Journal of Social Research

P-ISSN:2827-9832
E-ISSN: 2828-335x
Vol. 5, No. 8, July 2026
http://ijsr.internationaljournallabs.com/index.php/ijsr

Innovation Strategies for Reducing Greenhouse Gas Emissions Using the Design Thinking Method: A Case Study at the Offshore Field of XYZ Oil and Gas Company

Ageng Premana*, Octaviyanti Dwi Wahyurini
Institut Teknologi Sepuluh Nopember, Indonesia
Email: agengpremana27@gmail.com*

Keywords:
Design thinking; Innovation strategy; Greenhouse gas emissions; ESG; Offshore oil and gas.

ABSTRACT

This study aims to identify the main sources of GHG emissions, explore potential innovation opportunities, and formulate emission reduction strategies that align with the operational conditions of XYZ Oil and Gas Company's Offshore Field. This research employed the Design Thinking 3-IDEO model, which consists of Inspiration, Ideation, and Implementation stages. Data were collected through field observations, document analysis, in-depth interviews, stakeholder mapping, empathy maps, user personas, user journey maps, point of view (PoV), and how might we (HMW) analyses. The respondents included various stakeholders directly involved in offshore field operations. The collected data were analyzed qualitatively to identify user needs, operational challenges, and innovation opportunities that support emission reduction initiatives. The results indicate that the primary sources of GHG emissions originate from flare systems, fuel consumption in gas turbine compressors and generators, well unloading and well intervention activities caused by high back pressure, as well as diesel fuel consumption from offshore vessel operations. Through the ideation and stakeholder validation processes, four priority innovation strategies were identified: (1) utilization of gas released from the primary seal gas system as additional fuel gas, (2) optimization of operating pressure through modifications to existing facilities, (3) optimization of vessel operations through procedural improvements, and (4) installation of electrical submersible pumps (ESP) powered by micro turbine generators. All proposed strategies demonstrate strong alignment with ESG principles, operational excellence objectives, and the Sustainable Development Goals (SDGs), while offering potential environmental, operational, and economic benefits in a sustainable manner.

INTRODUCTION

Global warming and the impacts of climate change have become major issues faced by humanity today (Farooq Lone & Bhat, 2023). According to the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased by approximately 1.1°C since the late 19th century, a phenomenon that potentially increases the frequency and severity of natural disasters such as floods, droughts, and tropical storms (Dey, 2021). Mitigation and adaptation efforts are urgently needed, particularly for vulnerable countries such as Indonesia (Syarifuddin & Si, 2023). In 2015, the Paris Agreement was formulated with a target of limiting global temperature increases to below 2°C, with an ideal effort to stay below 1.5°C (Cheng & Li, 2023). Therefore, collaboration among all nations to reduce greenhouse gas (GHG) emissions is essential, particularly in the energy sector of the oil and gas industry, which contributes significantly to total global emissions (Dong & Kovács S., 2023).

According to the International Energy Agency (IEA), the energy sector contributes approximately 73% of global greenhouse gas emissions, with the oil and gas industry being one of the primary contributors (Climate change and the energy sector, 2023). Decarbonization of the energy sector is therefore urgently needed to achieve net-zero emissions targets by 2050 (Ismukurnianto, 2022). Many countries and companies have set ambitious emission reduction targets, including efforts to achieve reductions of up to 50% by 2030 (Blok et al., 2020). At the regional level, ASEAN has committed to achieving net-zero emissions through a roadmap for the 2021–2050 period (Lim et al., 2024).

XYZ Oil and Gas Company (referred to as XYZ Company), one of Indonesia's leading energy companies, has a vision to become a world-class energy company by 2030 and has formulated a decarbonization strategy targeting net-zero emissions by 2060 (Tim Internal Perusahaan Migas XYZ, 2024). The company operates an offshore field in the Java Sea, Bangkalan, Madura, East Java, producing 5,445 barrel oil equivalent per day (BOEPD) from an asset consisting of 12 wellhead platforms, 3 processing platforms, 1 floating storage offloading (FSO) facility, and 1 living quarter. The company has benchmarked its GHG emission intensity at 125.35 ton CO_2eq/1000 TOE, which places it at the 50% national average level indicating that it has not yet reached the top 25% performance category of ≤118.98 ton CO_2eq/1000 TOE as regulated by Indonesian environmental standards.

Specific operational challenges including aging equipment, extreme marine weather conditions, infrastructure limitations, and the complexity of offshore production systems create barriers to achieving the set emission reduction targets. The ongoing carbon capture utilization and storage (CCUS) project requires large investment and long implementation timelines. Therefore, there is an urgent need for innovative strategies that can be developed from the field worker perspective, where field workers have direct knowledge of the operational characteristics and challenges encountered in the offshore environment (Ivshina et al., 2015; Nathanael et al., 2024).

