Effective Circular Economy in Gas Processing Facilities Projects [1]

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Introduction

Circular economy remains one of the approaches that favors sustainability in the oil and gas industry. While this approach is often employed at the national level, organizations are incorporating it to enhance productivity and survive the highly competitive business environment. Circular economy in the oil and gas industry has become a core component that seeks to enhance competitive advantage and reduce overall environmental challenges. In the modern business environment, there are concerns about the negative environmental impacts arising from their production processes. The adoption of the traditional linear models (take-make-dispose) has proved inefficient in the long term. Therefore, organizations are embracing the circular economy principles to foster efficiency, recycling, and sustainability. Also, the growing need for a lower carbon footprint has pushed organizations to adopt more sustainable approaches. Circular economy integration is most suitable for gas processing facilities because normally the gas comes with impurities, which is a potential opportunity to re-use or recycle in addition to the high demand for energy, which can be converted to renewables.

The gas industry involves several systems that have a lot of by-products that might be considered as waste. A high number of chemical processing plants across the globe are currently using old processes leading to poor waste management, which is evident in many facilities (Sharma et al., 2023). In the gas industry, waste valorization, heat recovery, and resource looping consisting of circular economy principles can improve system performance. This therefore implies that organizations across the oil and gas sector can improve operational efficiency, reduce expenditures and therefore encourage compliance with environmental laws (Sharma et al., 2023). Nevertheless, the application of circular economy in the gas industry is still low and this calls for integration of specific industry-based frameworks to enhance these practices for the future. This paper explores the role of circular economy (CE) in enhancing sustainability within gas processing facilities and how to integrate its principles with project management.

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Literature Review

Circular economy can be described as a model of sustainable production and supply depending on recycling or regeneration of materials or products to extend the cycle of production sustainably and/or in an eco-friendly manner. It is a system focused on the reduction of waste and optimization of resource utilization (Geissdoerfer et al., 2017). Hence, organizations are seeking to achieve goals such as durability, material recycling, usage, and the adoption of a closed-loop system. The circular economy principles are based on the industrial ecology and systems approach focused on cost reduction and sustainability.

The circular economy approach has been implemented in a range of contexts in organizations such as manufacturing, construction, and energy organizations (Riadinskaia & Cherepovitsyna, 2023). In this case, project management aims to separate economic development and resource utilization, thus resulting in lower costs in the long run. Normally, this exercise takes place during the feed/design stage in which the project team optimizes the production processes as much as possible while maintaining the same excellent output. The implementation of circular economy in the gas facilities projects has its advantages, such as a decrease in carbon footprint and turning waste into useful materials. Similarly, several studies have established that CE is capable of promoting sustainability aspects particularly in core activities such as facility design, operations, and maintenance (Golagha et al., 2024). It also emphasizes the need for innovation, and the use of technology in achieving more effective and efficient circular strategies.

Despite the benefits, many of these facilities still utilize traditional technologies that lack recovery systems for heat, water, and chemical reuse (Waly et al., 2023). In most of these facilities, approaches to environmental compliance are often seen as a cost rather than an opportunity. With the increasing threats of global warming and climate change, studies show that there is an urgent need for the oil and gas industry to invest and adopt sustainable production technologies (Dua & Jain,2024). In this industry, some of the studies have pushed for the adoption of technologies such as waste valorization, including sulfur recovery and CO_2 capture, which is gaining traction (Golagha et al., 2024). By adopting these technologies, the gas realizes both economic and environmental performance.

Circular economy has been a major area of focus in project management owing to the immense benefits this approach provides to organizations. The project management concept in project planning entails the planning and implementation of the CE initiatives (Todorović & Obradović, 2023). The main roles that project management undertake in

this case include stakeholder alignment, risk management, and resource optimization. In project management, circular economy requires a shift in project life cycle thinking i.e., from cradle to grave to cradle. The adoption of the CE principles in research reiterates the need for integrating CE from feasibility studies to commissioning (Obradović et al., 2024). One of the major elements is CE cross-disciplinary collaboration, which plays a crucial role in lowering costs and enforcing efficiency (Bondar et al., 2022). In the quest to minimize the overall costs, project management therefore needs to push for the adoption of the circular economy principles to aid in the creation of sustainable projects.

