PRODUCTION OF BLUE HYDROGEN

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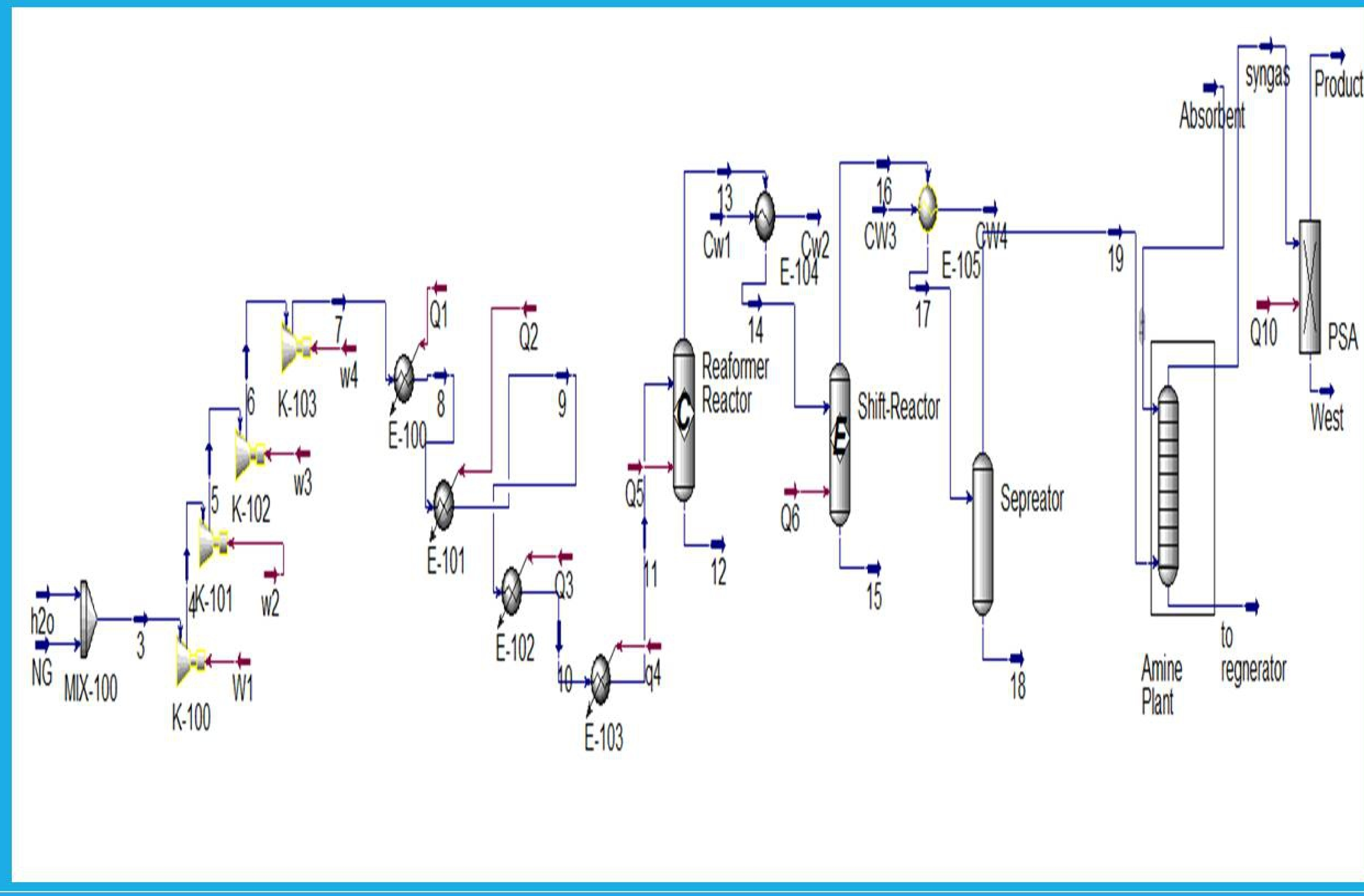
Abstract

Producing blue hydrogen from natural gas is an important step toward clean energy and reducing carbon emissions. This project focuses on designing a process to produce hydrogen from methane sourced from oil refinery off-gases, using carbon capture and storage (CCS) technologies to lower harmful emissions. A review of previous studies was conducted to select the best methods, followed by simulating the process using Aspen HYSYS software to complete the design and evaluate the system's efficiency in terms of production and environmental impact. The results show that the system can achieve a hydrogen purity of 99.99% and a carbon capture efficiency of 90%, supporting the process's economic and environmental effectiveness.

Problem Statement

With the growing need to reduce carbon emissions, blue hydrogen has become an essential option in this effort, making it necessary to improve production efficiency while minimizing costs related to raw materials and plant construction. Although several methods exist for large-scale blue hydrogen production, some studies lack the comprehensive improvements needed to increase efficiency and lower raw material use. Research shows that certain catalysts help enhance chemical reactions and improve methane conversion rates, while also reducing environmental issues like corrosion, making them suitable choices for industrial systems.



