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EFFECTIVE MANAGEMENT OF CCS PROJECTS: ADVANCING WITH AN INTEGRATED CCS MODEL

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Abstract

Drawing from past experiences in implementing carbon capture and storage (CCS) projects and the previously proposed model for managing them, this paper seeks to refine the model and expand our understanding to encompass the various aspects of these endeavours – including social, economic, ecological, technical, and more. The paper begins with a concise introduction to the topic of CCS and presents the key elements of an integrated CCS model that could be advantageous for both academia and practice in examining and managing CCS projects and related initiatives. Furthermore, we continue by explaining how the model should be utilized and how its core elements can be modified to improve the management of CCS projects and align it with industry best practices. Consequently, the outcome of the paper is an advanced integrated CCS model that functions as a conceptual framework for managing CCS projects. This model calls for further refinement to establish detailed, task-by-task guidelines that will clarify both conceptual and practical issues. Nevertheless, this paper offers valuable insights into the effective management of CCS projects and stimulates discussion on resolving the somewhat ambiguous perspectives on integrating all critical aspects of CCS endeavours, which demand substantial effort from both industry and society.

Key words: *CCS, Decarbonization, Sustainable Project Management, Oil and Gas Industry, ESG.*

1. Introduction

Global efforts to reduce CO_2 emissions and transition to a net-zero economy have elevated carbon capture and storage (CCS) as a viable solution to effectively tackle these challenges of the modern society Although the concept of CCS has been established in academic and practical fields for several decades, it has recently experienced a significant surge in interest as a means to slow climate change and

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mitigate its associated impacts. However, the widespread adoption of CCS remains somewhat uncertain due to the complexity of these endeavours, which we identified as an opportunity to enhance the management of CCS by introducing a model that addresses the various aspects of CCS implementation – geological, ecological, economic, and social. Consequently, this paper aims to advance the practice of CCS, primarily in the oil and gas industry, as well as from a broader perspective.

1.1 Carbon Capture and Storage

Carbon capture and storage (CCS) is a technology designed to remove CO_2 from various industrial and power sources and permanently store it in deep geological formations, underwater, or other secure locations to prevent future leakage (Leung et al., 2014; D'Amore et al., 2020; Steele et al., 2021). The most common form of CCS is enhanced oil recovery (EOR), which encompasses two aspects – the geological storage of captured CO_2 and the increased oil production due to better utilization of the oil field, thereby simultaneously addressing the issue of CO_2 emissions and achieving economic benefits (Riley, 2010; Hill et al., 2013; Leung et al., 2014). Consequently, CCS is acknowledged as a vital strategy for enhancing decarbonization efforts and attaining sustainability goals, thus mitigating the impact of climate change on nature, society, and the economy (Cook, 2012; Leung et al., 2014; Shirmohammadi et al., 2020).

Recent trends in CCS research focus on safety, scalability, public acceptance, machine learning, and cost efficiency, as well as the integration of these elements into roadmaps for successfully navigating CCS initiatives, leading to the development of the Integrated Phased Model for CCS Implementation (Küng et al., 2023; Yao et al., 2023; Liu et al., 2023; Fominykh, 2024).

1.2 Integrated Phased Model for CCS Implementation (IPM-CCS)

The Integrated Phased Model for CCS Implementation (IPM-CCS), introduced by the author earlier this year, serves as a comprehensive guideline for deploying CCS initiatives across any industry, regardless of the scale or complexity of the implementation. The IPM-CCS is structured into six subsequent phases, which can overlap and occur concurrently when feasible and reasonable. Between these phases, multiple checkpoints are established to assess the phase deliverables and facilitate decision-making regarding the acceptance of deliverables or the need for further alignment with the phase requirements. The core principle of this model is to enable the continuous development of project deliverables, ensuring that the project remains aligned with the strategic goals of the company and contributes to safe, responsible, and cost-effective CCS implementation.

