CCS PUBLIC PERCEPTION LEARNINGS APPLIED TO BRAZIL

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Abstract

Carbon Capture and Storage (CCS) is considered a relevant technology to deal with climate change mitigation. However, the technology is not yet known to the various audiences, be it by the government and legislators, by industry, by academia, by media, or by society, which are far from being aware of such technologies and their impacts. This paper aims to discuss the Brazilian citizens' public perception of onshore and offshore CCS projects. Based on the international literature on CCS public perception and a few studies conducted in the Brazilian context, some highlights and recommendations are drawn. The results show Brazil as a vast country of significant diversity and inequality that requires research approaches covering local, regional and national dimensions. A substantial part of the Brazilian population believes that global warming is happening and demands immediate mitigation actions. Such a mindset could be favourable to accept CCS projects as one of the possible solutions.

Keywords: *3 - 5 keywords (Keywords)Public Perception, acceptance, resistance, risk perception, knowledge*

1. Introduction

Carbon Capture and Storage (CCS) and Carbon Capture, Usage and Storage (CCUS) are considered relevant technologies to deal with climate change mitigation. These technologies consist in capturing carbon dioxide (CO_2) and other greenhouse gases resulting from industrial processes such as steel and cement production, combustion of fossil fuels in energy production and transportation to store these gases in onshore or offshore facilities. The storage could be made in geological reservoirs in depleted oil and gas fields, saline formations, coal beds [1], rock salt caverns [2] and absorption by plants through photosynthesis. The latter is a form of natural storage, although CO_2 will be released further in the process, requiring it to be cyclical to mitigate emissions. Mitigating or reducing the level of CO_2 in the atmosphere is critical to avoid dreadful climate impacts such as droughts, wildfires, intense heatwaves, ice melting in the pole areas, sea-level rises, floods and destruction due to severe storms, among many other possibilities [3]. Keep the rise of the average temperature of the planet limited to 2ºC, preferably 1.5ºC, is seen by scientists as the most recommended scenario [4], in which it is expected that human life may adapt. Through the Paris Agreement, launched in 2015 and signed by 193 countries, these have committed to take actions to limit the emissions with targets for 2030 and 2050 aiming for zero emissions and, in some cases, negative emissions.

Although CCS is a potential tool to achieve such targets, it does not come without controversy. Some argue that CCS has a local impact on the community or ecosystems close to the site where it is implemented. Impacts could be environmental landscape or land use resulting from the transport, drilling and storage on onshore locations. Other risks are related to CO_2 concentrated leakages driving water and atmosphere contamination, affecting human health, or possible seismic activity, even worse in denser populated areas [5]. However, there is also a positive aspect of economic growth, providing employment and commercial development, apart from the "clean" use of fossil fuel and decarbonising the economy [6].

However, the technology is still evolving and is not yet known to the various audiences, be it by the government and legislators, responsible for establishing laws and deciding on regional projects; by the industry, which still has no clear understanding of all the technical, economic and social aspects involved; by academia, that keeps furthering the analysis of the issues; by the media, which requires a better preparation to convey correct information; or by society, which is far from being aware of such technologies and their impacts. Understanding how people perceive and relate to energy technologies has been an essential aspect of the CCS process [7].

The objective of this paper is to discuss citizen CCS public perception within the Brazilian context. The following section details Brazil's scenario and opportunities to develop CCS projects. Section 3 presents the main aspects of public perception in the international literature, and section 4 aggregates the Brazilian studies. Section 5 discusses Brazilian CCS public perception, and section 6 concludes with the final remarks.

2. CCS opportunities in the Brazilian landscape

The increase in energy consumption in developing countries with the consequent escalation in greenhouse gas emissions has been highlighted [8]. To deal with such challenges, Román [8] points out that some of these countries could reduce the adverse effects by implementing large-scale CCS projects. However, CCS technology is relatively expensive and competes with resources for local priority economic development.