The adoption of circular economy principles in the oil and gas industry had yielded mixed results. Large oil and gas companies such as Aramco have realized the tremendous advantages of implementing circular economy systems. Based on the CE principles, Aramco has implemented modular designs, reusing byproducts and water recovery systems among others, which leads to reduced costs. Moreover, the adoption of this technology in the EU and the Middle Eastern gas processing plants showcased enhanced cost savings and minimal impact on the environment (Dua & Dadsena, 2025). In addition, the standard industry benchmarks continue to showcase that the CE frameworks lead to enhanced efficiency and lower operational costs. In addition, in Saudi Arabia, this technology has demonstrated that there is a positive ROI, which ultimately translates to enhanced stakeholder satisfaction (Pinto et al., 2022). Despite these benefits in the oil and gas industry, the documentation of CE in the oil and gas industry remains fragmented and context-dependent, which may limit its wide-scale adoption.

Gaps

The literature analysis shows that there are significant gaps in the literature, which may limit the adoption of circular economy principles in the oil and gas industry. One of the major constraints of empirical studies specifically focused on CE in gas processing facilities. Similarly, there are limited frameworks tailored to gas project environments and their complexities. In most of the studies only a few address the integration of CE into project management methodologies. Moreover, the literature shows that there is insufficient attention to cultural, financial, and organizational barriers to CE adoption. Similarly, there is a lack of standard metrics to evaluate the CE performance in gas processing plants. Based on these findings, there exists an opportunity for research to propose integrated models bridging CE and project lifecycle strategies.

Conceptualization and theoretical basis of the work

Circular economy remains a major component of project management since it entails pursuing cost-saving measures that are meant to give modern firm's competitive

advantage and realize environmental goals of minimizing the production of harmful greenhouse gases. In this study, the circular economy system (CE) is conceptualized as a closed-loop system focused on minimizing waste and maximizing resource efficiency (Digitemie et al., 2025). Within the gas industry, CE involves the reuse of process outputs, recovery of heat and water, and long-term sustainability planning. On the other hand, project management is viewed as a structured approach to planning, executing, and closing projects with defined goals and resource constraints (Obradović et al., 2024). The adoption of CE into project management therefore necessitates the reinvention of the linear processes, which may lead to the loss of reusable materials. In the gas industry, CE becomes a strategic objective embedded within the project lifecycle, from initial feasibility to operational handover (Obradović et al., 2024). However, effective circular project management demands organizations require the adoption of cross-functional planning, stakeholder engagement, and sustainability-focused KPIs.

The adoption of a circular economy in the oil and gas industry is founded on key theoretical, foundational system thinking and industrial ecology. In this analysis, the system's thinking perspective is the adopted model (AlMashaqbeh & Munive-Hernandez, 2023). The systems thinking model views gas facilities as interconnected subsystems influenced by material flows, energy inputs, and organizational processes. On the other hand, industrial ecology offers a new dimension for understanding how industrial operations may mimic natural ecosystems thereby ultimately minimizing waste and optimization of the various resources (Saavedra et al., 2018). This approach holds that the gas processing and manufacturing plants can be designed in a way that would see some of the common by-products such as heat, CO2, and water be repurposed within the same plant (Saavedra et al., 2018). Through an analysis of the key CE principles such as adaptive and dynamic systems, this study seeks to showcase the importance of CE in fostering long-term sustainability in the gas industry.

Analytical framework and hypotheses

This study aligns the core principles of circular economy and focuses on the five CE dimensions namely; resource efficiency, waste minimization, life cycle thinking, stakeholder integration, and performance metrics (Nika et al., 2021). Each of the above dimensions is assessed from the different phases of the project management, namely initiation, planning, execution, monitoring, and closure, to determine the extent of integration of CE principles. It incorporates both qualitative and quantitative measures, such as energy consumption, material recycling average, water reclaiming efficiency, and cost-effectiveness analysis (Nika et al., 2021).

