincing.

Analyses of community acceptance

A recent Canadian study by Boyd et al. (2016) provides a deeper dive into the place dimension around siting decisions for CCS. She describes an unsuccessful research initiative to implement a CCS field research project in the wider Calgary area. This initiative withdrew from the area as they were faced with resistance from the economically and socially strong local community including their prominent members. This finding is in line with earlier European case studies (Oltra et al. 2012; Dütschke et al. 2015) who point to the relevance of community characteristics and the socio-political context, project characteristics and the participation and communications processes, the engagement of local and other stakeholders influencing the perceived risks and benefits of the project and finally the level of acceptance for a project (see Figure 4).

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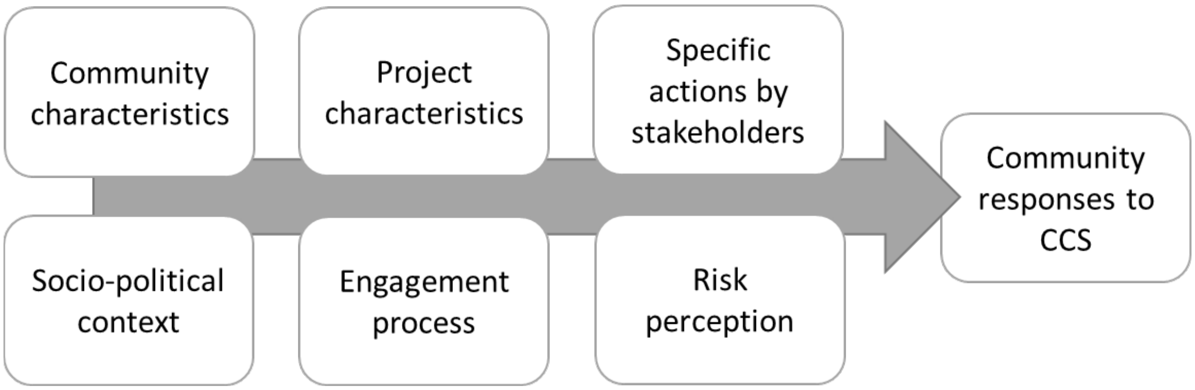

Figure 4: Relevant factors for community acceptance (figure based on Oltra et al. 2012)

Looking at Germany, a study finds that in areas where CO_2 storage is potentially possible, inhabitants seem to be more skeptical regarding CCS (Braun 2017). This finding is in line with results from a German project (Dütschke et al. 2015; Schumann et al. 2014), however, as outlined above Whitmarsh et al. (2019) come to different conclusions in a more recent study in a different set of countries.

A broader approach with regard to actors studied as well as from a conceptual point of view is presented by Gough et al. (2018) who try to set CO_2-storage into a broader context by exploring its perceptions within a social context. They attach to the literature on the "social licence to operate (SLO)" defining it as the "informal permission given by the local community and broader society to industry to pursue technical work" (p. 17, drawing on Thomson and Boutillier, 2011). They first conducted interviews with local stakeholders in two UK-regions which elicited mostly positive views on CCS (also compared to fracking) including trust that it can be implemented safely from a technical perspective and that it might be a strategy to keep industries within the region in the wake of fighting climate change. Focus groups with the public in the areas voiced more skeptical opinions. Interestingly, and different to what was found in earlier literature, participants had higher trust in industry than in policy makers.

3.2. Social acceptance of CCU

A recent overview by Jones et al. (2017) summarises the literature on CCU applications. They point out that the further development and commercialization of CCU will employ interactions with / between a diversity of stakeholders (including policy-makers, businesses, the general public, etc.) as argued in this deliverable. This review also applies explicitly the differentiation between socio-political, community and market acceptance.

Socio-political acceptance: Jones et al. (2017) argue that climate change mitigation emerges as the primary driver behind CCU which is taken up by policy makers on their way to achieve climate goals while industry fears penalties and restriction if not contributing to goal achievements. They therefore expect that these two actor groups will seek to actively influence public opinion. Regarding socio-political acceptance by the public they conclude: "The results of

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these studies generally confirm that awareness of CO_2 utilisation is currently very low and while there is some scepticism about the long-term environmental benefits of the technology, there is tentative overall support for the concept as a 'bridging technology' in the fight against climate change" (Jones et al., 2015, 2016). This support is, however, strongly caveated by people's self-professed lack of knowledge of the technology, questions over the techno-economic feasibility of the processes and uncertainty over the societal consequences of investment in the technology." (p. 5). The media is identified as a key shaper for public opinion; however, media has rarely been studied. As for further groups of actors, a recent study by Offermann-van Heek et al. (2018) on CCU supports the findings for CCS regarding trust in actors, i.e. that the industry is less trusted.

Market acceptance: Until recently, little research had looked at market acceptance of consumers; early (qualitative) studies lead to slightly optimistic findings (Jones et al. 2017). However, a big question in this regard is, that it is not clear if products will or need to be labelled as "CO_2-derived" (p. 7) at all. Thus, most likely, other actors in the value chain will be more important for a diffusion of CCU products, i.e. the industry employing the CO_2 as well as (potential) investors. This last group is regarded as hard to study, as their decision making process is usually confidential (Jones et al. 2017). Regarding the CO_2 using industry, Jones et al (2017) conclude: "it can be assumed that environmentally proactive firms, in addition to those with a comfortable competitive position, are more likely to advance the development and introduction of CCU" referring to the literature that these companies are more generally regarded as more innovative. Within organisations, change agents seem to be important which was also outlined for other sustainability innovations (Globisch et al. 2018).

Very recently studies from a team of researchers at the RWTH Aachen have been published on the market acceptance of CCU. They confirm the relevance of perceived risks and benefits and perceived uncontrollability as influencing acceptance (Arning et al. 2019b). Another study (Arning et al. 2018) looks into the case of carbon derived foam mattresses (n=305, convenience student sample). The respondents tend to be positive on CCU products as well as the technology per se and also indicate a willingness to use and buy CCU products, however, this willingness is not very strong. A more detailed analysis of the sample indicates three sub-clusters of which one is more appreciating of using and buying CCUS than the other. This group of approvers seems to be uncommitted and is not lead by environmental concern, but - as is guessed from a preceding focus group - more motivated by the innovativeness. There is also a cautious segment which appears to be interested in CCU mattresses, however, is skeptical about technologies in general and indicated green attitudes and higher risk orientations. Finally, a group of rejecters appears which score high on environmental concern but see CCU as the wrong solution.

Community acceptance: Jones et al. (2017) draw a very general conclusion as no research has looked into this type of acceptance for CCU so far. Process and place aspects have been identified as being important (see also the outline on community acceptance for CCS).

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3.3. Comparisons of CCU and CCS and studies beyond perceptions by the public

Arning et al. (2019a) compare acceptance for CCS and CCU based of sample of n=509 from Germany and find support for both technologies, however, more positive perceptions for CCU. CCS was associated with storage and transport risks while for CCU product risk played a role. Similarly, Linzenich (2019) identify comparable affective and cognitive evaluation profiles for CCS and CCU, again, with more positive findings for CCU. This is in line with the assumption by Jones et al. (2017) referred to at the beginning of this chapter that it is worthwhile to differentiate between the two application types.

Four studies could be identified that employ experts or certain groups into their analyses of societal perceptions on CCUS. Xenias and Whitmarsh (2018) look into expert views on public engagement on CCS. They interviewed 13 experts on CCS from industry, NGOs/Think tank, academia, freelance and research organisations. The main barrier to CCS from the perspective of these groups is lack of political support and a (reliable long-term) funding mechanisms. Public acceptance appears to be less prevalent. Regarding CCS communication experts saw the main challenge is correctly communicating complex information, especially as the public is perceived to be relatively unaware of the technology. From the experts' point of view, communication with the public has the goal to diminish opposition towards CCS projects and to address local concerns and benefits. Overall these findings are corroborated by a follow-up expert survey (n=99).

Mabon and Littlecott (2016) look into perceptions on Enhanced Oil Recovery (EOR) with CO_2 by the public and by stakeholders. They elicited opinion through focus groups, several of them consisting of selected groups with (1) an interest in the marine environment, (2) early career oil and gas professionals, (3) academics (4) professionals with an interest in environmental issues, (5) investors with a focus on green investments, (6) and environmental NGOs. While most of the groups claimed to be in favour of more climate ambitious scenarios they expect that less ambitious ones will come true. Across the groups the lines of argument discussed differ, e.g. the NGO groups more extensively questioning whether CO_2-EOR makes sense at all.

Experts from three countries, Germany, Norway and Finland, were interviewed by Karimi and Komendantova (2017). The study focuses on concerns from experts regarding CCS projects, especially their risk perceptions. They interviewed 19 experts, i.e. very small samples per country, who have been involved with CCS projects (research centres, companies, governmental bodies, NGOs). The expert perceptions are in line with findings from other sources, e.g. Eurobarometer surveys. In Germany, acceptance is perceived to be low questioning the need for CCS while in the two Scandinavian countries concerns evolve more around financial incentives and reliable policy support as well as lack of storage sites.

More specifically, Vercelli et al. (2017) focus on expert views on storage. They surveyed 45 international stakeholders in 2012, i.e. professionals working in the field of CCUS and one of their questions asks also about the "layman's perspective" (p. 7394), thus, capturing experts' perceptions of the public. What is emphasized most is the defined procedures could contribute

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to perceived safety, e.g. clearly defined roles within industry, strong environmental impact assessment procedures. In addition to that, information and communication is also frequently mentioned as contributing to perceived safety. Less often, but also repeatedly the experts point to the need of successful demonstrations, trust and distance to the storage site (i.e. that perceived safety increases if the site is further away).

The more general question on the future of CCU is at the heart of an expert exercise by Vreys et al. (2019) who explore factors that are likely to influence the development of the CCU technology in the next ten years. Methodologically they combine a Delphi study and a scenario development technique. Overall the expert Delphi comes to the conclusion that the potential contribution of CCU in mitigating climate change is most likely limited; however, it is regarded as a helpful bridging technology. In the scenario exercise participants were more optimistic, however, more on the longer run. Costs and regulatory issues together with technology development are seen as the main challenge.

Lastly, work by Kant and Kanda (2019) analyses innovation intermediaries for CCS defining them as “an organisation or body that acts [as] an agent or broker in any aspect of the innovation process between two or more parties; innovation intermediaries are recognized as crucial actors that can facilitate the innovation process". However, their approach is highly abstract and mainly contributing to the intermediaries literature.

One of the most comprehensive studies into stakeholder views was produced in the project NearCO2 (Reiner et al. 2012). They surveyed 171 local stakeholder from different categories (Media, Research, Administration etc.), most of them from Germany, however, a few also from Spain, the Netherlands, Poland and the UK. In parallel, a public survey including national as well as regional samples around planned CCS projects. What they found is that stakeholders were more knowledgeable on CCS than the public, but also more negative, especially in Germany, and did also hold the highest level of concern. They did also associate the least levels of potential benefits with CCS and had a more negative perception of public acceptance than indicated by the public.

Summarising the findings from the literature, it turns out that especially CCS, but also CCU has been frequently subject to social acceptance studies. Several studies from several, mostly Western, countries and across a time span of around 10-15 years have confirmed that knowledge and awareness for the public is usually low and acceptance levels are moderate regarding socio-political acceptance. Some of the countries where CCS projects were intended to be implemented like the Netherlands or Germany have experienced opposition to these projects resulting in low acceptance levels within communities. Influencing factors have been studied on the technology (e.g. CCU preferable to CCS, industry to coal as CO_2 sources) and the individual level, around communication, lines of arguments and towards categories of actors. Fewer studies have looked into different actors, their acceptance towards CCU and CCS. Mostly sample sizes in these studies are small, thus, comparisons across actor categories are difficult to draw. Partly the findings are in line with those on the public. Overall, experts seem to be less

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skeptical about the technology perceiving lower risks and are more concerned about the policy framework and the financing of a further development of CCUS. An exception to this is the study by Reiner et al. (2012) which employs a relatively big sample and finds very negative opinions by local stakeholders.

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4. Actor system for CCUS

4.1. European level

The goal of this chapter is to give a comprehensive overview of the CCUS engaged actors on the EU-level. The presentation of these actors is structured along the scheme introduced in section 2.2 and thus includes the following categories: politics & policies, research & education, supply, demand, support organisations and influencers. The categories of support organisations and influencers are merged as in our first screening it was difficult for some actors to come to a unique categorization.

4.1.1. Politics & Policies

On EU level, CCUS is assigned to the climate Directorate-General (DG CLIMA). DG CLIMA is currently headed by commissioner Miguel Arias Cañete. DG CLIMA maintains working relations to responsible ministries in EU member states and affiliated countries like Norway. DG CLIMA is supported in scientific and technological matters by the Group of Chief Scientific Advisors (SAM)[4].

4.1.2. Research & Education

The group of research and education organisations is subdivided into universities and research institutes. While the majority of European universities are largely financed by public funds, research organisations in most cases apply for additional funding from the public and private organisations. First organisations that are strongly engaged in CCUS technology development will be displayed. Subsequently, organisations that have participated in CCUS related projects, but cannot be considered core actors will be named, but their structure and work focus will not be further presented. The CORDIS database was used for the mapping process. For locating CCUS involved universities and research organisations the keywords "carbon capture and storage" and "carbon capture and use" were used. Each keyword produced a number of projects. These projects were filtered for projects from the Seventh Framework Programme (FP7) and the Horizon 2020 Framework Programme (H2020) to only include actors that have been active in the last 12 years. For each keyword, the first 15 project hits were taken into account, and the involved actors are listed in this report.