Among other developing countries, such as India and South Africa that have significant coal participation in their energy mix, Brazil has a comparable cleaner and renewable matrix, through hydropower, responsible for 73 per cent of its energy production. The high level of 83 per cent CO_2 eq emissions results from agriculture, land-use change and forest management [8].

Even though CCS is not a strong strategy for Brazil in emissions reduction planning, it has received government approval. Petrobras, the Brazilian oil and gas company, has developed two CCS projects, one in a saline aquifer and the other on enhanced coal bed methane (CBM).

Favourable conditions, such as the estimated capacity of 2000 Gt of CO_2 storage in onshore and offshore petroleum fields, saline aquifers, and deep coal, which corresponds to close to 20 per cent of the world's storage capacity, contrast with potential environmental impacts and development concerns [8]. One of the leading ecological limitations to the onshore storage of CO_2 in Brazil, despite the sizeable underground reservoir capability, is the Guarani aquifer that runs from the Paraná region in Brazil through Argentina, Paraguay and Uruguay. The risk of any CO_2 leakage can threaten the quality of drinking water, demanding the settlement of monitoring systems and ruling of long-term responsibilities [8, 9].

Conversely, the offshore pre-salt oil and gas fields discovered in 2006 on the coast of five states in Brazil represent another attractive alternative for CCS. The high content of CO_2, which represents between 10 to 40 per cent of the associated gas, could be stored, preventing it from being ventilated to the atmosphere [10, 11]. Technologies to separate these gases in salt caverns in the pre-salt layer before extraction are being developed by a group of researchers in the Research Centre for Gas Innovation at the University of São Paulo [10–13]. That would represent a great innovation that could boost CCS efforts in the pre-salt layer offshore, preventing the release of CO2 into the atmosphere.

Brazil, contrary to many developing countries, has a particular situation with a cleaner energy matrix. In that sense, economic development that leads to raising the demand for energy production is seen as decoupled from high greenhouse gas emissions, which impacts climate change [8]. However, the growing needs for energy alongside the pre-salt production availability may provide more fossil fuel in the Brazilian energy mix, scenario, in which CCS could be a possible solution, as it could enable the sustainable use of fossil fuel.

In favour of CCS development in Brazil, the source and sink match proximity is analysed by [8] as an advantage. In this sense, oil and gas are extracted in the pre-salt field, which may also store CO_2 in the same area, reducing the burden of transportation. Although offshore opportunities in Brazil are located very far from the coast, about 200 to 300 km away and in ultra-deep waters, meaning 2,000 to 5,000 meters below the ocean level. Technology to deal with such challenges is still under development, and the construction of salt caverns offshore is costly. If the CO2 could be separated in the process of oil and gas exploitation, it could be kept under the ocean in salt caverns with minimal impact on people and ecosystems [11]. The challenge currently lies in the possible use of the gas commercially. This would require, for example, the construction of extensive pipelines or arrangements for long journeys of maritime transportation to the consumer centres.

For example, pipelines significantly increase the cost in offshore facilities, although, compared to onshore pipelines in densely populated areas, the latter can be even more costly [8]. We argue that onshore and offshore alternatives in Brazil require further studies.

Onshore options include the Recôncavo Basin in the State of Bahia, which presents potential characteristics for CO_2 storage [14]. Another promising onshore technology is bioenergy with CCS, named biomass carbon capture and storage (BECCS). The carbon-neutral bioenergy, combined with CCS adoption, is potentially an enabler to net-zero or even below zero emissions [15].

Noticeable for Brazil, the opportunities for developing CCS projects are an alternative to avoid the release of CO_2 from the offshore extraction of oil and gas by storing it in caverns in the pre-salt formation. How would Brazilian citizens perceive such offshore endeavours? Would this public react differently towards onshore projects?

To further discuss the perception of the Brazilian population, the next section will present a brief international literature summary of the main aspects related to the theme.