Based on the literature review and the conceptual foundation the study seeks to explore three main hypotheses:

- H1: Gas processing facility projects that integrate circular economy principles from the planning stage exhibit higher operational efficiency than those that do not.
- H2: The implementation of circular strategies is positively correlated with improved environmental performance and regulatory compliance in gas projects.
- H3: Project teams that apply CE-specific project management tools demonstrate better stakeholder satisfaction and long-term cost savings.

Research Design

This research uses a qualitative research method, specifically a case study approach to analyze the incorporation of circular economy (CE) principles in Gas Processing Facility projects in Aramco. Sector-based case studies are the most fitting for investigating multi-faceted, real-life issues in detail and to sectors in distinct stages of change, such as energy and environmental management. The first case study that will be considered is how Aramco implements, especially through the gas processing projects, the CCE framework that consists of the 4Rs: Reduce, Reuse, Recycle, and Remove (Saputra et al., 2022). This case has been selected as it offers clear links with the sustainability theme of Saudi vision 2030 and because the company's CE strategies cover a large spectrum of efforts, including designing for the circular economy, building circular supply chain, reducing environmental impact, preserving and extending resources and asset life cycles, using regenerative and renewable resources, turning waste into resources and adapt innovative technologies.

Results and discussion

Aramco has promoted the adoption of circular economy principles to minimize the carbon emission in its oil and gas plants. At the core of this strategy, the company has adopted the circular carbon economy (CCE) framework. The adoption of the 4Rs model aligns with the core tenets of the circular economy since it is directed toward enhancing sustainability and overall progress in carbon-intensive sectors, such as oil and gas. By relying on these crucial principles, Aramco has been able to recover 99% of flare gas in its operational plants and joined the World Bank initiative Zero Routine Flaring 2030, and will be sharing best practices in flare minimization with the industry (Wallace, 2020).

Moreover, Aramco has been one of the pioneers in advancing the recovery and reuse of flare gas. In most plants, these hydrocarbons often undergo combustion, which leads to

the release of VOC, CO_2, and other harmful greenhouse gases (Almulhim & Al-Saidi, 2023). For example, the company has launched projects such as carbon capture, energy intensity monitoring, and large-scale mangrove afforestation as a part of sustaining its circular carbon economy due to the various gas processing plants. In addition, the company established a program in 2018 to plant 2 million mangrove trees, which will lead to eliminate more than 20 million kilograms of carbon sequestration on a yearly basis. The data and findings from Aramco's CE implementation act as a business model that can be adopted and followed in the gas processing plants in the region.

The application of CE at Aramco shows that a circular economy is feasible within the gas industry. Other companies such as SABIC and SIRC have adopted the CCE frameworks in a bid to lower their operational costs and minimize the overall impact to the environment. For instance, SABIC has developed a CE framework that can be utilized in the conversion of CO_2 into fertilizers and methanol. This approach is one of the main principles of CE as it involves transforming waste into a valuable product (Alsaud et al., 2025). Similarly, SIRC has developed a model of handling the waste through the synthesis of mixed waste into pyrolysis oil. This has been an integrated approach that demonstrates how ecology principles in CE can be improved for better results (Alsaud et al., 2025). These efforts align with the "reuse" and "recycle" dimensions of the 4Rs, which have demonstrated cost savings and less impact to the environment.

Recycling of waste products such as hydrocarbons has been a crucial part of Aramco's CE efforts. The captured hydrocarbons, which consist of CO_2, methane, and other gases have been recycled and used in the Master Gas System (MGS) (Shehri et al., 2023). This approach allows Aramco to access more affordable energy that may have been flared or left to escape into the environment. In addition, energy has been repurposed to sustain other projects. These include energy intensity monitoring to analyze energy performance across all Aramco facilities. As of 2020, energy intensity initiatives have saved a cumulative total of 238 million barrels per day oil equivalent, as well as CO_2 reduction of 27 million tons (Wallace, 2020). The adoption and expansion of the CE principles aligns with the tenets of the closed-loop energy system where waste is minimized, and renewables power industrial operations is adopted.