The analysis shows that a substantial number of universities and research organisations are involved in CCUS related research projects. Since the research for this report focused on EU funded projects, research organisations working with other funding were not detected.

[4] https://ec.europa.eu/research/sam/index.cfm?pg=ccu

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Universities

- University of Edinburgh's carbon capture group at the School of Engineering is one of the largest carbon capture research groups in the United Kingdom. Their research focuses on adsorption and membranes separations. Among the variety of projects they are involved in over the last year are five EU funded projects: ACCA , NanoMEMC2 , OFFGAS and the ALIGN-CCS as well as the current Strategy CCUS
- Uppsala University lead the EU FP-7 project MUSTANG , which focused on developing guidelines, methods and tools for characterising deep saline aquifers for the long-term storage of CO_2. The Department of Earth Sciences at Uppsala University is also involved in other CCUS projects such as the CO2CARE TRUST , PANACEA and CO2QUEST projects. Furthermore, it took a leading role in the production of a special issue on CO2 injection based out of a well in Israel.
- The University of Southampton features the National Oceanography Centre (NOC) which is the United Kingdom's center of excellence for oceanographic sciences. The NOC is currently engaged in five CCS related projects . One example is the STEMM-CCS project which is bound to provide a set of tools, techniques and methods to enhance our understanding of CCS in the marine environment.
- The research centre for carbon solutions (RCCS) at Heriot-Watt University focuses on the wider deployment of technologies needed to meet necessary carbon targets. It was formally known as the Centre for Innovation in Carbon Capture and Storage (CICCS) and has an extensive state-of-the-art laboratory facilities covering the whole CCS chain, including equipment for capture, transport, storage, utilization and monitoring. It has been involved in a variety of UK and EU funded projects – for instance the ALIGN-CCS project.
- The University of Bergen is one of leading Universities concerning petroleum and process technology in northern Europe. Their initiative focus largely on researching and improving technologies for enhanced oil recovery. They were involved in the EU funded ECO2 project.
- NTNU is the most important Norwegian technical university. A special focus is on the reduction of emissions. Together with SINTEF it operates one of the strongest developed science clusters for CO_2 capture and management. NTNU was involved among others in the EU funded ANCAP, DYNAMIS , DECARBit , iCAP , ECCSEL and the ALIGN-CCS projects.

Other universities that have been in involved in EU funded CCUS related projects are the following: Stuttgart University, Ghent University, University of Gothenburg, Sapienza University of Rome, TU Darmstadt, Ulster University, University of Cyprus, University College London, Polytechnic University of Milan, National Technical University Athens (NTUA), Babeș-Bolyai University, Imperial College London, Leiden University, RWTH Aachen, University of Groningen, National University of Political Studies and Public Administration – Bucharest, Technical university – Sofia, Graz University of Technology, Arctic University of Norway, Technical University of Denmark, Pilot-Scale Advanced Capture Technology (PACT) at the University of

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Sheffield, University of Trier, University of Gdańsk, University of Latvia, University of Évora, Faculty of Mining, Geology and Petroleum Engineering, Petroleum Engineering Department at the University of Zagreb, NOVA University of Lisbon,

Private and Public Research organisations

- Bureau de recherches géologiques et minières (BRGM), is France's reference research organisation for Earth Science applications in the management of surface and subsurface resources and risks. It is a research and consultancy agency under the supervision of the French Ministry of Higher Education and Research. BRGM was involved in the EU funded CO2CARE , ECCSEL, and coordinated CGS EUROPE, ULTimate CO2 and ENOS projects. Currently is coordinating the StrategyCCUS project.
- The Central Mining Institute of Poland (GIG) acts as a research and advisory body to the Polish mining industry, with a special focus on the Upper Silesia region. It is based in Katowice and has taken part in EU Geocapacity and is currently involved in the Strategy CCUS project.
- The Centre for Research and Technology Hellas (CERTH) is a public research in institute based in Thessaloniki. It has participated in several EU funded projects, for example SCARLET , ECCEL , ACT . It is also involved in the StrategyCCUS project.
- The Energy Research Centre of the Netherlands (ECN) is part of the Netherlands Organisation for Applied Scientific Research (TNO). ECN and TNO were involved in EU funded ECCEL and ECO2 project and coordinated the ALIGN-CCS project
- The GEOMAR-Helmholtz Centre for Ocean Research Kiel investigates chemical, physical, biological and geological processes of the seafloor, oceans and ocean margins and their interactions with the atmosphere. They were involved for instance in the EU funded ECO2 and the STEMM-CCS projects.
- German Research Centre for Geosciences GFZ is the national research center for earth sciences in Germany. It coordinated the EU funded CO2CARE project and was involved in the IMPACTS project.
- IFP Énergies nouvelles (IFPEN) was founded as "French Petroleum Institut". In 2010 it changed its name and is now known as a major research and training player in the fields of energy, transport and the environment. Regarding CCS they are involved in several EU funded projects as the "3 D DMX Demonstration in Dunkirk" and the Strategy CCUS project .
- The Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) is a state owned research institute in Triest. It's research focusses on oceanography, geophysics and marine geology. It has participated in the EU funded CO2CARE , ECCEL and ECO2 projects.
- The National Institute for Research and Development of Marine Geology and Geoecology – (GeoEcoMar) is a Romanian private institute and based in Bucharest. Was

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involved in CGS Europe and EU Geocapacity project. Currently is takes part in the ALIGN-CCS and Strategy CCUS projects.

- Norwegian state research institute (NORCE) was funded in 2017 as a merger of several university-owned research institutes. Now it is one of the largest research organisations of Norway. NORCE is currently involved in the EU funded STEMM-CCS project and the Strategy-CCUS project.
- Plymouth Marine Laboratory aims to develop and apply innovative marine science to ensure a sustainable future of oceans. It was involved among other projects in the EU funded ECO2 STEMM-CCS projects.
- SINTEF is an independent research organisation based in Trondheim Norway. It cooperates strongly with the Norwegian University of Science and Technology (NTNU). It hosts the Norwegian CCS Research Centre (NCCS), coordinated the ECCO project and was member of the CACHET II , ECCSEL and the ALIGN-CCS project.
- European Cement Research Academy (ECRA) was founded in 2003 as a platform on which the European cement industry supports, organises and undertakes research activities. One of its most important research projects is its CCS project, which was started in 2007 and is now in its fourth phase with the project of an Oxy-combustion pilot-plant for industrial scale demonstration of the technology.

Other research organisations have been involved in EU funded CCUS related projects are the following: Max Planck Institute for Chemical Energy Conversion (MPI CEC), Norwegian Institute for Water Research (NIVA), French National Institute for Industrial Environment and Risks (INERIS), Leibniz Institute for Baltic Sea Research Warnemünde, Kiel Institute for the World Economy, French Research Institute for Exploitation of the Sea (Ifremer), Alfred Wegener Institute (AWI), Jülich Research Centre, Spanish Research Center for Energy, Environment and Technology (CIEMAT), Fraunhofer Institute for Systems and Innovation Research (ISI), Federal Institute for Geosciences and Natural Resources (BGR), Czech Geological Survey, Geological Survey of Denmark and Greenland, LNEG, the portuguese National laboratory for Energy and Geology and IGME, the Spanish Geology and Mining Institute.

4.1.3. Supply

The supply side for CCUS includes technology providers for CCUS systems along the supply chain for capture technology, installations for transporting CO_2 by different means (trucks, pipelines, ships), installations for CO_2 use, as well as storage and injection. For this overview, we only focused on major companies that offer turnkey applications.

The analysis shows, that the number of companies that offer such turnkey solutions is very limited. They include Air Liquide, Linde group and General Electric. Up until 2012, also the German multinational Siemens was active in developing and offering CCUS related technology projects. However, nowadays Siemens does not operate CCUS specific webpages. This suggests that activities have been phased out, or are under reorientation.

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- Air Liquide is a French multinational company which supplies industrial gases and services to various industries including medical, chemical and electronic manufacturers. It has been investing in oxy-combustion technology for more than a decade through R&D and successful participation in pilot projects in the U.S., France and Australia . Oxy-combustion is a central process to generate CO_2 that is suitable for sequestration.
- Linde group is a large multinational gas process company with headquarters in Dublin, Ireland. Through its engineering Division it develops and helps implementing pilot plants for IGCC and Oxyfuel applications as well as post combustion CO_2 capture applications.
- General Electric is an American multinational conglomerate incorporated in New York City and headquartered in Boston. They have designed and constructed 13 CO_2 capture solutions (CCS) demonstration projects around the world. They primarily offer post-combustion applications and oxy-combustion applications.

4.1.4. Demand

The actor mapping shows that the demand for CCU and CCUS is large and that a substantial number of diverse actors from various backgrounds require CCUS if their business models are to be perpetuated at current levels. Demand actors come from energy intensive heavy industries, CO_2-intensive energy generation from fossil fuels as well as the CO_2 use industry and storage operators[5].

Heavy Industries

The IPCCs Fifth Assessment Report (Fischedick M. et al. 2014, pp. 753–763) differentiates between eight industries that emit substantial CO_2: Iron and steel production, cement production, chemicals, pulp and paper, non-ferrous metals, food processing, textiles and leather, mining. CCUS applications are most efficiently installed on point sources. Since food processing, textiles and leather are rather fragmented industries, they do not meet this criterion. Also mining industries will be excluded. The mining's CO_2 footprint is mainly dependent on high diesel combustion levels and electricity use for grinding (comminution) (Fischedick M. et al. 2014). Since capturing CO_2 emissions from dispersed diesel aggregates is not very efficient and electricity consumption is already covered by CO_2 intensive energy generation (next paragraph).

- *Iron and steel production:* One of the major representation groups for iron and steel production on the European level is the European Steel Association (EUROFER; http://www.eurofer.org/). EUROFER members list comprises major industrial members such as ArcelorMittal, ThyssenKrupp and Tata Steel as well as the national steel associations for instance from Spain, Romania, Germany, UK, Poland, Hungary etc.

[5] Since CCUS is still an emerging innovation system, EU-wide operator organisations do not exist yet.

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- *Aluminum and non-ferrous metals:* European Aluminum (https://european-aluminium.eu/) is a large association of aluminum producers. It represents aluminum companies such as Rio Tinto and Alcoa, as well as smaller national aluminum associations. European Aluminum is also associated with Eurometaux (https://eurometaux.eu/), which focuses on the non-ferrous metal industry. Eurometaux represents several non-ferrous metal producers such as KGHM, Atlantic Copper and Aurubis.
- *Cement production:* The representative organisation of the cement industry is CEMBUREAU, the European Cement Association (https://cembureau.eu/). The majority of European countries is represented in this association. Some of the largest cement producers are LafargeHolcim, HeidelbergCement, Cemex and UltraTech Cement.
- *Chemicals:* The chemical industry includes all industrial process where raw materials such as oil, natural gas, metals, and minerals that are used to produce highly advanced and specified products for businesses and end users. This paragraph focusses on oil refining and natural gas, since metals and minerals are covered by other categories such as iron and steel and cement. The European refining industry is represented on the European level by the FuelsEurope association (https://www.eurofuel.eu/). It represents large multinational companies such as BP, TOTAL, Equinor, Chevron, Shell, LOTOS, Statoil, and ExxonMobil. Other chemicals producers are organized in the European Chemical Industry Council (https://cefic.org/about-us/membership/). It represents more than 300 chemical companies and national chemical associations from all European states.
- *Pulp and Paper:* The European pulp and paper industries are represented by the Confederation of European Paper Industries (CEPI) (http://www.cepi.org/). Its members consist of several national paper associations such as Sweden, Finland, the UK, and Germany. Some of the most influential pulp and paper companies, such as UPM, SCA and Smurfit Kappa are also represented in the CEPI.

CO_2 intensive energy generation

Coal power plants as well as gas power plants emit substantial volumes of CO_2. Hence, large utility companies that run these plants are interested in CCS and CCU applications that decrease their CO2 emissions. The central voice of the European Electricity utilities is Eurelectric (https://www.eurelectric.org/). Eurelectric's members are national electricity associations from all European countries. Hence they indirectly represent companies such as EON, Vattenfall, Uniper, Endesa, and ENEL.

CO_2 use industry

Use options for CO_2 use are manifold. They can be differentiated in three classes: Direct use, biological use and chemical use (see Figure 5).