A review of the existing literature reveals that previous studies have predominantly focused on technical and top-down approaches to GHG emission reduction in the offshore oil and gas sector. Nguyen et al. (2016) and Voldsund et al. (2023) provided comprehensive reviews of low-carbon technologies for offshore operations, including electrification, renewable integration, and carbon capture. Recent research has examined low-emission offshore oil and gas production, finding that power-from-shore electrification can achieve up to a 95% reduction in carbon emissions when using low-emission grids. However, these studies provide strong technical foundations but tend to focus on "what" needs to be done rather than "how" to systematically develop innovation strategies within complex organizational contexts. There is a significant gap in the application of human-centered approaches such as design thinking in the context of offshore oil and gas GHG emission reduction. No previous studies have applied a design thinking methodology to develop emission reduction innovation strategies in offshore oil and gas operations.

Design thinking is an innovative, human-centered approach that prioritizes deep understanding of user needs, enabling the development of more effective and sustainable solutions across various industrial contexts (Quaiser & Pandey, 2023). According to Brown (2008), design thinking is a method that utilizes the designer's sensitivity to understand the alignment between societal needs and the technology or value offered. The 3-IDEO model consists of Inspiration, Ideation, and Implementation phases, facilitating teams in understanding user needs and generating relevant solutions (Foster, 2019). This study aims to: (1) identify the main sources of GHG emissions from offshore operational activities; (2) explore potential innovation strategies for reducing GHG emissions; (3) create innovation strategy ideas using the design thinking method; and (4) evaluate the feasibility and priority of the resulting innovation strategies.

METHOD

Research Design

This research employed the Design Thinking 3-IDEO model as the methodological framework, which prioritizes user experience and is particularly suited to complex, multi-stakeholder contexts such as offshore oil and gas operations. The research was conducted at XYZ Company's offshore field located in the Java Sea between Madura and Bawean Islands. The research design consists of three interconnected phases: Inspiration (understanding the problem context), Ideation (generating innovation strategies), and Implementation (developing and validating selected strategies). The research was conducted from August 2024 to March 2026, spanning 24 weeks of systematic research activities.

Stakeholder Mapping

Stakeholder mapping was conducted as a crucial step to identify and understand the various parties involved in the GHG emission reduction innovation strategy. Respondents were purposively selected from field operation personnel with direct operational knowledge, categorized by their power and interest levels. A total of 15 stakeholders from 11 role categories participated in the research.

Table 1. Stakeholder Classification and Participants

Stakeholder Role	Category	Number	Power/Interest Level
Field Operation Manager	Manage Closely	1 person	High Power / High Interest
Offshore Installation Manager (OIM)	Manage Closely	1 person	High Power / High Interest
Supervisor Production	Keep Informed	2 persons	Low Power / High Interest
Supervisor Maintenance	Keep Informed	2 persons	Low Power / High Interest
Senior Operator Production	Keep Informed	2 persons	Low Power / High Interest
Senior Maintenance Technician	Keep Informed	2 persons	Low Power / High Interest
Process Engineer	Keep Informed	1 person	Low Power / High Interest
Field Engineer	Keep Informed	1 person	Low Power / High Interest
HSSE Offshore Officer	Keep Informed	1 person	Low Power / High Interest
Leader Contract Service Employee	Keep Satisfied	1 person	High Power / Low Interest
Contract Service Employee	Monitor	1 person	Low Power / Low Interest
Total		**15 persons**	

Data Collection

The Inspiration phase involved: (1) field observations using shadowing, contextual inquiry, and non-participant observation techniques conducted over 7 days across all offshore production facilities; (2) in-depth interviews with all stakeholders using a semi-structured WHW (What-How-Why) interview format, conducted face-to-face and online via Microsoft Teams and Zoom; and (3) document analysis of production logs, maintenance records, engineering data, and operational procedures. The Ideation phase involved a 2-day co-creation workshop (20–21 February 2026) held in hybrid format at the offshore living quarter facility, attended by 13 key stakeholders.

Data Analysis

Interview data and observational findings were analyzed using design thinking tools: user persona (to understand stakeholder characteristics), empathy maps (to explore stakeholder needs, feelings, and pain points), user journey mapping (to identify pain points and innovation opportunities along the operational process), Point of View (PoV) analysis (to synthesize user needs and insights), and How Might We (HMW) questions (to direct ideation toward specific user-centered problems). Ideation results were organized using an affinity diagram to identify themes and clusters of innovation opportunities. Selected strategies were evaluated through SWOT analysis and alignment with the company's sustainability policy, followed by validation with the Field Operation Manager and Offshore Installation Manager.