Case Study: Aramco Jafurah Gas Processing Facilities – Acid Gas Removal Unit and Environmental Initiatives

Jafurah Project is one of the ambitious gas projects that is being constructed in the Eastern region of Saudi Arabia. The project constructs a grassroots gas facility to produce, process, and transport gas to meet the energy demand in Saudi Arabia.

Jafurah's gas facility project can be seen as one of the best examples of implementing circular economy approaches.

The first initiative that can be looked at is the Acid Gas Removal Unit (AGRU) that is installed in Gas processing trains. The AGRU is designed in a way that all the impurities that come with the gas are being reused or recycled such as hydrogen sulfide through the sulfur recovery units (SRUs) and the carbon oxide through the flaring system. By using chemical solvents to remove all the impurities from the product such as H_2S and Co_2. The unit contributes significantly in improving the environment by removing all the sulfur contaminants.

The second initiative is the greenhouse environmental initiative, showcasing sustainable practices and eco-friendly design. It highlights the importance of plant conservation, renewable energy use, and climate education. Through this initiative, the museum aims to inspire environmental awareness and action in the community.

Thirdly, the green initiative plantation drive at the Jafurah Project will serve to improve the environment by enhancing local biodiversity, reducing carbon emissions, and improving soil and air quality. As part of the Green Initiative Plantation, trees were planted in the laydown areas with the participation of subcontractors, EPC contractors, and members of Aramco management. The third initiative is air pollution control in which Aramco has managed airborne contaminants throughout the construction phase by implementing comprehensive dust control measures at the site.

Another initiative conducted at Jafurah project is waste management. The project management secured all cables on site and prevented them from sagging, a thousand "S" hooks made from scrap material where fabricated and secured with insulation. In addition, scrap wood was repurposed into items such as boxes, signage stands, and tool racks, contributing to effective waste management on site. Also, reusing of old vehicle tires as barriers, walkways, and pedestrian guides.

The fourth initiative is that the project has put a lot of efforts to reduce the greenhouse gas emissions by utilizing Solar power that generates electricity without releasing CO_2 or other greenhouse gases. It also does not require water for cooling, thereby conserving water and minimizing thermal pollution. Additionally, it decreases reliance on fossil fuels, which are major drivers of climate change. Jafurah Project will continue its efforts to implement the circular economy principles effectively and successfully to act as a role model among other projects in the region.

Opportunities and Gaps

Despite the benefits, the adoption of CE principles is still limited, and gas facilities still use other methods such as flaring (Emam, 2015). This therefore implies that there should be strategic and integrated planning with other stakeholders in order to ensure that CE strategies are properly implemented. In addition, the current policies need supplementation through guidelines and performance standards that can be tailored to particular sectors and can promote CE at the project management level (Shehri et al., 2023). However, extending the involvement of community leaders and experts in increasing awareness of CE could increase the public and industry support. Furthermore, the adoption of the CE model also brings an additional benefit of diversifying the economy to reduce reliance on oil resources, which is crucial for sustainable development. Addressing these gaps by strengthening the frameworks and capacity building interventions will enhance the global adoption of circular economy-based project development.

Conclusion

The circular economy remains one of the major frameworks for enhancing sustainability and overall success in gas processing projects. This is a novel approach in this sector but seeks to repurpose waste, foster sustainability, and drive environmental sustainability. Aramco's Circular Carbon Economy (CCE) framework reflects the company's commitment to environmental sustainability, economic progress, and gamer change in the oil and gas industry. In Aramco, the core CE values including reduce, reuse, recycle, and remove — are being actively applied in major facilities, which leads to the creation of enough gas supply for the million households in the country. The CE framework is evident in various associated companies namely; SABIC, and SIRC that have achieved significant outcomes such as emissions reduction and resource recovery. For successful CE implementation globally and to follow Aramco's lead, the global gas industry needs more supportive policies, stakeholder collaboration, and public engagement to encourage organizations to adopt circular economy approaches.

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