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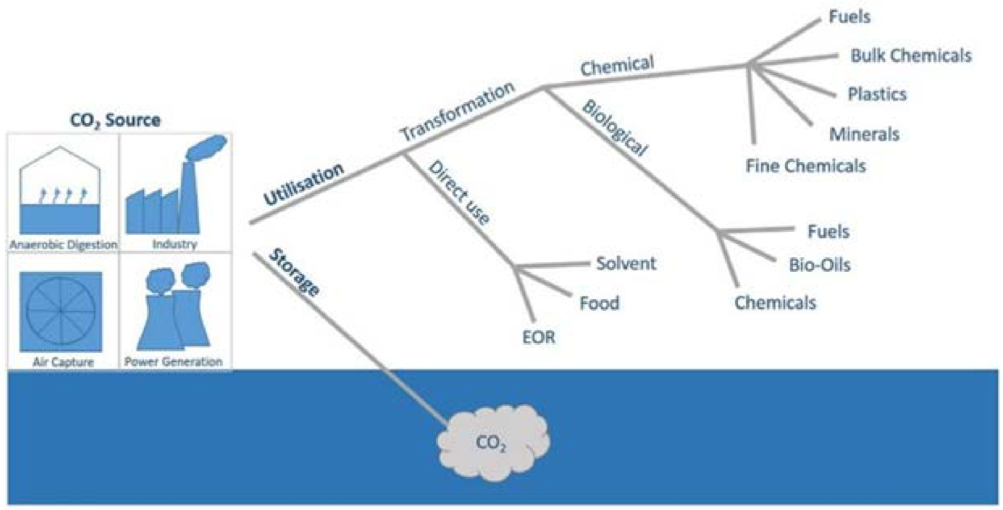

Figure 5: Carbon dioxide storage and utilization options (figure based on (Jones et al. 2017))

Direct use include for instance enhanced oil recovery (EOR), enhanced gas recovery (EGR) and enhanced geothermal systems (EGS), but also applications in fire extinguishers, carbonic acid or as a solvent. For example, CO_2 can be used to decaffeinate coffee beans. When used in biological or chemical processes CO_2 can be used for manufacturing fertilizers (urea), fuels (biodiesel, biogas, bioethanol), plastics (Polyurethan, Polypropylencarbonate), and other food stock products for example microalgae.

Due to the large variety of use applications, also the variety of actors that are in the CCU scope is very large. Since this variety goes beyond the scope of this mapping report, specific actors will not be further described.

Support organisations and influencers

Support organisations and influencers are subdivided into finance & capital, network organisations and consultants. The analysis shows that the number of financial actors that are visible online is very limited. In fact, only the Zurich Insurance Group pledged to be active with CCUC technology. On the other hand, the number of network organisations that are active on the European level is quite broad. In total nine organisations bring CCUS related actors together and promote CCUS on the European level. The number of consultants that are active in the CCUS field is limited. Altogether three consultancy companies present CCUS as a theme on their webpages.

Finance & Capital. The number of actors from the finance and capital industry is very limited. In fact, only the Zurich financial group has officially stated to support CCS and is member of the Carbon Capture and Storage Association (CCSA)[6].

[6] http://www.ccsassociation.org/about-us/our-members/zurich/

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Support organisations. Network organisations and promoters include the Global CCS institute, CO2 Capture Project, Bellona, Zero Emissions Platform (ZEP), Energy technologies Europe, CO2GeoNet, Carbon Sequestration Leadership Forum (CSLF), CO2-Value Europe.

The Global CCS Institute considers itself as an international think tank whose mission is to accelerate the deployment of carbon capture and storage (CCS), a vital technology to tackle climate change and deliver climate neutral https://www.globalccsinstitute.com/about/

- The CO2 Capture Project is a group of major energy companies working together to advance the technologies that will underpin the deployment of industrial-scale CO_2 capture and storage (CCS) in the oil & gas industry. https://www.co2captureproject.org/
- Bellona introduces itself as a foundation that supports CCS on a global basis https://bellona.org/
- The Zero Emissions Platform (ZEP) is a coalition of stakeholders that supports CO_2 Capture and Storage (CCS) as a key technology for combating climate change. Members are scientifc organisations (e.g., SINTEF and BRGM) as well as industrial players (e.g., GE, Shell, Equinor, Shell) http://www.zeroemissionsplatform.eu/.
- CO2GeoNet describes itself as a "network of excellence" and is a European scientific association which is committed to geo sequestration and in which 30 research institutes are currently involved http://www.co2geonet.com/about-us/.
- The Carbon Sequestration Leadership Forum (CSLF) is an international climate change initiative focusing on the development of improved, cost-effective technologies for CCS. Currently, 26 governments are members and the initiative operates globally https://www.cslforum.org/cslf/About-CSLF
- The European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) was founded in 2017 as a permanent pan-European research association https://www.eccsel.org/about/eccsel-eric/about-eccsel/
- The CCUS Advisory Group (CAG), established in March 2019, is an industry-led group considering the critical challenges facing the development of CCUS market frameworks and providing insight into potential solutions. It has member from industry, finance and legal consultants http://www.ccsassociation.org/
- Similarly to the CAG, the Carbon Capture & Storage Association (CCSA) brings together specialist companies in manufacturing & processing, power generation, engineering & contracting, oil, gas & minerals as well as a wide range of support services to the energy sector such as law, finance, consultancy and project management http://www.ccsassociation.org/.
- The CO_2 Value Europe is the industry-driven European Association which is committed to coordinate and represent the CO_2 utilisation community in Europe and to build up an integrated vision and action plan to develop CO_2 utilisation, so that industrial sector can make a significant contribution to Europe's low carbon economy.

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Consultants: Consultancy companies that are active in the CCUS field are Seascape Consultants Ltd, Pöyry Energy Consulting, MMI Engineering. They provide technical services such as hazard and risk mitigation, safety management and offshore CCS implementation, but also more corporate services such as gaining regulatory and public acceptance of the CCS sector or conducting economic and commercial analyses.

- Seascape consultants ld is a consulting firm founded in 2010 that supports players in the offshore sector (industry, decision-makers, supervisory authorities). The company is involved in several EU projects, including STEMM-CCS http://www.seascapeconsultants.co.uk/about-us/.
- Pöyry Energy Consulting is a British consulting and engineering company, mainly active in the energy sector and a member of the CCSA https://www.poyry.com/about-us/poyry-brief
- MMI Engineering is a consulting firm based in York that is part of CCSA and provides technical consulting in most industry sectors https://www.mmiengineering.com/about-us/
- Schlumberger Carbon Services offers a range of technical CCS related services such as methods for screening geological basins and comparing different sites (https://www.slb.com/business-solutions/carbon-services).

Five other consultancy companies have been active in EU funded research projects, but they do not show distinct CCUS related activities on their webpages: pic-oil (http://pic-oil.ro/en/), Navigant (https://www.navigant.com/), Pale Blue Dot (https://pale-blu.com/acorn/), DNV GL (https://www.dnvgl.com/), and Advanced Resources International (https://www.adv-res.com/).

4.1.5. Findings from the analysis of European CCUS related actors

The actors mapping on the EU levels shows six distinct findings: First, many universities and private institutes are active in CCUS research and involved also beyond their respective country. Even though the hubs of long-lasting research may be quite limited, there are a variety of universities and research organisations that are seemingly interested in CCUS research and have already collected research related knowledge. Second, the supply side of CCUS technology is limited to a small number of players. Only three multinational companies that offer turnkey CCUS applications could be easily identified. Furthermore, it seems, that the number has been even decreasing over the last years, since for instance Siemens has seemingly phased out CCUS related technology. Third, the demand side for CCUS applications is very diverse. It can be differentiated in three subdivisions: direct use of CO_2, biological transformation, and chemical transformation. However, even under each of these subdivisions, the number of applications is that large, that it goes well beyond of the scope of this report. Fourth, the number of actors from the financial and capital sector is very limited. A reason for this limited turnout can be that the methodology applied in this report is based on publicly available data only, which stands in stark contrast to the activities of players in this sector. Hence, financial products may be

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available, but just not be located by desk research. On the other hand, so far there have only be a limited number of CCS pilot projects implemented in Europe. Thus, it may also be the case that the demand for financial investments for CCUS applications in the EU is rather low or not available. Fifth, network organisations and influencers that are active on the EU level are quite well established. Altogether, nine of these organisations have been found. They help gathering CCUS related players as well as promoting CCUS at the national and EU levels. Sixth, the number of consultancy companies that offer services around CCUS applications is quite limited. Only three firms actively promote CCUS related services in their portfolios. Similarly to the low number of actors from the capital and financial sector, also the low number of CCUS related consultancies may be traced to the limited number of actually implemented projects.

Altogether, mapping the CCUS related actors on the European level shows signs of an innovation system that is still stuck in the formative phase. On the one hand, substantial research activities are undergone and the demand for CCUS is very large. On the other hand, due to the limited number of implemented projects industrial players that can offer CCUS related services such as plant engineers or industrial consultancy companies are limited and their number may even be decreasing. Also due to the limited number of real projects, supportive actors for instance from the financial sector do not see a need or large opportunities to enter CCUS related business opportunities. A mix of public (integrated EU and national funding programs as a key enabler) and private funding is required to trigger the deployment of this technology. A number of network organisations and NGO influencers is clearly visible on the EU level but seemingly they are not capable to channel industrial actors' needs or lobby successfully enough to give the CCUS innovation system the required push to take off.

4.2. National level

The Strategy CCUS project aims to develop strategic plans for CCUS development in Southern and Eastern Europe. For this reason eight regions in seven countries have been selected to prepare the implementation of CCUS related clusters. The countries are France, Spain, Portugal, Croatia, Romania, Greece, Poland. Hence, the analysis of national players will focus on these seven countries. The Strategy CCUS project has project partners in every of these countries. These partners were asked to submit comprehensive lists of national actors to be involved in the implementation of CCUS projects. These lists of actors can be found in the annex of this report. They are ordered according to the previously suggested TIS inspired actor structure: politics & policies, research & education, supply, demand, support organisations and influencers. The analysis of these lists of national actors lead to three general findings:

1. Most of the mentioned industrial actors can by classified as CCUS demand actors. For instance, they run heavy industry plants or operators of power plant. None of the regional partners named a single CCUS supply actor. This is not surprising, since the analysis for the EU level already showed that the number of technology supply actors is rather limited. In fact, the three supply actors that surfaced in the EU level analysis are all multinational operating players. This leads to the assumption that supply players are probably not very strongly active in the

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Strategy CCUS target countries, and that these need to be explicitly invited to join consultation processes.

2. Even though multinational CCUS supply actors are active across borders, they normally have national or regional operative hubs. For instance, the Linde group has close ties to southern Germany while Air Liquide is based out of Paris. Due to these national and regional clusters, it is presumably easier to engage with multinational companies such as Air Liquide in their headquartered country than in other countries where their operations are less pronounced. This may lead to extra challenges when inviting such CCUS supply actors to countries that feature less strong industrial ties with such potential CCUS supply actors.

3. Organisations that may use the CO_2 for further processes, i.e. the utilization step, were not mentioned by regional partners. This may be traced back to the large diversity of CCU applications. It is likely that due to the high diversity of CCU applications many organisations that may potentially make use of CCU potential, may not be aware of CCU benefits. Therefore, they may not (yet) be actively involved in the national CCUS discourse and/or networks.

4.3. Project Regions

The Strategy CCUS project aims at studying and developing eight potential CCUS regional clusters in Southern and Eastern Europe. These include: the Paris Basin (France), Rhône Valley (France), Lusitanian Basin (Portugal), Western Macedonia (Greece), Upper Silesia (Poland), Galati (Romania), Northern Croatia (Croatia) and Ebro Basin (Spain). These regions differ on many scales. For instance, they differ concerning, size of the region, CO_2 sources, CO_2 sequestration and use options, and regional experience with CCUS.

In the following, they will be presented along three general categories: Geography and Politics, Economy and Society, Current state of CCUS. Furthermore. The presentation of the eight regions are followed by a qualitative comparison. The data for the prepared texts were gathered by desk research and telephone interviews with partners in the projects regions (one interview per region and two for Romania).

4.3.1. Paris Basin (France)

Geography and politics

The Geological Paris Basin covers much of northern France and around a third of the whole country. Here, Paris Basin area covers two regions: Hauts-de-France, Île-de-France, and some departments of Centre-Val-De-Loire, the Grand-Est Normandie, Pays-De-La-Loire and Bourgogne-Franche-Comté. Four of these regions are currently governed by the republican party, while two are governed by the socialists and one is governed by the Union des démocrates et indépendants. Due to its size, the region encompasses departments all among the GDP development spectrum. For instance, it includes Île-de-France, which features the

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highest GDP per Capita in France (€ 62,000 per Capita 2016), as well as Hauts-de-France, which features the lowest GDP per Capita with €29,000 (2016). Due to its size, the region also includes several metropolitan areas as Paris, Le Havre, Lille, Reims, Orleans and Dunkirk.

Economy and Society

Due to the size of the basin, there is a large variety of industrial CO_2 emitters in the region, such as coal-fired power plants, steel plants, hydrogen production plants, cement plants, waste incinerators as well as biomass plants. While emitters in Paris are scattered all around the city, the Le Havre port area resembles a very concentrated area with high density of point sources. For instance, it hosts France's largest refinery, a thermal power plant, an automotive plant from Renault and an aircraft engine industrial plant. Due to this agglomeration of industrial compounds, the Le Havre port area emits around 2 MtCO2/year (IREP, 2017). The third highly industrialized agglomeration can be found in the north of the Paris Basin – in Dunkirk. In Dunkirk, a substantial heavy industries cluster with large CO2 emissions has developed along industrial actors such as Arcelor Mittal (steel), Liberty House (aluminium), Glencore Manganese (ferroalloy), Comilog (ferroalloy) and Befesa Valera (steel). Hence, even if there is a large variety of point sources all around the Paris basin area, it seems most reasonable to search for CO2 capture opportunities in the industrial areas of Le Havre and Dunkirk, as higher quantity could be captured in a reduced area, and then promoting capture clusters to share costs of the installations

Current state of CCS and CCU

In order to assess the feasibility of CO_2 injection in the Paris basin sufficient storage capacity needs to be available. To assess the geological structure in search for sufficient CO_2 injection capacity a consortium of four public research institutes and seven industrial partners evaluated deep saline aquifers in the Paris basin (Paris Nord project). In search for a site that would offer a potential of at least 200 Mt of CO_2 the consortium analyzed three potential injection sites (Keuper Nord, Keuper Sud and Buntsandstein). As a result, the consortium came to the conclusion, that each site was smaller than the target size and that a single site with that large of a storage capacity is not available. Hence, if CO_2 sequestration is to be implemented in the Paris basin, it will most likely be done in a scattered manner using a network that transports CO_2 to several smaller injection sites (see also results from EU Geocapacity project[8]). Apart from this exploration project, several CCUS related projects have been conducted. For instance in the Paris area coupling CO_2 storage with geothermal exploitation is envisioned (e.g.CO-Dissolved and GEOCO2 projects), as well as the CO_2 utilization to produce methane from power-to-methane technology. In Le Havre the COCATE project mapped all large emitters and found that 13 industrial compounds are responsible for about 95% of all emitted CO_2.

