Methods For Energy Transition to Achieve Zero emissions in Gas Processing Facilities [1]

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Abstract

Nations and companies are increasingly aligning their oil and gas operations to achieve net zero and remove as much carbon dioxide (CO_2) as possible to counter climate change. In the gas industry, fugitive gases can often escape the production process facilities. This is a major challenge that is hindering the gas processing facilities from achieving the net zero as outlined in the Paris Climate Agreement of 2015. There have been several strategies and approaches that are meant to reduce greenhouse gas (GHG) emissions, including carbon capture and storage technologies, direct air capture (DAC), and CO_2 sequestration. Carbon capture, utilization and storage (CCUS) technologies have gained a lot of attention in recent years owing to their effectiveness. This paper is a case study to evaluate the implementation of CCUS at Hawiyah NGL Recovery Plant. This case study showcases the immense benefits of this technology whereby it has been able to lower emissions by 30-35%. However, the technology is cost-intensive and still at the infancy stage, which therefore requires more advancements to reduce the cost of processing and ensure a worldwide adoption.

Introduction

Gas processing facilities are of prime importance around the globe since they supply a lower carbon form of energy. These facilities are responsible for extracting, treating, and distributing natural gas, which is used as a fuel across much of the world (Zavala-Araiza et al., 2021). The gas processing facilities are an integral part of the energy supply chain since they offer energy solutions to a wide range of industries, and provide fuel used for power generation and heating for domestic use and industrial operations. In recent years, there has been an urgent need to recognize the transition toward more sustainable energy solutions to reduce the impacts of climate change and realize global emissions reduction targets (Alsuwailem, 2021). The major focus of this transition revolves around lowering greenhouse gas (GHG) emissions starting with those originating from the extraction, processing, and utilization of fossil fuels such as natural gas.

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As the world is moving toward decarbonization, gas processing facilities present unique issues. In most cases, natural gas is considered a cleaner alternative to coal and oil since it is less carbon intensive (Gürsan & de Gooyert, 2021). However, the carbon footprint of gas processing facilities extends beyond the combustion phase. Normally, gas processing facilities are known for carbon and methane emissions, leaks, and flares during the extraction and processing phases, which contribute. This therefore means achieving zero-carbon emissions in gas processing facilities needs a comprehensive approach that would help address this issue across the entire hydrocarbon value chain (Gabrielli et al., 2021). The present study seeks to evaluate the various methods, technologies, and strategies that can help gas processing facilities move toward zero-carbon operations. Through a deep analysis of existing literature, analysis of technological tools, and policy frameworks, this paper explores a real-world case study to understand the current trends and approaches used to accelerate the decarbonization process in gas processing facilities.

Literature Review

One of the major challenges with gas processing plants is the presence of fugitive emissions, which constitute a significant environmental concern. These fugitive gases are known to create air pollution and contribute to increased GHG emissions (Ahmari & Mufti, 2022). Fugitive emissions are the types of leaks that emerge from the sealed surfaces of the various equipment that is used in the gas processing plants. Some of the common fugitive gases include aromatic hydrocarbons such as toluene, benzene, ethyl-benzene, and xylene; while the non-aromatic ones include ethane, propane, methane, pentane, and hexane (Oyewunmi, 2021). The major sources of the equipment leaks include valves, pumps, vessels and compressors. According to Dadashzadeh et al. (2011), understanding the impact of these emissions is integral to inventing solutions to address these concerns and realize net zero for gas processing plants.

Greenhouse gases are some of the biggest polluters in the environment and it is associated with climate change. A study by Mitchel et al. (2015) offers valuable insights into carbon emissions from natural gas processing facilities in the United States. The study incorporated 114 gas-gathering facilities and 16 processing plants dealing with natural gas in the U.S. The study revealed that there are high levels of GHG emissions with production rates ranging between 0.7 and 700 kg per hour. A study by Roscioli et al. (2015) addresses a critical aspect of methane emissions associated with natural gas production, gathering, processing, transmission, and distribution. The study used dual-tracer flux measurement and on-site observations, which evaluated the magnitude of the origins of the methane gas in G&P facilities. It was revealed that gas processing plants record emissions ranging from 20% to 47% of methane, ethane, carbon monoxide, and carbon dioxide. The study contributes significantly to the new study of understanding how to measure GHG emissions from the various gas processing facilities.

