

Carbon Capture, Utilization, and Storage (CCUS): The Oil & Gas Industry's Path to Net-Zero Emissions

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Abstract:

As countries set national net zero goals, and global carbon markets debate how to best achieve decarbonization, CCS (Carbon Capture, Utilization and Storage) is one of the most promising technologies to cut emissions from hard-to-abate sectors including the oil and gas industry, which is one of the largest emitters in the world and under increasing pressure to meet its carbon commitments. CCUS provides industry a means to continue supplying energy whilst significantly decreasing its environmental footprint. This study examines the potential of CCUS to support the oil and gas sector's 'Net Zero' transition, and builds on existing literature on technical, economic, policy and implementation challenges to CCUS. The analysis reveals that the industry has several potential strengths when it comes to scaling up CCUS, including significant experience and knowledge of subsurface operations, existing networks of infrastructure, and investment potential. The efficiency and commercial viability of the project are further enhanced through innovations in carbon utilization technologies, AI based monitoring and new carbon-use pathways.

However, there are significant obstacles to widespread use, including the need for large investments, regulatory uncertainty, limitations in infrastructure and acceptance, and these are still holding back widespread adoption. The study reveals that CCUS will be a key player in the global net zero future and a balanced clean energy transition, yet policy coordination and ongoing innovation is required to ensure the technology becomes a reality and stakeholders can continue to innovate and collaborate to invest in R&D.

Keywords: Carbon Capture and Storage (CCS); Carbon Capture, Utilization, and Storage (CCUS); Net-Zero Emissions; Oil and Gas Industry; Decarbonization; Energy Transition; Climate Change Mitigation; Carbon Management

1. Introduction

Human-induced greenhouse gas (GHG) emissions are one of the greatest challenges facing this century that human activities are contributing to climate change. Large economy-wide emissions reductions are needed to meet the temperature stabilization targets of the Paris Agreement, particularly for the energy intensive industries that are hard to abate (Regufe et al., 2021). A net-zero emission (NZE) is a state in

which the emission of GHGs is balanced by removals or offsets of GHGs, and is the blueprint for national and corporate climate targets all over the world (Oniemola et al., 2025).

Oil & gas is in a very special place in this transformation. In the past, and even more so today, the industry has been an important factor in global economic development and industrialization, and in energy access. Yet, fossil fuels extraction and combustion remains one of the largest contributors of global GHG emissions, and as governments, investors, and civil society have started putting pressure on fossil fuel companies to reduce their emissions to reach international climate targets (Aguilera & Aguilera, 2024). Now the industry discussion is not about change, but about the pace of change, and what technology will take them to this change.

In this context an interesting value proposition is the CCUS technologies that encompass all aspects of CO₂ capture, transport, geological storage and productive use. While renewable energy tries to address emissions in the future by displacing the fossil fuel generation, CCUS can address emissions from 'hard-to-abate' processes, such as cement, steel, petrochemicals, or natural gas processing, amongst others (Islam et al., 2022). The technology thus creates a link between the carbon-intensive industrial system of today and a future carbon-free.

CCUS is a critical pillar of all global energy and climate research institutes and all international energy agencies for pathways to net zero at the lowest cost. The scenarios involved, if not for implementing CCUS, then they would have to face a shorter and costly transition process and would mean higher risks to energy insecurity (Suleman & Nasir, 2023). It is appropriate and relevant to have an understanding of the role, potential and limitations of CCUS in the oil and gas sector in this context.

This paper will evaluate how CCUS can support the decarbonization path of the oil and gas industry. It detailed the current state of the CCUS technologies and the oil and gas industry benefits of implementing CCUS technologies, considers economic and policy considerations, and presents barriers and enablers that will impact future CCUS implementation. The analysis was carried out based on a systematic review of the 20 most significant sources published in peer-reviewed journals, conference proceedings, analyses from the industry and doctoral research for the period 2020 – 2026.

