SOCIETAL PERCEPTION OF CARBON CAPTURE, TRANSPORT AND STORAGE: OPPORTUNITIES AND RISKS, INSIGHTS FROM FOCUS GROUP MEETINGS

DOI: 10.26341/issn.2241-4010-2026-4a-3-L02217

Mendrinos Dimitrios
Senior expert, Head of department for geothermal energy and CO_2 storage, Centre for Renewable Energy Sources and Saving, 19th km Marathonos ave, 19009, Pikermi – Attiki, Greece
dmendrin@cres.gr

Oikonomou I. Theoni
Researcher, Centre for Renewable Energy Sources and Saving, Greece
thoikonomou@cres.gr

Karytsas Spyridon
PhD, Researcher, Centre for Renewable Energy Sources and Saving, Greece
spkary@cres.gr

Sprenkeling Marit
Researcher, Netherlands Organisation for Applied Scientific Research, The Netherlands
Marit.Sprenkeling@tno.nl

Terpstra Eva
Strategy & Innovation Advisor, Netherlands Organisation for Applied Scientific Research, The Netherlands
eva.terpstra@tno.nl

Rambharos Shanita
Medior Consultant, ICT, Strategy & Policy, Netherlands Organisation for Applied Scientific Research, The Netherlands
shanita.rambharos@tno.nl

Bannister Andrew
Principal Consultant, Risktec Solutions, The Netherlands
Andrew.Bannister@risktec.tuv.com

Wilkerson Brooke
PhD, Senior Researcher, Norwegian Research Centre, Norway
brwi@norceresearch.no

Ljones Marie Louise
Researcher, Norwegian Research Centre, Norway
malj@norceresearch.no

Bentsen Henrik Litlere
PhD, Senior Researcher, Norwegian Research Centre, Norway
heli@norceresearch.no

Otto Danny
PhD, Researcher, Department of Urban and Environmental Sociology, Helmholtz Centre for Environmental Research, Germany
danny.otto@ufz.de

Abstract
Carbon Capture, Transport, and Storage (CCS) is a key technology for mitigating climate change. To accelerate the implementation of CCS projects, it is important to integrate technical, economic, societal, and environmental disciplines to support the decision-making process related to permitting and ensure containment and conformance of CO2 during geological storage.

This is the scope of the RamonCO "Risk-based framework for assessing CO2 storage monitoring" project, supported by the Clean Energy Transition (CET) Partnership initiative (https://cetpartnership.eu/calls/funded-project/ramonco). It involves thirteen organisations from six countries: Norway, Germany, Greece, Romania, the Netherlands, and USA.

As part of RamonCO project, focus group meetings were held with key stakeholders in all participating countries to assess the societal perception of CCS. This study presents the results of the two Greek focus group meetings. The meetings, entitled "Social Acceptance of Carbon Capture, Transport, and Storage: Opportunities and Risks," were held in Athens in May 2025, bringing together key stakeholders from the academic and research community, environmental Non-Governmental Organisations (NGOs), industry, municipalities, and the marine sector.

During the meetings, participants identified and evaluated opportunities and risks associated with social acceptance of CCS. Findings indicate that stakeholders prioritize opportunities including economic development, job creation, energy transition, and advancements in know-how and CCS technology. Conversely, the primary risks identified were public concerns over environmental pollution, an unclear regulatory framework, and the credibility of control mechanisms. Our analysis of the results highlighted challenges and questions for societally embedding CCS in Greece, as well as implications for risk governance strategies.

Key words: CCS; social acceptance; opportunities; risks; stakeholders; risk governance.

1. INTRODUCTION

Carbon Capture, Transport, and Storage (CCS) is a key technology for mitigating climate change and achieving climate neutrality, namely zero net CO2 addition to the environment by the year 2050. To accelerate the implementation of CCS projects, it is important to integrate technical, economic, societal, and environmental disciplines to support the decision-making process related to permitting and ensure containment and conformance of CO2 during geological storage.

This is the scope of the RamonCO "Risk-based framework for assessing CO2 storage monitoring" project (Nottveit et al., 2024), supported by the Clean Energy Transition (CET) Partnership initiative (https://cetpartnership.eu/calls/funded-project/ramonco). It involves thirteen organisations from six countries: NORCE (coordinator), Reach Subsea and Equinor from Norway, UFZ from Germany, CO2CLUB and GEOECOMAR from Romania, CRES from Greece, EBN BV, TNO, Neptune, Risktec, ENI and HARBOUR ENERGY from The

Netherlands, and LLNL Lawrence Livermore National Laboratory and UCSD University of California from USA.

The main objectives of RamonCO are to develop (i) an integrated set of geophysical methods for imaging and monitoring CO2 geological storage fields, (ii) risk governance strategies for societal embeddedness of CCS, and (iii) a multi-dimensional decision support framework.

Towards the development of societal risk governance strategies an interdisciplinary and transdisciplinary research approach is adopted, which involves identification, conceptualisation, assessment and evaluation of risks hindering the social embeddedness of CCS, and formulation of mitigating measures and risk reducing strategies (Sprenkeling et al., 2024).

The research is informed by the results of the Digimon project "Digital Monitoring of CO2 Storage Projects", which interpreted insights from semi-structured interviews, surveys, and stakeholder workshops across Norway, Greece, Germany and The Netherlands with an inter- and trans- disciplinary methodology, in order to develop a societally embedded CO2 storage monitoring system (Otto et al., 2024).

As part of RamonCO project and towards developing risk governance strategies for societal embeddedness of CCS, informed public opinion surveys were organised in Norway, The Netherlands, Germany, Romania and Greece to define attitudes and risk perceptions towards all CCS phases, namely capture, transport, storage and monitoring (Bentsen et al., 2025).

In addition, focus group meetings with key stakeholders here held in each country to examine opportunities and concerns towards societal embeddedness across the entire value chain of CCS. This study presents the results of the two focus group meetings, held in Athens, Greece in May 2025.