A study by Zielinska et al. (2014) evaluated the impact of emissions from gas production on ambient air quality in the Barnett Shale region in Texas. The study included various key approaches; namely, volatile organic compounds (VOC) from active wells and their saturation and transition to the nearby communities. The study revealed that the dominant nonmethane VOC species released from these plants include ethane, propane, n-butane, isobutane, isopentane, and n-pentane. Many of these were emitted from the condensed tasks adjacent to the gas well, which cumulatively make around 90% of the VOC emissions. Similarly, the 10% was comprised of minor VOC including 2- and 3-methylpentane, n-hexane, and methyl-cyclopentane.

Similarly, a study by Zavala-Araiza et al. (2017) investigates the concept of super-emitters in the gas production industry that increase production of GHG emissions and their release into the atmosphere. The study uses Monte-Carlo simulation to evaluate emissions from the various gas production sites in the Barnett Shale gas production area. The authors argue that the presence of abnormal process conditions, such as from upstream equipment malfunctions and other equipment issues, can lead to an increase in methane emissions. The authors argue that the lack of proper approaches to managing emissions can also lead to the emission of a substantial proportion of a site's gas production into the atmosphere.

Various strategies are being implemented in gas processing facilities to support the harvesting of carbon dioxide from the processing plants. According to Wang and Song (2020), one approach is carbon capture and storage technologies. This technology has proved effective in capturing CO2 emissions from the gas processing facilities and storing them underground, thereby limiting their escape into the atmosphere. Other methods include direct air capture (DAC), which, according to estimates, can capture more than 12 tons of CO2 every year. According to Santos et al., (2021), this technology entails drawing air into the plant using huge fans and then the air comes into contact with chemical solutions. This, in turn, forces the air to bind to the CO2 molecules and then pass through several reactions, which helps separate, purify and compress it. The resulting CO2 is then stored in tanks or used in the production of other products. Finally, according to Sminchak et al. (2020), there have been experiments to incorporate CO2 sequestration in gas processing facilities. This process entails dissolving the CO2 in water and injecting it into volcanic rocks. This helps prevent the release of CO2 and other CHG gases into the atmosphere.

Conceptualization and Theoretical Basis

One of the major theoretical bases for the achievement of net zero in the gas processing facilities is the Environmental Kuznets Curve. This curve showcases an inverted U-shaped relationship between environmental damage and economic development (Ansari et al., 2020). This theory was proposed by Simon Kuznets and it holds that environmental degradation is worse during the early stages of economic growth since countries are only focused on industrialization and extracting the resources within the maximum capacity. However, as nations achieve a certain level of development, societies begin focusing on environmental protection which enhances the overall environment (Ansari et al., 2020). During this stage, there are better approaches to utilize cleaner energy sources and production as well as better environmental regulations. In the context of gas flaring, during the early stages (between the late 1800s and early 1900s) the oil and gas companies were less concerned with the impact of their gas mining operations, which led to increased greenhouse emissions and climate change as global temperatures hit past 1.5 degrees Celsius.

Currently, according to the Environmental Kuznets Curve, the world's gas processing plants are in the transition phase. Many economies have become stable and there has been a concerted effort to enhance environmental awareness (Htike et al., 2021). Recently, there has been an influx of technological tools that are meant to tackle gas flaring through policies such as the Paris Climate Agreement, which seeks to reduce global temperatures by at least 1.5°C. The focus is to reduce global emissions by 45% by 2030 and realize the 2010 baseline levels. These initiatives are expected to push the world to the next stage of the Environmental Kuznets Curve, known as advanced development (Htike et al., 2021). This stage is expected to feature a widespread adoption of sustainable approaches and greater use of renewable energy sources, and will ensure all 192 countries in the Paris Agreement adopt strict emissions standards (Gyamfi et al., 2021). At this stage, it is expected that gas plants will have controlled their GHG emissions and reduced overall flaring. However, there are challenges to realizing the expectations of this stage since countries have not enforced standard strategies and strict measures to curb emissions.