[7] IREP: French Record of Pollution Emission (http://www.georisques.gouv.fr/dossiers/irep-registre-des-emissions-polluantes)

[8] https://cordis.europa.eu/project/rcn/78777/factsheet/en

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Furthermore, a CO_2 capture pilot was operated at a coal-fired power plant (C2A2 project) and another one is currently operating at a steam methane reforming hydrogen production unit (Cryocap™ H_2process). Le Havre is also targeted in the SET Plan TWG9 on CCS and CCU. In Dunkirk the "3D DMX Demonstration in Dunkirk" is being conducted. The goal of the project is to capture carbon dioxide from the local ArcelorMittal steel plant's blast furnaces as well as to develop technology for conditioning, transporting and storing the CO_2.

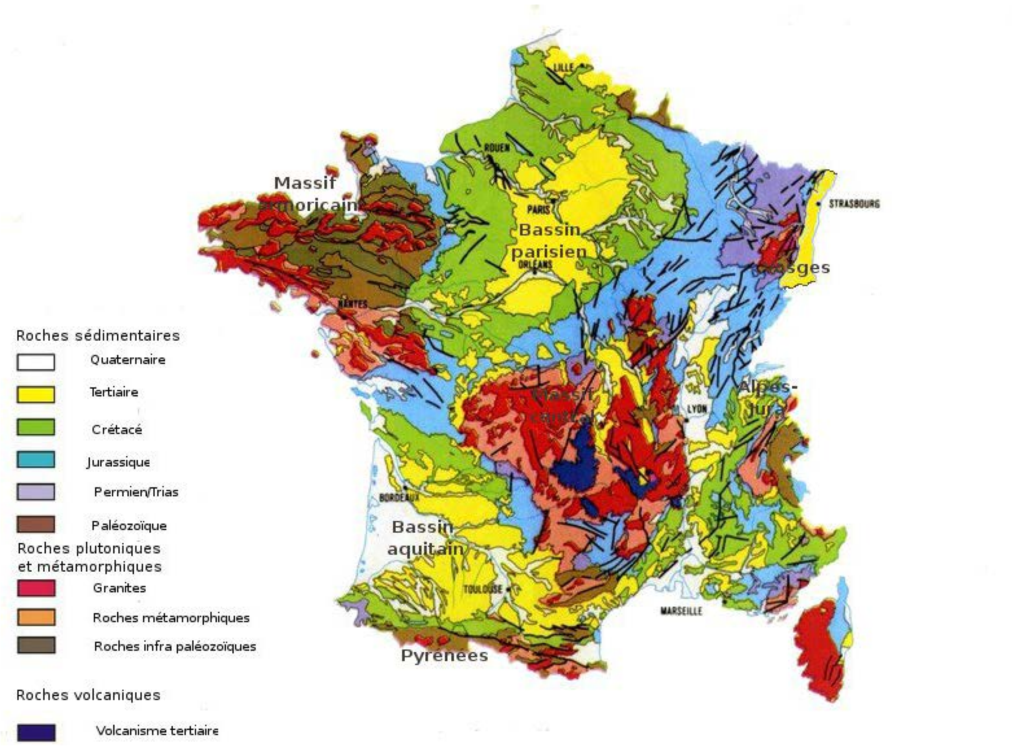

Figure 6: Main geological formations in France, simplified map from BRGM geological map (Limoge University)

4.3.2. Rhône valley (France)

Geography and politics

The Rhone valley focus region is situated in the French region of *"Provence-Alpes-Côte d'Azur",* including Lyon Metropole in the Auvergne-Rhône-Alpes region*. Provence-Alpes-Côte d'Azur* region includes large metropolitan areas as Marseille, Toulon and Nice. The region is currently ruled by the conservative republican Party. *Provence-Alpes-Côte d'Azur"* administrative region is one out of 13 French metropolitan regions and is organized in six departments. Of these six departments, the two departments of *Bouches-du-Rhone* and *Vaucluse* encompasses a large part of the Rhone valley region. Altogether these two regions account for around 2,5 million inhabitants (France 67 million total). The region of "*Provence-Alpes-Côte d'Azur*" features the third highest nominal GDP per Capita among the French regions – 38,213 US$ PPP (2016).

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Analogously *Bouches-du-Rhone* finds itself among the top ten regions (out of 95) concerning GDP per Capita (2015). *Vaucluse* was rated nr. 32 concerning GDP per Capita.

Economy and Society

The economic activity in the Rhône valley is largely based on services and the tertiary sector. However, the south of *Bouches-du-Rhone* hosts the second largest port in France – Fos-sur-Mer – which is very strong concerning hydrocarbons and bulk goods. *Fos-sur-Mer* is located directly adjacent to the Regional Nature Park of the Camargue, which is an UNESCO biosphere reserve. Fos-sur-Mer, the nearby Martigues as well as the shoreline of the Étang de Berre lagoon feature a high density of petroleum processing industry as well as other heavy industry compounds that host steel industry plants and synthetic materials plants.

Current state of CCS and CCU

The Fos-Berre/Marseille CCU cluster is targeted by the SET Plan TWG9 on CCS and CCU (as a Flagship Project): a feasibility study was completed in 2013 with the aim of finding synergies between industrial emitters and potential CCU pathways, by developing a circular approach (industrial symbiosis), therefore sustaining the industries in the area by reducing their CO_2 emissions. In the near future, an important infrastructure component (pipeline collecting CO_2 from different sources and feeding different applications) is planned to be set up. This initiative is supported by the *piicto association* as an intermediary body https://piicto.fr/en/.

Adjacent to the Rhône delta, the Durance river flows through the Durance valley before it confluences with the Rhône near the city of Avignon. Underground salt cavities in Durance valley are currently being used for storing crude oil, heating oil, gasoline, domestic fuel and naphtha. The injection takes place at the Manosque underground storage facility site which is among the largest storage site in the EU (9.2 million m3 in 28 salt caverns). The site is connected by oil and saltwater pipeline to Fos-sur-Mer. Local actors may hope to be able to use the saline aquifer also for storing CO_2.

Apart from that, potential for early storage development is seen in the South-East geological basin, both onshore and offshore in the Mediterranean Sea. Furthermore, it is considered to develop small to medium CCUS hubs-and-clusters within this southeast of the basin. Additionally a connection to the North Sea and it's large storage sites offshore may be considered through a transport corridor along the Rhône Valley, or to explore connections with neighbouring countries (Italy, Spain, North Africa/Middle-East).

In the region of *"Provence-Alpes-Côte d'Azur"*, more than 80 industrial sites are rated as Seveso industrial sites – meaning they contain large quantities of dangerous substances and are therefore prone to major accident hazards. To decrease the harzardous risk of these sites the regional directorates for the Environment, planning and housing (DREAL) continuously review

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the precautionary measures. Local environmental organisations support and supervise the DREAL's monitoring activities.

In the local media CCS or CCUS does not seem to be a major topic.

4.3.3. Ebro Basin (Spain)

Geography and politics

The Ebro Basin region is located in the northeast of Spain. It covers three out of 17 distinct autonomous communities (states) (Catalonia, Valencia and Aragon). Catalonia is ruled by the Junts per Catalonia – an alliance of left Catalonian Republicans, while Valencia and Aragon are ruled by the Spanish socialist workers Party. Since Spain is not a federation, but a highly decentralized unitary state, the distinct autonomous communities have strong influence on their territorial lands. Each autonomous community is subdivided in provinces. The Ebro Basin includes lands from Tarragona province, Castellón province and Teruel province.

Economy and Society

The three communities that are covered by the Ebro Basin are among the economically stronger communities in Spain. Catalonia has a GDP per capita of € 28,800, Aragon € 26,100 Euro and Valencia € 21,200.

Tarragona, Castellón and Teruel feature a large variety of high CO_2 emitters, including refineries, chemical industry, cement plants, pulp and paper industries and ceramics. While Tarragona is strongly diversified among industry, agriculture and tourism, Teruel traditionally focuses more coal mining facilities. Over the last decades, the coal industry has been in constant decline in Teruel province, which led to job losses in the region. To ensure that no region is left behind in the move towards a climate neutral economy, the European Commission accepted Teruel as one of the "regions in transition" which will give it access to specific development funds. In Castellón economic activity is strongly linked to cement and ceramic industries.

Concerning large industry projects, the population in the region experienced a large fail with the so-called castor project. The castor project was planned to be an artificial natural gas deposit in the Mediterranean of the coast of Castellón and Tarragona, but failed soon after inception due to substantial seismic activity. The cost of the project were partly recovered by billing gas consumers in the region.

Current state of CCS and CCU

The Ebro Basin has the highest estimated CO_2 storage capacity in Spain according to national CO_2 geological storage capacity estimation (ALGECO project) and the EU GeoCapacity project. Many CO_2 storage sites in the region have been identified. Most of them are offshore saline aquifers and oil reservoirs.

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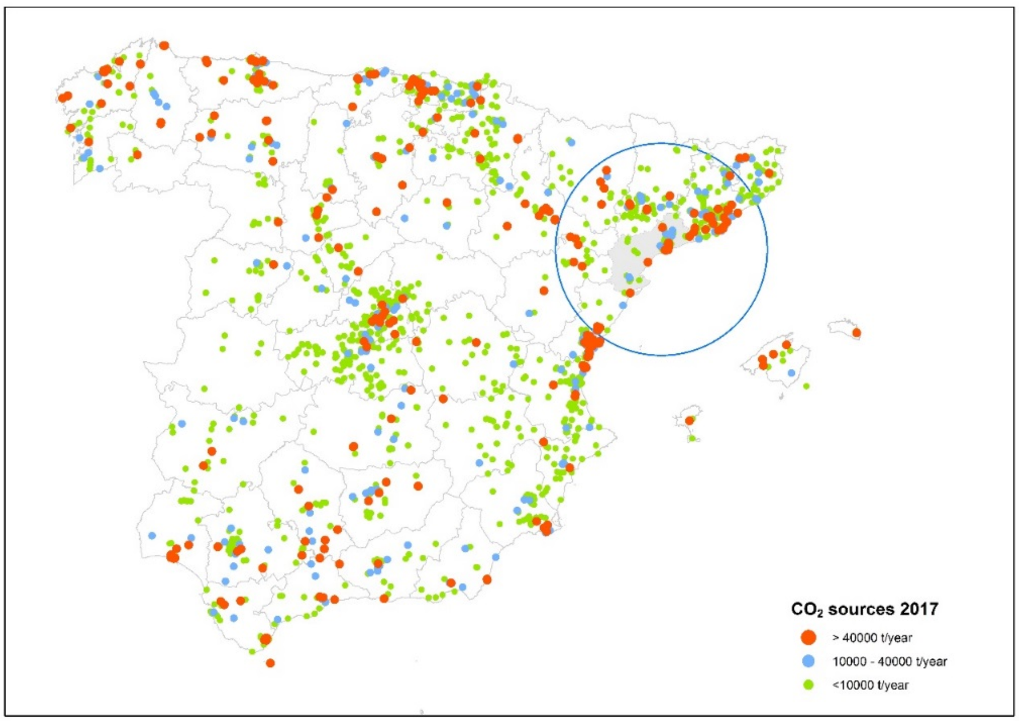
Concerning CO_2 transport, the region is close to the Port of Barcelona and there is a network of pipelines that connects with France and the rest of Spain. This network could be used as a blue print for CO_2 pipelines. CO_2 emitters in the region have been selected and classified according to their levels of emissions. These include industrial compounds from the following industries: cement, chemical, ceramic, petrochemical, urban solid waste and steel.

So far, there have not been substantial attempts to store ore use CO_2. However, there is interest among local industries and platforms in the region. For instance, REPSOL as well as the Spanish Cement Platform have shown interest in the Strategy CCUS project.

Even though, there are not shovel-ready CO_2 storage initiatives, some storage areas have been studied, for instance in the ALGECO Project. Furthermore a pilot project has been implemented in Hontomín area[9].

CCUS is not a topic that is frequently discussed in national or regional media so far.



CO_2 sources (IGME, 2017)+

Figure 7: CO_2 point emissions in Spain; the circle indicates the Ebro Basin (IGME, 2017)

[9] http://www.ciuden.es/index.php/en/tecnologias/instalaciones/pdt-hontomin

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4.3.4. Lusitanian Basin (Portugal)

Geography and politics

The Lusitanian Basin is located on both mainland and continental shelf of the west-central coast of Portugal. It covers about 20,000 km2 area and extends from the city of Aveiro, in the north to Sines, in the south, and is structurally divided by major faults into three sectors, STRATEGY CCUS focusing in the north sector, as delimited by the Nazaré Fault to the south and the Aveiro Fault to the north. Administratively, Portugal is *de jure* a unitarian and decentralized state. Nonetheless, operationally, it is a centralized system with administrative divisions organized into three tiers: *Distritos (*Districts), *municípios (*municipalities) and *freguesias (*civil parishes); it includes two autonomous regions in the Madeira and Azores archipelagos, with regionally governments and parliaments. The northern sector of the Lusitanian basin spreads through 3 out of these 18 Districts.

