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Public perception and acceptance of CCUS: preliminary findings of a qualitative case study in Greece.

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CASE STUDY

Public perception and acceptance of CCUS: preliminary findings of a qualitative case study in Greece [version 1; peer review: 2 approved with reservations, 1 not approved]

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Abstract

The development and implementation of carbon capture, utilisation and storage (CCUS) technologies plays an increasingly important part in European Union (EU) and global decarbonisation policies and strategies that seek to address climate change to achieve the Paris Agreement goals. Several studies have shown the important role social acceptance plays in determining the outcomes of CCUS projects and how social acceptance is shaped by the national and local contexts. Yet most studies on CCUS and social acceptance have focused on countries in northern Europe and North America despite the increasing numbers of CCUS projects in other regions of the world. This study seeks to help address this gap by conducting a case study on how local dynamics shaped people's acceptance and awareness of CCUS in a Greek community. Based on semi-structured interviews with community members near a CCUS pilot plant, this single case study explores the factors and dynamics that shaped the interviewees' perceptions of CCUS technologies. Our findings indicate that, despite the low level of awareness of CCUS technologies, participants could draw on their situated knowledge to identify potential drawbacks with their application. We identified scepticism regarding the adoption of new technologies and the organisations involved based on past experiences, and a notable lack provision of technology and location-specific information as well public engagement by the project consortium. Our recommendations for future projects and community engagement include the early involvement of the public in project development, location-based transparent information, appropriate channels to facilitate knowledge exchange, and educational initiatives to build communities' capability to influence projects.

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Any reports and responses or comments on the article can be found at the end of the article.

Keywords

Carbon capture, Utilization, Storage, Climate change, Greece, acceptance, public, qualitative, case study



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Introduction

Technology development and implementation plays an increasing role in climate change policy and initiatives. Both the United Nations (UN) and the European Union (EU) have emphasized the use of technological advancements for reaching their climate goals. For example, the UN established the “[Technology Mechanism](#)” in 2010 with the scope of advancing climate technologies and transferring expertise, and large parts of the EU’s flagship research and innovation programme “[Horizon 2020](#)” support technological advancements in climate change technologies. Companies and corporations are in the “hunt” for decarbonisation as their products and activities often contribute to the increase of greenhouse gases, contributing to climate change. Alongside governmental organisations, the private sector places emphasis on the deployment of technological advancements to reduce both their environmental and social impacts ([Bokka & Lau, 2023](#); [Krzywdzinski, 2019](#); [Seemungal et al., 2021](#)).

Carbon capture, utilisation and storage (CCUS) has received increased support as a decarbonisation solution and climate change mitigation technology. Main greenhouse gas emitters such as the UK, EU, US, and China have put in place a range of [policies](#) and schemes that support the development and implementation of CCUS in order to meet their climate targets ([Friedmann et al., 2020](#); [Matschoss & Repo, 2018](#); [Yang et al., 2019](#); [Zhang et al., 2016](#)).

In the debates around whether and how to develop and implement CCUS much of the focus has been on the role that scientists, organisations and governments play ([Bowen, 2011](#); [Haszeldine, 2009](#); [Mace et al., 2007](#)). However, it is increasingly recognised that it is necessary to take account of social acceptance through the implementation of relevant policies. The focus on social acceptance is partly due to how projects in the past have been cancelled due to community resistance, but it also stems from a concern with preventing adverse outcomes for local communities ([Anderson et al., 2012](#); [Reiner et al., 2006](#); [Shackley et al., 2009](#); [Wong-Parodi & Ray, 2009](#)). Scholars have therefore pointed out that to ensure just and effective outcomes of climate change initiatives it is necessary to understand the dynamics that inform public acceptance and awareness ([Upham et al., 2022](#); [Williams et al., 2021](#)).

Social acceptance of new technologies is deeply embedded in social dynamics and influenced by multi-dimensional political, educational, social, economic, cultural, and historical factors. To understand social acceptance, it is therefore necessary to examine it in relation to a complex and changing local context ([Bertsch et al., 2016](#); [Krupnik et al., 2022](#); [Sovacool & Ratan, 2012](#); [Wüstenhagen et al., 2007](#)), whilst also recognising that local contexts are shaped by wider national and global dynamics ([Burawoy et al., 2000](#)). Despite this, most previous research on social acceptance is based on studies from a limited number of countries mainly located in Northern Europe or North America ([Nielsen et al., 2022](#)). This is perhaps not surprising given that many of the initial CCUS projects took place

in these regions, however there are increasingly new CCUS projects being implemented in other parts of the world, including in many EU member states in South Europe. Given the importance of the local context and how that context is shaped by national and global factors it is therefore necessary to examine wider sets of experiences to gain a broader and more fine-grained understanding of the dynamics that shape social acceptance of CCUS projects.