2. METHODOLOGY

On May 12th and May 27th, 2025, we conducted two focus group meetings entitled "Social Acceptance of CO2 Capture, Transport, and Storage: Opportunities and Risks", each lasting one working day. Both meetings represent an important research initiative aimed at understanding the social dimensions of carbon capture and storage technology from the perspective of stakeholders and interested parties.

The meetings operated under strict data protection protocols, ensuring that all participant information is used exclusively for scientific research purposes, with participants retaining the right to request deletion of their personal data at any time.

Focus groups participants came from local Authorities, environmentally oriented non-governmental organizations (CO2 Storage), the marine sector (CO2 Transport), industry (CO2 Capture) and the academic and research fields. Specifically, the focus groups were attended by professionals from the MUNICIPALITY OF KAVALA, the independent assurance and compliance services to maritime company LLOYD'S REGISTER, the MOTOR OIL refinery, the TITAN cement industry, the non-governmental organization ECOCITY, the higher education institution NTUA (National Technical University of Athens) and the research centre CRES (Centre for Renewable Energy Sources and Energy Saving).

The primary objectives of the focus groups were to document valuable stakeholder perspectives on CCS in Greece, investigate the social risks associated with CCS deployment, and explore the opportunities that could enhance social acceptance of the technology. More important, the meetings recognize that there are no "correct" or "incorrect" answers, as all perspectives are equally valid contributions to understanding this complex issue.

The analytical framework guiding the focus group meetings examines social acceptance across four interconnected dimensions. The environmental dimension considers the direct environmental impacts of CCS, as well as strategies for controlling, preventing, and reducing these impacts, spatial planning considerations, and broader social consequences. The public and stakeholders dimension explores how different groups perceive and respond to CCS, including their arguments, opinions, interests, and concerns about the technology. The policy and institutional dimension examines the regulatory environment, industry objectives, and the clarity of roles and responsibilities. Finally, the market and financial resources dimension analyses the economic benefits and risks, available funding mechanisms, and the viability of different business models. (Mendrinos et al., 2022)

The focus groups were planned by the Greek team in collaboration with researchers from the RamonCO WP2 work package and implemented in (more or less) the same format with the cases in the other countries. The Greek focus groups were conducted in person. Participants were invited from a broad spectrum of interest groups, including industry representatives, NGOs, academia, and public authorities, providing comprehensive insights from various perspectives.

The focus groups were facilitated by a moderator from the Greek research team, supported by five additional team members. The first part of the focus group began with a brief introduction to the RamonCO project, followed by an explanation of the focus group's objectives. Participants were informed that the goal of the session was to identify societal opportunities and risks along the entire CCS value chain from capture to storage and monitoring, followed by a ranking and evaluation of these risks.

Each meeting was structured throughout a full day, beginning with participant introduction and moving into a collaborative process of identifying and analysing risks and opportunities. Participants were guided to think critically about how CCS technology might affect various aspects of society across four CCS stages: CO2 capture, transport, storage, and monitoring.

Through a structured three-phase methodology, participants firstly individually identified risks and opportunities across each CCS stage, considering how they might impact both their own work and society more broadly (early morning).

Secondly, after participants identified risks and opportunities, the CRES research team synthesized these responses and presented them for collective discussion (late morning). In parallel, other members of CRES team presented findings from the ongoing CCS research projects MOF4AIR (https://www.mof4air.eu/), SHEETS (https://axel-one.com/les-projets/sheets/), and HERCCULES (https://www.herccules.eu/home-page-en).

Thirdly, these presentations, combined with the preliminary synthesis of risks and opportunities identified by participants, provided context for subsequent discussions in the afternoon and helped frame the more detailed analysis task on evaluating opportunities and risks. Then, participants prioritized the most significant risks and opportunities, engaging in deeper conversations about what would actually happen if these risks materialized or opportunities emerged, why they matter, and how they would respond.

On screen excel file presentation was used both as a tool for collaboration and for visualizing the opportunities and risks and their rankings. This provided a structured and transparent way to work, specifically suited for in-person meetings, while encouraging interactive participation. We found the format to be engaging and effective in summarizing and evaluating the identified opportunities and risks, which was the primary goal of these focus groups. From the participants' perspective, it was evident that they possessed substantial knowledge on the subject, and that they were very much interested and had the desire to dedicate one full day to the discussions. We took the opportunity to inform participating stakeholders that future stakeholder engagement activities may arise later in the project.

3. LIMITATIONS

This study focused specifically on the Greek context, with stakeholder perspectives shaped by national regulatory environments, environmental sensitivities, and economic conditions. While many findings likely have broader applicability, caution should be exercised in generalizing conclusions to substantially different contexts.

The focus group methodology, while providing rich qualitative insights, captures perspectives at a specific moment in time. As CCS technology matures, regulatory frameworks develop, and implementation experiences accumulate, stakeholder perceptions may evolve. Longitudinal studies tracking changing attitudes over time would provide valuable complementary insights.

4. RESULTS

Top-Ranked Opportunities

Participants identified as most important opportunities towards improving societal embeddedness of CCS the (1) job creation, (2) development of know-how and technology in CO2 capture, (3) strengthening energy transition and (4) increase in economic activity.

<u>Job Creation</u>

Stakeholders perceive job creation through CCS as a comprehensive opportunity extending far beyond immediate employment. They emphasize that CCS generates immediate job opportunities for local communities, particularly benefiting areas remote from urban centres where such projects are typically implemented. The technology creates positions across multiple phases, namely in construction, engineering design, operational maintenance, and ongoing support activities. There is strong recognition that each direct job has a multiplier effect by creating several ancillary positions. For every construction activity or technical role, additional support positions emerge to serve worker needs including food services, accommodation, and local infrastructure. This multiplier effect generates significant economic activity both directly for those employed and indirectly through increased local turnover. Stakeholders highlight the need for highly skilled personnel who understand and can effectively communicate CCS technology, creating the need for development of specialized workforce. These specialized positions, accompanied by high financial rewards, create incentives for professional development and career advancement in emerging technology sectors. Job creation spans a broad spectrum including construction workers, engineers, designers, support staff, decision-makers, and customer communication specialists. This sectoral diversity ensures opportunities across skill levels and professional backgrounds.