2. Literature Review

2.1 Evolution of Carbon Capture, Utilization, and Storage (CCUS)

From a small-scale environmental idea to a large-scale industrial solution CCUS has developed. It can be traced back to the Carbon Capture and Storage (CCS) initiative, which was mainly dedicated to capturing CO₂ from sources of emissions and storing it in geological formations. The scope was broadened over time to encompass utilization, as CO₂ has gradually been seen as a potential economic resource for fuel production, chemicals and construction, i.e., as a feedstock, which resulted in the more comprehensive CCUS designation (Latif et al., 2024).

As the urgency to act when it comes to climate change increased, these technologies started to take off. In addition to the measures for decarbonization through renewable energy and energy efficiency, however, measures are required for carbon management to achieve the required emissions reductions under the Paris Agreement, particularly in the case where decarbonization is technically and/or economically unattainable (Regufe et al., 2021). The CO₂ injection for Enhanced Oil Recovery (EOR) has been an early CO₂ use case for large-scale underground carbon management (Saldana, 2026) in North America for decades. The technical feasibility of stable underground storage of CO₂, the basis of modern CCUS was demonstrated in these EOR projects.

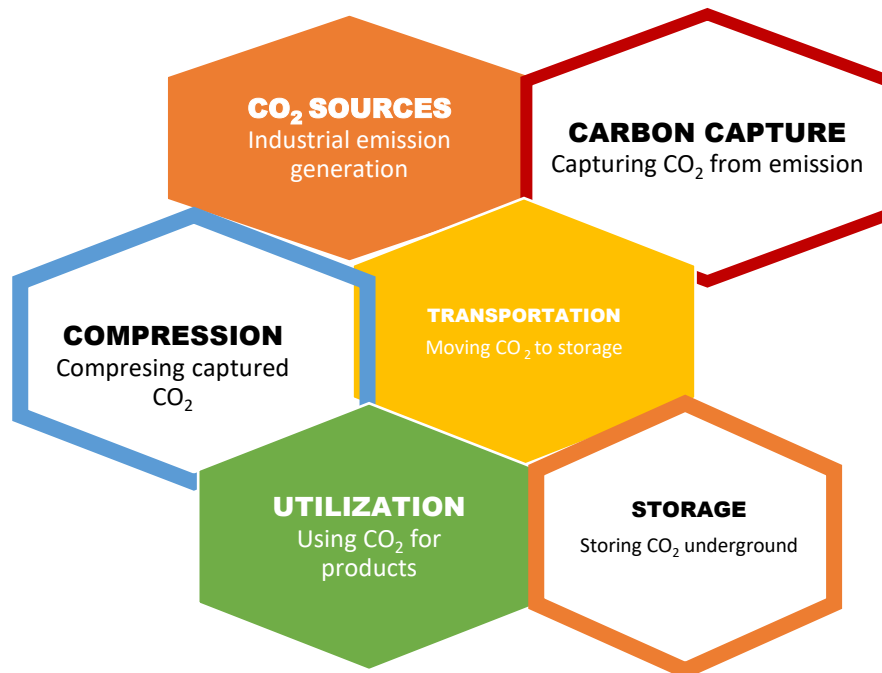
In the last ten years, investments in CCUS have increased significantly and governments and the private sector have invested billions of dollars in demonstration projects and pilot facilities, as well as in commercial-scale operations. The increased interest in the possibility of net-zero pathways has led to the recognition that carbon removal and management (Oniemola et al., 2025) is essential, alongside clean energy production. Based on this, the viability and appeal of CCUS are further boosted by the new capture materials, AI monitoring and digital twin systems. There are further improvements in the viability and appeal of CCUS, notably with the new materials for capture, AI monitoring and digital twin systems.

2.2 The CCUS Value Chain

CCUS includes a list of related process steps within a carbon management value chain: capture, compression and transport, and geological storage or utilization. All the phases need to be put together in an effective way to make the CCUS project effective. The overall performance and economic feasibility of the transportation system can be impacted by the weakness of any component, including storage capacities, utilization markets (Regufe et al., 2021; Latif et al., 2024; Ahmad et al., 2026).

Carbon capture is typically the most technically challenging and costly part, and usually accounts for the majority of project costs (Ahmad et al., 2026). A captured CO₂ must then be compressed and transported (typically by pipeline) to where it will be stored or used. Geological storage is the only way to store for the long-term in depleted hydrocarbon reservoirs, deep saline aquifers or unmineable coal seams. The utilization pathways can create revenue streams that can help improve the project economics by converting the captured CO₂ into a valuable economic product.