RESULTS AND DISCUSSION

Field Observation Results

1. **GHG Emission Sources**

   The offshore operational system of XYZ Company consists of three main areas: wellhead platforms (WHP), processing platforms, and a floating storage offloading (FSO) facility. Field observations identified the following GHG emission sources and their average daily contributions:

Table 2. GHG Emission Sources from Offshore Operational Activities of XYZ Company

No.	Emission Source	Equipment	Avg. Daily Emission (ton CO_2eq)	Emission Parameters
1	Gas Turbine Compressor (GTC)	GTC-A, GTC-B (fuel gas combustion)	69.764	CO_2, CH_4, N_2O
2	Flare System	Flare stack (avg. 0.6 MMscfd gas burned)	21.664	CO_2, CH_4, N_2O, SOx, NOx
3	Offshore Vessel Operations	5 vessels (4 crew boats, 1 logistics boat; diesel-fueled; 2.8 million liters HSD B35/year)	18.78	CO_2, CH_4, N_2O, SOx, NOx
4	Power Generation (Generators)	Gas engine generator, diesel engine generator	3.31	CO_2, CH_4, N_2O
5	Fugitive Emissions	Pipeline connections, valve leaks, instrument tubing	0.844	nmVOC, CH_4, TOC
6	Well Service Activities	Well unloading, well intervention (3rd-party rigs)	~0.03+	CO_2, CH_4, N_2O

2. **Key Operational Findings**

Several critical operational issues were identified during field observations:

(a) Fuel Gas Consumption Anomaly: Following multiple leaks in instrument air supply tubing connections in August 2024, fuel gas consumption by the gas engine generator (GEG) increased from an average of 1.91 MMscf/month (August–November 2024) to 3.07 MMscf/month (December 2024–August 2025) an increase of 1.16 MMscf/month. This increased consumption contributes directly to higher GHG emissions.

Table 3. Fuel Gas Consumption Data from Gas Engine Generator (GEG), Aug 2024–Aug 2025

No.	Month	Total Fuel Gas Consumption (MMscf)
1	August 2024	1.75
2	September 2024	1.92
3	October 2024	1.85
4	November 2024	2.11
5	December 2024	3.25
6	January 2025	3.06
7	February 2025	3.11
8	March 2025	3.15
9	April 2025	3.09
10	May 2025	3.21
11	June 2025	3.04
12	July 2025	3.03
13	August 2025	3.07

(b) GTC Unplanned Shutdown: Gas Turbine Compressor A experienced 3 unplanned shutdowns in 2024 due to primary seal discharge flow high, resulting in 80 hours of downtime, a drop in equipment reliability from 98% (target) to 92%, a loss of 738 barrel oil equivalent (~IDR 768 million/year), and increased flare emissions.

(c) High Back Pressure: GTC-A performance degradation caused well area production losses of 120 BOPD (oil) and 3 MMscfd (gas), with surface facility pressure at 200 psig, creating back pressure that shut in wells. Well service costs reached IDR 3.87 billion/day.

(d) Vessel Operations: Five offshore vessels (4 crew boats, 1 logistics vessel) operate continuously using diesel fuel, consuming approximately 2.8 million liters HSD B35/year with no integrated scheduling optimization, generating 18.78 ton CO_2eq/day.

(e) Flare Gas Volume: Average flare gas burn rate of 0.6 MMscfd, the highest contribution among all fields within XYZ Company, representing the largest single GHG emission source overall at 21.664 ton CO_2eq/day.

Design Thinking Analysis

1. **Inspiration Phase**

The inspiration phase generated rich qualitative insights from 15 stakeholders through in-depth interviews, empathy maps, user personas, and user journey maps. Analysis of all personas and empathy maps across all stakeholder groups revealed the following converging themes: (1) all stakeholders prioritize operational continuity and safety over innovation risk; (2) existing facilities have significant untapped potential for emission reduction through operational optimization rather than new infrastructure; (3) vessel operations are widely recognized as a quick-win opportunity with low implementation risk; (4) the primary seal gas system gas release is consistently identified as a direct innovation opportunity; and (5) back pressure on surface facilities is the most critical barrier to production and a key driver of well service emissions.

Point of View (PoV) analysis synthesized the needs and insights of all stakeholder groups. From the PoV analyses, 21 How Might We (HMW) questions were formulated to guide ideation, addressing key user needs related to emission reduction, production optimization, facility reliability, and vessel efficiency. Representative HMW questions included: "How might we reduce GHG emissions while simultaneously maintaining or increasing oil and gas production?"; "How might we utilize energy and gas currently being wasted to support lower-emission operations?"; "How might we reduce back pressure in the processing facility to increase well production while reducing emissions from well intervention activities?"; and "How might we optimize vessel movements to reduce fuel consumption and emissions without hindering daily operations?"