Economy and Society

Portugal has around 10.5 million inhabitants. Being a seafaring nation, most of them reside along the Atlantic coastline. Analogously, most of heavy industries and CO_2 emitters are located along the coast. Due to the higher economic activity along the coastline the average GDP per capita is higher than for instance in the regions further away from the coast. The GDP per capita in the Lusitanian Basin regions varied between € 22,000 in the Oeste province to about € 26,000 in the Leiria province (2015).

Portugal is not among the most intense CO_2 emitter within the European Union, since high shares of electricity are generated from renewable sources. More than 50 % come from hydropower and wind farms[10]. Currently two coal power plants are in operation in Portugal. Although there is the political goal of phase-out coal before 2030[11].

The largest point emitters in the project region are from cement, pulp and paper and glass industries, as well as gas power plants. Around the Lisbon region and around the Leiria-Figueira axis there are several natural gas power plants (CCGT Lares, GN Ribatejo), cement factories (CIMPOR-Souselas, CMP-Maceira-Liz, CMP-Pataias, CIMPOR-Alhandra, and Secil-Outão) and pulp-and-paper factories (Portucel-Soporcel) that could be integrated into a CCUS network.

Bellona, CENSE research group (NOVA University), CGE research group (Évora University), National Laboratory of Energy and Geology (LNEG) and REN - Redes Energéticas Nacionais, SGPS, S.A. 12 for Portugal, that found that the cement sector should be the primary target

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10 https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20180921-1

11 https://beyond-coal.eu/wp-content/uploads/2019/02/Overview-of-national-coal-phase-out-announcements-Europe-Beyond-Coal-March-2019.pdf

12 https://bellona.org/news/ccs/2015-04-ccs-roadmap-portugal

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for CCS in Portugal (Seixas et al., 2015). The study was undertaken with financial support from the Global CCS Institute (GCCSI).

Apart from heavy industries, also biomass plants as well as CHP plants (CHP Carriço, CHP Soporgen) exist in the same region, for which CCUS applications could be considered.

The relevance of CCUS for the country was confirmed by the national Roadmap for Carbon Neutrality by 2050[13]. The results indicate that carbon neutrality cannot be achieved for Portugal without resorting to CCUS if cement production level continue or increase.

Current state of CCS and CCU

The Lusitanian basin has been indicated in previous projects (notably FP7 COMET and the nationally funded KTEJO and CCS_PT) as the primary target for CO_2 storage in Portugal, with CO_2 injection site options both onshore and in the near offshore. The onshore theoretical capacity is relatively limited (340 Mt), but the offshore theoretical resources are much higher, estimated to be around 1.6 Gt. The geological structure of the basin is complex and additional research needs to be conducted using geophysical information acquired in recent years to better constrain the potential storage sites.

A possible CO_2 transport network to the nearby CO_2 emitters has been studied in detail, with possible transport corridors. Transport from the Sines and Lisbon ports have also been considered as an alternative to the offshore sites (Seixas et al., 2015).

The major CO_2 emitters in the region include ceramic, glass, paper and pulp, cement and combustion of fuels by power and heat production, including the natural gas combined cycle and the coal Pego power plants. There will be a first attempt to use CO2 from the CMP-Pataias cement unit to produce microalgae.

Some of the industry players potentially most interested in the CCUS technology in Portugal, were previously involved in the aforementioned projects to identify storage capacity and transport options, namely GALP (a Portuguese upstream/downstream oil and gas company), EDP and TEJO ENERGIA (major electricity producers from coal and natural gas power plants) and REN (operators of the energy infrastructure networks).

Social opposition and local demonstrations were reported against activities in the cement industry, concerning incineration of toxic materials in the end of the 1990. CCUS is not a topic frequently discussed about in the Portuguese media.

[13] https://descarbonizar2050.pt/en/roadmap/

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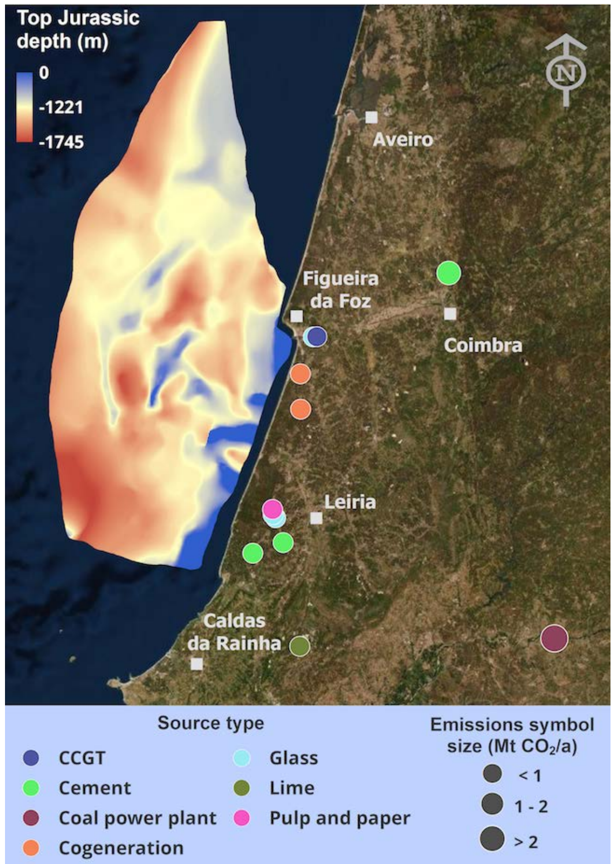

Figure 8: Overview of the Portuguese project region, with main CO_2 emitters and depth to a potential offshore CO_2 storage reservoir

4.3.5. Northern Croatia (Croatia)

Geography and politics

The region of Northern Croatia covers the North-Eastern area of Croatia that is surrounded by Slovenia, Hungary and partly Serbia (red area in Figure 9). Croatia is subdivided into 20 županije (counties) and the city of Zagreb. Each county is headed by a county government which in turn is headed by a county prefect. The region of northern Croatia covers about 13 of these counties. Local government in Northern Croatia are lead by prefects all along the political spectrum: the conservative HDZ, the social democratic SDP, the centrist HHS party as well as the liberal HNS party. Northern Croatia is a term that is not used in official documents but is present as a regional designation.

Northern Croatia was chosen for from several reasons to the be Croatian target region in the Strategy CCUS project: First, most of hydrocarbon research, development and production activities are concentrated in Northern Croatia (Pannonian basin in red; Figure 9). Second, large potential is available in this region for CO_2 use in hydrocarbon fields as a part of CO_2-enhanced

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oil (or gas) recovery. Third, the region possesses a well-developed gas transmission network that could be of use as a potential blueprint for a CO_2-network.

Figure 9: Overall geothermal gradient in Republic of Croatia (source: Energy Institute Hrvoje Požar, www.eihp.hr, Borović, S. and Marković, I., 2015. Utilization and tourism valorisation of geothermal waters in Croatia. Renewable and Sustainable Energy Reviews, 44, pp.52-63)

Economy and Society

The economy of Croatia is a developed high-income service-based economy with the tertiary sector accounting for 60% of total gross domestic product (GDP). While population and heavy industry is gathered around the national capital of Zagreb, and most touristic regions are found at the coast, most areas of northern Croatia focus their economic activities on food processing, chemical industry, and agriculture.

Average GDP differs substantially among the Croatian counties. While in the city of Zagreb GDP per capita was about € 22,000 in 2018, most other counties only featured GDP levels of around 10,000 Euro. Three of the least affluent counties per capita can be found in Northern Croatia: Požega-Slavonia, Krapina-Zagorje and Bjelovar-Bilogora.

Oil products account for around 40%, natural gas for 25%, coal for 8%, and renewable energy (including hydro) around 25% of the total primary energy supply. At the same time, Croatia imports around 40% of electric power, 60% of natural gas and 80% of oil. The building of an LNG terminal on the island of Krk is planned to diversify supply routes and bring higher security of gas supply.

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Currently the new energy strategy from the Croatian government is in its final stage after the public debate. By the end of the summer 2019 it is expected to be published. CCS is mentioned as one option in the Energy Strategy, but the main goal is to increase the share the renewable sources in energy production. GHG emissions reduction is planned by more than 40% until 2030 and 52 – 77% until 2050, in comparison to the 1990 as base year.

Current state of CCS and CCU

While Croatia depends heavily on the import of oil and gas, it covers substantial demand from its own oil and gas fields that are located in Pannonian Basin. Offshore, there are several natural gas fields, but they are near the end of production and probably will be abandoned in the next ten years.

Oil drilling is mainly conducted by the state owned INA Group holding that controls Croatia's oil and gas exploration, production, transportation, trading, refining, and retailing. Due to INAs explorations there are about 3500 wells drilled in Northern Croatia. Of these 3500 wells drilled in Northern Croatia, about 1000 currently operate as oil or gas production wells. This large amount of wells offers potential for CO_2 use in enhanced oil recovery operations (EOR). The biggest problem in CO_2-EOR projects in Croatia are high CO_2 compression cost and constant availability of CO_2.

Several projects have been conducted concerning CCU and CCS in northern Croatia. Among them are the CASTOR , GeoCapacity , CO2NetEast , CO2Stop , ENOS and ESCOM projects. As a part of these projects, mapping of regional aquifers suitable for CO_2 storage and assessments of CO_2 storage into aquifers and depleted hydrocarbon fields were performed.

Almost all point sources where large amounts of CO_2 can be captured are associated with thermal power plants, operated by Croatian Electricity Utility Company (HEP). The other significant point source is a natural gas processing plant in Molve (INA d.d.) where CO_2 is already separated from produced gas and is used for EOR.

Similar to other Strategy-CCUS regions, neither CCS nor CCUS seem to play a major role in public discourse.

4.3.6. Galați Region (Romania)

Geography and politics

Galați is a county in the East of Romania. It hosts the city of Galați, which is situated on the Northern banks of the Danube River – about 11 km away from the boarder of Moldova. It is close to the Black Sea and only about 100 km away from the Danube delta. A census performed in 2011 found that about 250,000 people live the boundaries of the city – which makes it the 8th most populous city in all of Romania. Since the beginning of the 1990s, the city has lost about 80,000 residents. Romania features 41 counties as a second level administrative tier. In the

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process of the upcoming accession to the European Union, eight regional divisions where created that correspond to NUTS II-level divisions in European Union member states. The development regions are constituted by voluntary association of neighboring counties. The development region is not an administrative–territorial[14]. At the level of each development region, a Council for Regional Development (CRD) is formed from the presidents of associated county councils and a representative of each municipal, communal or city council within the region. Despite becoming increasingly significant in regional development projects, Romania's development regions do not actually have an administrative status and do not have a legislative or executive council or government. Galați is placed in the Sud-Est region, which features a GDP per capita score of € 7,400. This is an average value amongst the Romanian NUTS II regions.

Economy and Society

Galați features a substantial heavy industrial compound close to the city. This compound entails a steel plant (Galați steel works) as well as the Damen Shipyards Galați, which is the second largest shipyard in Romania. The steel plant emits approximately 3.9 Mt/year. Apart from the steel plant, two other major emitters exist in the region. First, a co-generation coal plant that is operated by Societatea Electrocentrale Galati SA, which emitted in 2017 203,975 t CO_2. Second, a calcination installation that emitted around of 273,169 t CO_2, that is operated by S.C. Alum S.A. (Tulcea).

Current state of CCS and CCU

Galați is based at the Black Sea Romanian continental shelf. Several hydrocarbon reservoirs are located in the area, which could be considered as possible sinks using the CO_2 in enhanced oil recovery processes (e.g. in Lebada Est and Lebada Vest fields) (Sava et al. 2017). Also deep saline aquifers are available both onshore and offshore (e.g. Iris, Tomis, Lotus structures) (Dudu et al. 2017; Trasca-Chirita et al. 2017).

Due to the geographic fragmentation of point sources in the region, it may be sensible to aggregate geographically closely situated point emitters into clusters and organize combined removal. Potential transport options include a pipeline network or ship transport over the Danube River either to onshore or offshore injection points.

So far, there have not been any CO_2 pilot projects in the Galați region. Currently CCUS is not a predominant topic in the public discourse in the Galați area.