Figure 1. General CCUS Value Chain



Carbon Capture Reduces CO₂ Emissions

Source: Adapted from Regufe et al. (2021), Latif et al. (2024), and Ahmad et al. (2026).

To achieve the effectiveness of a CCUS project, integration of each stage is important. A lack of supporting transportation or storage infrastructure, or utilization markets, may have a negative impact on system performance and economic viability.

2.3 Carbon Capture Technologies

There are three main methods for capturing the principals that are being used on an industrial scale. Post-combustion capture captures CO₂ from flue gases generated after fuel combustion, usually with chemical solvents, such as amines. It is mainly advantageous due to its retrofitability to the existing plant, but it has relatively high energy requirements and has high costs for solvent management (Saxena et al., 2024; Latif et al., 2024). Pre-combustion technologies convert fossil fuels into synthesis gas (syngas) and remove CO₂ prior to combustion, resulting in a low carbon fuel, hydrogen. This is more efficient at capturing but is more appropriate for new facilities, rather than retrofits (Handaja et al., 2024). Oxy-fuel combustion is a process in which fuel is combusted in near-pure oxygen to generate a stream of CO₂ and water vapor which makes it easier to capture, but the energy cost of oxygen production restricts its application. New emerging technologies are membrane separation and adsorption-based technologies. There are advanced membranes that can be used for reduced maintenance, and novel adsorption materials (such as metal-organic frameworks, MOFs, and nanostructured adsorbents) that exhibit improved selectivity and energy efficiency under industrial conditions (Saxena et al., 2024). AI-powered process control systems also boost capturing efficiency and facilitate predictive maintenance, cutting down operational expenses (Fortunate et al., 2025). All of these developments together suggest a direction for significantly more cost competitive capture systems over the next decade.

Table 1. A Major Carbon Capture Technologies Comparison

Technology	Principle	Advantages	Limitations
Post-Combustion	Captures CO ₂ after combustion	Retrofit capability; mature technology	High energy demand; solvent costs
Pre-Combustion	Captures CO ₂ before combustion	High efficiency; hydrogen production	High capital costs; better for new plants
Oxy-Fuel Combustion	Burns fuel with pure oxygen	High capture rates; concentrated CO ₂ stream	Expensive oxygen production
Membrane Separation	Selective gas filtration	Lower maintenance requirements	Performance limitations at scale
Adsorption Systems	Surface-based gas separation	Energy efficiency potential	Material degradation issues

Source: Adapted from Saxena et al. (2024), Ahmad et al. (2026), and Latif et al. (2024).

2.4 Oil and Gas Industry's Strategic Advantage

The oil and gas industry is uniquely positioned to drive and lead large scale deployment of CCUS. This expertise acquired over decades of subsurface work is directly relevant to carbon storage projects, particularly for reservoir characterization, understanding fluid flow dynamics, drilling and injection of

fluids underground. These technical capabilities have the effect of lowering the learning curve and project risk related to CO₂ storage.

Another competitive edge is the existing infrastructure. Pipelines, offshore platforms, processing facilities, and depleted hydrocarbon reservoirs can be utilized for carbon transportation and storage, significantly reducing capital expenditure and shortening project timelines, especially when compared to industries that have to construct new facilities (Handaja et al., 2024). The big multinationals also have the funds to invest in research, pilot projects and commercial deployment at scale. As environmental laws and regulations are tightened and the pressure of investors for environmental, social and governance (ESG) criteria increases, many companies are incorporating CCUS into their long-term sustainability plans (Cherepovitsyna et al., 2024).

Table 2. Oil & Gas Industry Assets Supporting CCUS Deployment

Existing Industry Asset	Contribution to CCUS Development
Reservoir engineering expertise	Geological storage assessment and management
Drilling technologies	Carbon injection operations
Pipeline infrastructure	CO ₂ transportation networks
Depleted oil and gas fields	Long-term geological storage sites
Monitoring systems	Storage verification and safety assurance
Financial resources	Project investment and scaling
Skilled workforce	Technical implementation and management
Offshore facilities	Carbon storage and injection operations

Source: Adapted from Hastings & Smith (2020); Aguilera & Aguilera (2024); Handaja et al. (2024).