Analytical Framework and Hypotheses

Reducing GHG emissions in the atmosphere and achieving net zero entails a careful approach that integrates various dimensions, including technological approaches, policy framework, socio-economic factors, and economic concerns. The technological approaches seek to evaluate the various solutions used in gas processing plants to reduce GHGs. The policy and regulatory framework seek to evaluate the role of governments and international agreements in adopting the various net-zero interventions. The social-economic approach seeks to evaluate the potential impacts of technological interventions in mitigating the negative impacts of emissions such as the cost-saving benefits of attaining net zero. Finally, the environmental perspective seeks to understand the impacts of GHGs, climate change, and the benefits of the potential solutions.

Hypothesis

- H0: Implementing carbon capture, utilization, and storage (CCUS) technologies in gas processing plants will significantly reduce GHG emissions, making it an ideal approach for achieving net-zero emissions.

- H1: The implementation of CCUS technologies in gas processing plants will not result in a significant reduction in GHG emissions, thereby rendering it ineffective in achieving net-zero emissions.

Research Design

This study adopts a case study design to investigate the implementation of CCUS technologies specifically at the Hawiyah Natural Gas Liquids (NGL) Recovery Plant in Saudi Arabia. Based on the case study design, it is expected that this approach will yield a comprehensive understanding of the approaches used in CCUS within a real-life context. Using the Hawiyah NGL Recovery Plant, it will be possible to gather an in-depth understanding of the challenges, successes, and key technological benefits of using the CCUS approach in minimizing GHGs within a gas processing facility. By engaging with the various stakeholders, and acquiring data on its implementation and capabilities, this study seeks to create a better understanding of the technology. These insights can be used to provide decision-making and foster the worldwide adoption of the CCUS for gas processing plants around the world.

Cass Study: Carbon Capture, Utilization, and Storage (CCUS) at Hawiyah NGL Recovery Plant

Several studies have explored the various approaches to reduce site emissions in the gas processing facilities in Saudi Arabia, with many leanings towards the use of CCUS. Ahmari and Mufti (2022) demonstrated the successful implementation and operation of the Carbon Capturing and Injection (CC&I) project at the Hawiyah NGL Recovery Plant (HNGLP) in the Eastern Province of the Kingdom of Saudi Arabia. Saudi Aramco is the national oil company of the Kingdom of Saudi Arabia, and has adopted different technologies to reduce emission in alignment with Saudi Vision 2030. This case study sheds light on one technological approach to use of CCUS taken by the Hawiyah NGL Recovery Project. The main objective of this technology is to lower GHG emissions, which is a major focus for Saudi Aramco. The CC&I approach entails the capturing of 750 Kton per year of carbon dioxide released from the acid and gas removal units (AGRU) at HNGLP (Ahmari & Mufti, 2022). The gas is injected into the wells and it undergoes sequestration. This is against the traditional approach whereby CO2 is treated before it undergoes the thermal oxidizing process.

The CC&I project, initiated in 2015, involves capturing approximately 750 Kton per year of CO2 from the AGRUs at HNGLP and injecting it into oil wells for sequestration and enhanced oil recovery. Traditionally, acid gas (primarily CO2 and H2S) is treated before thermal oxidizing, but with the implementation of the CC&I project, only CO_2 is captured instead of undergoing thermal oxidizing (Ahmari & Mufti, 2022). According to this project, this method has proved quite effective since it relies on new technologies such as high-capacity compressors mechanical ejectors, a standalone dehydration system a CO_2 recovery system, granulated activated carbon (GAC) for water treatment, and a dense phase pump for transferring dehydrated CO_2 at supercritical phase through an 85 km pipeline to South Ghawar Field Wells (Ahmari & Mufti, 2022). The implementation of this project led to significant environmental and business benefits.

