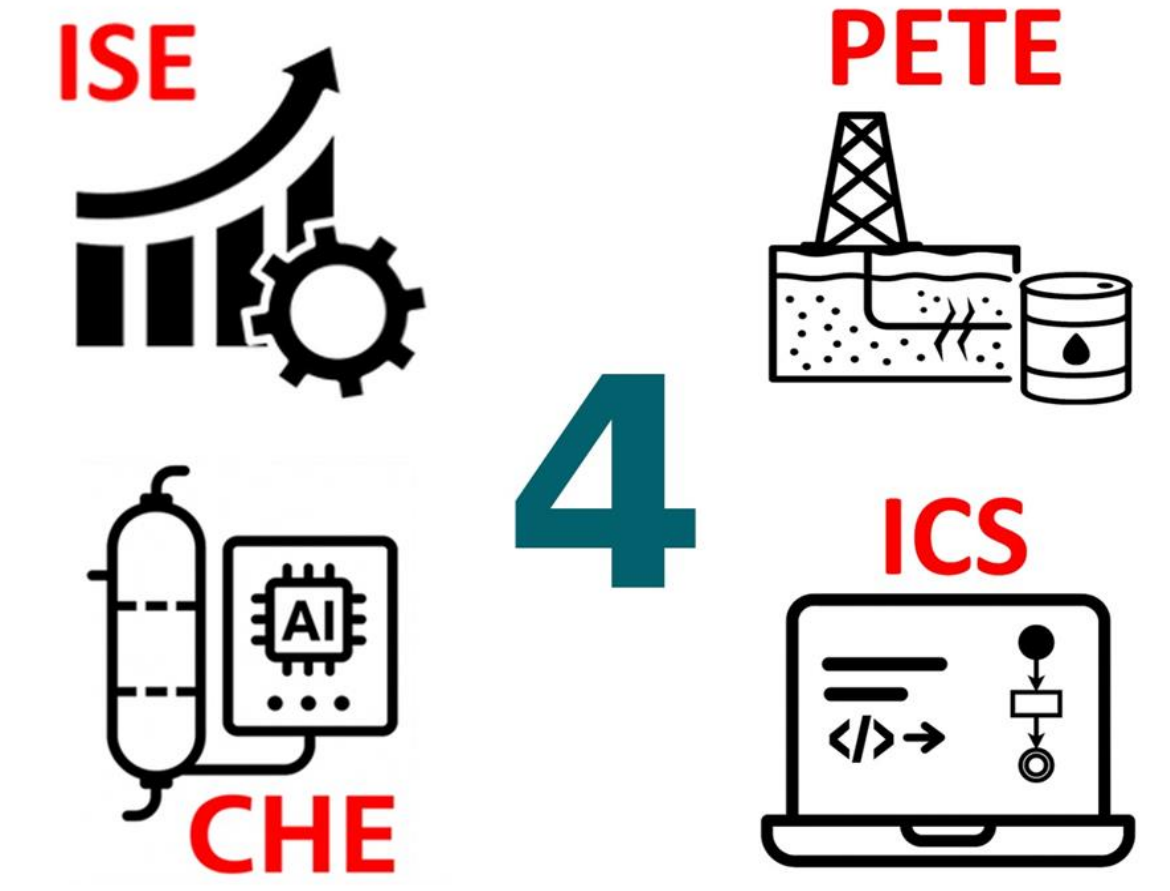


Optimization of a Mixed-Feed Steam Cracker: Energy Efficiency, Hydrogen Purity & Recovery, CO₂ Management with an Interactive Application

Joud Almatrood, Zainab Alamer, Fatima Bazroun, Safana Aljughaiman, Munirah Alobaid, Dona Alsaud
Coach: Khadijah Alsafwan



Introduction

A **Mixed-Feed Steam Cracker** converts hydrocarbon feedstocks into valuable petrochemicals through thermal cracking. This project focuses on improving energy efficiency, enhancing hydrogen purity and recovery, and reducing CO₂ emissions. An interactive application was also developed to compare scenarios and support decision-making