2.5 CCUS in the Net-Zero Context

The net zero-emissions concept is the first and foremost goal of international climate policy, which means that GHG emissions must be balanced by their removal due to technological or natural processes (Oniemola et al., 2025). CCUS can make a direct impact on this objective, either by avoiding the release of CO₂ to the atmosphere or by removing CO₂. Importantly, renewable energy and efficiency options can only reduce the emissions from the future whereas CCUS can reduce the existing emissions from the industrial processes, which is especially important for hard-to-abate industries (Regufe et al., 2021).

Suleman and Nasir (2023) have modelled the impact of climate change on the costs of the pathways and highlighted that the cost and impact of net-zero pathways without CCUS is significantly higher than with CCUS. In a study on the energy transition in Canada, Ihejirika (2021) has shown how CCUS can help the country meet its national net-zero goals without compromising the economy of energy-producing regions. comparable results have been obtained in European, Asian and Middle Eastern contexts. CCUS also has the potential to offer a pathway to low-carbon hydrogen production from natural gas, which is being increasingly recognized as a significant contribution to decarbonize some sectors, such as heavy transport, industry, and heating (Aguilera & Aguilera, 2024).

2.6 Carbon Utilization Pathways

Carbon utilization (CU) pathways are increasingly being explored as a way to enhance the economics of CCUS projects by producing value-added products using captured CO₂. Enhanced Oil Recovery (EOR)

is the oldest pathway in the oil and gas industry, which involves injecting CO₂ into reservoirs to increase reservoir pressures and hydrocarbon recovery, while also sequestering CO₂ underground (Migdadi, 2025). In addition to EOR, captured CO₂ can also be used as feedstock for the production of synthetic fuels, chemicals, plastics, fertilizers, construction materials and mineralization processes (Cherepovitsyna et al., 2024).

It is proven by Hao et al. (2022) that with optimized carbon utilization strategies, the system level can maximize the economic value, while minimizing the environmental impacts. Ahmad et al. (2026) emphasizes the need to develop carbon utilization markets to ensure sustainable revenue streams for future investments in CCUS. Other utilization options include emerging electrochemical conversion technologies that can convert captured CO₂ into fuels and specialty chemicals using renewable electricity and carbon mineralization technologies that yield long-term stable carbonate compounds for building construction. These innovations are likely to enhance the commercial viability and social acceptance of CCUS projects in the next decade.

2.7 Global Deployment Trends

The international roll-out of CCUS is growing, but not fast enough to achieve the net-zero goals. North America is the leader in operational capacity owing to the various policy measures that have been put in place such as tax credits, regulatory frameworks, which have encouraged commercial scale projects in power generation, oil and gas and industrial sectors (Ihejirika, 2021). There is a considerable public and private investment push in Europe for offshore carbon transport and storage facilities, and the North Sea region is becoming a major player as it has the right geological structure for storage capacity and a long history of offshore projects.

Many Asian nations, such as China, Japan, South Korea and Indonesia, are incorporating CCUS into national climate strategies. Rimbono et al. (2025) highlight that the oil and gas industry in Indonesia is increasingly recognizing the importance of CCUS, with regulatory frameworks, public support, and communication being crucial factors to move projects forward. While this progress has been made, the total global CCUS capacity is still far from what is needed for a net-zero scenario. However, financing, infrastructure, technology, and regulatory challenges remain, and multi-sector collaboration is essential for continued progress on the path to scale-up (Suleman & Nasir, 2023).

3. Materials and Methods

3.1 Research Design

A qualitative and descriptive type of study was used which was designed as a systematic literature review. Secondary analysis of the scholarly and professional literature was selected because the project's goal—to synthesize what is known and estimate trends, evaluate emerging technologies, and determine deployment challenges—is suitable for secondary analysis of literature. A primary data collection using interviews, survey or case studies was not possible in this review but could be useful when using the findings for further research.