The innovative nature of CCS technology presents opportunities to reverse brain drain, potentially attracting Greeks working abroad to return. This contributes to both local economic development and national decentralization efforts. Implementation in remote areas can transform regional economic prospects, creating positive multi-level impacts on society. The projects bring economic activity to communities that may have limited alternative opportunities. CCS deployment creates pressure and incentives for educational institutions to develop appropriate training programs. While relevant specialized education currently exists primarily abroad, domestic job creation could stimulate local educational capacity building. The presence of innovative technology projects can also enhance regional and national image. Opportunities to host conferences and events in project areas provide additional promotional benefits, positively impacting tourism alongside direct employment. Companies currently engaged in extraction of hydrocarbons may transition to CCS technology as extraction activities conclude, preserving employment and leveraging existing expertise in new applications.

For organizations and individuals in related sectors, CCS represents significant opportunity for professional development. Young professionals and those dealing with similar technical or environmental issues view this as a career advancement pathway. Expanding organizations anticipate challenges integrating highly skilled new personnel and managing internal communication with specialized teams, which are viewed as positive growth challenges. Organizations recognize economic benefits for hiring young employees and potential direct and indirect participation opportunities in CCS projects. Stakeholders express intention to actively participate throughout the CCS implementation process, drawing parallels to major economic events such as the Olympic Games in terms of comprehensive community involvement.

Participants indicate strongly positive reactions to job creation opportunities by expressing their intension to actively pursue participation in CCS processes, to attempt to secure both direct employment and indirect economic benefits, recognising CCS as an opportunity relevant to the entire local community and appreciating the positive publicity, which job creation brings to CCS technology.

Development of Know-How and Technology in CO2 Capture

Stakeholders perceive that the development of technology can contribute to social acceptance, as it responds to people's concerns about environmental issues and safety, offering solutions that protect society. When the indicators related to CO2 capture are optimized through the development of technology, social acceptance will be achieved by maximizing the commitment and its positive impacts for the environment, people, living conditions, etc. The development of technology requires development of a regulatory framework and the establishment of rules that will support its normal application. There is pressure to develop the technology quickly, evaluating also costs, as the achieved now-how will form the basis for stakeholders to become more receptive to CCS, promoting and making CO2 capture acceptable.

Know-how development provides added value through workforce training and attracting new investments.

Stakeholders report positive impact from this opportunity on their organizations. There are several people in their service with advanced qualifications who are involved and willing to deal with new technology issues. Technology development leads to more data, better information and increased options. For some stakeholders, technology development contributes to achievement of their professional and personal goals.

Strengthening Energy Transition

The energy transition is considered an important and necessary change for participating stakeholders’ companies, aiming to adapt to new frameworks and protect the environment. CCS technology is linked to the energy transition by assisting reduction of environmental impacts and improving the environmental footprint. As CCS captures CO2, it supports the energy transition. It creates trust in society and consumers, as a technology with a positive environmental impact.

The energy transition also includes energy security. As there will be penalties for non-compliance, many companies are affected. In that context, CCS technology is expected to help the growth of the shipping sector.

Increasing Economic Activity

Stakeholders recognize both direct and indirect economic benefits in the preparation, configuration, construction and operation phases of CCS. Examples include procurement and new business activities, and local economic growth including personnel and supplies.

Economic activity increases because know-how is transferred, creating the need for new supporting businesses, driving development at local and national level and leading to more accessible and acceptable technology for local communities.

Organizations report positive impact due to the growth created. Participants express their willingness to be engaged with the specific subject due to the development of technology, and the arising of new professional prospects in which they could be employed.

Participating stakeholders express positive reaction and effort to contribute to the implementation of the technology, to be active in all phases of CCS projects, identifying the need and effort to provide relevant services, indicating attempt to deal with issues of design, construction, and maintenance.

Top-Ranked Risks

The focus groups identified significant risks across the CCS value chain, with four concerns ranking as highest priority:

Unclear Regulatory/Legislative Framework

Unclear Regulatory/Legislative Framework emerged as the most prominent risk for both capture and transport phases. Stakeholders perceive this as creating insecurity comparable to "a game without rules," causing problems in procedure implementation, licensing delays, and potential loss of funds.

Stakeholder consultations revealed a pervasive concern regarding the absence of clear guidelines and standards governing CCS technology. This regulatory gap manifested across multiple dimensions of project development and implementation. Environmental permitting processes proved particularly problematic, as regulatory authorities lacked clear standards and conditions to reference when issuing permits. Engineers and project developers reported fundamental uncertainties about design specifications and implementation protocols, noting the absence of regulatory frameworks to guide technical decision-making.

The monitoring phase presented especially acute challenges. Critical operational parameters remained undefined, including the definition of CO2 leakage events and threshold levels triggering regulatory intervention. Stakeholders expressed concern that the state had proceeded with technology implementation without first establishing the regulatory boundaries necessary to govern operations effectively. This sequencing problem - implementing before regulating - represented a fundamental reversal of prudent governance practice.

The lack of defined monitoring standards raised significant questions about accountability and transparency. Citizens identified substantial uncertainty regarding what aspects of CCS operations would be monitored and which entities would bear monitoring responsibilities. Stakeholders emphasized that public trust would be enhanced if monitoring fell under state oversight rather than private company control, with results made transparently available to the public.

In the shipping sector, regulatory ambiguity was particularly pronounced. Critical specifications remained undefined, including the precise nature of transported and stored materials. These unanswered questions generated substantial concern among citizens observing CCS development initiatives.