3. CCS public perception

3.1 Main features of CCS public perception in the literature

Public perception has become a relevant factor in implementing CCS and other large projects, as public opposition can lead to project cancellation. An iconic example is the Barendrecht project in the Netherlands [16, 17] that is often discussed in the literature. In that case, the project, which had neutral or positive support from the politicians, ended up cancelled, in part due to the strong public opposition that emerged and influenced the decision-makers to vote against its implementation [16]. That situation points to the need to understand the public views, opinions and attitudes towards CCS to develop adequate and timely communications.

From the start, relationships should be developed based on trust, which is also valid when planning and implementing CCS projects. The most successful ones created a dialogue space with society, articulating stakeholders divergencies and interacting with the local community through an open debate [18, 19].

Therefore, building awareness, meaning that people understand the technology, considering its benefits and risks, is crucial, as it seems to be low in general. The technology involves three stages: capture, transport, and storage, each comprising various possible technological applications. Such processes are complex and somewhat technical for the understanding of the lay public. Hence, it is essential to develop reliable communication enhancing public knowledge of CCS and its role in climate change mitigation. This effort can be challenging, as the level of non-believers on climate change has increased in the United States, according to [20], despite scientific advice that argues based on the anthropogenic effect over the planet. In this narrative, humankind intervention in nature is leading to global warming [21, 22].

Beyond awareness and knowledge, benefit and risk perception influence the public acceptance of a CCS project. Possible risks are described in the literature as CO_2 leakages and water contamination that may affect human and animal health [23]. Seismic activity is another risk that might impact property value in the vicinity [24].

Another well-known reaction to new technologies is NIMBY, "Not In My Back Yard" syndrome, in which people disapprove of the project implementation in their area. This kind of opposition is described in many large-scale projects, such as CCS, nuclear power plants, and renewables, when people oppose wind turbines in their land or neighbourhood [25].

Socio-demographics, culture, specific circumstances, previous experience with the technology, or the stakeholders responsible for the project also play a part in how the public perceives new technologies, including CCS. However, there is no 'one fits all' formula to deal with the diversity of reactions resulting from these factors.

In some locations, a part of CCS financing is expected to be coming from the energy consumer's bill to provide cleaner and greener energy [26]. Research demonstrates that people's willingness to pay for new technologies, including CCS, may be affected by the acceptance and preferences between technologies, as people have different perspectives about the energy transition they would support [26]. The discussion is mostly on whether CCS is a technology that would bridge the path out of fossil fuels towards renewables or would be a solution to maintain 'business as usual' [27].

Governmental policies often result from the interactions among stakeholders sharing their interests, which are not always aligned to the society's views. However, policies in similar areas may support new ones to approach emerging technologies such as CCS.

3.2 Cross-country studies in CCS public perception

Many studies about CCS public perception were developed in the United States, United Kingdom, Australia, Norway, China, Canada and Europe [17, 28, 29]. As a top common finding, they identify low public awareness and a tendency of unstable public opinions, as people oscillate depending on several circumstances [30].

In research that investigated the perception of CCS in six European countries [30], the level of awareness among male respondents was higher than among females. Group ages and level of education also varied. Older people (65-75 years old) were less aware of the technology than the middle age group (50-64 years old), and those with higher education responded as being more informed about it. Another factor the research pointed out is that in Norway and in the Netherlands, the general level of knowledge of CCS is 62.6% and just over 50%, respectively. In Norway, Romania and Greece, about 75% of the respondents never heard about such technology. The authors argue that "information and education strategies regarding CCS technologies must be tailored to the specific context of each country and group being targeted" [30].

When considering the best way to contain global warming [30], a study comparing CCS with other energy technologies such as nuclear power, wind, and solar, CCS is one of the least favourably evaluated, excepting nuclear. Nevertheless, the overall reactions to CCS are neutral or slightly positive [30]. However, CCS projects have still been very recently implemented, demanding more time to better verify people's thoughts and feelings in the long term within the region the technology is in operation.