The question are: (1) what role can CCUS play in reaching net zero emissions in the oil and gas sector? (2) What are technology developments that enhance the effectiveness of the CCUS systems? (3) What are the main challenges in the introduction of CCUS in the sector? (4) Which economic, regulatory and operational issues are there for large-scale implementation? (5) What processes and policies might help speed up the deployment of CCUS and its impacts on global carbon reduction?

3.2 Data Sources and Collection

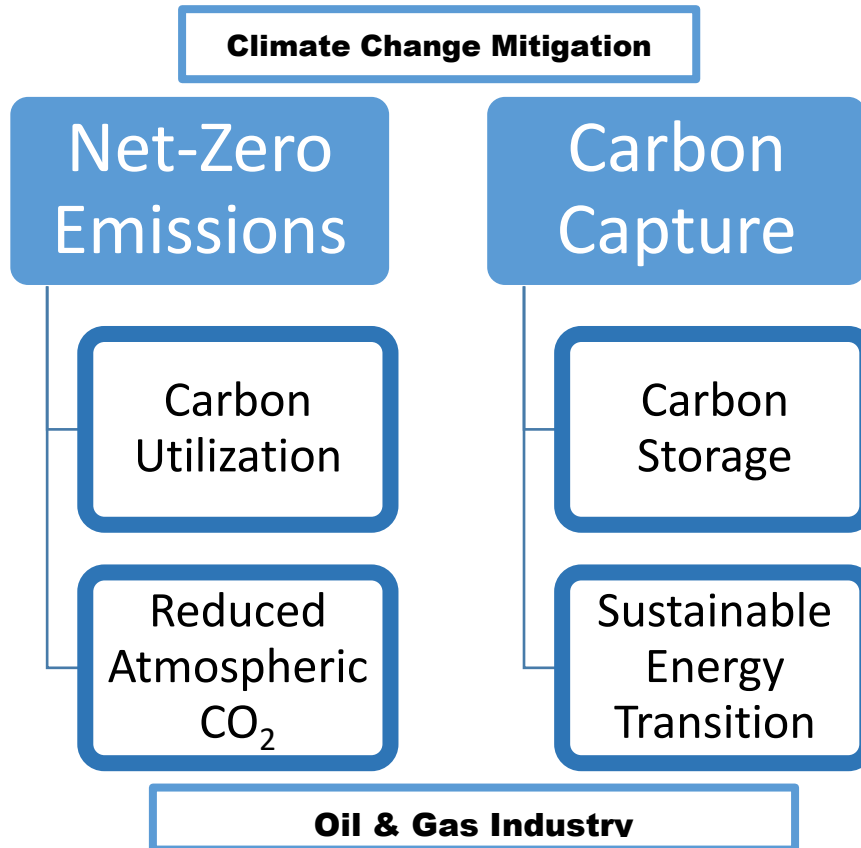
Twenty peer-reviewed journal articles, conference proceedings, academic book chapters, doctoral dissertations, and policy-related research published in the last five years (2020-2026) were selected for the study. The sources were then chosen according to their relevance to carbon capture, carbon utilization, geological storage, net-zero strategies, policy frameworks and oil and gas decarbonization. Geographically balanced analysis and sensitivity to regional differences in the policy, technology uptake and infrastructure context has been achieved by including research from North America, Europe, Asia, and emerging economies.

The information was pulled and mapped out in 4 thematic areas: Technological (capture technologies, storage methods, utilization applications, AI integration), Economic (project cost, workforce, monitoring systems, stakeholder engagement, investment requirement, revenue opportunities, carbon pricing), Policy (regulatory framework, government support, international commitments), and Operational (infrastructure requirement, workforce, monitoring systems, stakeholder engagement). A comparison and synthesis of the findings from various sources were done to find convergences, divergences, and research gaps.

3.3 Analytical Framework

Thematic analysis was used as the main analysis which systematically involved identifying, organizing and interpreting the themes that emerged in the source materials. The analysis was carried out in four dimensions: technological (judging the efficacy of capture, storage safety, methods of utilization, and new innovations); economic (considering capital and operating costs, revenue generation, market development, and financial incentives); environmental (assessing emissions reduction potential, sequestration efficacy, and contribution to climate mitigation); and policy and governance (regulatory frameworks, government support mechanisms, international agreements, and stakeholder interaction). This multidimensional approach allowed for an interdisciplinary analysis and synthesis of evidence across multiple discipline perspectives. In terms of reliability, only trusted academic and professional sources were used and validity was enhanced by triangulating the studies and finding consistent results in both geographic and industrial settings.