The regulatory vacuum created significant operational challenges for organizations implementing CCS technology. Without established standards, technology deployment became an exercise in interpretation rather than compliance. Companies struggled to understand requirements for project financing and basic operational execution. The absence of clear protocols in the shipping sector prevented the establishment of standardized procedures for CO2 transfer to vessels.

Project timelines suffered as teams found themselves unable to determine concrete requirements and deliverables. Substantial time and resources were diverted to unproductive activities, including interpreting ambiguous legal frameworks and seeking clarifications that should have been provided within initial regulatory guidance.

Regulatory ambiguity fundamentally undermined stakeholder confidence in CCS projects. Without standards of comparison or established roadmaps, doubt and suspicion emerged as natural responses to uncertainty. The situation was compounded by reported understaffing in relevant public regulatory bodies, further limiting capacity for effective oversight and guidance.

When individual companies determined their own implementation approaches rather than following state-established frameworks, citizens questioned whether projects would be executed appropriately. This lack of standardization raised concerns about consistency, safety, and environmental protection across different CCS initiatives.

The regulatory vacuum significantly impaired both internal organizational communication and external public engagement. Without clarity regarding necessary actions and requirements, organizations found it nearly impossible to properly inform the public about project activities and implications. This communication deficit was particularly problematic given that public trust and acceptance are essential prerequisites for successful CCS deployment.

Stakeholders emphasized that perpetuating regulatory ambiguity itself constituted a significant risk. Numerous fundamental questions required institutional frameworks to provide authoritative answers, including basic operational clarity regarding roles, responsibilities, and procedures.

Faced with persistent regulatory uncertainty, stakeholders outlined several pragmatic response approaches. Civil society organizations indicated they would convene all involved parties for structured discussions to address regulatory gaps and implementation challenges. The scientific community committed to informing local communities about CCS technology realities and requirements, enhancing public understanding.

Collaborative problem-solving emerged as a central theme in stakeholder responses. Working groups, expert consultations, and participation in European projects were identified as vehicles for addressing regulatory challenges. Significantly, stakeholders emphasized the importance of examining international experiences, seeking guidance from countries that had already developed CCS regulatory frameworks. This comparative approach offered potential pathways for developing appropriate domestic regulatory structures.

The regulatory vacuum surrounding CCS implementation in Greece represented a fundamental governance challenge with far-reaching implications for technology deployment, stakeholder confidence, and public acceptance. The documented concerns underscore the critical importance of establishing clear regulatory frameworks prior to technology implementation rather than developing regulations reactively.

Effective CCS deployment requires comprehensive regulatory frameworks that define technical standards, monitoring protocols, oversight responsibilities, and accountability mechanisms. Without such frameworks, uncertainty persists, resources are inefficiently deployed, and public trust remains elusive. The experiences documented here highlight the necessity of proactive, transparent, and comprehensive regulatory development as a prerequisite for successful CCS technology implementation.

Environmental Impacts

Focus group discussions revealed multifaceted concerns regarding the environmental impacts of Carbon Capture and Storage (CCS) technology, spanning both specific threats to groundwater resources and broader ecosystem considerations. Stakeholder perspectives reflected tension between acknowledged environmental risks and the potential benefits of CCS deployment, complicated by public uncertainty about this emerging technology.

Participants identified groundwater pollution as a serious concern in the event of CO2 leakage from storage sites. Specific threats included potential acidification of aquifers through pH reduction, release of pollutants into groundwater when storage occurs in depleted oil reservoirs, and possible contamination from heavy hydrocarbons. Stakeholders noted that risks could manifest either through actual leakage events or through public fear of potential leaks stemming from inadequate understanding of the technology. The disruption of natural aquifer equilibrium represented an additional concern requiring careful consideration. These groundwater risks proved particularly challenging given what participants characterized as insufficiently developed risk management technology, coupled with the inherent difficulty of addressing subsurface environmental contamination, including potential oil residue contamination and water quality degradation.

Beyond groundwater concerns, stakeholders recognized that environmental impacts could occur across all stages of CCS technology implementation. Secondary waste generation, accidental spills posing risks to biodiversity, and impacts throughout the entire technology life cycle required comprehensive assessment. Participants acknowledged that all technological interventions produce some environmental effects, emphasizing the necessity of conducting thorough life cycle assessments to understand the full environmental footprint of CCS projects. Several stakeholders contextualized these concerns by noting that inaction on climate change also poses environmental risks, arguing that the comparative benefits of CCS deployment need careful evaluation alongside potential negative impacts.

The lack of clarity regarding environmental outcomes emerged as a significant issue. Participants expressed concern that public ignorance about CCS technology fuelled anxiety and opposition, with fear of the unknown driving negative perceptions. Stakeholders emphasized what they characterized as an imbalanced focus on negative environmental consequences, while positive effects of CO2 sequestration received insufficient attention. This perspective held that the public needed better information about technology's beneficial environmental effects to counter unwarranted fears. The challenge, as articulated by participants, involved minimizing negative consequences while maximizing positive environmental impacts from CCS application, though the absence of an established control and maintenance framework for projects complicated these objectives.

For organizations involved in CCS development, environmental concerns manifested in multiple operational dimensions. Long-term installation safety posed particular worry, with potential corrosion over extended operational periods creating leakage risks that required ongoing attention. The need to shape and, when necessary, modify public perception emerged as a significant organizational concern. Participants stressed the importance of contextualizing negative consequences appropriately while highlighting positive environmental effects in public communication. Negative public perception was identified as directly influencing decision-maker attitudes, creating obstacles for organizations pursuing environmentally beneficial solutions. From technical perspectives, organizations emphasized the necessity of identifying negative consequences early, studying appropriate remediation approaches, and planning prevention strategies to avoid recurrence.