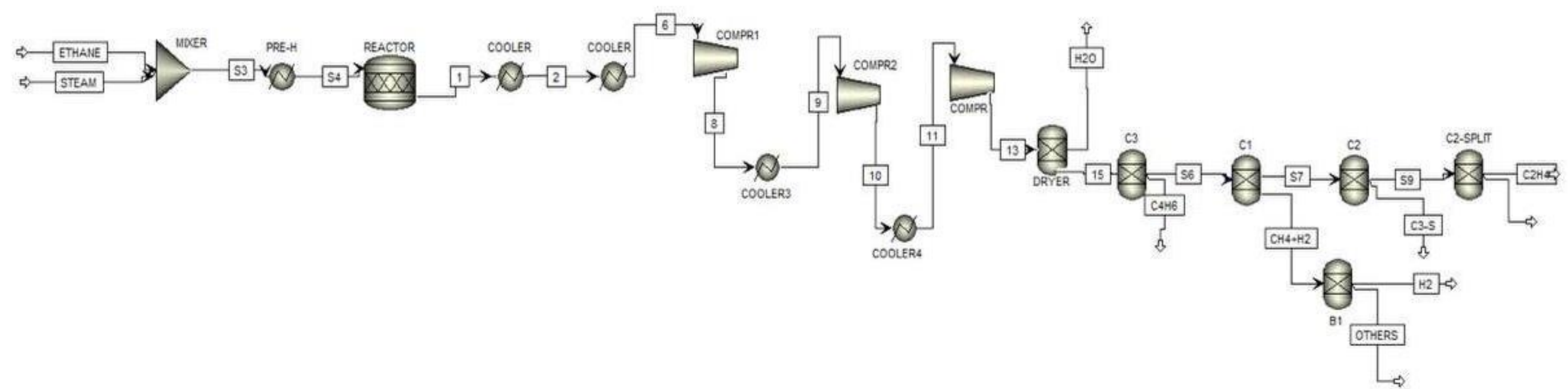
Problem Statement

Steam cracking processes face challenges in energy consumption, CO₂ emissions, and hydrogen recovery, requiring an integrated optimization approach with practical decision-support tools.

Achievement

- CHE:** Ethylene yield up to 70% | H₂ purity 99.5% | Energy -59%
- ISE:** Predictive models R² ≥ 0.90 | 3 scenarios optimized via MCDM
- PETE:** Screens CO₂ storage feasibility based on injectivity and pressure limits
- SWE:** Cloud-native app integrating multidisciplinary KPIs and scenario-based decisions | Cross-platform iOS & Android | Auto-generated PDF report

Prototype



Deliverables

SWE (SOFTWARE ENGINEERING)

- Develop cross-platform mobile application (UI/UX)
- Integrate backend + APIs (CHE, PETE, ISE models)
- Deploy cloud system (performance, scalability, security)
- Testing + documentation

CHE (CHEMICAL ENGINEERING)

- Process design (Aspen Plus simulation)
- System performance evaluation
- CO₂ emissions & hydrogen recovery analysis
- Ethylene production assessment

ISE (INDUSTRIAL & SYSTEMS ENGINEERING)