Figure 2. Conceptual Framework on how CCUS can be linked to Net-Zero Emissions



Based on Regufe et al., (2021), Oniemola et al., (2025) and Ahmad et al., (2026).

The conceptual framework illustrates how and how much the three pillars of CCUS contribute to the net zero emissions. Carbon capture prevents carbon emissions from entering the atmosphere, carbon use benefits the economy in some way from the captured carbon and carbon storage stores the carbon for the long term. These mechanisms are complementary, and contribute to the implementation of the objectives of climate mitigation and decarbonization of the oil and gas sector.

3.5 The reliability and validity of the study.

A high level of reliability was achieved by using only trusted, academic or professional sources. The references chosen were from peer reviewed journals, published conference proceedings and reputable academic publication. This minimized the possibility of bias and enhanced the credibility of the results. The results of the validity were supported by several studies which were triangulated. Findings of the results of the various geographic areas and research settings seemed to be similar, which supported the findings. Also, recent publications were added to ensure the analysis is as current as possible with latest developments in technology and policies.

This review was also comprehensive thanks to its use of different sources types. Both academic and industry oriented analysis was performed and it gave us an in-depth view on both the theoretical and practical experiences taken in the study.

3.6 Limitations of the Methodology

The methodology has some certain limitations although it has its strength. This study is totally secondary and there is no survey, interview or case study to gain primary data. As such, the outcome of the results will rely on the existing literature.

Second, new developments in the CCUS sector are occurring at a fast pace, which could result in new developments after the completion of the study. Thus, there is a possibility that some information contained in the results will be further amended in the future in line with the development of technology and policies.

Thirdly, national regulations, market players, and geology may impact the performance of CCUS. There are some regional differences that may not be sufficient in the study, however international insights are incorporated into the study.

The methodology used in the approach, however, provides a strong foundation for evaluating the potential of CCUS for Net Zero, and for the future potential of the oil and gas industry.

4. Results and Discussion

4.1 Overview of Findings

Based on the literature review, four main findings are obtained. First, CCUS technologies are developing at a rapid pace, and the efficiency of CO₂ capture, safety of storage, and use of CO₂ are improving. Second, economic constraints – especially the cost of capital – are also important and will further be overcome by policy support, market development and technological learning. Third, CCUS provides a real environmental benefit, and has a critical role to play in achieving net-zero – especially for sectors that are hard to abate. Fourth, enabling regulatory frameworks, coordinated stakeholder involvement and continued investment are key to successful deployment.

4.2 Technological Findings

4.2.1 Carbon Capture Technology Advances

The steady result among the studied literature is technological advancement in carbon capture. Early capture systems were high energy consuming and had high operating costs, which made them unattractive for commercial use. Adopting various sophisticated solvents, membrane separation, adsorption materials and hybrid capture configurations, has significantly enhanced the capture performance, while minimizing energy penalties (Saxena et al., 2024). As integrated capture systems are adapted to a variety of industrial applications, Ahmad et al. (2026) note that the reliability of the systems has improved and costs have decreased over the years.

One of the most important innovations is an AI-based process control system. Fortunato et al. (2025) show that machine learning algorithms can be used to analyze large operational datasets, which can be useful for identifying inefficiencies, optimizing the performance of captures and for predictive maintenance. Digital twin technologies also enable operators to model complex system behaviors, forecast potential risks and make proactive decisions. These capabilities lead to lower operational costs and less unplanned downtime, enhancing the investment case for CCUS.

4.2.2 Geological Storage

It is consistently confirmed in the literature examined that the geological storage is both technically possible and safe for long-term retention of CO₂. There is a combined storage capacity of billions of tonnes of CO₂ from depleted oil and gas reservoirs, deep saline aquifers and unmineable coal seams

(Fadda, 2023). Existing injection projects have generated operating data that shows that CO₂ can be stored for long times in a proper injection site that is properly managed. The oil and gas industry has built up a wealth of knowledge in subsurface characterization, drilling, and fluid injection, which can be directly applied to increase confidence in geological storage and to lessen the technical risks of new projects.