Furthermore, it is important to consider the specifics of the technologies and how generic terms like “wind energy” or “CCUS” refer to clusters of diverse technological constellations, constituent parts of which may have different implications for social acceptance ([Hmielowski et al., 2019](#); [Lin et al., 2007](#)). Most research on CCUS has so far focused on the social acceptance of specific storage technologies, perhaps because much of the initial resistance to CCUS was centred around storage sites. However, CCUS includes a range of different technologies with different environmental and social implications that could each create different sets of perceptions and reactions from the public. It should not be assumed that resistance to CCUS will only occur in relation to one aspect of the technologies.

To address the above gap concerning the different aspects of CCUS technologies in a location where the social dimensions of CCUS has been inadequately studied, this study explores public perceptions and awareness of CCUS technologies within a Greek context, focusing on a rural area where a pilot project has been scheduled to operate. The pilot plant will be adjacent to an industrial plant that operates in the area, and the goal of the pilot is to capture part of the carbon dioxide emitted by the industrial plant. Despite the pilot plant only capturing carbon dioxide, this study expands social acceptance to carbon utilisation and carbon storage as well to include the different societal, environmental, and economical dimensions of CCUS technologies.

Greece is one of the EU member countries that has received little attention regarding public perceptions and CCUS. Anecdotal evidence suggests that, since the early 2000s, universities and research institutes in Greece have been experimenting with the development of carbon capture and storage (CCS) technologies through EU-funded projects. This may add to confusion locally as terms for CCS and CCUS are often used interchangeably with little explanation. We have identified only limited understanding of public perceptions and social acceptance of CCS/CCUS in Greece. For example, [Pietzner et al. \(2011\)](#), [Koukouzas et al. \(2022\)](#) and [Sprenkeling et al. \(2022\)](#) have looked at Greece in tandem with other EU citizens, but not as a distinct entity and not in relation to a specific project. This is in contrast to other decarbonization technologies such as windfarms and solar panels where several studies have been conducted exploring public perceptions and social acceptance in Greece ([Botetzagias et al., 2015](#); [Kontogianni et al., 2014](#); [Stigka et al., 2014](#); [Tsantopoulos et al., 2014](#)).

Greece, therefore, makes an important case study for understanding the relationship between the implementation and development of CCUS and social acceptance. For one, given how CCUS are likely to play an increasing role in the Greek decarbonisation strategy it is important to understand the dynamics that shape local Greek social acceptance in relation to CCUS projects. Furthermore, by looking at case studies from understudied areas like Greece we can broaden our general understanding of how local and national dynamics shape social acceptance. Finally, our paper will examine social acceptance in relation to a specific CCUS project where, despite carbon capture being the main focus, to have a complete understanding it is also important to consider the implications carbon capture and utilisation could have in the local community.

Methods

Research design

To get a richer understanding of the phenomenon of CCUS perceptions we followed a single case study design (Creswell, 2013; Yin, 2009) focusing on community experiences, knowledge, and acceptance of CCUS. A single case study design was chosen as it satisfies Yin's (2009) five rationales; 1) theoretical perspective, 2) extreme cases, 3) capturing a revelatory case, 4) access to a previously inaccessible case, and 5) the longitudinal nature of the case. In more detail, this embedded single case study is exploring the phenomenon of social perceptions and acceptance towards CCUS technologies in Greece (Yin, 2009). As this study is part of a bigger project that aims to inform the European Union on CCUS policy matters, we have employed an instrumental approach to our case study as our inquiry is based on that final product of policy writing (Stake, 1995). We do not seek to generalize to the wider public, but to have a better understanding of the specific subunits we engaged with (Stake, 1995; Yin, 2009).

Case context-phenomenon

The phenomenon explored in this case study is the role of CCUS technologies in addressing industrial emitted carbon dioxide (CO₂) in a small town in a mainly agricultural area of rural Greece. As with all case studies, it is important to define the boundaries of the case study including the sources of data and defining the unit of analysis (Merriam & Tisdell, 2015).

The spatial boundaries where the phenomenon takes place are a small town in Greece and the surrounding villages. One of the project's industrial partners operates in the area, and a pilot CCUS project will be installed on their premises for demonstrative purposes. The pseudonym of "Schatz GMBH" has been given to the industrial partner for this study. It is important to note that the area and the regional residents' living there, have been previously disrupted by the operations of an ore mining company, but not the mining company of this project. In the past regional and national protests have taken place to show the public's opposition towards the company's operations due to health and environmental degradation concerns in relation to extraction techniques and natural resources exploitation. For the purposes of this paper, this company is identified as "Ore Extraction Limited".

The industrial partner's commercial activities are in the mining industry and the development of products for use in industries such as iron and steel, nutrition, industrial and manufacturing, as well as mining and metallurgy. The company has been active in the area for more than five decades with a continuous presence in the mining history of the area.

Both the factory and the mining operations of the company are located in a settlement that did not exist prior to the mining activities. The settlement was built around those activities with workers moving from nearby villages closer to the factory by building houses leading to the development of this settlement. Today the local community is well integrated with the mining activities as most of the people living in the area are employed in this facility.

The company takes pride in their sustainability and societal initiatives for which they have received multiple awards and participated in several EU-funded sustainability projects. The current project that the company is a partner of, is another example of the initiatives that the company has taken to promote more environmentally friendly actions within their operations.