2. **Ideation Phase**

A 2-day hybrid co-creation workshop (February 20–21, 2026) was conducted with 13 key stakeholders. Brainstorming sessions generated over 80 ideas across all 21 HMW questions. An affinity diagram was used to cluster ideas into five strategic groups: (1) GTC reliability and seal gas utilization; (2) operating pressure optimization and back pressure reduction; (3) vessel operation optimization; (4) artificial lift installation with low-emission power sources; and (5) flare system integration and gas recovery. Through evaluation of feasibility, investment requirements, implementation time, emission reduction potential, production impact, and safety considerations, 16 innovation strategies were identified. Following confirmation and evaluation sessions with the Field Operation Manager and OIM, five priority strategies were selected, presented in Table 4.

Table 4. Priority Innovation Strategies for GHG Emission Reduction in XYZ Company's Offshore Field

Strategy	Innovation Strategy	Problem Addressed	Expected Benefit
1	Utilization of gas release from the primary seal gas system vent as additional fuel gas for gas engine generator	Continuous gas release to flare from GTC-A primary seal gas vent (0.006 MMscfd, 80 psig)	Eliminate 0.006 MMscfd vent-to-flare; improve GTC reliability; reduce CO_2 emissions; use existing warehouse materials
2	Fluid flow optimization through operating pressure reduction via existing facility utilization and pipeline modification at header manifold	High back pressure (200-220 psig in MP header) causing well shut-in and increased well intervention	Reduce surface facility pressure by 90–100 psig; reactivate shut-in wells; reduce well service emissions; increase production
3	Optimization of vessel operations through improved SOP and integrated field decision-making	Unintegrated vessel scheduling generating unnecessary fuel	Reduce diesel fuel consumption; lower vessel operational costs; reduce

Strategy	Innovation Strategy	Problem Addressed	Expected Benefit
		consumption and USD 3M/year operational cost	GHG emissions from marine activities; quick-win implementation
4	Installation of Electrical Submersible Pump (ESP) with power from micro turbine generator at Well Head Platform C	Natural decline rate 30–40%/year in WHP-C; wells approaching shut-in due to declining THP	Reactivate declining wells; increase production; reduce emission intensity; utilize low-emission micro turbine power source
5	Flare system integration through operating mode change: combining flare systems of Processing Platforms A and B	Platform B flares 0.2–0.4 MMscfd despite far below-design production; duplicated flare system operating cost	Reduce redundant flare operations; optimize asset utilization; reduce GHG emissions from flare system

3. SWOT Analysis of Priority Innovation Strategies

SWOT analysis was conducted for each of the five priority strategies to assess implementation feasibility. Table 5 presents the consolidated SWOT findings.

Table 5. Consolidated SWOT Analysis of Priority Innovation Strategies

Strategy	Strengths	Weaknesses	Opportunities	Threats
1 – Seal Gas Fuel Reutilization	Low investment; uses existing materials; low implementation risk; improves GTC reliability; reduces direct emissions	Gas release flow rate may be unstable; gas quality verification required; limited economic benefit if gas volume is small	Replicable to other offshore facilities; supports regulatory compliance; potential quick-win program	Seal gas system disturbances may interrupt gas supply; strict process safety requirements
2 – Pressure Optimization	Supports production increase and decarbonization simultaneously; optimizes existing facilities; extends natural flow period	Complex implementation involving piping changes; requires detailed technical study; may need partial shutdown	Can be applied to other offshore fields with similar back pressure issues; reduces well intervention frequency	Risk of production disruption during modification; reservoir changes may reduce effectiveness
3 – Vessel SOP Optimization	No large investment; rapid implementation; reduces diesel consumption and costs; improves inter-field coordination	Dependent on discipline and commitment; smaller emission reduction vs. technology-based strategies; requires behavioral change	Scalable to other fields; potential quick-win; replicable operational model	Weather conditions affect vessel planning; urgent operational needs may override schedules
4 – ESP with Micro Turbine Generator	Increases well productivity; uses efficient micro turbine; extends field life; dual benefit of production increase and emission reduction	Relatively high initial investment; long implementation timeline; requires specialized expertise	Supports production and emission reduction simultaneously; applicable to other declining wells	ESP or power system failure risk; oil price fluctuation impacts investment feasibility; space constraints
5 – Flare System Integration	Reduces GHG from flare; optimizes asset utilization; reduces	Requires piping and control system modification; high	Model for other offshore asset	Production disruption during modification;