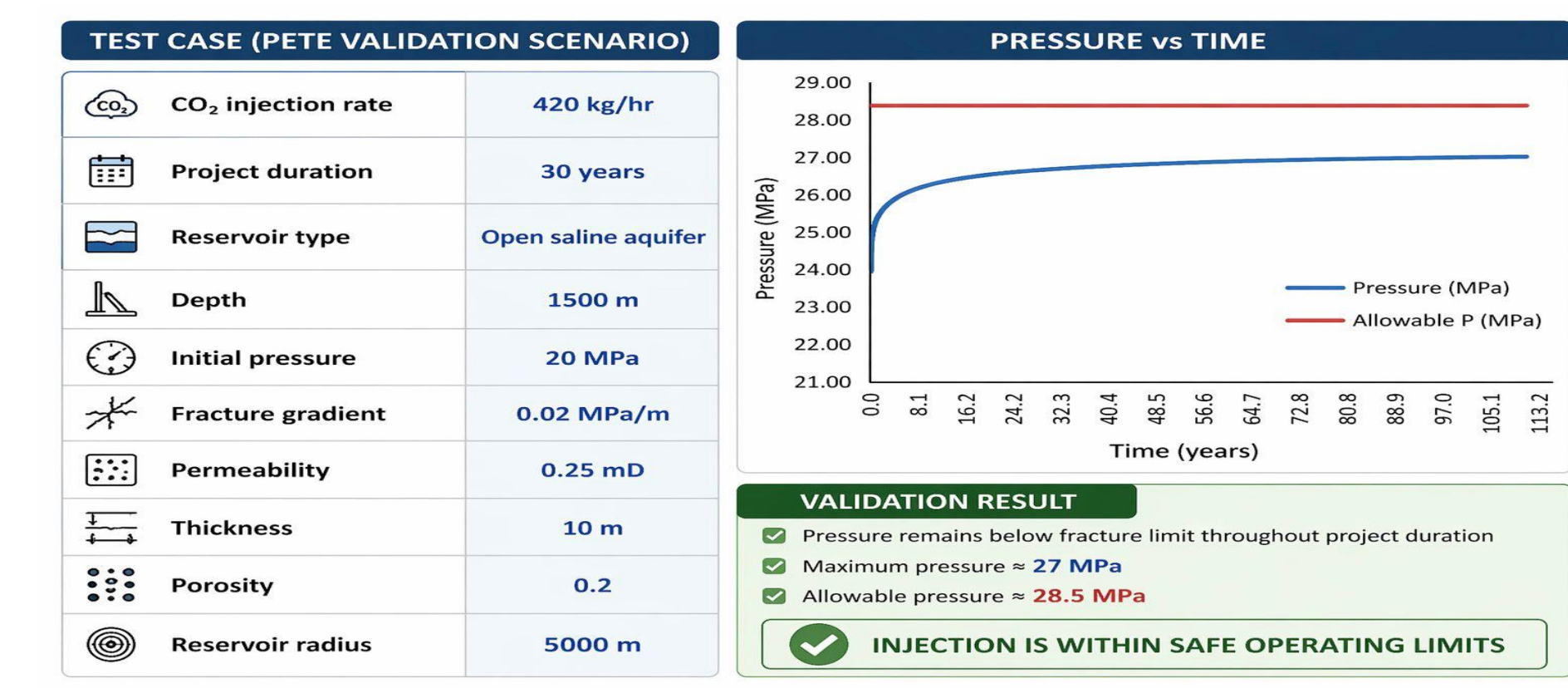
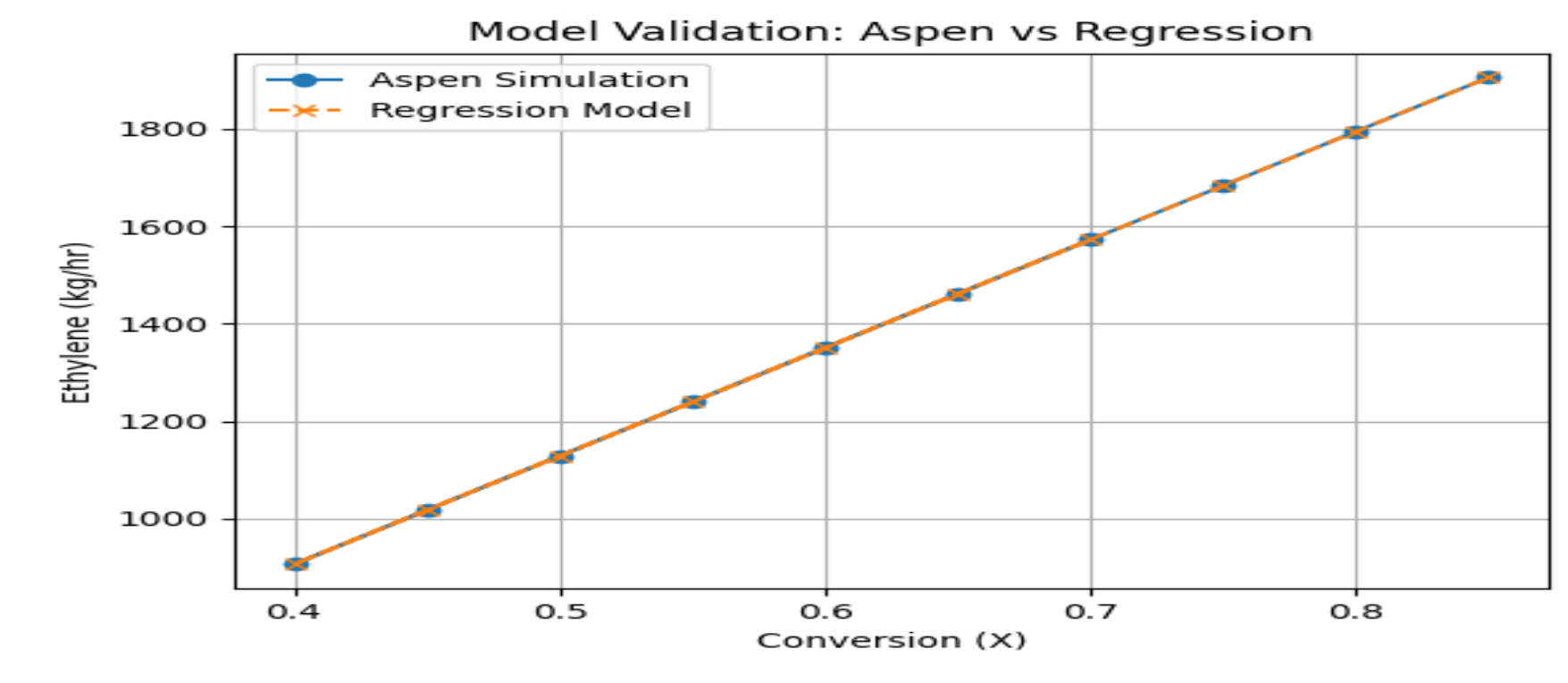
- Multi-objective optimization (cost, emissions, production)
- KPI evaluation (C₂H₄, H₂, CO₂)
- Decision-support model (MCDM)
- Generate recommendations