Stakeholder response strategies to environmental impact concerns centred on three interconnected approaches: proactive assessment and planning, strategic communication and education, and collaborative problem-solving. Participants advocated for conducting comprehensive simulations before project implementation and creating detailed protocols to address adverse environmental impacts. The goal involved reducing negative consequences, while increasing positive impacts to optimize overall environmental performance. Several stakeholders emphasized participation in consultation processes, though some noted that past consultations had not proven particularly effective, suggesting room for improvement in stakeholder engagement mechanisms.

Communication strategies featured prominently in proposed responses. Stakeholders recommended identifying influential individuals capable of positively shaping public opinion, informing these opinion leaders first, and leveraging their influence to disseminate knowledge to broader populations. Organizations indicated they would attempt to reframe public understanding through scientifically documented information, aiming to calm reactions that could be mitigated through better knowledge. The importance of accessible information in building credibility was repeatedly emphasized, with participants proposing various educational initiatives including information days featuring qualified scientists and organized site visits to CO2 capture and liquefaction facilities to combat fear of the unknown.

Collaborative approaches included creating initiatives for expert discussions aimed at studying potential problems and dissemination strategies, with findings directed toward decision-makers to inform policy development. Stakeholders recognized that addressing environmental impacts required collective effort across scientific, technical, regulatory, and public engagement domains. The establishment of comprehensive frameworks for project control and maintenance emerged as a foundational requirement for managing environmental risks effectively throughout the CCS technology life cycle.

The environmental impact concerns articulated by stakeholders reflect the complex challenge of deploying CCS technology in contexts where public understanding remains limited, regulatory frameworks are underdeveloped, and long-term environmental consequences remain incompletely characterized. Successfully navigating these concerns requires integrated approaches combining rigorous technical assessment, transparent communication, meaningful stakeholder engagement, and adaptive management strategies responsive to emerging evidence about environmental effects.

Distrust of Control Mechanisms

Focus group participants identified distrust of control mechanisms as a significant challenge for Carbon Capture and Storage (CCS) project implementation, though perspectives varied regarding the nature and severity of this risk. The discussions revealed complex relationships between communication practices, institutional credibility, and public confidence in oversight systems.

Participants characterized distrust as fundamentally rooted in communication failures that eroded public confidence in oversight processes. The purpose of control mechanisms, as articulated by stakeholders, is to mitigate potential distrust of companies implementing CCS projects by providing independent verification and accountability. When these mechanisms themselves become objects of suspicion, a lack of trust in audit outcomes emerges, undermining the legitimacy of the entire oversight framework. However, perspectives on the significance of this risk varied among participants. One stakeholder did not consider distrust of control mechanisms to be particularly significant, while another argued that the primary problem was not distrust of existing mechanisms, but rather the absence of adequate control mechanisms altogether. This distinction proved important, suggesting that concerns about oversight encompassed both the perceived inadequacy of existing systems and scepticisms about their effectiveness.

The consequences of distrust in control mechanisms manifested at multiple levels of CCS project development and implementation. Stakeholders emphasized that such distrust fundamentally undermined the credibility of CCS initiatives and created substantial obstacles to project execution. When public confidence in oversight is absent, the belief emerges that projects will not be implemented correctly or that problems, should they arise, will not be adequately addressed. This erosion of confidence created cascading difficulties for organizations attempting to advance CCS technology deployment.

For organizations involved in CCS projects, distrust of control mechanisms produced both opportunities and challenges. Some stakeholders noted that the existence of public distrust could catalyse civil society action, potentially serving as a mechanism for increased accountability and engagement. From this perspective, scepticisms functioned as a form of public vigilance that, while complicating implementation, could ultimately strengthen project oversight. Others emphasized that proper actions should be standard practice regardless of external control mechanisms, suggesting that robust internal governance should not depend on external monitoring to ensure appropriate conduct.

The practical impacts on organizational operations proved substantial. Distrust necessitated heightened transparency in project implementation processes, requiring organizations to document and communicate their activities more extensively than might otherwise be necessary. This increased transparency demand, while potentially beneficial for accountability, created operational challenges. Project implementation became more difficult as organizations faced inefficiencies and delays stemming from the constant requirement to demonstrate that actions were being taken correctly. The burden of proof shifted, with organizations needing to continuously validate their practices to sceptical audiences rather than operating under presumptions of good faith compliance.

Response strategies proposed by stakeholders centred on enhanced communication, institutional engagement, and transparent demonstration of compliance. Organizations indicated they would pursue dialogue with relevant authorities to address concerns and establish clearer oversight parameters. Increased communication emerged as a primary response mechanism, with stakeholders emphasizing the need to convince citizens to overcome scepticisms through concrete actions rather than merely rhetorical assurances. This approach involved communicating specific procedural steps that had been followed and sharing collected data to demonstrate compliance and effectiveness.

Stakeholders proposed proactive engagement with relevant regulatory bodies, including transparent communication about invitation processes and collaborative discussions. The goal involved creating mechanisms that demonstrably showed work was being conducted correctly, moving beyond assertions to provide tangible evidence of appropriate implementation. Participants emphasized the importance of presenting scientific evidence in accessible formats, recognizing that effective communication required both technical rigor and comprehensibility for non-specialist audiences. The challenge involved proving project integrity through scientifically sound approaches while simultaneously simplifying presentations to ensure public understanding.

The distrust of control mechanisms identified by focus group participants reflects broader challenges in establishing legitimate governance structures for emerging technologies. When oversight systems lack credibility, whether due to perceived inadequacy, poor communication, or insufficient transparency, the resulting distrust creates operational obstacles and undermines public confidence essential for technology acceptance. Addressing this challenge requires integrated approaches combining robust control mechanisms, transparent communication about oversight processes, meaningful stakeholder engagement, and demonstrated commitment to accountability. The tension between the need for rigorous oversight and the operational burdens such oversight can create, highlights the importance of designing control mechanisms that are both effective and efficient, building public confidence without creating unsustainable compliance demands on implementing organizations.