A substantial percentage of the company's carbon emissions is a result of the kiln operations that are an essential part of its manufacturing process. For the company to be compliant with EU and national regulations and directives, including the European Union Emission Trading Scheme¹ (EU ETS), they need to find a solution to decrease their carbon emissions.

Data collection and analysis

When conducting research in a social setting that the researchers are not members of, it is important that the researcher gains the social acceptance of the community and identifies him/her-self (Gillham, 2000). To this end, one of the authors (KS) spent an extended amount of time in the area, and throughout this time he established connections and befriended members of the local community. Despite the researcher not being from the area, he had knowledge of prior resistance to industrial activities in the area due to environmental and health concerns associated with the extraction of gold. He is a native speaker of the Greek language, and that allowed him to approach individuals that were more confident discussing CCUS matters in the Greek language, as well as pick nuances in the discussions that were linguistically particular to the Greek language.

¹ It is important to note that the company is registered with the EU ETS. EU ETS refers to an EU wide mechanism that monitors and trades carbon emissions that are a result of industrial activities such as aviation, power stations, oil refineries, cement factories and oil and steel production. The EU ETS operates under a "cap and trade" foundation, where an allowance limit is set on greenhouse emissions per industrial company, and this maximum allowance is then converted to trading emission allowances (Commission, 2021; Teixidó et al., 2019). If companies exceed their emissions allowance, then they can buy additional allowances at a cost that is determined by the carbon market. To abate those emissions and avoid paying for extra allowances, the company needs to find solutions to reduce their carbon emissions, and CCUS is part of that effort.

Semi-structured interviews

To gain the necessary in-depth description of the phenomenon a series of semi-structured interviews were conducted with members of the local community (Creswell & Clark, 2017; Gillham, 2000). We followed a convenience sampling approach within the spatial boundaries of this case study. Participants were recruited through informal discussions and putting up posters for an upcoming community event in relation to this EU funded project. Data collection spanned from November 2021 to January 2023. During this time the study site was visited three times and interviews were conducted at different times. The purpose of the interviews was to gain an understanding of participants' awareness of CCUS technologies and how they perceived their application in their local context.

Prior to conducting the interviews participants were provided with a study information sheet, explaining the purpose of the study and their role as participants. Additionally, a consent form (both Greek and English versions were available) were provided to the participants to sign confirming their participation and comprehension of the ethical dimensions of their participation. This study has received ethical approval from Aberdeen Business School Research Ethics Committee at Robert Gordon University on the 10th May 2022.

To initiate the discussion, a 3-minute video was shown to the participants. The video was produced by the communication team of this CCUS project as a communication tool to the wider public, and it was the main mode of communication about the project.

The content of the video covered the aims of this current CCUS project as well as the promotion of CCUS as a decarbonisation strategy to reach net zero. The input of this study's researchers to the video was minimal. To supplement the video the researcher provided some extra context in relation to potentially important issues such as CO₂ transport and usage of resources such as water and energy.

In total five interviews were conducted exploring the role of CCUS as a decarbonisation strategy and the installation of such technologies in their area with six members of the public. All interviews were conducted by the author KS. The interviews had an average duration of 45 minutes and were audio-recorded and later transcribed verbatim. Four of the interviews conducted were one-to-one interviewer and interviewee and one was a dyadic interview (Polak & Green, 2016).

As four of the interviews were conducted in Greek and not all members of the research team spoke and comprehended the Greek language, it was essential that the interviews were translated into English for the analysis. The translation was done by one of the researchers, KS, who is bilingual in both English and Greek. Both Fersch (2013) and Filep (2009) have discussed the complications and necessary strategies in regard to translating interviews for analysis. We followed their recommendations for translating proverbs

(Filep, 2009) and considered the implications of our translation in the analysis of the interviews (Fersch, 2013).

The translated transcription text was entered in a qualitative data analysis software, and thematic analysis followed. To conduct the thematic analysis, we followed Braun and Clarke's (2012) six-phase approach including data familiarisation, generation of initial coding, themes identification, themes review, theme naming, and report production. The coding was done both inductively and deductively considering both the data derived from the interviews, as well as from pertinent literature. The first author did the initial coding which was later refined with the input of the other two authors.

Results

As the community where this case study took place is very small, to protect the interviewees' identities no information on education level, or position in the community will be shared. The individual participants will be distinguished below with their pseudonym initials in brackets, i.e. [T] for Tim, [A] for Alex, [P] for Peter, [J] for John, [O] for Olga and [M] for Maria. We present our findings here within the three themes identified within the data, namely: knowledge, societal context, and project specifics. It is important to note that although the themes are presented below in an individual basis, the intersections amongst them are the novelty of this paper.

Theme 1: knowledge

Before being shown the project video, the participants had little awareness of CCUS.

[O]: *"I didn't know anything before I saw this particular video and I hadn't heard of it [CCUS] before, I just heard about it at some point, it may be that I saw an advertisement on TV about it"*.