4.2.3 Emerging Utilization Technologies

Carbon utilization is branching out beyond EOR. Some pathways under development include electrochemical conversion with renewable electricity, carbon mineralization for construction applications, and CO₂-derived synthetic fuels and chemicals. Hao et al. (2022) demonstrate that the integrated utilization system optimization can achieve higher reduction in emissions compared to the utilization in storage alone, because the utilization of the captured carbon can be maximized. Ahmad et al. (2026) stress the importance of developing carbon utilization markets for the commercial sustainability of CCUS in the long-term.

4.3 Economic Findings

4.3.1 Cost Challenges

Economic challenges are still the main barrier to the deployment of CCUS, with high capital and operating costs being the biggest challenges. The cost of CCS is often the most significant cost of the total project, which varies by the type of technology, energy costs, source CO₂ concentration, and transportation distances (Migdadi, 2025). Although costs have been reducing due to technological learning, the majority of the studies reviewed here agree that there is need to further optimise costs for large-scale commercial viability without policy subsidy.

It is also very costly to have transportation and storage facilities. Up-front capital costs may be a barrier for individual project developers where pipelines networks need to be constructed or expanded, or monitoring systems put in place. These costs are additive and policy support (such as grants, tax credits, and risk-sharing arrangements) is very important for early stage deployment.

4.3.2 Economic Opportunities and Investment Trends

CCUS creates significant economic opportunities, despite cost issues. Carbon utilization projects can generate revenue streams from value added products, such as fuels, chemicals, construction materials, which can increase the overall project profitability (Cherepovitsyna et al., 2024). Carbon pricing mechanisms, where in place, also make the economic case for CCUS more compelling, with the higher the carbon price, the greater the economic benefit of CCUS.

CCUS investments are on the rise. Among large energy companies, climate commitments, regulatory tightening and corporate sustainability initiatives are driving the capital allocation to CCUS projects, according to Handaja et al. (2024). There is growing integration of CCUS in longer-term business change strategies, as the carbon management skills will have commercial applications in a net-zero economy.

4.4 Environmental Findings

Literature exists supporting the environmental case for CCUS. By avoiding large quantities of CO₂ emissions to the air in various hard-to-abate industries, CCUS can directly contribute to global climate targets. Regufe et al. (2021) highlight the particular importance of CCUS for industries that currently don't have technically or economically viable alternatives for decarbonization. Several studies estimate that carbon capture will need to play a material role in meeting global emissions targets towards 2050, if they are to be met at an affordable price.

CCUS can also help a more orderly transition to a low-carbon energy future. CCUS offers a solution to decarbonize without drastically disrupting energy supply systems in the economies where fossil fuels remain crucial for energy security and economic stability (Aguilera & Aguilera, 2024). This role is particularly important for the transition of developing economies that have a high energy demand and long time horizons for renewable investments.

4.5 Policy and Regulatory Findings

There is consensus in the literature that supportive policy frameworks are needed to deploy CCUS at scale. Government incentives, such as tax credits, grants and financial support programs have been playing a major role in encouraging investment in North America and Europe. Ihejirika (2021) also draws attention to the Canadian experience as an example of how CCUS can be accelerated through policy, and research in Europe and Asia demonstrates that regulatory clarity can significantly drive down investment risk and draw in private-sector participation.

But regulatory issues remain. There are uncertainty issues about liability of stored CO₂, permitting process, cross-border transportation rights, and postclosure monitoring obligations, all of which pose risks for project developers. Literature indicates that there is a need for harmonised transparent regulations including ownership of stored carbon, environmental monitoring obligations, post closure duties for facilitating international cooperation and investor confidence. In the absence of such structures, technically and economically viable projects may not progress.

4.6 Stakeholder Engagement

Good stakeholder management comes out as an important, and sometimes little-known, factor in project success. Rimbono et al. (2025) conclude that the multi-stakeholder involvement—including government, industry, local communities, research institutions, and financial—is associated with more successful CCUS project development in Indonesia. These issues can result in delays or opposition if not addressed up-front, and have been a public concern with regard to both safety and environmental impact as well as long-term integrity of storage sites.