ECONOMIC STUDY

Table 5: Capital cost of the chemical plant

Equipment Type	Equipment Code	Purchasing Cost ($)
Heater	E-100	610,000
	E-101	610,000
	E-102	610,000
	E-103	610,000
Composer	C-101	634,000
	C-102	634,000
	C-103	634,000
	C-104	634,000
Heat-Exchanger	E-104	892,000
	E-105	892,000
Reactor	R-101	1630,000
	R-102	633,000
Tower	T-101	176,000
	T-102	440,000
	T-103	4,160,000

Table 5: Utility Cost Summary

Unit	Code	Utility type	Unit cost [$ /GJ]	Heat flow [kJ/h]	Annual utility cost [$ million /year]
Heater	E-100	MP (steam)	17.70	1271402	1.87
	E-101			-5854482	1.87
	E-102			1158655	1.87
	E-103			2074814	1.87
Heat-Exchanger	E-104			23961	2.74
	E-105			65764	2.64
Composer	C-101	Electric distortion	16.8	450	2.46
	C-102			450	2.46
	C-103			450	2.46
	C-104			450	2.46
Towers	T-103	Steam from boilers	13.28	451890103	1.61
Total utility cost					24.31

PROCESS BLOCK DIAGRAM

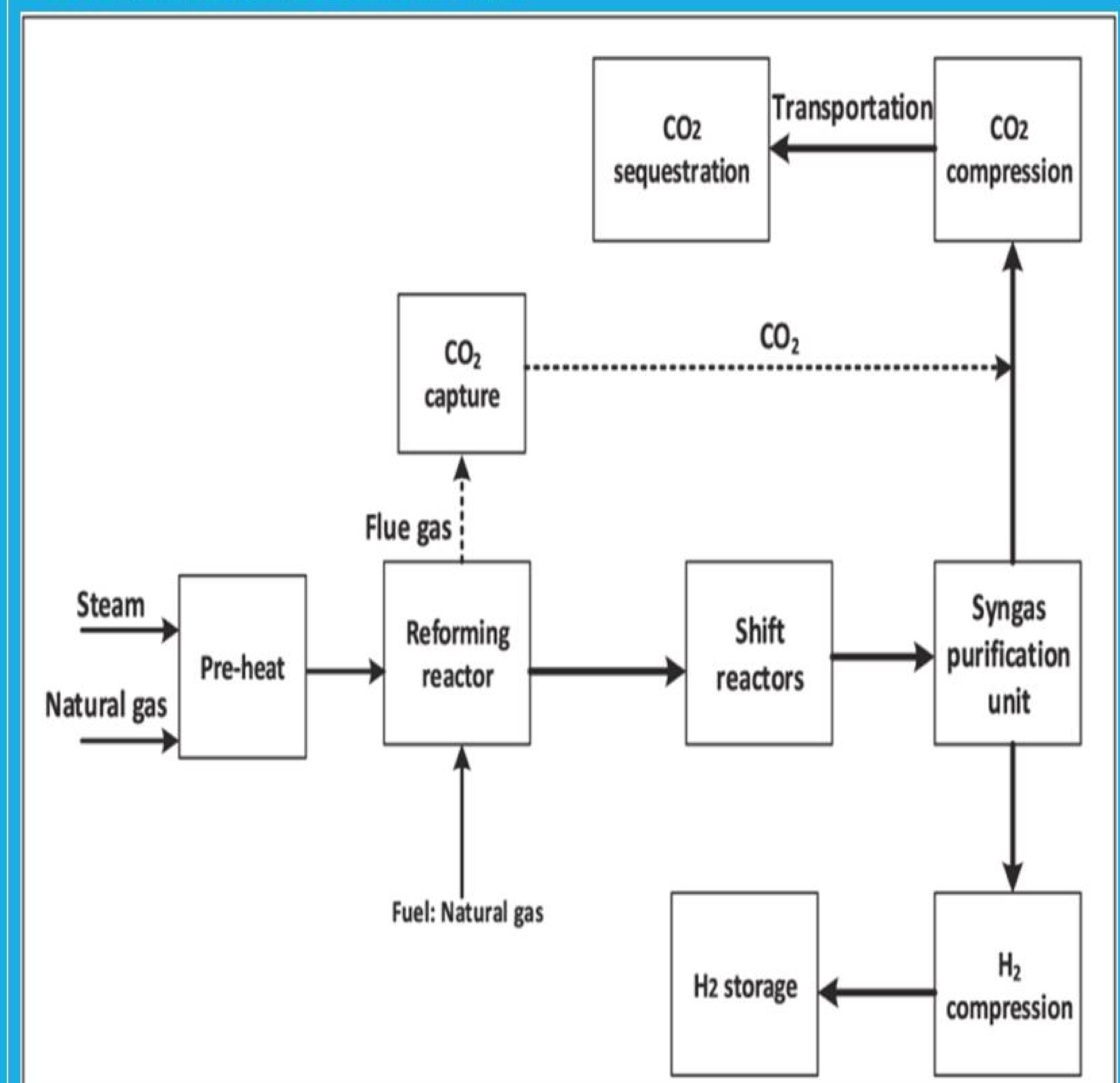


Figure 1:Process block diagram for SMR

EQUIPMENT DESIGN

Table 1: physical properties of the shell side

SHELL SIDE NG [HOT]	1	MEAN	2	UNIT
TEMPERATURE	626.85	401.85	176.85	ºC
PRESSURE	35.46	35.46	35.46	Bar
MOLAR FLOW	14799.2	14799.2	14799.2	kmol/h
MASS FLOW	184514.2234	184514.2234	184514.2234	kg/h
SPECIFIC HEAT	2.7	3	3.3	KJ/kg.ºC
DENSITY	5.885680901	9.124223678	12.36276645	kg/m3
MOLAR DENSITY	0.472068587	0.731820065	0.991571544	kmol/m3
VISCOSITY	2.42E-02	0.023682547	2.32E-02	cp
MW	12.4678512	12.4678512	12.4678512	g/mol
THERMAL CONDUCTIVITY	0.176716282	0.169158141	0.1616	W/m.ºC
PRESSURE DROP		0		-
Molare Enthalpy	-281394.8564	-195415.0484	-109435.2405	KJ/Kmol
Enthalpy	-4164418759	-2891986385	-1619554011	KJ
Q		2544864748		KJ/h

Table 2: physical properties of the tube side

TUBE SIDE H_2O	1	MEAN	2	UNIT
TEMPERATURE	36.85	61.85	86.85	ºC
PRESSURE	1.01325	1.01325	1.01325	bar
MOLAR FLOW	57748.78989	57748.78989	57748.78989	kmol/h
MASS FLOW	1040350.252	1040350.252	1040350.252	kg/h
SPECIFIC HEAT	2.8	3.2	3.6	KJ/kg.ºC
DENSITY	998.3643293	978.5948592	958.8253892	kg/m3
MOLAR DENSITY	55.41819378	54.3208105	53.22342722	kmol/m3
VISCOSITY	0.692443475	0.507683962	0.322924449	cp
MW	18.02	18.02	18.02	g/mol
THERMAL CONDUCTIVITY	0.627494566	0.650796452	0.674098338	W/m.ºC
PRESSURE DROP		0		-
Molare Enthalpy	-285299.7773	-283347.3168	-281394.8564	KJ/Kmol
Enthalpy	-16475716895	-16362964667	-16250212439	KJ
Q		225504455.8		KJ/h

Table 3: Shell and tube heat exchanger data summary.

		E-105	
Q (kw)	1271402	Number of tubes	4350
Shell pass	1	Tube arrangement	triangular
Tube pass	2	Tube pitch (mm)	23.75