[14] https://www.mdrap.ro/dezvoltare-regionala/-2257/programul-operational-regional-2007-2013/-2975

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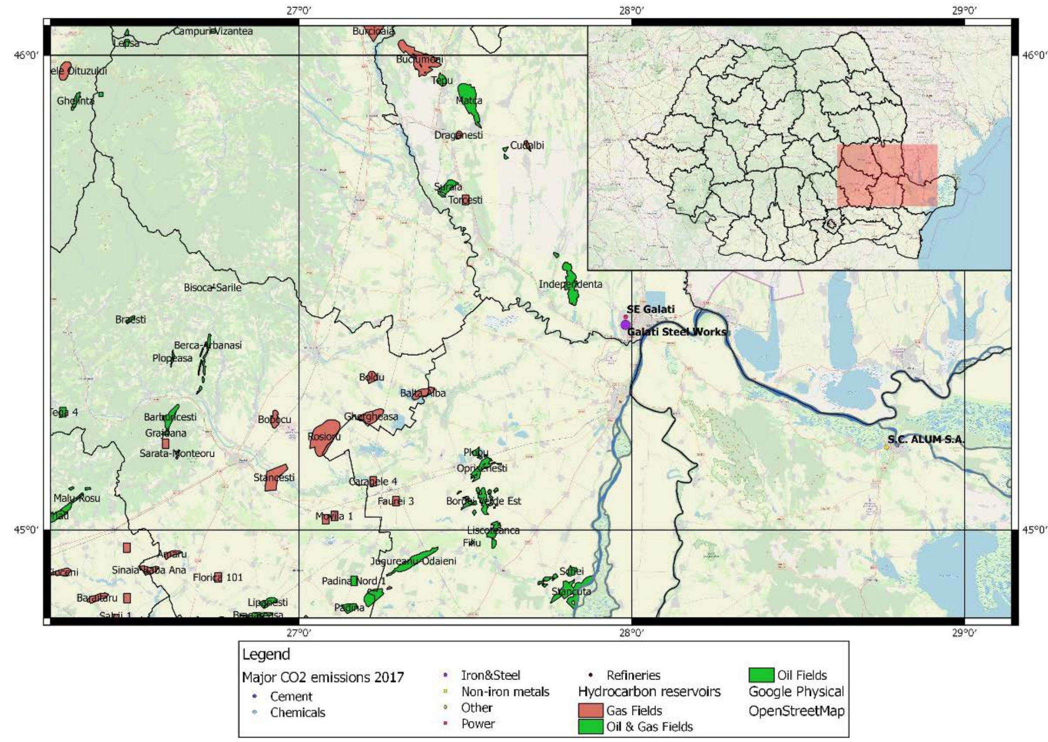

Figure 10: Map of the Galați region

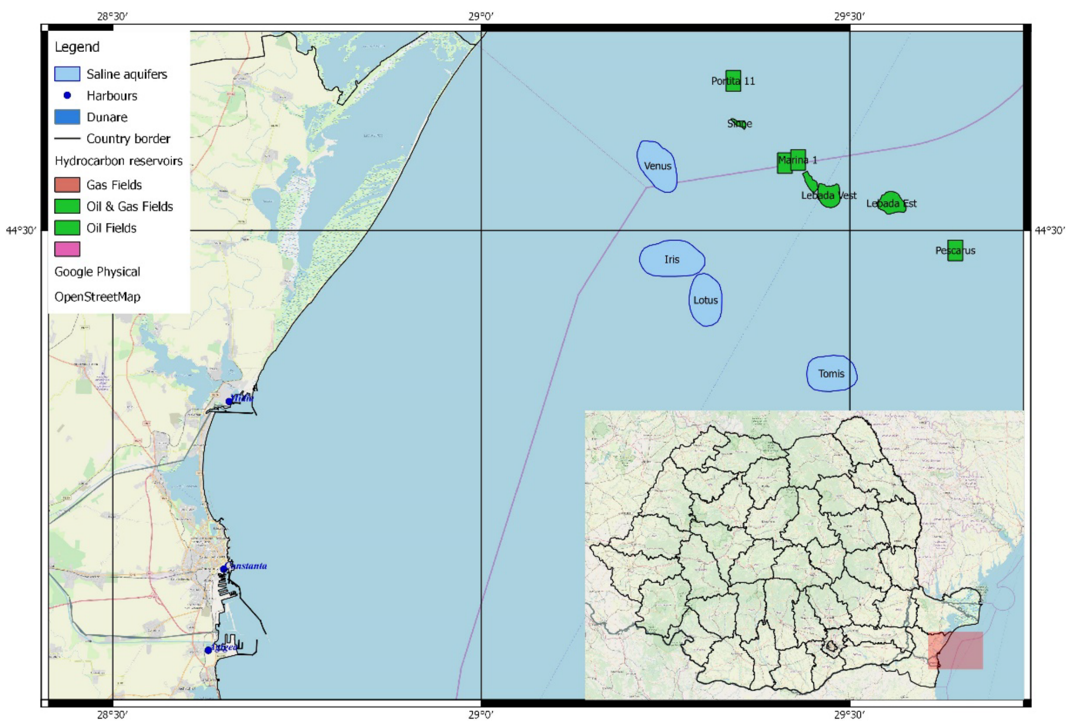

Figure 11: Storage possibilities in the Black sea for CO_2 from Galați region

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4.3.7. West Macedonia (Greece)

Geography and politics

Western Macedonia is situated in northwestern Greece. It is one out of the 13 regions in Greece and shares borders with Central Macedonia (East), Thessaly (South), Epirus (West) and has international borders with North Macedonia and Albania in the North. It covers a total surface of 9,500 km^2 (7.2% of country's total), and has a total population of 283,689 inhabitants (2.6% of the country's total). It is a region with a low population density. Western Macedonia is currently ruled by an independent governor.

Economy and Society

Greece's electricity production is highly dependent on fossil fuel sources. In 2017, about 60% of generated electricity came from burning lignite as well as natural gas. The new national energy and climate plan issued by the Greek government in February 2019 vows a €35 billion investment into the energy transitions[15], however it anticipates a long term continued dependence on fossil fuels[16] and does not foresee a phase out of coal based electricity production.

Western Macedonia economy is strongly involved in lignite mining but also in steel and cement production, chromite mining and fur-leather production. It hosts a large variety of various sizes of CO_2 emitters such as waste incinerator cement plants and biomass plants that are present in the Kozani and Ptolemaida industrial areas. It also hosts the Ptolemaida-Florina Coal Mine, which has coal reserves amounting to 1.82 billion tons of lignite, which is one of the largest reserves in Europe. Due to high lignite exploitation, about 70% of the country's electricity supply is generated in Western Macedonia and distributed all along the country. Prices for electricity in Greece are among the cheapest within the European Union. Hence, in a case of higher cost due to higher CO_2 emission prices within the EU ETS or due to CCUS applications, prices are likely to rise. This may result in purchase relocations away from Greece to other non-EU states that feature lower production costs. Even though CCUS would increase prices for electricity production from coal; it could prolong mining and electricity generation activities in the region. West Macedonia features a GDP per capita of €21,000, which places it fourth among the 13 Greek regions. However, it features one of the highest unemployment rates in all of Greece, about 27% in 2018[17].

15 https://www.euractiv.com/section/energy/news/greece-vows-e35-billion-investment-for-energy-transition/

16 https://www.euractiv.com/section/climate-strategy-2050/opinion/big-fat-greek-lignite-sale-burns-eu-climate-policies/

17 https://tradingeconomics.com/greece/unemployment-rate based on the Hellenic Statistical Authority

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Current state of CCS and CCU

The main sink for CO_2 emissions in Western Macedonia is the Pentalofos reservoir and Eptahori reservoir. Both reservoirs are part of the Mesohellenic Trough, which is the largest and most important molasse basin in the area. It extends from Albania to the North towards Thessaly to the South. According to scientific modelling, the Pentalofos and Eptahori reservoirs are characterized by horizontal maximum dimensions of 47 km by 100 km and cover a surface area of 3813 km^2. Maximum storage capacity is estimated to be up a maximum of 728 Gt of CO_2.[18]. Possible injection points are at about 100 km from the CO_2 emission points. Hence, transportation could be conducted via pipeline network to the Mesohellenic Trough. Other options for CO_2 transport and sequestration may include depleted oil wells in Romania as well as Northern African countries that currently ship LNG to Greece.

Figure 12: Map of Greece; the indicated grey area in the north west of Greece is West Macedonia

Currently there is one CO_2 capture project is in the process of being tendered for development operational in the region.

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[18] Tasianas and Koukouzas 2016 https://www.sciencedirect.com/science/article/pii/S1876610216000369

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The population in West Macedonia as well as policy makers are not very familiar with CCUS technological applications; therefore, the attitude towards the environmental impact of CCUS needs to be identified.

4.3.8. Upper Silesia (Poland)

Geography and politics

Upper Silesia is situated in the Southern Polish voivodeship of Silesia. The capital of Upper Silesia is Katowice. A voivodeship is the highest-level administrative subdivision of Poland, corresponding to a region or province in other countries. Silesia is one out of 16 Polish voivodeships and is divided into 36 powiats (counties). These include 19 city counties (far more than any other voivodeship) and 17 land counties. The Silesian voivodeship's government is headed by the province's *voivode* (governor) who is appointed by the Polish Prime Minister. The *voivode* is then assisted in performing his or her duties by the voivodeship's marshal, who is the appointed speaker for the voivodeship's executive branch and is elected by the *sejmik* (provincial assembly). The Silesian voivodeship is currently ruled by the national conservative PiS party. Even being the third smallest voivodeship, it is home to the second largest population after the Masovian voivodeship and its capital Warsaw. The population density that is about three times higher than the country's average. Silesia features the fourth highest gross regional product (GRP) per capita among the polish voivodeships – 21,600 Euro (2017).

Economy and Society

The economic activity in Upper Silesia is largely based on hard coal mining and power plant operations since it hosts large hard coal reserves in the upper Silesian Coal basin.

However, for years the role of the mining industry has been significantly reduced and many mines were closed down. The region has been undergoing transformation for many years. Furthermore, heavy industrial operations are based in the region such as iron and steel production facilities, chemical plants or automotive branches. Due to this abundance of economic activity, the Upper Silesia Coal Basin is the most industrialized region of Poland.

Since the hard coal mining is mainly based in the upper Silesian region, most of Poland's coal workers are also situated in the region. They are highly organized in unions. Due to cheap availability of coal, concerns about dependency from Russia, attachment to mining traditions in the region, lack of funds to change the heating systems , many households use coal for heating of buildings instead of natural gas or other renewable sources. This leads frequently to rather strong air pollution in the wintertime. To phase out the use of coal for heating the "regional law and program" was established by the regional authority (Sejmik Wojewodztwa Slaskiego and Marshal Office) to reduce coal burning for heating individual households and to improve air quality.

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In 2018, the Polish government has published its energy policy plan for 2040 (PEP2040). This plan suggests that by 2040 the share of electricity generated from coal is to be cut in half. This slump of electricity generation from coal is planned to be replaced by the installation of six nuclear power plants. This energy policy plan does not entail strong diffusion of energy capacity from renewable sources, nor a strategy for CCUS.

Current state of CCS and CCU

Since the 1990s Poland saw a wide variety of programs that supported the initiation of CCS projects (https://books.openedition.org/iheid/4655?lang=en). Among them several KIC InnoEnergy research programs[19] and three EU funded research projects: MOVCBM (6th Framework Programme), REMOVE (6th Framework Programme) and TOPS (7th Framework Programme).

In addition to these research projects, specific pilot program was promoted at the Bełchatów Power Station and in Kędzierzyn. At Bełchatów Power Station – Europe's largest lignite power plant a CCS demonstration project was hosted. However, a larger investment into CCS capacity failed to receive sufficient funding and was abandoned in 2013. In Kędzierzyn a “Zero-Emission Power and Chemical Complex” that integrated IGCC generation technology with CCS was intended to be build. However, this project was also eventually abandoned due to a lack of funds.

In Upper Silesia Coal Basin CO_2 can either be injected into aquifers or into coal seams. Injection into coal seams can increase the output of methane. This method of increasing the methane output of coal seams is known as *enhanced coal bed methane recovery* (ECBM). So far, there has been research concerning ECBM in upper Silesia including a test site[20]. Due to land development, active hard coal mines and environmentally protected areas (Natura 2000 sites), only one area associated with aquifers and three areas associated with CO_2 storage in coal seams seem to be feasible for CO_2 injection. The aquifers tank capacity was estimated to allow about 44 million tons of CO_2 to be deposited[21]. Three areas associated with CO_2 storage in coal seams were estimated at 55-75 km^2 each.

So far, no geological explorations have been conducted in the upper Silesian region. Hence, no reliable injection capacity estimates for these seams are available. Furthermore, in the local media CCS nor CCUS does not seem to be a major topic.

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19 https://slideplayer.com/slide/8029336/

20 https://www.adv-res.com/Coal-Seq.../ECBM.../02_05_04.pdf

21 https://skladowanie.pgi.gov.pl/twiki/pub/CO2/WebHome/sekw-pods.pdf

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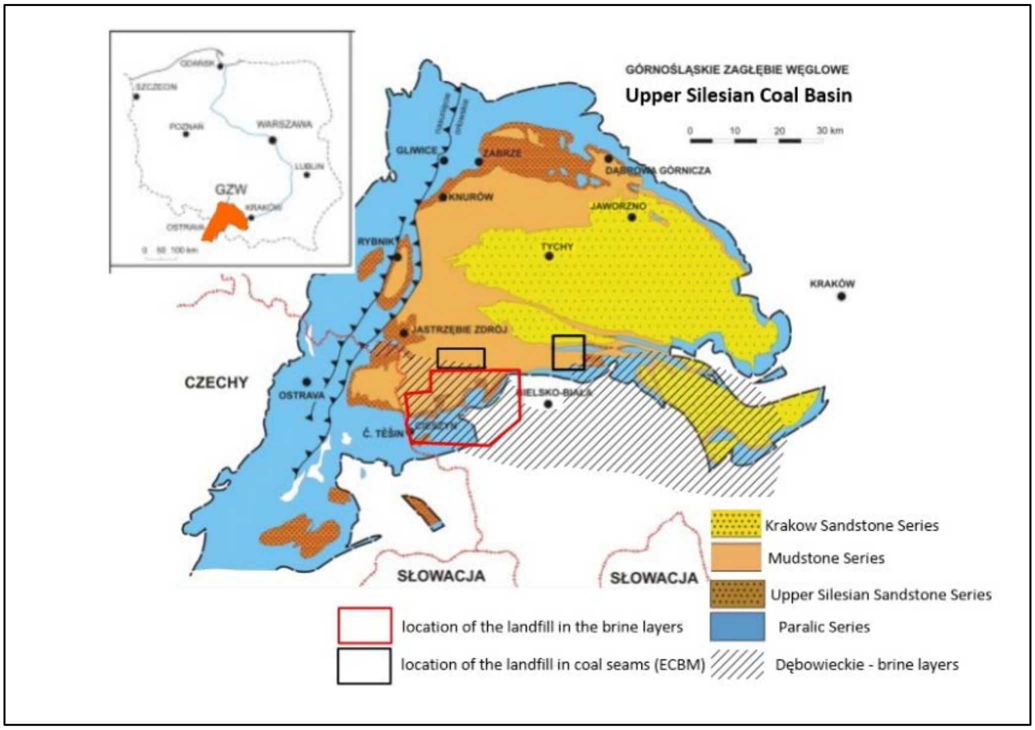

Figure 13: Main geological formations in Upper Silesia region

4.3.9. Comparison of regions

Among the eight presented regions, substantial differences were identified for example concerning the sources of CO_2, the potential of CCUS as well as their size and political administrative structure. These will briefly summarised in the following.