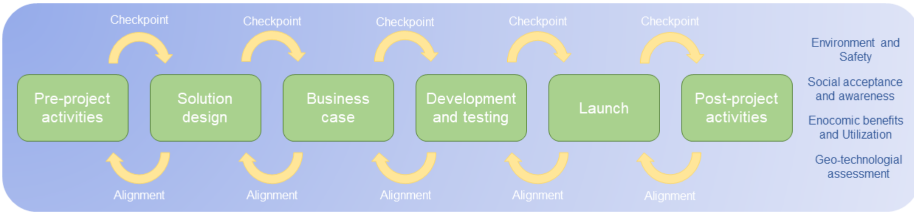

Figure 1: IMP-CCS

As depicted in Figure 1, the IPM-CCS comprises the following phases: pre-project activities, solution design, business case, development and testing, launch, and post-project activities. Each phase includes recommended steps to be conducted during the implementation of a CCS initiative, which allows for the acceptance of ongoing changes and ensures the continuity of the project. This approach is distinctive due to its quasi-agile nature; however, due to numerous technical, geological, physical, and other constraints of CCS projects, various issues arise when attempting to shift entirely to fully agile methods and models.

2. Methodology

The methodological framework of this research consists of data collection and analysis activities that were conducted to gain a comprehensive understanding of CCS, theoretical frameworks for managing these endeavours, and potential enhancements to advance industry practices.

2.1 Data collection

We conducted a systematic literature review to identify key insights into the management of CCS projects. Initially, the literature pool contained over a hundred papers; however, we narrowed our focus to those that exclusively examined various aspects of managing CCS and similar complex projects. Consequently, the systematic literature review in this study encompasses more than twenty papers that discuss the explanation of CCS and its components, different management approaches for CCS projects, and the latest developments in enhancing current practices within the oil and gas industry. It is important to note that we employed a mixed-methods approach in our systematic literature review, thereby organizing existing knowledge about CCS and transforming it into new theoretical concepts that reduce uncertainties surrounding the management of such projects.

2.2 Data analsis

We categorized the identified papers into two groups: 1) core elements of CCS and its management, and 2) innovative strategies for managing complex projects. For each category, we analysed the current state, challenges, trends, and particularities, thereby pinpointing their intersections to propose potential enhancements to CCS practices, applicable not only to the oil and gas sector but to industry as a whole. Furthermore, we employed case analysis to deepen our understanding of managing CCS projects by examining various CCS initiatives implemented worldwide, with a particular focus on the CO2 EOR project at the “Rusanda” oil field and the construction of Europe’s first *HiPACT* plant. By integrating new findings into the existing model, we structured and refined the IPM-CCS that will be presented as follows.

3. Results

The IPM-CCS, introduced earlier, provides fundamental definitions of the steps involved in each phase of the model (Fominykh, 2024). Nonetheless, managing CCS projects goes beyond these steps, delving into risk assessment, technological feasibility, and scalability, which are crucial for the successful deployment of CCS technology and for meeting the dynamic societal demands regarding general safety and environmental protection. Therefore, the IPM-CCS will be further developed by detailing its adaptations in line with the aforementioned considerations.

Larkin et al. (2019) proposed an integrated risk assessment framework that identifies three groups of factors influencing CCS implementation: 1) government and industry factors; 2) environmental risk factors; and 3) socio-economic factors. The authors recommend that these factors should be regularly assessed and reassessed as CCS implementation progresses, complementing the IPM-CCS and its established practice of multiple checkpoints at the beginning and end of each phase of the model. However, Larkin et al. (2019) also outline ten phases of risk assessment that facilitate risk mitigation based on the risk factors and stakeholders involved, thereby offering a structured approach to ensure that technical, environmental, economic, social, and regulatory requirements are met throughout the CCS implementation process. Therefore, the integrated risk assessment framework should be adopted as the standard risk assessment practice and integrated into the checkpoints as an essential gatekeeper before progressing to the next phase of implementation, as proposed within the IPM-CCS.

The technical feasibility of CCS endeavours was not explicitly addressed in the previous version of the IPM-CCS, although it encompasses the selection of potential technological solutions, aligning them with project-specific requirements (such as site characteristics, type of geological formations, seismic parameters, capture or storage capacity, etc.), and concurrently developing and testing these solutions. Therefore, the pre-project phase of the IPM-CCS should incorporate a comprehensive techno-economic analysis, which also includes the assessment of the technology readiness level, thereby eliminating technical barriers to implementing certain CCS solutions or deferring their implementation until a minimum set of technical requirements is met (Dziejarski et al., 2023; Rowaihy, 2024). Furthermore, it is notable that the assessment of technological feasibility also extends through other phases of the IPM-CCS, necessitating the abandonment of CCS implementation if any significant but irresolvable risks emerge, even at advanced stages of the project, such as during the testing or launching phases (Küng et al., 2023; Liu et al., 2023). Upon the implementation of CCS solution, i.e., during the post-project activities phase, the focus shifts to leakage prevention which is shared responsibility of both the implementor and the government; while the model considers this to some extent, it is more broadly a matter of long-term corporate and social responsibility.