Strategy	Strengths	Weaknesses	Opportunities	Threats
	O&M costs; centralizes flare management	initial investment; comprehensive process safety study needed	optimization; supports ESG targets	dependency on single flare system increases risk; complex approval process

4. Implementation Phase

The implementation phase translated selected innovation strategies into detailed technical recommendations. The following describes the key implementation details for the four highest-priority strategies:

Strategy 1 (Seal Gas Fuel Reutilization): The modification involves adding a tie-in pipeline from the primary seal gas vent of GTC-A to the fuel gas header of the gas engine generator. Required components include 4 ball valves, 1 liquid trap, 1 pressure control valve, 1 check valve, and 10 meters of ½-inch stainless steel tubing. All materials are available in the company warehouse, requiring no new procurement. Internal fabrication eliminates the need for external tender processes. The estimated implementation timeline is 2.5 months with no unplanned shutdown required. Key validation requirements include: (1) optimization of the seal gas conditioning unit parameters; (2) gas composition analysis of the seal gas outlet versus GEG fuel gas inlet specifications; and (3) technical verification with the GTC manufacturer.

Strategy 2 (Pressure Optimization): The modification involves installing an 8-inch carbon steel pipe (2–3 meters) connecting the medium pressure (MP) header manifold to the test header manifold in Processing Platform A. Components include 1 ball valve, 1 check valve, 2 flange connections, and gaskets all available in the company warehouse. Implementation by internal workforce; estimated timeline 3–4 months. The expected pressure reduction of 90–100 psig in the network will enable shut-in wells in WHP-A to return to natural flow without well service intervention.

Strategy 3 (Vessel Operation Optimization): The proposed SOP changes include: (a) Boat A (big fleet) to conduct material and foodstuff delivery every 10 days in a single combined trip; (b) Boat B (110-pax crew boat) contract not renewed (off-hire); (c) Crew change and interplatform activities to be served by Boats C, D, and E (60-pax capacity) with scheduling managed by the marine team as integrator; (d) Dedicated lunch delivery to NUI platforms eliminated; lunch distributed during morning personnel transport; and (e) All crew change and material deliveries consolidated under a single marine team authority. The expected savings include a significant reduction in annual vessel operational costs and a measurable decrease in diesel fuel consumption and associated GHG emissions.

Table 6. Proposed Vessel Activity Schedule Under Innovation Strategy 3

Vessel	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Boat A (Big Fleet)	Material & foodstuff delivery every 10 days (combined trip), standby offshore 7–8 days, backload on day 9						

Vessel	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Boat B	**OFF HIRE – Contract not renewed**						
Boat C	Interplatform & food East/North/West	Interplatform & food East/North/West	Crew change or interplatform (decided by marine integrator)	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West
Boat D	Interplatform & food East/North/West	Interplatform & food East/North/West	Crew change or interplatform (decided by marine integrator)	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West
Boat E	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West	Interplatform & food East/North/West

Strategy 4 (ESP with Micro Turbine Generator): The installation of an ESP system at WHP-C uses a micro turbine generator (MTG) as the low-emission power source, supported by a variable speed drive (VSD) and transformer. The MTG converts fuel gas to electricity with higher efficiency and lower emissions compared to conventional diesel generators. The process flow design connects Well C-1 and C-2 production through the ESP system to stabilize declining production. This strategy directly addresses the 30–40% annual natural decline rate at WHP-C while reducing emission intensity through use of a more efficient power source. The implementation requires a detailed engineering study, procurement, and commissioning over an estimated 6–12 month period.

ESG and Sustainability Policy Alignment

All five priority innovation strategies were evaluated for alignment with XYZ Company's sustainability policy across Environmental, Social/Operational Excellence, Governance, and SDG dimensions. Table 7 presents the consolidated alignment analysis.

Table 7. ESG and SDG Alignment of Priority Innovation Strategies

Strategy	Environmental	Operational Excellence	Governance	SDGs Supported
1	Reduces direct GHG emissions by eliminating vent-to-flare; improves energy efficiency	Improves GTC reliability; reduces energy loss; no new facility required	Maintains process safety standards; complies with regulations	SDG 7 (Clean Energy), SDG 12 (Responsible Consumption), SDG 13 (Climate Action)
2	Reduces emissions by minimizing well intervention; optimizes existing facilities	Increases well productivity; improves system reliability; reduces corrective interventions	Requires detailed technical and risk assessment; HSE standards maintained	SDG 7 (Clean Energy), SDG 9 (Infrastructure), SDG 13 (Climate Action)

