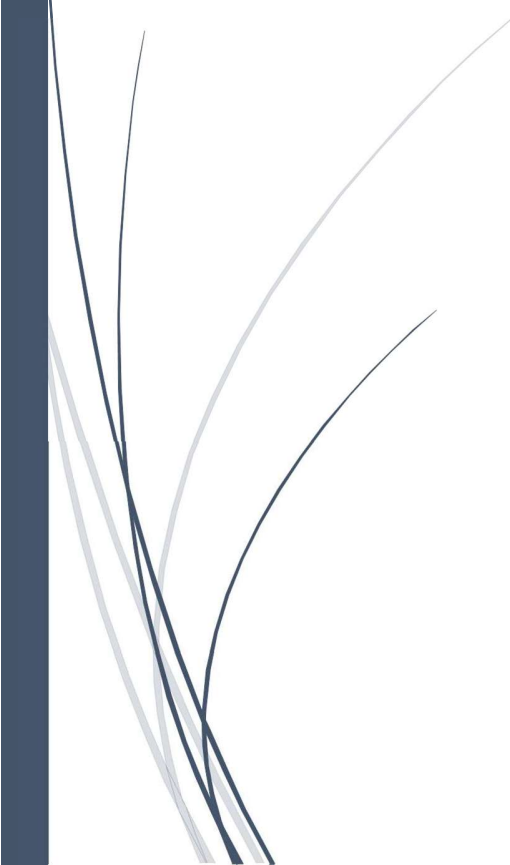




Final Project 2

PMG 497



Midocean University

Faculty of Management

Department/ Specialization



**Techno-Economic Feasibility and Implementation
Roadmap for CO₂ Capture in [BHIG company]:
Comparative Assessment of Post-Combustion Solvent,
Adsorption, Membrane, and DAC Pathways**

Abdullah Aljasim

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Final Project - 2

Faculty of Management - Midocean University

Supervisor

Dr.

Faculty member- Faculty of management- Midocean University

Date of submission – number of Semester

Abstract

Purpose:

Purpose: This study evaluates technical, economic, environmental, and regulatory feasibility of deploying CO₂ capture at [facility/region], comparing mature post-combustion amine systems with adsorption, membrane, oxy-fuel, and direct air capture (DAC) options, and delivering a phased development roadmap from concept to FEED and early operations with MRV integration.

Methodology:

The project synthesizes state-of-the-art technology reviews, screening-level process models, order-of-magnitude cost estimation, and comparative life-cycle assessment, aligned to a standard CCUS project funnel: feasibility, modeling, characterization, permitting, execution, and operations with MRV.

Findings:

For flue-gas CO₂ at 8–15% concentration, advanced post-combustion solvent systems remain most deployment-ready and cost-effective at scale; adsorption and membranes can be competitive in niche duty cycles or smaller modular units; oxy-fuel is site-specific; DAC remains strategic for removals but currently higher cost and energy-intensive. Policy signals and market growth (16% CAGR 2025–2034) and maturing supply chains improve bankability.

Originality & Implication:

Integrates 2025 innovations (modular hardware, improved sorbents, AI-enabled materials discovery, electro-swing approaches) with practical permitting and TRL-based stage-gates, translating global trends to a site-specific decision path.

Keywords:

Carbon capture; CCUS; post-combustion; adsorption; membranes; oxy-fuel; DAC; feasibility; TEA; LCA; MRV; permitting; TRL; storage; utilization

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1. Chapter 1: Introduction

1.1. Research Background

Industrial decarbonization increasingly relies on CCUS to mitigate process and combustion emissions where electrification or fuel-switching are constrained by cost, technology readiness, or reliability needs in sectors like power, cement, steel, refining, hydrogen, and ammonia. Post-combustion capture has matured with next-gen solvents offering reduced energy penalties, while adsorption, membranes, and hybrid systems provide modularity and potential OPEX savings under specific conditions. DAC has emerged as a complementary pathway for durable carbon removals, yet near-term implementations must overcome current energy and cost hurdles pending scale and policy support.