Once provided with some basic information about CCUS, the participants were able to draw on their knowledge to critically examine and identify the local implications the technology could have on natural resources, agriculture, tourism, health, and transport.

There were some concerns about the use of natural resources in connection with the implementation of CCUS, particularly the existential need for water and in terms of supporting the agricultural industry that relied on access to water resources.

[T]: *"For the mines that already using water for the mining activity. So, we'll need extra water in order to separate this thing. That means more resources for the mines water, uh, resources of the region will be used... sorry, but the water, what somebody water is the basic, uh, biological need for life. I mean, is the, the, the, the number one thing that people should be concerned in this area to have enough water. Because there is also another mining activity in the west, uh, of the region, Woodend that is, uh, has to do with ores, and on this area that they're doing, the mining activity is*

practically the resources for the whole water resources”.

[J]: *“Water in principle is an issue for all of us in the coming years everywhere. If we take our own region, Woodend, but also by extension and as a reference point that we are talking about Timberville, it is a big gamble in the coming years. Why? Because the edible olive ripens at the very time when we have tourism in the respective region and the corresponding arrivals and visitor numbers. If we would need 1 litre of water when we had no tourists or vice versa for a tree I say it randomly, now we need 3”.*

To a somewhat lesser extent, the issue of where the electricity to power the carbon capture facilities would come from was raised.

[A]: *“Do we have enough solar energy in the area to [power the plant]? ... It said [video] that’s gonna be powered by renewable energy.”*

For context, the region has already experienced an increase in solar energy that has displaced some agricultural activities.

Tourism is an important source of employment in the area and there were some considerations about what the implementation of new CCUS technologies would mean for the relationship between the tourism, agriculture, and extraction industries.

[J]: *“Of course, and for the tourists that’s a concern, but we also have the primary production which is also very close by. As it is a tourist activity, you see hotels at a distance from the flue gas with an example of Timberville and “GMBH”, the distance to the nearby hotel is 500 meters in a straight line. It may be 2 km, rather Guest House in a straight line is 1 km, so next-door. And an olive tree grown edible is one meter <laughs ironically>”.*

Potential health issues were also discussed regarding the use of amines for the capturing process. Despite not using amines in this project, amines are one of the most common absorbers to use in the capturing process and might have potential health impacts (Gentry et al., 2014).

[R]: *“Another issue with carbon sequestration is when carbon dioxide is released and we want to capture it, we use chemicals”.*

[O]: “A” (okay)

[R]: *“So, its what chemicals do we use? Because in the past, for example, they used what they call amines and amines can be carcinogenic”.*

[O]: *“So, these are going into the environment? Or to the employees?”*

As a rural area with somewhat limited transport infrastructure, there were also concerns that the implementation of CCUS could cause issues.

[T]: *“...personally, I would like to see some numbers in the sense the whole process is what we were also saying the other day, the whole process ...the part of the transportation. Do we have any idea, sorry, uh, how many trucks we will be leaving daily from the place in order to go? Because Woodend doesn’t have really roads, big roads, it’s very small roads, it’s one lane, one lane each, old roads”.*

The participants also critically identified and analysed issues that were not local. For example, one participant questioned the premise that some industrial CO₂ emissions were unavoidable.

[A]: *“That it’s saying, the problem is that for some industrial activities, we cannot avoid producing CO₂. Not even, we cannot avoid reducing the productions. We cannot avoid the production of CO₂. So, we are trying to solve this problem because we are basing the whole idea that this is something that we can’t change. Why guys? Is there that we need to do research?”.*

Despite storage not taking place in their location, participants raised critical questions about the implications of this part of the CCUS process.

[T]: *“Are we sure that this, uh, CO₂ under sea or underneath on the earth is not damaging the microcosmos of the underground? And because we don’t see it on the air, we think we solve the problem. It’s like the problems we put under the carpet. Do we know that the microorganisms who live inside there, and I’m sure there are, uh, are not, um, affected by all this? Do we know it? What have we put to see what happens inside there? Did we count the microorganisms inside the caves before and after? Do we know that? Or we just save the atmosphere, and we messed up the earth?”.*

Participants enhanced the conversation with their local knowledge and cultural perspectives that are important elements in public engagement and knowledge production.

Theme 2: societal context

The participants’ perceptions of the CCUS project were understood in relation to past experiences and perceptions of companies and political institutions. The participants voiced concerns related to issues of transparency, trust, and political-economic dynamics.

In all interviews, the company “Ore Extraction Limited” whose activities some years before had led to prolonged protests and conflict was mentioned in some capacity or another. The way the conflict was handled by the company and the local and national politicians meant that there were concerns about how new initiatives would be handled.

[P]: *“...there was also deception, meaning that they were telling us that the mining process here had*

been used previously in other places and that was not true. It had only used in preliminary studies and pilot projects, meaning no proper mining was done like that and it will never be done, it is not possible. The production cost of this process is too high, and they eventually turned into open cast mining, like we are living in the 1800s”.

This in turn led to a hesitant stance on any new initiatives even those that might turn out to be a good thing for the area.