Strategy	Environmental	Operational Excellence	Governance	SDGs Supported
3	Reduces diesel fuel use and marine transport GHG emissions	Improves fleet utilization; reduces operational costs; strengthens inter-field coordination	Strengthens structured, collaborative decision-making; improves transparency	SDG 7, SDG 12, SDG 13 (Climate Action), SDG 17 (Partnerships)
4	Reduces emission intensity through use of efficient power source; reduces well intervention emissions	Supports production continuity; extends field life; improves energy efficiency	Requires thorough economic and risk analysis; maintains safety standards	SDG 7, SDG 8 (Economic Growth), SDG 9 (Innovation), SDG 13
5	Reduces flare GHG emissions through system integration; minimizes environmental impact	Optimizes asset utilization; reduces O&M costs; centralizes facility management	Requires comprehensive process safety and risk study; supports good governance	SDG 7, SDG 9, SDG 12, SDG 13

The alignment analysis confirms that all five innovation strategies demonstrate strong coherence with XYZ Company's sustainability policy, contributing to the company's ESG objectives and supporting the achievement of multiple Sustainable Development Goals. Strategies 1, 2, and 3 are characterized as low effort–high impact initiatives, suitable for near-term implementation with limited investment. Strategies 4 and 5 require more extensive planning, investment, and risk assessment but offer greater long-term emission reduction and production enhancement potential.

1. **Emission Reduction Estimation per Strategy**

   Based on field data and technical calculations, Table 8 presents the estimated GHG emission reductions achievable through each priority innovation strategy.

Table 8. Estimated GHG Emission Reduction and Implementation Characteristics of Priority Strategies

Strategy	Primary Emission Source Addressed	Est. Emission Reduction	Implementation Timeline	Investment Level	Priority Level
1 – Seal Gas Fuel Reutilization	GTC-A primary seal gas vent to flare	Elimination of 0.006 MMscfd vent; reduction in GEG fuel gas consumption	~2.5 months	Low (materials available in warehouse)	High / Quick Win
2 – Pressure Optimization	Well intervention and well service emissions due to high back pressure	Reduction in well service frequency; recovery of ~120 BOPD and 3 MMscfd; reduction in associated GHG	~3–4 months	Low-Medium (internal workforce, available materials)	High / Quick Win
3 – Vessel SOP Optimization	Diesel fuel consumption from 5 vessels; unintegrated scheduling	Reduction in vessel trips; off-hire of 1 vessel; significant diesel fuel savings and CO_2 reduction from marine operations	Immediate (~1 month for SOP update)	Very Low (SOP revision only)	Very High / Quick Win

Strategy	Primary Emission Source Addressed	Est. Emission Reduction	Implementation Timeline	Investment Level	Priority Level
4 – ESP with Micro Turbine Generator	Well productivity decline; diesel generator use at NUI; emission intensity	Reduced emission intensity from well; avoidance of additional well service activities; lower specific emission per BOE	~6–12 months (full project cycle)	Medium-High (ESP + MTG equipment, installation)	Medium / Strategic
5 – Flare System Integration	Flare emissions from Processing Platform B (0.2–0.4 MMscfd)	Elimination of redundant flare operations; consolidation reduces total flare GHG contribution	~12–18 months (study + construction)	High (piping, control system modifications)	Medium / Long-term

2. Design Thinking Tool Outputs Summary

The comprehensive application of design thinking tools across 15 stakeholders generated rich qualitative data that formed the foundation for the innovation strategies. Table 9 summarizes the outputs from each design thinking tool and their contribution to the overall research process.

Table 9. Summary of Design Thinking Tools Applied and Key Outputs

Design Thinking Tool	Purpose	Key Output/Finding
Stakeholder Mapping	Identify and prioritize stakeholders by power and interest	15 stakeholders in 4 categories: Manage Closely (FOM, OIM), Keep Informed (operational staff), Keep Satisfied (leader contractor), Monitor (contractor staff)
In-depth Interview (WHW Format)	Gather detailed operational insights and pain points	Confirmed 4 primary GHG sources; identified high back pressure, GTC reliability issues, and unoptimized vessel operations as key drivers
User Persona	Understand stakeholder characteristics, goals, and barriers	13 personas developed; common theme: preference for low-risk, operationally compatible solutions using existing facilities
Empathy Map	Explore stakeholder thoughts, feelings, observations, and actions	All stakeholders recognize emission reduction importance but face real constraints: budget limits, aging equipment, safety risks during modification
User Journey Map	Map stakeholder experience across operational phases	Identified 5 key pain points: GTC shutdown, back pressure, flare, vessel inefficiency, aging equipment; and corresponding innovation opportunities
Point of View (PoV) Analysis	Synthesize user needs and insights into problem statements	21 PoV statements developed across all stakeholder groups; needs converge on: operational compatibility, low investment, safety preservation
How Might We (HMW) Questions	Direct ideation toward specific user-centered opportunities	21 HMW questions generated; key questions focused on: pressure reduction,