1.2. Research Problem

- 1.2.1.** [BHIG company] faces tightening emissions limits and net-zero commitments, requiring credible, costed pathways for CO₂ abatement that integrate with existing assets and local storage/utilization options. Decision-makers need a comparative, site-specific assessment of capture routes, balance-of-plant implications, storage vs. utilization logistics, and permitting/MRV to reduce risk before FEED.

Theoretical Gaps

There is a need to harmonize recent materials and process innovations with bankable project delivery frameworks that reflect TRL, regulatory constraints, and evolving incentive regimes to bridge lab-to-project transitions. Robust comparisons across varying flue compositions, load profiles, and integration constraints remain under-represented in generalized techno-economic studies.

1.2.2. Practical Gaps

Owners lack integrated views of capture technology fit, transport/storage readiness (geology, rights-of-way), MRV stack selection, and phased permitting aligned to execution risk and financing

milestones within regional policy contexts. Supply-chain scale-up and merchant CCUS models are advancing, but off-taker structures and credit monetization require clear project gating.

1.3. Research Significance

1.3.1. At the theoretical level

The study links capture-technology selection to a formal framework of technology readiness, energy penalty mechanisms, and verifiable carbon accounting, integrating multi-criteria decision analysis across solvents, adsorption, membranes, oxy-fuel, and DAC under consistent MRV definitions. This advances theory by connecting materials/process performance and system integration to quantifiable outcomes such as capture rate, levelized cost of capture, and permanence under recognized MRV typologies.

1.3.2. At the practical level

The study delivers a stage-gated roadmap from feasibility to pre-FEED/FEED that specifies data needs, site tie-ins, permitting pathways, transport/storage options, and MRV plans, enabling bankable CCUS decisions in real projects and jurisdictions. It operationalizes policy and market signals into implementation steps and risk controls relevant to regions like the GCC with strong storage potential and emerging CCUS hubs

1.4. Research Questions

- Which capture pathway best fits [BHIG company] considering flue gas specs, utilities, footprint, and integration constraints?
- What is the expected capture rate, energy penalty, and cost range at AACE Class 5–4 accuracy?
- What transport and storage/utilization options are viable regionally, and what are the key permitting and monitoring requirements?

- How do policy incentives and market trajectories affect project bankability and phasing?

1.5. Research Objectives

- Screen and compare solvent, adsorption, membrane, oxy-fuel, and DAC options for [BHIG company].
- Produce preliminary mass/energy balances, plot plans, and tie-ins for top options.
- Map transport (pipeline/truck/ship) and storage/utilization pathways with permitting/MRV.
- Deliver a stage-gated roadmap to pre-FEED and FEED with cost, schedule, and risks

1.6. Research Hypotheses

- H1: For [BHIG company] flue composition and duty, next-gen post-combustion solvent capture minimizes levelized capture cost vs. alternatives at $\geq 90\%$ capture.
- H2: Adsorption/membranes yield competitive NPV for smaller, modular, or intermittent sources when waste heat or low-carbon power is available.
- H3: DAC becomes viable if removal credits/offtakes are accessible and low-carbon energy is available at scale.

1.7. Research Model

The study applies a multi-criteria decision model integrating technical KPIs (capture rate, energy intensity, degradation), economic metrics (CapEx/Opex/LCOC), environmental outcomes (LCA, leakage risk), and regulatory fit (permitting, MRV, incentives) across project phases.

1.8. Scope of The Study

Covers capture unit integration at [facility], utility impacts, CO₂ conditioning and compression, transport corridor screening, storage/utilization readiness, permitting/MRV framing, and a pre-FEED readiness plan; excludes detailed FEED and construction execution plans.

1.9. The Project Structure

Chapter 2 reviews technology pathways;

Chapter 3 details methodology;

Chapter 4 presents screening results and discussion;

Chapter 5 provides recommendations, limitations, and future research.