[P]: *“...Of course, I will agree that social acceptance is needed in anything that is new because there is the bad from the past. Meaning that people are cautious in anything that happens, and many times they are cautious in good things”.*

The relationship with *Schatz GMBH*, the company involved in testing the CCUS unit, was also complex. On the one hand, the jobs it created were seen as being integral to the local community. On the other hand, in the past there had been issues with pollution and the decisions not to act up on it, as one participant described.

[T]: *“I see around also my family back in the days used to work for the mines, Okay? That families living from the mines, uh, local, uh, community, most of them, let’s say, because it’s a small village, work in the mine. And I see that some things that perhaps mining activity is uh, uh, uh, um, getting lower the quality of life, like the dust that we breathe every day from the mines, I see that people put it on the scale and they say, okay, but we have work.”*

The EU was brought up by most participants in most interviews, with notable ambivalence. On the one hand, there was the perception that the EU was lacking transparency and supported the interest of the companies at the cost of the environment and society. On the other hand, the EU was also seen to have the potential to ensure social and climate-beneficial outcomes when these new technologies.

[O]: *“...if it’s to serve the interests of the industries, which it (EU) potentially does in many cases because lobbying and behind the scenes is everywhere. So, in this case and the way you present it, it seems that the idea of the European Union is what touches the citizens and works for society. So, in that sense it is clear research-wise that these approaches, these storage options are worth to invest money, I now take it differently. Now coming from you, since the European Union is funding these kinds of proposals, is it clear that these options do not degrade the environment?... it should be, because I am thinking about it for the citizens and for their good, but at the same time I am thinking about it. Am I (EU) funding proposals that offend and degrade the environment in which the societies, the European ones, live. There is a bit of an inaccuracy here”.*

For some, the EU was seen as important in creating the legislative pressures to push companies to decarbonise.

[J]: *“Because without having, having probably 10–20 years ahead or whatever it is in exploitation, they want at all costs that this is profitable and for it to be profitable they have to be okay with the legislation. They have to comply with what the national and possibly European legislation dictates”.*

Despite the potential benefits of addressing climate change that EU support for CCUS could have, there was some scepticism about the lack of transparency, especially in terms of who would receive the financial benefits from these projects.

[T]: *“What the European citizen wins, uh, at the end of all this?”*

[A]: *“Take the CO2”.*

[T]: *“So cleaner air?”*

[A]: *“And this project is financed by...”*

[T]: *“Yeah, but some other people will get (money) <laugh>. That’s the funny part. You know, we, we pay some others are gonna be profitable. And with this data, with this lack of data, let’s say, and all this process that it has vague, points, I would say that is another, I don’t, um, I don’t see it in a good, uh, way after all, if I start looking all the details, where they’re gonna go, who’s gonna take the money? Who, who’s gonna do this?”*

In the above statements the participants demonstrated some of their experiences with industrial partners, while expressing their opinions on the role of the EU in decarbonisation.

Theme 3: technology

Most participants believed that technologies and potentially CCUS could play a role in addressing climate change. They were however critical of the little information they had received about the technologies used in the local CCUS project. To form a proper opinion on the specific technologies used in the project they expressed the need for better communication and education. Interestingly, most participants had a positive attitude towards technologies like CCUS addressing climate change. One participant who was involved with the local commons discussed how the research advances and societal changes have contributed to technology being an important element.

[J]: *“I think the way our society has formed, and the way research has evolved in general, I think technology is a key element that can address these kinds of problems, ... I think it is impossible that something can happen without the intervention of any technological (applications). As the video shows, you are producing this dioxide from an industrial facility, showing that you can have underground storage for example, all of that again gives you the opportunity in finding the solution, but again having a storage,*

randomly I will say, either above ground or underwater without technology again you can't actually cope".

Another participant discussed the importance of scalability, as well as the complementary role that nature-based solutions and technological innovations should have.

[M]: *"Yes, I think they are complementary (nature and technology), but I think if a technological solution is found it will be more effective, just because of the scale... I "Yes, I think they are complementary (nature and technology), but I think if a technological solution is found it will be more effective, just because of the scale... I think technology can always play a very positive role, as long as it's used properly". think technology can always play a very positive role, as long as it's used properly".*

Despite this receptivity to technology and generally positive attitude to the potential of CCUS, there was some criticism about the project video.

After the interview, one of the participants described the video as propaganda, as they thought it oversimplified the CCUS process and was lacking important information. Another participant said that the video did a very good job explaining the CCUS process, but that it could be confusing as important information was not mentioned.