Design Thinking Tool	Purpose	Key Output/Finding
		gas reutilization, vessel optimization, and ESP deployment
Co-creation Workshop & Brainstorming	Generate diverse innovation ideas from multi-stakeholder perspective	80+ ideas generated across 5 affinity clusters; refined to 16 innovation proposals; validated to 5 priority strategies
Affinity Diagram	Cluster and organize ideas by theme and relationship	5 strategy clusters: GTC seal gas, pressure optimization, vessel operations, artificial lift, flare integration
SWOT Analysis	Evaluate feasibility, risks, and opportunities of each strategy	All 5 strategies feasible; Strategies 1, 2, 3 assessed as low effort-high impact; Strategies 4 and 5 as medium-high effort with strategic long-term value

This study demonstrates that the Design Thinking 3-IDEO method is effective in generating human-centered, operationally feasible innovation strategies for GHG emission reduction in offshore oil and gas settings. Unlike previous studies that focused predominantly on technical and top-down approaches (Nguyen et al., 2016; Voldsund et al., 2023; Farajzadeh, 2022), this research centers the innovation process on field workers' direct knowledge and lived experience an approach consistent with Tushar et al. (2020) and aligned with Buhl et al.'s (2019) framework for design thinking in sustainability contexts.

The findings extend existing literature in several important ways. First, the research confirms that design thinking can bridge the gap identified in the literature between technically available emission reduction solutions and their effective organizational implementation (de Paula et al., 2020). Second, the study demonstrates that significant emission reduction opportunities exist in operational optimization and existing facility utilization an approach that is often more feasible in mature offshore fields than large-scale capital investment projects such as CCUS (Sanggomaro & Anggoro, 2023). Third, the research shows that stakeholder involvement in the innovation development process increases the relevance and acceptance of proposed strategies, consistent with findings from Tantiyaswasdikul (2020) and Foster (2019).

The four validated priority strategies address the four main emission sources identified in the field observations: flare system and GTC seal gas (Strategy 1 and 5), surface facility pressure optimization (Strategy 2), vessel operations (Strategy 3), and well productivity with low-emission power (Strategy 4). The strategy prioritization reflects the operational context of a mature offshore field: Strategies 1, 2, and 3 are prioritized as quick-win, low-investment initiatives that can be implemented within 2.5–4 months using existing materials and internal workforce, while Strategies 4 and 5 require more planning but offer longer-term benefits. This multi-layered approach to emission reduction is consistent with the comprehensive innovation framework advocated by Isong (2023) and Ekemezie & Digitemie (2024) for the upstream oil and gas sector.

CONCLUSION

This study successfully formulated five GHG emission reduction innovation strategies for XYZ Company's offshore field through the Design Thinking 3-IDEO method, encompassing Inspiration, Ideation, and Implementation phases. Field observations identified four primary GHG emission sources: the flare system (21.664 ton CO_2eq/day), gas turbine compressor fuel consumption (69.764 ton CO_2eq/day), offshore vessel operations (18.78 ton CO_2eq/day), and power generation (3.31 ton CO_2eq/day), along with operational issues including unplanned GTC shutdowns, high surface facility back pressure, and unoptimized vessel scheduling. Through co-creation workshops with 13 stakeholders, four priority strategies were identified and validated: (1) reutilization of primary seal gas release as additional fuel gas for the gas engine generator a low-investment quick-win requiring only available warehouse materials and approximately 2.5 months to implement; (2) operating pressure reduction via pipeline modification to the header manifold, which is projected to reduce surface pressure by 90–100 psig, reactivate shut-in wells, and reduce well service emissions; (3) vessel operation SOP optimization through integrated marine scheduling, including off-hiring one vessel and eliminating dedicated lunch delivery trips; and (4) ESP installation with micro turbine generator power at WHP-C to maintain production from declining wells with lower emission intensity. All strategies demonstrate strong alignment with ESG principles, the company's sustainability policy, and multiple SDGs. For future research, development of quantitative models to measure emission reduction potential and economic value of each strategy is recommended, along with expansion of the design thinking approach to other offshore fields and exploration of renewable energy integration as low-emission power sources for offshore facilities.

REFERENCES

Blok, K., Afanador, A., Van der Hoorn, I., Berg, T., Edelenbosch, O. Y., & Van Vuuren, D. P. (2020). Assessment of sectoral greenhouse gas emission reduction potentials for 2030. *Energies, 13*(4).

Brown, T. (2008). Design thinking. *Harvard Business Review, 86*(6), 84–92.