Clear communication, community engagement initiatives and specific public education strategies are recognized as key elements of an effective CCUS approach. Enabling trust with affected communities and the wider public leads to a greater likelihood of project acceptance as well as fewer regulatory and social risks. These results point towards the importance of investment in stakeholder processes for CCUS deployment, and not as an add-on.

Table 3. Key Challenges and Potential Solutions for CCUS Scale-Up

Challenge	Impact	Potential Solution
High capital costs	Limits private investment	Government incentives and tax credits
Energy-intensive capture processes	Increased operating costs	Advanced capture technologies and AI optimization
Limited transportation infrastructure	Restricts scalability	Expansion of CO ₂ pipeline networks

Regulatory uncertainty	Investment risk	Clear and consistent policy frameworks
Public acceptance concerns	Project delays and opposition	Stakeholder engagement and public education
Storage monitoring requirements	Increased operational complexity	Digital monitoring and AI systems
Narrow carbon utilization markets	Reduced revenue and profitability	Development of carbon-based industries and carbon pricing

4.7 Future Opportunities

The results show significant future potential of the oil and gas industry based on CCUS. CCUS presents opportunities for new business models and revenue streams, in addition to regulatory compliance. Prominent opportunities include producing low carbon hydrogen from natural gas with CO₂ capture; providing carbon management services for other industries that lack the technical skills to manage their carbon themselves; growth in carbon use - fuels, chemicals and construction materials; continued EOR projects - revenue generation and carbon sequestration; Building of CO₂ transportation infrastructure as a fee-based service; and AI-powered digital carbon monitoring services. These opportunities suggest an evolution of the top oil and gas companies from “fuel suppliers” to “carbon management and low carbon energy service providers.”

4.8 Discussion

Findings were synthesized to conclude CCUS is a key enabling technology for global net-zero targets. Unlike other decarbonisation strategies, it can be implemented in a manner that is complementary to renewable energy expansion, particularly because of its ability to cut emissions from existing industrial processes that are incapable of being replaced with renewable energy or where the cost of renewable energy is prohibitive.

The oil and gas sector has a structural edge in deployment of CCUS at scale, both in terms of technical know-how and infrastructure assets, and financial capacity. But it is only through more than technical capability that the potential can be realized. Certainty of policy, development of the carbon market, coordinated involvement of stakeholders, and continued investment in R&D are all conditions. Evidence suggests that CCUS should be viewed not as an option to clean energy transition, but as an integral part of a pragmatic, resilient clean energy transition strategy that will allow achieving ambitious climate targets alongside energy security (Gabrielli et al., 2020).

5. Conclusion

This review has discussed the importance of Carbon Capture, Utilization and Storage (CCUS) for oil and gas industry in achieving net zero emissions. Twenty scholarly and professional sources collectively constitute the evidence base, which shows a technical feasibility, growing economic viability, and strategic importance of using CCUS as a means to decarbonize hard-to-abate sectors.

The oil and gas industry has a strong foundation for leading the way in deployment and application of CCUS with its subsurface expertise, existing infrastructure, and investment capacity. Capture, geological storage, AI-based monitoring, and carbon utilization pathways are all continuously evolving

with technological advances improving performance and reducing costs. At the same time, an increase in policy support in North America, Europe and Asia is fostering enabling conditions for commercialization at scale.

There are still major challenges to overcome, such as high capital costs, regulatory uncertainty, infrastructure gaps, and a lack of public acceptance. To overcome these obstacles, a coordinated and integrated policy approach is required, with clear and consistent regulations, strong financial incentive measures, open stakeholder participation and ongoing investments in research and innovation. The deployment of CCUS without the enabling conditions will not be adequate to achieve credible net-zero pathways.

In summary, CCUS is a solution for the climate challenge, but is an essential part of a wider and cost-effective climate decarbonisation solution. In combination with increased deployment of renewable energy, energy efficiency and electrification, CCUS can play a key role in the transition of the oil and gas industry from a leading global emitter to a key global carbon management player, enabling the industry to contribute to economic resilience and ambitious international climate targets.

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