[J]: *"This video is very good as far as I would say in the everyday spoken language that describes it very well so that one can understand where we're going from here...It is true that this video here combines that, it gives you a picture of what is going on and how the research wants to proceed in a certain way and it has it very nicely written graphically, it just obviously needs other information about maybe where this is going. It shows in here that it will be reused for example in the process. What does reuse mean? Why on the one hand you say I want to have a low carbon footprint and on the other hand you store it and recycle depending on circumstances? What does that mean? Perhaps the person who hears and sees it gets confused?".*

The participants expressed that better and more educational information was needed, but they differed in terms of who should be responsible for this. One participant suggested that communication about the project should come from the industrial partner involved in the project and the company should start by involving their employees and their families,

[J]: *"I think we first start from the company itself or the companies that are creating the problem inside outside of quotes let's say and create the production of let's say carbon dioxide and have a large human resource within the organisation. That workforce means that one employee is at least one family, and we are not even multiplying it. So, I would say that*

if you put our own region of, where we are, which is a partner and has almost 300 employees, that's a small community, since it's basically a thousand. It's a thousand people who from the company itself can be involved in the whole process. So, I think that the company itself through its own people should be the first to start any information and any dissemination of knowledge, so what is going on? what is it? How, are we going to deal with it? what is coming? what are the initiatives that other countries are taking let's say? What is Europe doing?".

Another participant suggested that should not be done only by the industrial partner, but there should also be an independent body.

[M]: *"...what is certain is that it cannot only come from the companies involved. It should also come from someone independent who will also tell them the opposite point of view. Because surely everyone will say what is in their own interest. What I think is a bit subtle is that in this case, let's say, to say to society that it's very important to reduce carbon dioxide emissions and for that, we're going to do, we're going to use some new technologies. You should tell them <laughs wryly> that there is a problem with the carbon dioxide being released, which they may not even be aware of".*

This opinion was echoed by a participant who suggested that scientists might take on the role of communicating more unbiased information about CCUS.

[O]: *"The one who has the qualifications, the one who yes, maybe not so much communication skills. That's why I'd be pretty buttoned up myself. I agree with you on what you found. That gives it to a company that may know the techniques to approach, but there's a reservation people have towards that. I would agree that a scientist, a research centre, comes in and is more not neutral, and unbiased and that it doesn't lean on vested interests, possibly".*

As demonstrated above, beliefs on the role of technology are not clear cut, as important information on the proposed technologies were absent from the communication video.

Discussion

The findings from our study indicate that how CCUS was understood and perceived was influenced by interrelated factors including local knowledge and previous experiences, modes of communication, and perceived impacts of the technology on the local area. Although we delineated these dimensions, they were all interrelated.

All the participants knew little about CCUS before the interviews. This aligns with past research that indicates general low public awareness of CCUS technologies (Boyd *et al.*, 2017; Li *et al.*, 2014; Perdan *et al.*, 2017; Whitmarsh *et al.*, 2019).

However, we found that when the participants were presented with even very limited information about CCUS they were able to relate it to their own situated knowledge and critically identify both local and wider potential issues with the technology. This resonates with previous studies on climate mitigation and adaptation projects that have shown how people can use their situated knowledge to critically assess new technologies regardless of complexity. Furthermore, the use of local knowledge can also help ensure social and environmentally better outcomes for these projects (McNamara & Buggy, 2017; Rojas Blanco, 2006).

The societal context, including the history of experiences with companies and the local, national, and supranational political systems, shaped the participants' perception of new technological initiatives in the area. For some interviewees those past experiences were associated with deception and misinformation, often leading them to be sceptical about social acceptance as they were concerned about the information sources as well as the company's motivations. This aligns with extant research that indicates the important role past experiences play in shaping future perceptions and acceptance of new technological developments (Holzinger *et al.*, 2011; Sulaymani *et al.*, 2022).

On an abstract level participants were mostly positively inclined towards the role that CCUS could play in addressing climate change. However, when it came to a more specific and in-depth analysis, they raised several questions and concerns. They were uncertain about the exact implications the technologies would have in terms of resource usage, transport, and local economy. As discussed in the methods section, water issues were not mentioned in the communication video, so the researcher added that extra element in the discussion. This allowed for a co-construction of knowledge between the researcher and the participants, with the former using their local knowledge to contextualise CCUS within their community. Furthermore, they were not certain that the technologies would be implemented in a transparent and beneficial way that would benefit the local communities.

This concern about the exact implications of a CCUS project also stemmed from the limited information they had received. In many cases, participants could not form an opinion about CCUS as the information they had was very limited and did not answer their questions. They discussed how some of the information communicated through the video was confusing and, in some cases, misleading. For them to be able to take decisions they wanted to have concrete data that were specific to their location. According to some of the participants, the video presented CCUS technologies as something that is well established, and that scientists are aware of all limitations, but that generated scepticism as to why despite the limitations those technologies were still pursued.

Aligning with participants' perceptions, several researchers have indicated the uncertainties and limitations associated

with CCUS technologies (Beddies, 2015; Boyd, 2016; Lane *et al.*, 2021; Lee *et al.*, 2019). Pertinent literature suggests that when risks and uncertainties are not communicated towards the public, then the public becomes more sceptical of a project (Ashworth *et al.*, 2012), supporting the value of two-way communication when it comes to the development of a carbon capture project (Gough & Mander, 2014).