Changing perceptions was also evaluated in the six European countries [30], denoting that for some of them, when the population was offered negative information, the tendency was driven to negative perception, and the opposite, when exposed to positive information, the results tended to move towards a slightly more positive perception. Curiously, Romania respondents with relatively little knowledge moved to a somewhat more positive response even though exposed to negative information. In turn, Germany moved to a slightly more negative position when exposed to positive data.

These results are an invitation for researchers to look into their assumptions and search for more in-depth aspects of human behaviour, understanding the irrational decision making and attitudes that people often assume. The outbreak of the global coronavirus pandemic in 2020 evidenced the diversity of people's reactions when exposed to uncertain and controversial subjects such as climate change and mitigation actions. Denial of the situation, and the severity of the consequences, discredit of scientific evidence, the growth of misinformation and social media fake news, conspiracy theories and many other interpretations of reality.

Therefore, the need to discuss and further investigate public perception is stressed. This summary of features affecting the public perception and acceptance will

support the discussion of these aspects in the specific Brazilian case, the aim of this paper, and presented in the next section.

4. CCS public perception in Brazil

4.1 Brazil and global warming perception

Considering the aspects pointed out in the international literature when analysing CCS projects implementation in Brazil, it is essential to comprehend the country's specificities. Brazil is a vast country with continental territorial dimensions, occupying 8.516 million km². It is the fifth-largest country on the planet, after Russia, Canada, the United States and China, and the largest in Latin America. Currently, Brazil has over 210 million inhabitants unequally distributed within five regions and 5,568 municipalities [31]. Brazil is also well known for its diversity of regional landscapes, rich in coast and inland cities, that vary in size, with large and cosmopolitan busy towns, such as São Paulo, beautiful coastal cities, such as Rio de Janeiro, the natural ecosystems of the Amazon forest, and many diverse human settlements.

Nevertheless, a new survey conducted in October 2020 [32] with 2600 participants from the five regions of Brazil showed that 92 per cent of Brazilians believe that global warming is happening and it is urgent to protect the planet. Seventy-seven per cent believe it is caused by human activity and that government (35 per cent), industry (32 per cent), citizens (24 per cent) and NGO (4 per cent) can best contribute to the solution. Seventy-four per cent of the respondents adopted waste separation practices for disposal and recycling. For 72 per cent of the participants, global warming can severely damage the current generation, and for 88 per cent, it will significantly harm future generations.

The survey also pointed out that 77 per cent of Brazilians consider it more important to protect the environment, even though such a position could reduce economic growth and employment. However, the federal government currently in charge has been adopting opposed actions, drastically reducing environmental defence policies and minimising the control of areas of environmental protection in the country.

4.2 Research in CCS public perception in Brazil

One of the very few studies related to CCS public perception in Brazil was published in 2020 [14]. The authors analyse 57 interviews with local citizens in the Recôncavo Basin region in the State of Bahia, an area of ten potential CCS onshore injection fields, primarily aiming at enhanced oil recovery (EOR). The results point out the familiarity of the local population with the oil business as the members live close to or within areas of previous oil exploration. This proximity is perceived on the one hand as positive, as the industry enables the creation of jobs, takes care of the road maintenance, and qualifies the payment of royalties. On the other hand, during the previous exploration phase, no money from royalties was paid to those who leased the land for oil prospection because the regulation was not in place. The traffic of heavy trucks has damaged the roads and cracked the walls of houses by the roadway. Part of the group has complaints about the lack of information about risks and guidance about dealing with possible water contamination or other accidents. Even though it is not conclusive or subject to generalisation, the data from this limited sample offers some insights into the local population's troubles and expectations. The interviewees mentioned their interest in sharing their opinions and being heard by the stakeholders in charge, providing them with a sense of empowerment. The majority of the interviewees was optimistic about the possibility of influencing decisions, especially in locations with higher density.