Concerning the sources of CO_2 a substantial share of regions intend to use CCUS technology to decarbonize their heavy industry compounds. This is the case in both the French regions, the Ebro basin, the Lusitanian Basin, and the Galati region. In contrast, Western Macedonia and upper Silesia aim to use CCUS technology to decarbonize their thermal energy plants running on fossil fuels and hence keep these power plants running as well as the local mining industry.

In most regions, the captured CO_2 is to be injected into aquifers. This is the case for the two French regions, the Lusitanian basin, the Galati area, the Ebro basin and Western Macedonia. Northern Croatia and Upper Silesia have the potential for distinct use cases. In both regions, local actors aim to use CO_2 capture for enhancing the efficiency of their fossil fuel extraction processes. While in Upper Silesia CO_2 can be used for enhanced coal bed methane recovery (CO_2-ECBM), in Northern Croatia it is likely to be used to increase the output of natural gas and oil fields. Both use cases, increase the production of fossil fuels and hence the original emission of CO_2. So far, it seems as if in no region, options for substantial use for the captured CO_2 have been developed nor discussed.

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The focus region differ substantially in size. While the Paris Basin covers most of northern France, the Romanian focus area resembles only one county and its capital – Galati. While Galati city has around 250,000 inhabitants, the Paris basin hosts several large cities and metropolitan areas such as Le Havre, Dunkirk as well as Paris, with several million inhabitants. Due to the differences in size also the anticipated administrative processes are likely to deviate across the regions. While Western Macedonia is one out of 13 regions in Greece, the Ebro Basin covers three autonomous communities (regions). Also the administrative structure of the host countries is likely to influence the implementation of CCUS technology. While the regions in Spain are known for being quite independent, other countries like France, Croatia and Romania feature more centralized political decision making processes. Regarding public perception and social acceptance, no country reported to have an ongoing discourse around potential CCUS developments.

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5. Conclusions

The objective of the STRATEGY CCUS project is to develop strategic plans for the implementation of CCUS applications in eight focus regions in Southern and Eastern Europe.

The diffusion of innovations such as CCUS applications is not only a technological one but takes place in socio-technical innovation systems and requires the acceptance of several stakeholder groups. In the past, the diffusion of CCUS application has been substantially hampered by the lack of active societal support. To reflect the importance of actors in the CCUS innovation system development, the CCUS Strategy project has a dedicated work package that deals with stakeholders and CCUS acceptance. The aim of this first deliverable is to summarise the latest social acceptance related research on CCUS as a basis for further work and to identify and map relevant CCUS stakeholders on three levels: The European level, the national level and the regional level.

To collect the latest social acceptance related research, a comprehensive literature analysis was performed for CCS and CCU applications respectively. This literature review showed for instance, that the awareness of CCS and CCU technologies in the broader public continues to be rather limited and that acceptance levels are found to be moderate on average. Regarding the local acceptance, the review showed that social acceptance is also influenced by the CO_2 source. Specifically, combining coal-fired power plants with CCUS is less embraced by the public than e.g. integration in heavy industries (Dütschke et al. 2016). CCU is evaluated more positively than CCS (Whitmarsh et al. 2019; Linzenich et al. 2019; Arning et al. 2019a). On a national level, some variety in social acceptance was found. While in the past community acceptance for CCS was found to be lower than on the national level e.g. for Germany, more recent research in the UK detected also more positive evaluations on the local level (Whitmarsh et al. 2019). While a few studies have looked into different groups of stakeholders and experts, the majority of social acceptance research focuses on the broader or the local public. Regarding stakeholders, most approaches involve only very small samples and a differentiation between stakeholder categories is therefore difficult to draw. A more detailed analysis of stakeholder perceptions is therefore part of the second task of this WP.

To identify and map CCUS relevant stakeholders, a desk research was performed that was informed by a combination of innovation system theories and social acceptance research. It showed that all innovation system related actor groups can be found in the European CCUS innovation system. However, it also shows, that the number CCUS supply actors is very limited. For the stakeholder mapping on the national and regional level interviews with partners in all eight-focus regions were performed. The results show that in some countries the CCUS related stakeholder density is higher than in other countries. For instance in Spain there are a number of governmental bodies that deal with CCUS related topics, while this is seemingly not the case in some of the Eastern and Southeastern European countries. The regional analysis showed that the focus regions have very different points of departure for the successful implementation of CCUS applications. For example, the regions differ in size, population density, economic

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development, CO_2 sources and opportunities for CO_2 sequestration or use respectively. Concerning social acceptance of CCUS applications, the interviews support the findings from the literature review that CCUS is generally a topic that is sparsely touched upon in the local discourse be it among lay people or the news media. No earlier social acceptance research could be identified that focused specifically on the regions under study. Overall, relatively little publications refer to the countries under study (exceptions include e.g. Oltra et al. 2010; Reiner et al. 2012).

The report provides a good overview of the current CCUS related social acceptance literature. It also gives a good overview of CCUS related actors on the EU level, the national level as well as the regional level. For these reasons, it is a valuable input for CCUS related policy makers, industrial actors as well as for further tasks in the WP3 of the STRATEGY CCUS project.

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6. Annex - List of national stakeholders

France

- Politics & policies
  - ADEME (French Environment and Energy Management Agency)
  - DREAL (Regional Direction for Environment, Development and Housing)
  - Ministry of ecology and solidarity Transition
- Research & education
  - Centre Scientifique et Technique Jean Féger (Total)
  - IFpen (French petroleum institute)
  - BRGM
- Supply
  - Air Liquide
- Demand
  - TOTAL S.A.
  - STORENGIE
  - GeoSTOCK
- Support organistions and influencers
  - France Nature Environnement
  - Réseau pour la transition énergétique
  - Reseau Français des Etudiants pour le Développement Durable

Spain

- Politics & policies
  - Centro Nacional de Educación Ambiental (CENEAM) (MITECO)
  - Oficina Española del Cambio Climático (MITECO)
  - Dirección General de Calidad y Evaluación Ambiental y Medio Natural (MITECO)
  - Dirección General de Sostenibilidad de la Costa y del Mar (MITECO)
  - Consejo Nacional del Clima (CNC) (MAPAMA)
  - Comisión de Coordinación de Políticas de Cambio Climático (CCPCC)
  - Comisión Interministerial para el Cambio Climático y la Transición Energética (ver directorio de ONGs de medio ambiente)
- Research & education
  - Spanish Research Center for Energy, Environment and Technology (CIEMAT),
- Supply
- Demand
  - Industrial organisations that represent ceramics and related products: ASCER, HYSPALYT, ANFFECC, AEI, ITC
  - Industrial organisations that represent glass, windows, and facade systems: ANFEVI, ASEFAVE, CONFEVICEX
  - Industrial organisations that represents chemicals: FeiQue

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- Industrial organisations that represents biomass: AVEBIOM
- Support organisations and influencers
  - Asociación Coordinadora Ecológica Gente del Campo
  - Grupo de Estudios y Protección de los Ecosistemas del Campo
  - Asociación para la Conservación de los Ecosistemas Naturales
  - Fundación Cataluña La Pedrera
  - Ambiente Europeo
  - Asociación Paisaje Limpio
  - Fundación Global Nature
  - Hombre y Territorio
  - Real Sociedad Española de Química
  - Fundación Biodiversidad

Portugal[22]

- Politics & policies
  - Direcção Geral de Energia e Geologia (Already a project partner)
  - DGRM: Direcção Geral dê Recursos Naturais, Segurança e Serviços Marítimos
  - Comissão de Coordenação e Desenvolvimento Regional do Centro
  - Comissão de Coordenação e Desenvolvimento Regional de Lisboa e Vale do Tejo
- Research & education
  - ICNF – Instituto da Conservação da Natureza e das Florestas
  - LNEG – Laboratório Nacional de Energia e Geologia
- Supply
  - Associação Portuguesa de Seguradores
- Demand
  - AIVE - Associação dos Industriais de Vidro de Embalagem
  - SPCV - Sociedade Portuguesa de Cerâmica e Vidro
  - CTCV: Centro Tecnológico da Cerâmica e do Vidro
  - APICER – Associação Portuguesa das Indústrias de Cerâmica e de Cristalaria
  - ATIC - Associação Técnica da Indústria de Cimento
  - Celpa – Associação da Indústria Papeleira
  - APEB – Associação dos produtores de energia e biomassa
- Support organisations and influencers
  - Agência Portuguesa do Ambiente (APA)
  - Liga para a Protecção da Natureza: LPN
  - EMEPC – Estrutura de Missão para a Extensão da Plataforma Continental
  - ANMP – Associação Nacional de Municípios Portugueses

[22] a more extensive list of stakeholders is available for Portugal and will be utilized in the next work packages

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Croatia

- Politics & policies
- Research & education
    - University of Zagreb (UNIZG), Faculty of Mining, Geology and Petroleum Engineering, Petroleum Engineering Department (RGNF)
- Supply
- Demand
    - INA-Industrija nafte, d.d.
    - Cemx Hrvatska D.D.
    - Našicement Tvornica cementa, dioničko društvo
    - Holcim (Hrvatska) d.o.o.
    - Vetropack Straža d.d.
    - Hep-Proizvodnja d.o.o.
    - UNI Viridas društvo s ograničenom odgovornošću za energetiku
    - Univerzal d.o.o.
    - Tvornica Šećera Osijek d.o.o
- support organisations and influencers

Romania

- Politics & policies
    - National Agency for Mineral Resources
    - Ministry of Economy
    - Ministry of Energy
    - Ministry of Environment
- Research & education
    - National University of Political Studies and Public Administration - Bucharest
    - GeoEcoMar
- Supply
- Demand
    - Galati steel works
    - OMW Petrom
    - ROMGAZ
    - Societatea Electrocentrale Galati SA
- Support organisations and influencers
    - CO2 Club

Greece

- Politics & policies
    - Ministry of Energy and Environment
- Research & education

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- Certh
- Supply
- Demand
    - Mytilineos
    - GEK Terna Group
    - Energean Oil & Gas
    - Viohalco S.A.
    - Public Power Corporation of Greece – PPC
- Support organisations and influencers

Poland

- Politics & policies
    - the Voivodship Office
    - the Marshal Office of the Silesian Voivodship
    - Mayor of Katowice City
- Research & education
    - Polish Geological Institute, National Research Institute
    - Silesian University of Technology, Faculty of Environmental Engineering and Energy
- Supply
- Demand
    - Tauron company, dept. of innovation
    - PGG
    - JSW
    - JSW-Innovation
    - SRK- Mines Restructuring Company
    - Euro-Centrum Industrial Park Synthos Group (Chemical companies)
    - Orlen (Chemical companies)
    - PGNIG- Polskie Górnictwo Naftowe i Gazownictwo SA
    - Węglokoks Energia
- Support organisations and influencers
    - "BoMiasto Association"
    - Śląski Związek Gmin i Powiatów (Silesian Association of Municipalities and Poviats)

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7. References

Arning, K.; Offermann-van Heek, J.; Linzenich, A.; Kaetelhoen, A.; Sternberg, A.; Bardow, A.; Ziefle, M. (2019a): Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany. In *Energy Policy* 125, pp. 235–249. DOI: 10.1016/j.enpol.2018.10.039.

Arning, Katrin; Offermann-van Heek, Julia; Sternberg, André; Bardow, André; Ziefle, Martina (2019b): Risk-benefit perceptions and public acceptance of Carbon Capture and Utilization. In *Environmental Innovation and Societal Transitions. DOI:* 10.1016/j.eist.2019.05.003.

Arning, Katrin; van Heek, Julia; Ziefle, Martina (2018): Acceptance profiles for a carbon-derived foam mattress. Exploring and segmenting consumer perceptions of a carbon capture and utilization product. In *Journal of Cleaner Production* 188, pp. 171–184. DOI: 10.1016/j.jclepro.2018.03.256.

Bergek, A.; Jacobsson, S.; Carlsson, B.; Lindmark, S.; Rickne, A. (2008): Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. In *Research Policy* 37 (3), pp. 407–429.