The Process

Carbon capture, utilization, and storage (CCUS) is one of the main approaches that can be applied to gas processing plants to reduce CO_2 and other greenhouse gases. Removing CO_2 from the natural gas is essential since it helps improve the quality of the natural gas; meaning that it can be easily extracted from the atmosphere and sequestered (Aramco, 2021). At this plant, acid gas, which consists primarily of CO_2 and H_2S, is treated to achieve the right parameters before undergoing the thermal oxidizing process (Aramco, 2021). After the CC&I project, the CO_2 gas for HNGLP is captured to undergo the thermal oxidizing process. This process entails other sub-processes including, the 7-stage compressor process, tri-ethylene glycol (TEG), dehydration system, CO_2 recovery system**,** and granulated activated carbon (GAC) meant to treat water from the compression and dehydration systems.

Next, the CO_2 is moved to the dehydration unit and then taken back to the compressor to complete the sixth and seventh stages. During the final stage, the gas is compressed to 1,500-1,600 psi. The captured CO_2 gas is pushed through an 85 km pipeline to the South Ghawar Field Wells (Aramco, 2021). Once at the field wells, the CO_2 is pushed into four injector wells where it undergoes further processing. According to Saudi Aramco, since its inception, the project has injected more than 800,000 tons of CO_2, which enhances considerable CO_2 sequestration and makes the natural gas cleaner while at the same time lowering the carbon emissions.

Results and Discussion

This project has been successful due to the combination of various technologies such as enhanced compression capabilities, utilizing a mechanical ejector to enhance CO_2 recovery, pumping the supercritical fluid at high pressure, and utilizing TEG to dehydrate the CO_2 (Ahmari & Mufti, 2022). Since its inception, the HNGLP has been able to reduce the GHG emissions from the various combustion areas in the gas plants by around 30-35% as compared to before its implementation. Similarly, this project has been critical in reducing around 75-89% of the consumed fuel gas to power the thermal oxidizers in the ARGRUs and sell it as a gas product.

Similarly, this project has helped enhance the HNGLP sustainability index regarding energy consumption and water use (Ahmari & Mufti, 2022). Through this project, the company has realized an 8-9% reduction in energy use and 5-6% less use of water.

Despite the immense benefits, CCUS projects are capital extensive, which means that only the companies with high capital, such as Saudi Aramco, are capable of acquiring the setup costs, which may discourage its worldwide adoption. Secondly, the carbon capture processes are energy intensive, which means that they require additional power for capturing, compressing, and transporting CO2, which may further increase the carbon-footprint (Alsuwailem, 2021). Similarly, CCUS entails adopting storage facilities for the GHG and identifying an ideal location can pose difficulties; ensuring long-term storage and security could be a major challenge in the long run. Moreover, using this approach has been linked to high levels of noise pollution emanating from the compressing process. There is a need to incorporate firm policies to support these elements (Ahmari & Mufti, 2022). Finally, although the CCUS has demonstrated great efficiencies, the technology is still in its infancy stage. This, therefore, means that there is a need to further enhance the technology to ensure that it is commercially viable and adaptable to other geographical regions.

Item	Impact
Reduced Greenhouse Gas Emissions	30-35%
Reduced Fuel Gas Consumption	75-89%
Improved Energy Efficiency	8-9%
Water Use Efficiency	5-6%

Conclusion

Achieving net zero for the gas processing plants aligns with the goals of the Paris Climate Agreement, which seeks to reduce global temperatures by 1.5 degrees Celsius. Flaring and fugitive gases are responsible for most of the onsite emissions around the world. According to the 2018 Global Gas Flaring Data from the World Bank Group, the total gas flaring in the oil and gas industry amounted to 5.1 trillion cubic feet of natural gas, which led to the loss of more than 770 billion kilowatt-hours and the release of more than 310 tons of carbon dioxide into the atmosphere. The incorporation of the CCUS approach is promising, and if adopted it can mitigate the extent of gas flaring across their supply chains. In Saudi Arabia, the country's oil and gas industry flared more than 4 billion standard cubic feet before 1975. However since, the construction of the CCUS, the country has seen a reduction in overall emissions pushing its gas industry towards net zero. Adopting new technologies can improve and support the goal of achieving net zero.

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