Given that the issue of scalability of CCS technology has not been fully addressed within the IPM-CCS model, it is crucial to acknowledge that the technical feasibility, general safety, and cost-effectiveness of CCS implementation are the main factors affecting the potential for broader deployment; therefore, the pre-project activities and development-related phases of the model are critical in determining the level of scalability (Küng et al., 2023; Golombek et al., 2023; Shu et al., 2023). Scalability as such is determined by the number of potential storage sites (Hill et al., 2013; Küng et al., 2023), available technologies for capturing and storing captured CO_2 (Markewitz & Bongartz, 2015; Dziejarski et al., 2023), possibilities for low-cost implementation of CCS (Kuckshinrichs & Vögele, 2015; Küng et al., 2023), ensuring that safety requirements are met (Goren et al., 2024), and provision of social acceptance (Schumann, 2015). Additionally, scalability in terms of the simultaneous implementation of multiple CCS projects does not fall within the current scope of the IPM-CCS and could potentially be considered for further development.

In summary, the initial version of the IPM-CCS has been expanded to include new perspectives on risk assessment, technological feasibility, and scalability, integrating these considerations into the existing phases of the model. As a result, the structure of the model remains unchanged, but its qualitative dimension has been enhanced, offering a more thorough understanding of the complexity of CCS implementation and the comprehensiveness of activities required for the successful delivery of these projects.

4. Discussion

The current IPM-CCS is adequate for individual initiatives, such as constructing and operating a *HiPACT* plant or carrying out a CO_2 EOR project in the “Rusanda” oil field, which are viewed as exemplars of operational excellence in the CCS domain (Okazaki et al., 2018). Stemming from this experience, the IPM-CCS could be applied to the construction of similar projects or the further modification of existing *HiPACT* or EOR plants, considering technical, geological, health, safety, and other enhancements to the initially implemented solution. Given the potential of the project implemented at the “Rusanda” oil field, especially in terms of technological and operational excellence and the capacities for capturing, transporting, and storing CO2 (Karas & Nesic, 2019; Fominykh, 2022), the IPM-CCS could influence a broad spectrum of CCS projects globally and serve as a roadmap for the successful implementation of such initiatives, irrespective of the industry, geographic location, and technological solutions employed. Furthermore, the IPM-CCS could transcend the scope of individual projects and contribute to the advancement of standards, policies, and regulations concerning environmental and safety considerations, social acceptance and awareness, economic benefits and monetization, as well as ongoing geo-technical assessment, which are represented in the model as the critical dimensions that encompass an operational CCS plant (Fominykh, 2024).

The qualitative improvements made to the IPM-CCS through this research have not directly modified its structure but have highlighted the need for further refinement of the model, thereby elevating it to the level of a framework for managing CCS initiatives. Accordingly, the further refinement of the model should concentrate on creating step-by-step guidance for conducting CCS initiatives that includes developing detailed risk assessment tool, compiling a list of thorough acceptance criteria for each checkpoint, and establishing comprehensive post-project oversight. These enhancements will finalize the model and tailor it for large-scale implementation, thereby elevating CCS practices to new heights and promoting their broader adoption.

5. Conclusions

The IPM-CCS facilitates the successful implementation of CCS initiatives and, as such, can also be viewed as an instrumental tool for navigating the success of decarbonization efforts. The wider application of the IPM-CCS in the oil and gas industry and across various sectors will hinge on advancements in both CCS technology and the model itself, thus the authors recommend enhancing the model to facilitate large-scale implementation and applicability across industries. In the future, we can anticipate the evolution of integrated frameworks for CCS implementation that weave together project management, environmental, social, and governance (ESG) aspects, as well as carbon capture, transport, storage, and utilization considerations, thus enabling a comprehensive and high-performing approach to CCS initiatives.

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