Bögel, Paula Maria; Upham, Paul (2018): Role of psychology in sociotechnical transitions studies. Review in relation to consumption and technology acceptance. In *Environmental Innovation and Societal Transitions* 28, pp. 122–136. DOI: 10.1016/j.eist.2018.01.002.

Boyd, Amanda D. (2016): Examining Community Perceptions of Energy Systems Development. The Role of Communication and Sense of Place. In *Environmental Communication* 11 (2), pp. 184–204. DOI: 10.1080/17524032.2015.1047886.

Boyd, Amanda D.; Hmielowski Jay; David, Prabu (2017): Public perceptions of carbon capture and storage in Canada. Results of a national survey. In *International Journal of Greenhouse Gas Control* 67, pp. 1–9. DOI: 10.1016/j.ijggc.2017.10.010.

Braun, Carola (2017): Not in My Backyard. CCS Sites and Public Perception of CCS. In *Risk Analysis* 37 (12), pp. 2264–2275. DOI: 10.1111/risa.12793.

Broecks, Kevin P.F.; van Egmond, Sander; van Rijnsoever, Frank J.; Verlinde-van den Berg, Marlies; Hekkert, Marko P. (2016): Persuasiveness, importance and novelty of arguments about Carbon Capture and Storage. In *Environmental Science & Policy* 59, pp. 58–66. DOI: 10.1016/j.envsci.2016.02.004.

Devine-Wright, P.; Batel, S. (2017): My neighbourhood, my country or my planet? The influence of multiple place attachments and climate change concern on social acceptance of energy infrastructure. In *Global Environmental Change* 47, pp. 110–120. DOI: 10.1016/j.gloenvcha.2017.08.003.

Dudu, Alexandra; Morosanu, Ion; Sava, Constantin; Iordache, Gabriel; Avram, Corina; Anghel, Sorin et al. (2017): CO2 Geological storage possibilities in histria depression - Black Sea (Romania). In *Geo-Eco-Marina* 23, pp. 171–176.

Dütschke, Elisabeth; Burghard, Uta; Oltra, Christian; Sala, Roser; Lopez, Sergi (2019): Socio-political acceptance findings. Market Uptake of Solar Thermal Electricity through Cooperation. Available online at http://mustec.eu/node/98, checked on 7/26/2019.

Dütschke, Elisabeth; Choi, Su-Min; Sala, Roser; Oltra, Christian (2018): Stakeholder mapping report. Deliverable 3.1. Market Uptake of Solar Thermal Electricity through Cooperation. Available online at http://mustec.eu/node/72, checked on 19/07/19.

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

Dütschke, Elisabeth; Schuhmann, Diana; Pietzner, Katja (2015): Chances for and Limitations of Acceptance for CCS in Germany. In Axel Liebscher, Ute Münch (Eds.): Geological storage of CO2 - long term security. Cham [Germany]: Springer (Advanced Technologies in Earth Sciences), pp. 229–245.

Dütschke, Elisabeth; Upham, Paul; Schneider, Uta (2017): Report on results of the stakeholders survey. Deliverable 5.1. Edited by Project HYACINTH. Available online at http://hyacinthproject.eu/wp-content/uploads/2017/12/HYACINTH-D5_1-Report-on-results-of-the-stakeholders-survey_v02_DEF.pdf, checked on 12/3/2018.

Dütschke, Elisabeth; Wohlfarth, Katharina; Höller, Samuel; Viebahn, Peter; Schumann, Diana; Pietzner, Katja (2016): Differences in the public perception of CCS in Germany depending on CO 2 source, transport option and storage location. In *International Journal of Greenhouse Gas Control* 53, pp. 149–159. DOI: 10.1016/j.ijggc.2016.07.043.

Fischedick M.; Roy, J.; Abdel-Aziz, A.; Acquaye, A.; Allwood, J. M.; Ceron, J.-P. et al. (2014): Industry Industry. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press,. Cambridge, United.

Geels, Frank W. (2014): Reconceptualising the co-evolution of firms-in-industries and their environments. Developing an inter-disciplinary Triple Embeddedness Framework. In *Research Policy* 43 (2), pp. 261–277. DOI: 10.1016/j.respol.2013.10.006.

Globisch, Joachim; Dütschke, Elisabeth; Wietschel, Martin (2018): Adoption of electric vehicles in commercial fleets. Why do car pool managers campaign for BEV procurement? In *Transportation research. Part D, Transport and environment* 64, pp. 122–133. Available online at http://publica.fraunhofer.de/documents/N-473986.html.

Gough, Clair; Cunningham, Rebecca; Mander, Sarah (2018): Understanding key elements in establishing a social license for CCS. An empirical approach. In *International Journal of Greenhouse Gas Control* 68, pp. 16–25. DOI: 10.1016/j.ijggc.2017.11.003.

Hameed, Mumtaz Abdul; Counsell, Steve; Swift, Stephen (2012): A conceptual model for the process of IT innovation adoption in organisations. In *Journal of Engineering and Technology Management* 29 (3), pp. 358–390. DOI: 10.1016/j.jengtecman.2012.03.007.

Hekkert, Marko; Negro, Simona; Heimeriks, Gaston; Harmsen, Robert (2011): Technological Innovation System Analysis. A manual for analysts. Edited by Universiteit Utrecht. Utrecht.

Jones, Christopher R.; Olfe-Kräutlein, Barbara; Naims, Henriette; Armstrong, Katy (2017): The Social Acceptance of Carbon Dioxide Utilisation. A Review and Research Agenda. In *Front. Energy Res.* 5, 1-13. DOI: 10.3389/fenrg.2017.00011.

Kant, Marvin; Kanda, Wisdom (2019): Innovation intermediaries. What does it take to survive over time? In *Journal of Cleaner Production* 229, pp. 911–930. DOI: 10.1016/j.jclepro.2019.04.213.

Kanudia, A., Berghout, N., Boavida, D., van den Broek, M., Cabal, H., Carneiro, J., Fortes, P., Gargiulo, M., Gouveia, JP, Labriet, M., Lechón, Y., Martinez, R., Mesquita, P., Rimi, A., Seixas, J., Tosato, G., (2013). CCS infrastructure development scenarios for the integrated Iberian Peninsula and Morocco energy system. Energy Procedia 37, 2645 – 2656

Karimi, Farid; Komendantova, Nadejda (2017): Understanding experts' views and risk perceptions on carbon capture and storage in three European countries. In *GeoJournal* 82 (1), pp. 185–200. DOI: 10.1007/s10708-015-9677-8.

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

Karimi, Farid; Toikka, Arho (2018): General public reactions to carbon capture and storage. Does culture matter? In *International Journal of Greenhouse Gas Control* 70, pp. 193–201. DOI: 10.1016/j.ijggc.2018.01.012.

Kuhlmann, S.; Arnold, E. (2001): RCN in the Norwegian Research and Innovation System (Background report No 12).

L'Orange Seigo, Selma; Dohle, Simone; Siegrist, Michael (2014): Public perception of carbon capture and storage (CCS). A review. In *Renewable and Sustainable Energy Reviews* 38, pp. 848–863. DOI: 10.1016/j.rser.2014.07.017.

Linzenich, Anika; Arning, Katrin; Offermann-van Heek, Julia; Ziefle, Martina (2019): Uncovering attitudes towards carbon capture storage and utilization technologies in Germany. Insights into affective-cognitive evaluations of benefits and risks. In *Energy Research & Social Science* 48, pp. 205–218. DOI: 10.1016/j.erss.2018.09.017.

Mabon, Leslie; Littlecott, Chris (2016): Stakeholder and public perceptions of CO2-EOR in the context of CCS – Results from UK focus groups and implications for policy. In *International Journal of Greenhouse Gas Control* 49, pp. 128–137. DOI: 10.1016/j.ijggc.2016.02.031.

Mander, Sarah; Cunningham, Rebecca; Lever, Louise; Gough, Clair (2017): Comparing Online and Offline Knowledge Networks of Carbon Capture and Storage. In *Energy Procedia* 114, pp. 7326–7332. DOI: 10.1016/j.egypro.2017.03.1863.

Nuortimo, Kalle (2018): Measuring public acceptance with opinion mining. The case of the energy industry with long-term coal R&D investment projects. In *Journal of Intelligence Studies in Business* 8 (2). Available online at https://ojs.hh.se/index.php/JISIB/article/download/319/188.

Offermann-van Heek, Julia; Arning, Katrin; Linzenich, Anika; Ziefle, Martina (2018): Trust and Distrust in Carbon Capture and Utilization Industry as Relevant Factors for the Acceptance of Carbon-Based Products. In *Front. Energy Res.* 6, p. 73. DOI: 10.3389/fenrg.2018.00073.

Oltra, C.; Sala, R.; Solà, R.; Di Masso, M.; Rowe, G. (2010): Lay perceptions of carbon capture and storage technology. In *International Journal of Greenhouse Gas Control* 4 (4), pp. 698–706. DOI: 10.1016/j.ijggc.2010.02.001.

Oltra, Christian; Upham, Paul; Riesch, Hauke; et al. (2012): Public Responses to CO2 Storage Sites: Lessons from Five European Cases. In *energy & environment* 23 (2&3), pp. 227–248.

Reiner, David; Riesch, Hauke; Chyong, Chi Kong; Brunsting, Suzanne; Best-Waldhober, Marjolein de; Duetschke, Elisabeth et al. (2012): Opinion shaping factors towards CCS and local CCS projects: Public and stakeholder survey and focus groups. WP2. Edited by Near CO2. Judge Business School. Cambridge. Available online at https://www.communicationnearco2.eu/fileadmin/communicationnearco2/user/docs/WP2.1_Report_Final.pdf, checked on 01/08/19.

Sava, Constantin; Dudu, Alexandra; Anghel, Sorin; Dinu, Corneliu; Soare, Rome; Burlacu, Andreea; Alexe, Iolanda (2017): Multimodal Transport of CO2 for Implementing CCUS in Romania,. In *Geo-Eco-Marina* 23, pp. 223–227.

Schumann, Diana; Duetschke, Elisabeth; Pietzner, Katja (2014): Public Perception of CO2 Offshore Storage in Germany. Regional Differences and Determinants. In *Energy Procedia* 63, pp. 7096–7112. DOI: 10.1016/j.egypro.2014.11.744.

Seixas, J., Fortes, P., Dias, L., Carneiro, J., Mesquita, P., Toscano, T., Boavida, D., Aguiar, R., Marques, F., Fernandes, V., Helseth, J., Ciesielska, J., Whiriskey, K. (2015). CCS in Portugal –A bridge to a low carbon economy. CENSE – FCT/UNL, CGE –UE, LNEG, REN –Rede Eléctrica Nacional, S.A., Bellona Foundation. ISBN 978-972-8893-36-1, Lisboa, Portugal

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Special Eurobaromenter (2011): Public Awareness and Acceptance of CO2 capture and storage. With assistance of TNS Opinion & Social. Edited by Directorate-General for Energy. European Commission. Brussels.

Trasca-Chirita, Nicolae; Anghel, Florentina; Gheorge, Bogdan; Dudu, Alexandra; Anghel, Sorin; Sava, Constantin S.; Burlacu, Andreea (2017): CO2-EOR Possibilities In Romania. A First Screening For The Implementation Of CO2-EOR Technology In Romania. In *Geo-Eco-Marina* 23, pp. 229–232. DOI: 10.5281/zenodo.1459642.

Upham, Paul; Oltra, Christian; Boso, Àlex (2015): Towards a cross-paradigmatic framework of the social acceptance of energy systems. In *Energy Research & Social Science* 8, pp. 100–112. DOI: 10.1016/j.erss.2015.05.003.

Vercelli, Samuela; Lombardi, Salvatore; Bigi, Sabina; Tartarello, Maria Chiara; Finoia, Maria Grazia; Dolcetti, Francesca (2017): Topic and Concerns Related to the Potential Impacts of CO2 Storage. Results from a Stakeholders Questionnaire. In *Energy Procedia* 114, pp. 7379–7398. DOI: 10.1016/j.egypro.2017.03.1869.

Vreys, Kim; Lizin, Sebastien; van Dael, Miet; Tharakan, Joe; Malina, Robert (2019): Exploring the future of carbon capture and utilisation by combining an international Delphi study with local scenario development. In *Resources, Conservation and Recycling* 146, pp. 484–501. DOI: 10.1016/j.resconrec.2019.01.027.

Warnke, Philine; Koschatzky, Knut; Dönitz, Ewa; Zenker, Andrea; Stahlecker, Thomas; Som, Oliver et al. (2016): Opening up the innovation system framework towards new actors and institutions. Edited by Fraunhofer ISI. Karlsruhe (Fraunhofer ISI Discussion Papers Innovation Systems and Policy Analysis, 49).

Whitmarsh, Lorraine; Xenias, Dimitrios; Jones, Christopher R. (2019): Framing effects on public support for carbon capture and storage. In *Palgrave Commun* 5 (1), p. 7410. DOI: 10.1057/s41599-019-0217-x.

Wüstenhagen, Rolf; Wolsink, Maarten; Bürer, Mary Jean (2007): Social acceptance of renewable energy innovation. An introduction to the concept. In *Energy Policy* 35 (5), pp. 2683–2691. DOI: 10.1016/j.enpol.2006.12.001.

Xenias, Dimitrios; Whitmarsh, Lorraine (2018): Carbon capture and storage (CCS) experts' attitudes to and experience with public engagement. In *International Journal of Greenhouse Gas Control* 78, pp. 103–116. DOI: 10.1016/j.ijggc.2018.07.030.

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