Heat transfer Area(m²)	953	Bundle dimeter (m)	1.16
Tube dimension		Shell dimeter (m)	1.254
d_o (mm)	19	Baffle spacing (m)	0.629
		Baffle cut	25%
d_i (mm)	13.46	Length (m)	3.66
U_t (m/s)	0.94	u_s (m/s)	35.43

Table 4: Summary design of absorber

Item	unit	value
ΔP_{Flood}	H_2O/ft	1.827
v_G	m/s	12.36
G_G	$kg/m^2.s$	99.498
$Area$	m^2	0.732
D	m	0.966
Z	m	3.2475
Total Hight	m	5.2475
t	mm	3.68

Table 7: Summary for Payback period

Item	Amount (USD)
Assumed Annual Revenue	$45,000,000
Total Annual Cost	$29,529,921
Net Cash Flow	$15,470,079
Payback Period	4 years

CONCLUSION

Blue hydrogen is considered a promising option in the field of sustainable energy. It is produced by using a process called Steam Methane Reforming (SMR), where natural gas reacts with steam to produce hydrogen, and the resulting carbon dioxide (CO_2) is captured and stored instead of being released into the atmosphere. This helps to reduce the environmental impact of hydrogen production, making it a cleaner alternative compared to traditional methods.

The goal of this project was to explore the technical and economic feasibility of producing blue hydrogen using advanced equipment, such as an efficient heat exchanger and optimized reactors, to make the process more sustainable and environmentally friendly. The project looked into different design aspects and focused on how to improve the efficiency of the equipment and reduce overall energy consumption. By doing so, the project aimed to support the transition toward cleaner energy and reduce greenhouse gas emissions.

The findings of this study showed that the project offers a positive return on investment with a relatively short payback period, which makes it attractive for large-scale applications. The project required an initial investment of approximately $60.4 million, with annual manufacturing costs estimated at around $29.5 million. Given the projected annual revenue of $45 million, the payback period for this investment is approximately 4 years. This result highlights the economic viability of producing blue hydrogen and suggests that this approach could be beneficial for industries looking to adopt more sustainable practices. In conclusion, this study demonstrates that blue hydrogen production is not only technically feasible but also economically attractive. With the right design and careful management of resources, blue hydrogen can play a significant role in reducing carbon emissions and supporting global efforts to combat climate change.