In Greece, we found that apart from the information and the communication that we provided as researchers, there was no other information or communication from any of the industrial partners or the project managers towards the local community. In addition, some participants reported that the information provided through the video was lacking substance and not adequate to address their questions. The lack of transparency can have a negative impact on the social acceptance of carbon capture projects and often lead to the cancellation of such projects (Beddies, 2015; Brunsting *et al.*, 2011; Oltra *et al.*, 2012). This presented a dilemma in the conduct of this study as there was confidential information regarding the project that we were not at liberty to relay that information to the public, inhibiting fully transparent discussion.

In addition to transparency, concerns over the use of tax-payers money were raised when the role of the EU was discussed. Similarly, to other studies, participants were concerned with potential environmental, health and societal negative impacts associated with CCUS. There was some uncertainty on how and why private companies were financed by tax-payers money to help with finding a solution to a problem that could potentially have serious implications for their ability to operate and be profitable.

Implications, limitations, and future research

Despite the explorative nature of this study, our findings contribute to expanding understanding of public perceptions of CCUS in Greece and similar contexts, enabling policymakers, organisations and institutions to better engage and involve the local communities in future energy projects (Kurath & Gisler, 2009; Perlaviciute & Squintani, 2020). Our future research will expand on these preliminary findings as local implementation of a CCUS demonstration facility continues. Due to the lack of available information and the novelty of the technologies, future research should consider more comprehensive information and dissemination methods to maximise peoples' understanding of CCUS and their implications. As an example, one of the researchers during the interviews brought up the utilisation of water during the capture process and that might have framed CCUS in a negative manner (de Vries *et al.*, 2016; Druckman & Bolsen, 2011). Adding to the above, there is also a time constraint associated with the interviews and the opinions participants form on a new subject can be limited. As discussed by Jones *et al.* (2017), more time and more information could alter peoples' opinions on new technologies. Finally, this study has not explored the involvement of communities during an environmental permitting process, and such research would be important to be considered in the future.

Conclusions

The aim of this study was to explore local perceptions about CCUS in a Greek national context to broaden our understandings about the dynamics that shape awareness and acceptance of CCUS. This preliminary study shows the importance of examining CCUS and social acceptance in relation to the specific social context of a project. The dynamics that applied to this case study in a small agricultural Greek location with previous experiences and controversies around extraction cannot be directly translated to other social contexts. What it is possible to say is that a place-based approach that can take account of social relationships and dynamics is more likely to give a detailed understanding of the factors that shape people's perception of new technologies in that specific location.

Our findings suggest that despite the low awareness of CCUS amongst the participants, with limited information they were able to critically assess the technology and envision what potential environmental, economic, and social impacts it would have in the local area. Participants expressed some scepticism towards how the technology would be implemented and this was at times enhanced by the social and historical context of the area. Furthermore, the lack of detailed information meant that the participants did not feel they had adequate information to take a stance on any future CCUS project in the area. In our case, participants were asked to discuss something they had little or no knowledge of. Although some information was related to them via the video, that was not adequate for them to form an educated opinion. That brings to the forefront the importance of communication and education that should be taking place within these communities during such projects.

Community members should be involved in the process from early on and help shape the project.

Furthermore, the study also indicates that local communities can play an important role in enabling a deeper understanding of the impact CCUS technologies might have in the local area by use their detailed local knowledge to identify and potentially tackle important issues that might only otherwise become evident later in any CCUS project. However, to do that in a more comprehensive way there would need to be more comprehensive educational and communicational provisions that can give the communities the capabilities to understand and shape CCUS projects. Whilst it has been suggested that lack of knowledge is a limitation to public participation in decision-making (Wang *et al.*, 2019), we argue that lack of transparency, and lack of collaboration from organisations, limit public engagement in energy-related projects.

Data availability

Despite our efforts to anonymise the interviews, due to the small geographical location the data were collected, sharing the whole transcripts of the interviews could result in the identification of some of the participants.

Acknowledgements

The authors would like to thank all the participants that gave their valuable free time to share their knowledge and experience with the researchers and provide important feedback on the project.

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Dimitrios Xenias

Cardiff University, Cardiff, Wales, UK

Public perception and acceptance of CCUS: preliminary findings of a qualitative case study in Greece

Thank you for this well-written paper, which I read with interest. The authors explored public perception / acceptance of a novel CCUS scheme in a mining/industrial community in Greece. This was part of a wider EU funded research programme.

It is right and important to explore such topic qualitatively and in depth, as they are usually novel and unprecedented in the areas and communities involved. So it is useful to explore the understanding of such innovations at a local community level, as well as the meanings attributed to each scheme, and any anticipated impacts and expectations from it.

However, doing so on the basis of just five interviews sounds quite minimal and I would hesitate to put much faith on results that are based in such small sample. Although this is a very good preliminary exploratory study, to be followed by a larger sample or replication, I find it too small to be published as a standalone paper as it stands. Does this journal support the publication of small pilot studies?

Could this research be followed up with further interviews? Larger sample? Focus group discussion or similar? Or if the above are not possible, then other types of research and analysis that might complement the picture and add to our understanding of the local history, context and community as well as the company, its activities, and industrial relations. For example, there is mention of past promises and events within the same region with the same industry, and this might need to be exposed further for the benefit of this paper.