2. Chapter 2: Literature Review

2.1. Introduction

CCUS literature in 2025 consolidates around four principal capture families—post-combustion solvent, adsorption, membranes, and oxy-fuel—with DAC as a removal pathway, and emphasizes modular designs, improved materials, and advanced controls. Cross-cutting themes include energy penalty reduction, solvent/sorbent stability, hybridization, and verifiable carbon accounting under evolving standards.

2.2. The independent variable

- Post-combustion solvents: Advanced amines (e.g., optimized solvent blends) delivering lower regeneration energy, higher stability, and integration packages for ammonia/hydrogen/power. [4]
- Adsorption: Zeolites, MOFs, and engineered sorbents for VSA/PSA with potential low OPEX and modularity; performance sensitive to humidity and cycling stability. [1][3]

- Membranes: Polymeric/inorganic membranes suited to specific partial pressures and staged compression, offering compactness and low maintenance in modular deployments. [3][2]
- Oxy-fuel: High CO₂ purity flue gas via oxygen firing; advantageous where air separation and retrofit constraints are manageable. [1][3]
- DAC: Solid/liquid sorbents and emerging electro-swing adsorption for atmospheric CO₂ removals; strategic for high-integrity credits with strong MRV.

2.3. The dependent variable

project outcomes

Capture rate and energy intensity drive cost per tonne, while integration constraints affect footprint, tie-ins, and downtime; MRV and permitting determine verifiability and schedule risk; market and policy influence revenue and financing.

2.4. The relationship between the independent and the dependent variables

Technology choice interacts with site utilities and flue characteristics to set energy penalties and CapEx; MRV readiness and storage access shape bankability; policy incentives can shift optimal choice toward removals or hybrid portfolios.

2.5. Conclusion

For most near-term brownfield sources, solvent post-combustion is the anchor option, with modular adsorption/membranes as adjuncts and DAC as a removals complement contingent on energy and credit markets.

3. Chapter 3: Research Methodology

3.1. Introduction

A mixed-methods approach combines technology review, process screening, preliminary costing, and regulatory/MRV mapping aligned to recognized CCUS project stages.

3.2. Operational definitions for research variables

- Capture rate: Fraction of CO₂ removed from inlet gas.
- LCOC: Levelized cost of capture per tonne CO₂ captured and conditioned.
- MRV: Measurement, reporting, verification of captured, transported, and stored/used CO₂ per accepted protocols.

3.3. Research design (research onion)

The design uses a pragmatic paradigm, multi-criteria decision analysis, and staged uncertainty reduction through data gathering, modeling, and stakeholder interviews leading to a pre-FEED recommendation.

3.4. Research population & Sampling methods and technique

Data population includes technology OEMs, standards bodies, regulators, transport/storage developers, and site owners; purposive sampling targets stakeholders with current projects or regulatory authority.

3.5. Data collection method

Secondary sources include peer-reviewed reviews, vendor white papers, market outlooks, and regulatory guidance; primary inputs include site utility data and flue gas composition from [facility]

3.6. Types of data

Quantitative: performance ranges, energy penalties, CapEx/Opex factors, schedule milestones; qualitative: permitting pathways, MRV options, stakeholder risk perceptions.

3.7. Statistical analysis procedures

Screening TEA with order-of-magnitude estimates, sensitivity to energy price and capture rate, and scenario analysis under different policy credit values and storage fees.

3.8. Conclusion

The methodology yields a defensible, stage-gated recommendation with defined next steps and data gaps for pre-FEED.

4. Chapter 4: Statistical Analysis & Findings discussion

4.1. Introduction

4.2. Sample profile (descriptive statistics for research sample)

4.3. Validity & reliability tests for the questionnaires

4.4. Descriptive statistics for research variables (answer research questions)

4.5. Testing Hypotheses & Findings Discussion

4.6. Conclusion

5. Chapter five: Research limitations, Recommendations & Conclusion

5.1. Research Limitations & Future Research

5.2. Research Recommendations

5.3. Conclusion

References

Appendix