PETE (PETROLEUM ENGINEERING)

- CO₂ injectivity & storage modeling
- Pressure + fracture limit analysis
- Reservoir feasibility classification
- Storage capacity estimation

Test and Validation

- System tested through deployed application (AWS-based)
- Model accuracy validated vs Aspen simulation data
- Strong agreement observed (R² ≥ 0.90)
- Consistent outputs across scenarios
- CO₂ feasibility verified (P < P_{allow})
- Injection within safe limits



Constraint and Speciation

CHE	C1	Simulation based, Aspen	S1	≥1 wt% ethylene ↑
	C2	Limited scenarios	S2	≥3% fuel duty ↓
	C3	Fixed T & P (industrial range)	S7	H ₂ : 60–70% @ 99.9% purity
PETE	C2	Limited reservoir scenarios	S3	Max sustainable CO ₂ injection rate estimated
	C7	Injection pressure < fracture pressure	S12	Feasibility classified (Feasible / Conditional / Infeasible)
	C8	Saline aquifer only		
SWE	C5	Based on Aspen simulation data (scenario comparison only)	S6	Handles input errors with clear messages
	C6	Basic validation only (no AI or advanced analytics)	S9	Exports ≥80% of results to PDF within 120 sec
			S10	Cloud deployment with restart time ≤ 15 min
ISE	C4	Predictions within 750 ≤ T ≤ 900°C	S3	Estimates max sustainable CO ₂ injection rate
	C5	3 predefined scenarios: Balanced Ethylene CO ₂ -Focused	S4	Predictive model for ethylene production
			S8	Estimates furnace fuel cost & savings vs. baseline
INTEGRATED	IS1	All KPIs met (↑ Ethylene, ↓ Fuel, ↑ H ₂ , CO ₂ storage feasibility ✓)		
	IS2	Unified interface for technical, economic, and environmental scenario comparison		
	IS3	Unified economic and environmental report from all disciplines		

Conclusion

This project developed a multidisciplinary decision-support prototype integrating simulation, analysis, and CO₂ feasibility to evaluate steam cracker operations. Results highlight the need to balance yield, energy, hydrogen, and CO₂ for a practical and sustainable solution.

What is Next?

integrate AI for smarter decision-making and Integrate real-time plant data for live optimization.