5. ANALYSIS

Challenges and questions

The focus group discussions revealed a complex landscape of interconnected challenges spanning regulatory, technical, social, and economic dimensions. These challenges manifest as critical questions that must be addressed for successful CCS implementation in Greece.

Regulatory and Governance Uncertainties

The absence of a comprehensive regulatory framework emerged as a fundamental obstacle, with stakeholders characterizing the current situation as operating within undefined parameters. This regulatory vacuum raises critical questions about the establishment of standards and monitoring protocols prior to technology deployment. The ambiguity extends to the distribution of responsibilities across governmental levels and private sector entities, creating uncertainty about accountability structures. A particularly contentious issue concerns whether monitoring functions should be state-controlled or privately operated, with significant implications for public trust and credibility.

The regulatory gaps identified in the capture and transport phases create implementation insecurity, potentially leading to licensing delays and unclear delineation of institutional roles. Without established frameworks, stakeholders struggle to navigate approval processes, risking project delays and financial losses.

Environmental and Technical Concerns

Environmental impacts constitute a significant area of stakeholder concern across all CCS phases. Participants expressed apprehension about secondary waste generation, biodiversity threats, and broader life cycle implications of the technology. The novelty of CCS technology amplifies these concerns, as stakeholders grapple with uncertainties about long-term environmental consequences.

Groundwater pollution emerged as a specific high-priority risk, with stakeholders highlighting potential water acidification, pollutant release, and disruption of aquifer equilibrium. The perception that risk management protocols remain insufficiently developed compounds these concerns. Technical questions arise regarding the standardization of CO2 purity specifications across different phases, the adequacy of monitoring point distribution, and the prediction and prevention of chemical reactions between injected CO2 and geological reservoir components.

The question of appropriate Technology Readiness Levels and Operational Readiness Levels for large-scale implementation remains unresolved, reflecting stakeholder uncertainty about whether current technological maturity justifies widespread deployment.

Communication and Public Trust Deficits

A significant challenge lies in bridging the gap between technical complexity and public understanding. Stakeholders identified the difficulty of communicating scientific information to citizens in accessible formats without sacrificing accuracy. This communication challenge is compounded by the proliferation of superficial or misleading information from unreliable sources, which can shape public perception more effectively than scientific evidence.

The monitoring phase faces particular credibility challenges, with stakeholders expressing distrust toward control mechanisms. This distrust stems from concerns about inadequate communication, lack of independent oversight, and questions about the integrity of monitoring processes. The challenge of identifying and engaging influential community members who could facilitate positive public opinion formation, adds another layer of complexity to stakeholder engagement strategies.

Furthermore, stakeholders noted insufficient public awareness about the magnitude of climate change, which affects the perceived urgency and necessity of CCS technology.

Social Acceptance and Community Relations

The implementation of CCS infrastructure faces potential resistance from local communities, including NIMBY (not in my backyard) opposition. Stakeholders identified the challenge of balancing community demands for reciprocal benefits with project economic feasibility. The relatively new nature of the technology raises legitimate public health concerns, that must be addressed through evidence and transparent communication.

Managing rivalries between affected communities and involved parties presents an additional social challenge. The question of how tourism and property values might be affected by CCS infrastructure development, adds economic dimensions to community acceptance issues.

Economic and Infrastructure Constraints

Financial feasibility emerges as a critical concern, particularly regarding how expensive CCS solutions can be financed, when costs fall primarily on implementing companies. The absence of existing transport infrastructure poses logistical challenges for establishing effective CO2 transport networks.

CCS must also compete with alternative decarbonization technologies, including green fuel production and hydrogen infrastructure. This competitive landscape raises questions about optimal resource allocation and technological prioritization within broader energy transition strategies.

Implications for risk governance strategies

The challenges identified through stakeholder engagement point toward specific governance strategies necessary for successful CCS implementation. These implications span institutional, procedural, and communicative dimensions of risk governance.

Regulatory Framework Development as Foundation

The establishment of a comprehensive regulatory framework must precede large-scale implementation to provide legal clarity and institutional stability. This framework should define measurable standards and limits for all CCS phases, establish clear jurisdictional boundaries, and delineate responsibilities across state entities, local governments, and private operators. Regulatory development should include realistic licensing timelines, to prevent project delays while maintaining rigorous safety standards.

The framework must also establish institutional mechanisms for managing potential impacts, including threshold definitions for intervention and protocols for addressing adverse outcomes. This proactive regulatory approach can transform the current "game without rules" into a structured, predictable environment that facilitates investment while protecting public interests.

Independent Monitoring and Transparency Mechanisms

To address credibility concerns, risk governance strategies must prioritize independent monitoring systems separated from private operator control. State-led or independently managed monitoring bodies can enhance public trust by providing unbiased oversight. These systems should incorporate transparent reporting mechanisms that make monitoring data accessible to citizens in interpretable formats.

Monitoring protocols must be sufficiently comprehensive, with adequate spatial distribution of measurement points across storage areas. Pre-implementation simulations can help identify potential failure modes and inform monitoring network design. The development of emergency response procedures for potential leaks and environmental incidents represents a critical component of protective monitoring strategies.

Proactive Communication and Stakeholder Engagement

Risk governance must incorporate robust communication strategies that engage qualified scientists in public information campaigns. These strategies should utilize multiple channels, including information days, facility site visits, and accessible digital platforms. Scientific documentation should be translated into simple, understandable formats without compromising accuracy.

Early identification and engagement of influential opinion leaders can facilitate knowledge dissemination through trusted community networks. Communication strategies must be proactive rather than reactive, addressing concerns about unknown risks before they solidify into opposition. Stakeholder engagement should begin at early project stages, incorporating local community input into planning processes and creating mechanisms for ongoing dialogue.

The development of frameworks for reciprocal benefits to local communities can help align project implementation with community development goals, transforming potential opposition into partnership opportunities.