As in other countries, the level of awareness about the technology is low, and in this research [14], no one was knowledgeable about CCS application. Consequently, reactions of opposition were not manifested at that time, probably because the situation was new. The majority had a reasonable level of trust in the oil and gas company, despite some mistrust related to the company not presenting the complete picture of pros and cons when communicating the impacts of applied technologies.

Noticeably, the planning and implementation of CCS projects in Brazil are incipient. However, it is imperative to consider the social aspects and establish communication channels with the local community of prospect areas for CCS implementation.

5. Discussion

The [32] survey results indicate that the Brazilian population is sensitive to global warming and is concerned with the environment. Therefore, this evidence suggests possible support for technologies such as CCS to prevent global warming. When communicating the benefits of CCS projects, this feature should be stressed. However, job creation and economic growth require to be balanced with environmental preservation to meet the local community's expectations and the broader Brazilian population.

The Brazilian population demonstrates a willingness to change behaviours if they understand their contribution to shaping a low carbon society. The substantial number (74 per cent) of adopters of separating waste for disposal and recycling suggest so [32].

Brazil is a country of great inequality, with a significant part of the population with a low level of education. In this scenario, implementing CCS projects in impoverished locations can be well received as the opportunity for job creation, and economic growth would be attractive. Social justice elements become relevant, balancing the needs of progress and preserving the local environment and the community's culture.

As noticed by [14], familiarity with oil and gas companies may be favourable to reduce opposition if the relationship is positive. In this situation, community members of denser settlements might feel optimistic and

empowered to make themselves heard and take actions otherwise.

As trust in stakeholders has a positive influence on acceptance [33], open and frequent public conversations are highly recommended to keep the community informed of the activities and their consequent impacts. However, the lack of efficient communication channels between the stakeholders and the community can lead to mistrust, NIMBY reactions, and rejection, threatening project continuity.

More research is required to assess the local population's risk and benefit perception in sites where CCS project are intended to be settled. Nevertheless, some of the risk issues are related to the safety of the technology, water and air contamination, damage and dust caused by heavy trucks in the area. The perceived benefits are job creation and economic growth, and with the current regulation of royalties, financial reward from the land leasing.

Brazil has a good set of environmental protection laws that the federal government is currently amending to benefit economic development. However, there is not a specific regulation about CCS technologies. The previous government approval [8] should be further discussed to produce appropriate standards for CCS projects.

As there are very few CCS projects in operation in Brazil, many aspects should be further investigated, such as the financing modelling, building different scenarios that support decision making. If one of the options considers the contribution from energy consumers, the willingness to pay for the technology and the preferences among low carbon technologies should be further investigated.

CCS public perception seems to be critical in onshore projects, as described previously. Although the public might not be very interested in technologies being developed and implemented offshore, there are few studies, for example, Tomakomai offshore storage [34], that prove otherwise, in which fishermen and the fishing industry were concerned about the effect of CO_2 leakages in the maritime ecosystems and ocean acidification. Offshore CCS public perception studies in Brazil would be highly recommended.

6. Final remarks

The literature on CCS public perception has highlighted the main features that are attributed to diverse populations. Namely, awareness, knowledge, NIMBY, benefits and risk perception, socio-demographic factors, willingness to pay for CCS, trust, acceptance and preferences between technologies, governmental policy and interaction between stakeholders [1] should be further investigated in Brazil.

As Brazil is a vast country with significant inequality, it would be recommended to pursue research at many levels, approaching local, regional, and national dimensions to understand the 'publics perceptions'. Onshore and offshore CCS public perception must be investigated to comprehend the nuances in each situation and contribute to the bulk of knowledge to support CCS projects.

Considering such diversity within the country, lessons learned indicate communication will be more effective if direct and straightforward, supported with visual aids that facilitate apprehension by everyone, regardless of age or educational level. Democratic, open and frequent communication with the community is highly recommended to build and to maintain trust between the public and stakeholders.

This study is limited by the insufficient literature on CCS public perception in Brazil and the lack of field studies that could expand the analysis. Therefore, carrying out research to fill this gap is crucial.

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