Buhl, A., Schmidt-Keilich, M., Muster, V., Blazejewski, S., Schrader, U., Harrach, C., Schäfer, M., & Süßbauer, E. (2019). Design thinking for sustainability: Why and how design thinking can foster sustainability innovation. *Journal of Cleaner Production, 231*, 1248–1257.

Cheng, V. S., & Li, G. (2023). Roadmap of decarbonization. In *Decarbonization of cities in Asia* (pp. 17–47). Springer.

Climate change and the energy sector. (2023). In *Energy and climate change* (pp. 1–6). Elsevier.

de Paula, T. R., Amancio, T. S., & Flores, J. A. N. (2020). Design thinking in industry. *IEEE Engineering Management Review, 37*(2), 49–51.

Dey, R. (2021). Natural disasters linked to climate change. In *The impacts of climate change* (pp. 177–193). Elsevier.

Dong, H., & Kovács, L. S. (2023). Oil and gas industry: Environmental and sustainability in the energy transition to net-zero. *EAGE Annual Conference & Exhibition*.

Ekemezie, I., & Digitemie, W. N. (2024). Climate change mitigation strategies in the oil & gas sector: A review of practices and impact. *Engineering Science & Technology Journal, 5*(3), 935–948.

Farajzadeh, R. (2022). Improved oil recovery techniques and their role in energy efficiency and reducing CO_2 footprint of oil production. *Journal of Cleaner Production, 375*, 134098.

Farooq Lone, S., & Bhat, S. A. (2023). The global challenge of climate change: Impacts, causes, and solutions. *International Journal of Multidisciplinary Research, 5*.

Foster, M. K. (2019). Design thinking: A creative approach to problem solving. *Management*

Teaching Review, 6(2), 123–140.
Ismukurnianto, D. A. (2022). Mitigation of carbon dioxide and greenhouse gases. *LEMIGAS Scientific Contributions*.
Ivshina, I. B., Kuyukina, M. S., Krivoruchko, A. V., Elkin, A. A., Makarov, S. O., Cunningham, C. J., Peshkur, T. A., Atlas, R. M., & Philp, J. C. (2015). Oil spill problems and sustainable response strategies through new technologies. *Environmental Science: Processes & Impacts, 17*(7), 1201–1219.
Lim, C. J., Chung, J. X., Lim, C. H., Tan, C. K., & Chua, S. C. (2024). ASEAN net-zero emissions pathway: A roadmap for 2021–2050. *Renewable and Sustainable Energy Reviews*.
Nathanael, J., Khairilmizal, S., & MF, H. (2024). Challenges in managing emergency offshore: A comparison of offshore and onshore perspectives. *Journal of Loss Prevention in the Process Industries, 88*, 105275.
Nguyen, T., Tock, L., Breuhaus, P., Maréchal, F., & Elmegaard, B. (2016). CO_2-mitigation options for the offshore oil and gas sector. *Applied Energy, 161*, 673–694.
Quaiser, R. M., & Pandey, S. K. (2023). Design thinking enabling innovation: A literature review. *The European Journal of Social Science Research, 36*(4), 579–601.
Sanggomaro, I. M., & Anggoro, Y. (2023). Exploring the feasibility of carbon capture, storage (CCS) integration in offshore oil and gas operations. *IAES International Journal of Artificial Intelligence*.
Syarifuddin, E. M., & Si, M. (2023). *Prediksi hujan untuk manajemen bencana dan risiko pertanian*. Orasi Ilmiah Dies Natalis XXV.
Tantiyaswasdikul, K. (2020). How design thinking can foster environmental sustainability: Integrating design thinking into circular design guide. In *Proceedings of the International Conference on Industrial Business and Engineering (ICIBE '20)*.
Tim Internal Perusahaan Migas XYZ. (2022). *Sustainability journey report*.
Tim Internal Perusahaan Migas XYZ. (2023). *Dokumen ringkasan kinerja pengelolaan lingkungan 2023*.
Tim Internal Perusahaan Migas XYZ. (2024). *Laporan tahunan lingkungan Perusahaan Migas XYZ tahun 2024*.
Tushar, W., Lan, L., Withanage, C., Sng, H. E. K., Yuen, C., Wood, K. L., & Saha, T. K. (2020). Exploiting design thinking to improve energy efficiency of buildings. *Energy, 197*, 117141.
Voldsund, M., Reyes-Lúa, A., Fu, C., Ditaranto, M., Nekså, P., Mazzetti, M. J., Brekke, O., Bindingsbø, A. U., Grainger, D., & Pettersen, J. (2023). Low carbon power generation for offshore oil and gas platforms. *Energy, 267*, 126548.