Comprehensive Environmental Risk Management

Life Cycle Assessments must be conducted for all CCS phases to provide evidence-based evaluation of environmental impacts. Risk management protocols should specifically address groundwater protection, given stakeholder prioritization of this concern. The objective study of both positive and negative environmental consequences demonstrates scientific rigor and builds credibility.

Long-term maintenance protocols for facility operation ensure that environmental protection extends beyond initial implementation phases. Emergency response procedures must be established before operations begin, providing clear protocols for addressing potential adverse impacts.

Strategic Economic Opportunity Framing

Risk governance strategies should leverage economic opportunities, particularly job creation, as prominent elements of project communication. The development of domestic educational programs can support specialized workforce needs, while demonstrating long-term commitment to local capacity building. Creating transition pathways for existing fossil fuel industry workers acknowledges economic transition challenges, while providing concrete solutions.

Frameworks for local business development alongside CCS projects can embed economic benefits within affected communities. Using CCS projects to enhance regional branding and attract complementary investments extends economic benefits beyond direct project impacts.

Multi-Level Governance Coordination

Successful risk governance requires alignment across national, regional, and local government levels. Spatial planning must explicitly consider CCS infrastructure needs to prevent land-use conflicts. Multi-sectoral expert working groups can integrate diverse knowledge domains into coherent governance approaches.

Participation in European and international projects provides opportunities to learn from international experiences and adopt proven practices. Long-term planning frameworks recognize that CCS infrastructure represents multi-decadal commitments requiring sustained governance attention.

Trust Building Through Demonstrated Competence

Risk governance strategies must recognize that trust emerges from demonstrated competence rather than rhetorical assurance. Verifiable scientific approaches to implementation provide tangible evidence of safety and effectiveness. Engaging civil society organizations in oversight roles incorporates diverse perspectives into governance processes while enhancing legitimacy.

Addressing distrust through increased transparency rather than defensive responses acknowledges legitimate stakeholder concerns. Proper communication, as stakeholders emphasized, is vital for trust and acceptance, making communication strategy a central rather than peripheral element of risk governance.

Integrated and Adaptive Approach

The implications point toward integrated risk governance that is coordinated across institutions, comprehensive in scope, and proactive in orientation. This approach addresses stakeholder concerns before they become implementation barriers, transforming potential opposition into informed support. The governance strategies must be adaptive, incorporating stakeholder feedback and adjusting approaches based on monitoring evidence and changing circumstances.

Successful CCS implementation in Greece requires simultaneous attention to regulatory clarity, environmental protection, economic opportunity, and public trust. Risk governance strategies that integrate these dimensions while maintaining transparency and accountability offer the most promising pathway towards societal acceptance and effective climate action through CCS technology.

Implications for future research

Future research should examine the effectiveness of different governance strategies in building social acceptance, comparing outcomes across legal frameworks with varying regulatory approaches, communication strategies, and stakeholder engagement mechanisms. Quantitative assessment of public attitudes towards CCS, complementing the qualitative focus group findings, would provide a more comprehensive understanding of social acceptance dynamics.

Additionally, research examining the long-term outcomes of CCS projects in terms of delivered benefits and managed risks, would provide empirical evidence, either supporting or challenging stakeholder expectations documented in this study. Such evidence could inform more effective governance strategy design and stakeholder communication approaches.

6. CONCLUSIONS

This study examined societal perceptions of Carbon Capture, Transport, and Storage technology in Greece through structured focus group discussions with diverse stakeholders representing academia, industry, local authorities, and civil society. The research provides valuable insights into the complex interplay of opportunities, risks, and governance requirements necessary for successful CCS implementation within the Greek context.

The focus group discussions revealed that stakeholder perspectives on CCS are characterized by simultaneous recognition of both substantial opportunities and significant concerns. Job creation emerged as the most compelling opportunity, transcending simple employment generation to encompass broader economic transformation through multiplier effects, specialized workforce development, and potential reversal of brain drain. Stakeholders viewed CCS as a catalyst for regional development, particularly benefiting communities remote from urban centres, while creating pathways for professional advancement across diverse skill levels.

The development of technological know-how, strengthening of energy transition, and increased economic activity were identified as additional critical opportunities. These opportunities are interconnected, with technology development driving social acceptance, regulatory framework evolution, and workforce capability enhancement. Stakeholders demonstrated genuine enthusiasm for active participation in CCS deployment, drawing parallels to major economic initiatives in terms of potential community-wide impact.

However, this optimism is tempered by substantial concerns that must be addressed for successful implementation. The absence of a comprehensive regulatory framework emerged as the most fundamental obstacle, creating what stakeholders characterized as operating within a "game without rules." This regulatory vacuum generates uncertainty across all project phases, potentially undermining investment confidence and delaying implementation timelines.

Environmental concerns, particularly regarding groundwater pollution, ranked as priority risks requiring robust management protocols. The novelty of CCS technology amplifies these concerns, as stakeholders grapple with uncertainties about long-term consequences and the adequacy of current risk management capabilities. Distrust of control mechanisms, rooted in communication deficits and lack of independent oversight, presents additional challenges to social acceptance.

The research findings point toward clear governance imperatives for successful CCS deployment in Greece. Regulatory framework development must precede large-scale implementation, providing legal clarity, institutional stability, and defined accountability structures. This framework should establish measurable standards, realistic licensing timelines, and clear delineation of responsibilities across governmental levels and private operators.

Independent monitoring systems separated from operator control emerge as essential for building public trust. These systems must incorporate transparent reporting mechanisms, comprehensive spatial coverage, and pre-implementation simulations to identify potential failure modes. The integration of state-led or independently managed oversight bodies can provide the credibility necessary for social acceptance.

Proactive communication strategies engaging qualified scientists and utilizing multiple channels represent critical components of risk governance. These strategies must translate technical complexity into accessible formats without sacrificing accuracy, while addressing concerns about unknown risks before they solidify into opposition. Early identification and engagement of influential opinion leaders can facilitate knowledge dissemination through trusted community networks.