Nonetheless, sample size remains my main concern. Perhaps, if there is no room for further sample, replication or another complimentary study, a combination with other samples of this EU project might help bolster the conclusions of this paper? E.g. if other partners of this EU project ran similar community studies elsewhere, then their results could be compared and synthesised?

To more specific comments:

p.3 I would be cautious to describe CCUS, CCS, Wind, Solar and others collectively as 'decarbonisation technologies'. Yes they all broadly contribute to decarbonisation targets, but I see a fundamental difference between a system that does not produce any CO₂, to a system that

actively sucks CO₂ out of the atmosphere' and is normally part of a nearby larger industrial complex.

P.5 The authors mention that "although the themes are presented below in an individual basis, the intersections amongst them are the novelty of this paper." Please can you clarify what this means?

P.8 The authors discuss the role of contextual factors and I observed a notable exception from the list: the role of trust. This is a common finding in this kind of research and although it was only mentioned once in the summary of Theme 2, therefore I wonder whether the authors were not aware of this or did not think it was important to discuss.

Is the background of the case's history and progression described in sufficient detail?

Yes

Is the work clearly and accurately presented and does it cite the current literature?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

No

Are the conclusions drawn adequately supported by the results?

Partly

Is the case presented with sufficient detail to be useful for teaching or other practitioners?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Environmental Psychology, Climate Change, Behaviour Change

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 02 January 2024

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Christian Oltra

Centro Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid, Spain

Introduction

The literature review on public perceptions and acceptance of Carbon Capture and Storage (CCS) appears limited, lacking depth and breadth. The research justification is weak, with an unclearly articulated problem statement. Moreover, the absence of a defined research question and specific objectives further dilutes the study's foundation. The rationale for conducting research on social acceptance in the context of the CCUS project is not clear, especially given its design - a pilot plant adjacent to an existing industrial plant for partial carbon dioxide capture. The justification for selecting Greece as a unique case study for understanding the interplay between CCUS implementation and social acceptance is not convincingly argued.

Method

The methodological approach, particularly the use of a case study research design as per Yin (2009), is inadequately connected to this study's specific design. Furthermore, the limited number of interviews conducted raises questions about the comprehensiveness of the findings. The ambiguity surrounding the profile of the interviewees, whether they are residents or stakeholders and their sociodemographic details, further weakens the methodological robustness.

Results

The analysis of the data seems disjointed from the study's analytical dimensions. There is a lack of clear linkage between the collected data and the predefined aspects of the study, which hampers the effectiveness of the results section.

Discussion

While the discussion presents some interesting ideas, the overall lack of focus in the article undermines the significance of this section. An example of this is the reference to previous research on the impact of past experiences on perceptions and acceptance of new technologies. This idea, although relevant, is not sufficiently developed or integrated into the broader narrative of the study, resulting in a discussion that lacks relevance and depth.

Is the background of the case's history and progression described in sufficient detail?

Partly

Is the work clearly and accurately presented and does it cite the current literature?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Is the case presented with sufficient detail to be useful for teaching or other practitioners?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Risk perception; public attitudes towards energy technology; environmental attitudes

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Reviewer Report 24 November 2023

<https://doi.org/10.21956/openreseurope.17994.r36355>

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Paul Upham

IREES, ESRIG, University of Groningen, Groningen, Groningen, The Netherlands

This paper describes the background, methods and results of a small number of interviews with members of the public living close to a prospective site that will capture and store CCS for reuse (CCUS).

The authors need to provide more information on exactly what the interviewees were told - e.g. via a link to the video referred to and via appending other information conveyed. The authors also need to provide more information on the proposed CCUS development - is carbon storage to be onsite, in what form, how transported out etc.

The paper is generally well-written, analysed and executed. However the number of interviewees seems very small and the research design justification relating to this is under developed. Did I understand correctly that 5 people were interviewed once each? Or were they each interviewed multiple times? Please clarify this. Either way, I think you also need supplementary justification. If you interviewed each individual multiple times, then this is a longitudinal form of interviewing that would add strength to the empirical part of the case, and more should be made of this.

If you only interviewed 5 people once, then you again need to strengthen the justification for this. You can (i) estimate the fraction of the village that this constitutes; (ii) you can and should give us a little more demographic information on the interviewees, so we know a little about them; (iii) you can and should make a case for in-depth, semi-ethnographic work in which the researcher has embedded themselves in the community (as you seem to have done); (iv) for the benefit of people concerned about representativeness, you can explain a little more about the value of small n qualitative work.

One other thing: theme 1 on Knowledge: although knowledge was involved, I read these

comments as being also, or even primarily, about a concern with impacts.

Is the background of the case's history and progression described in sufficient detail?

Yes

Is the work clearly and accurately presented and does it cite the current literature?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Not applicable

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Is the case presented with sufficient detail to be useful for teaching or other practitioners?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Social acceptance of low carbon energy technology, including CCS.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.