Comprehensive environmental risk management, including Life Cycle Assessments across all CCS phases and specific protocols for groundwater protection, addresses stakeholder priorities while demonstrating scientific rigor. The strategic framing of economic opportunities, particularly job creation and local business development, can transform potential opposition into partnership opportunities, when embedded within frameworks for reciprocal community benefits.

The Greek case study provides insights relevant beyond national boundaries. The challenges identified, namely regulatory uncertainty, environmental concerns, communication deficits, and social acceptance barriers, represent common themes in CCS deployment contexts globally. The governance strategies emerging from stakeholder engagement in Greece may offer transferable lessons for other legal environments navigating similar implementation challenges.

The research underscores that successful CCS implementation requires simultaneous attention to multiple dimensions: regulatory clarity, environmental protection, economic opportunity, and public trust. These dimensions are not independent but interconnected, with progress in one area facilitating advancement in others. Regulatory clarity enables environmental protection measures; economic opportunities enhance social acceptance; public trust supports political will for regulatory development.

The findings also highlight the importance of proactive rather than reactive governance approaches. Addressing stakeholder concerns before they become implementation barriers proves more effective than attempting to overcome established opposition. This requires early-stage stakeholder engagement, transparent communication about uncertainties and risks, and genuine incorporation of community input into project planning.

Carbon Capture, Transport, and Storage represents a potentially significant tool for climate change mitigation, but its successful deployment depends on achieving social acceptance alongside technical and economic feasibility. The Greek stakeholder engagement experience demonstrates that such acceptance is achievable, when governance strategies address legitimate concerns through regulatory clarity, independent oversight, transparent communication, comprehensive environmental protection and strategic economic opportunity framing.

The challenges are substantial but not impossible to overcome. Stakeholders demonstrated willingness to engage constructively with CCS technology, when provided with credible information, opportunities for meaningful input, and confidence in governance systems. This constructive engagement, combined with coordinated, comprehensive and proactive governance approaches, offers a pathway towards societal embeddedness of CCS technology.

The success of CCS in contributing to climate neutrality goals will ultimately depend not only on technical performance, but on the ability to build and maintain social trust through demonstrated competence, transparent communication and genuine responsiveness to community concerns. The risk governance strategies identified through this research provide a foundation for such trust-building, transforming CCS from a technology imposed on communities into a collaborative effort toward shared climate objectives.

7. ACKNOWLEDGEMENTS

The RamonCO project (CETP 2022-00032) is supported by CET Partnership initiative https://cetpartnership.eu/ and funded by: The Research Council of Norway; Netherlands Enterprise Agency; Department of Energy (USA); Saxon State Ministry; General Secretariat for Research and Innovation (Greece); Executive Agency for Higher Education; Research, Development and Innovation Funding (Romania); as well as by the private enterprises: EBN BV; ENI; Equinor Energy AS; Harbour Energy.

References

Bentsen H.L., Otto D., Gross M., Sprenkeling M., Rambharos S., Terpstra E., Duroiu A., Wilkerson B., Ljones M.L., Bannister A., Mendrinos D., Karytsas S. (2025). Abstract: Public Perceptions of Carbon Capture and Storage: A Cross-Country Survey of Risks, Concerns, and Trust in CCS Technologies. 13th Trondheim CCS Conference, 17 - 19 June, Norway.

Mendrinos, D.; Karytsas, S.; Polyzou, O.; Karytsas, C.; Nordø, Å.D.; Midttømme, K.; Otto, D.; Gross, M.; Sprenkeling, M.; Peuchen, R.; Geerdink T and Puts H. (2022) Understanding Societal Requirements of CCS Projects: Application of the Societal

Embeddedness Level Assessment Methodology in Four National Case Studies. Clean Technol. 2022, 4, 893–907. https://doi.org/10.3390/cleantechnol4040055

Nottveit, A., Midttomme, K., Mannseth, T., Sprenkeling, M., Van der Heijden, J., Otto, D., and Koning, M. (2024, April). Risk-Based Framework for Assessing CO2 Storage Monitoring. In EAGE GeoTech 2024 Fourth EAGE Workshop on Practical Reservoir Monitoring (Vol. 2024, No. 1, pp. 1-5). European Association of Geoscientists & Engineers, https://doi.org/10.3997/2214-4609.202430019

Otto, Danny and Sprenkeling, Marit and Rambharos, Shanita and Terpstra, Eva and Bentsen, Henrik Litlere and Wilkerson, Brooke and Ljones, Marie Louise and Bannister, Andrew and Dempsey, Mylan and Carr, Connie and Burlacu (Duroiu), Andreea and Mendrinos, Dimitrios and Karytsas, Spyridon and Gross, Matthias, How to Organize Inter- and Transdisciplinary Work in International Carbon Capture and Storage Research Projects? Insights From Ccs Research in Norway, Greece, Germany, Romania and the Netherlands (December 22, 2024). Proceedings of the 17th Greenhouse Gas Control Technologies Conference (GHGT-17) 20-24 October 2024, http://dx.doi.org/10.2139/ssrn.5068164

Sprenkeling, Marit and Otto, Danny and Rambharos, Shanita and Terpstra, Eva and Bentsen, Henrik Litlere and Ljones, Marie Louise and Wilkerson, Brooke and Mendrinos, Dimitrios and Karytsas, Spyridon and Bannister, Andrew and Dempsey, Mylan and Carr, Connie and Burlacu (Duroiu), Andreea and Gross, Matthias, Societal risk governance for Carbon Capture and Storage projects: Using interdisciplinary and transdisciplinary approaches in Norway, the Netherlands, Germany, Greece and Romania (December 20, 2024). Proceedings of the 17th Greenhouse Gas Control Technologies Conference (GHGT-17) 20-24 October 2024, http://dx.doi.org/10.2139/ssrn.5071917