BLUE HYDROGEN, optimization of steam reforming method (SMR)

Team design CLUSTER#2 Team# 92 | **Coach: Dr. Ismael Al-Maraj**

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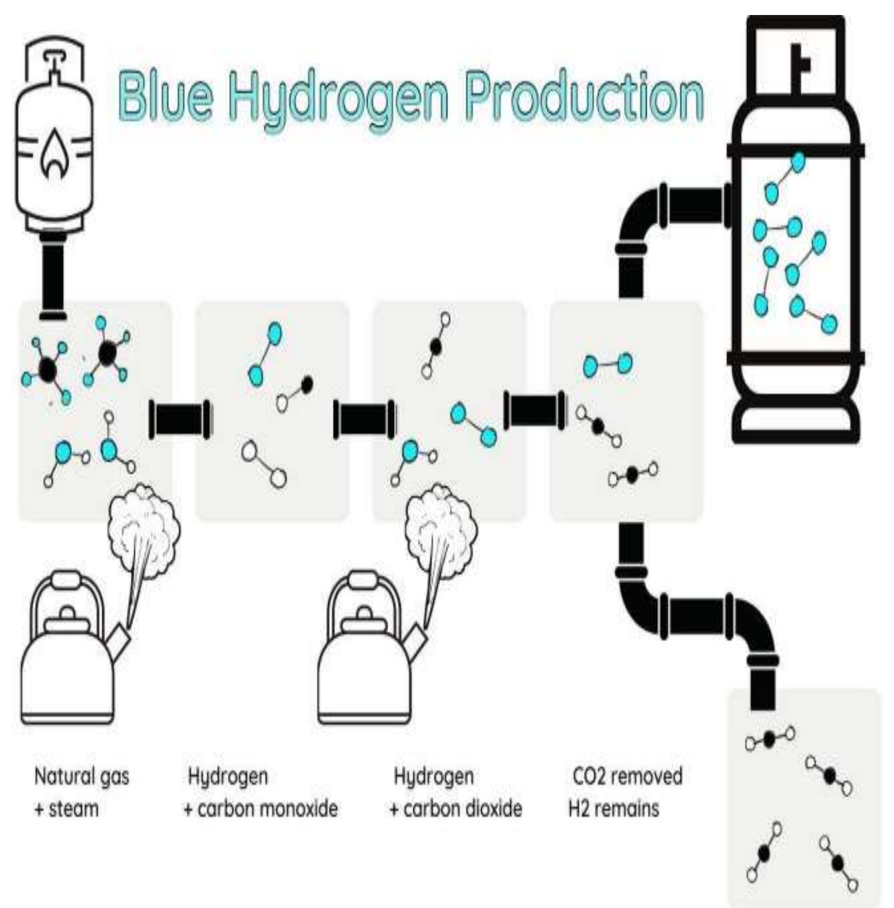
Problem Statement

In 2060, Saudi Arabia aims to achieve carbon neutrality by reducing and optimizing its CO2 emissions from all sectors. Thus, the kingdom initiated multiple programs to limit CO2 emissions from the industrial and public sectors. One particular area of focus is hydrogen, a versatile and environmentally friendly fuel that has the potential to revolutionize multiple sectors. However, the current methods of hydrogen production. Steam Methane Reforming (SMR) offers a promising pathway to produce hydrogen with reduced carbon emissions through the utilization of carbon capture and utilization (CCU) technologies.

Objective

The objective of this project is to design, develop, and validate a prototype system for the production of blue hydrogen through Steam Methane Reforming (SMR) with carbon capture and utilization (CCU).



Specifications and Constraints

1 High H2 purity Percentage (≥ 99.99%)

2 High CO2 purity percentage (>99.9%)

3 High CO2 capture rate with 99%

4 Affordability of the price
(Between 10 $/Kmol and 14 $/Kmol)

5 Steady supply (11,200 Kg/h)

Results and validation

1- The Hydrogen capacity produced (H2) is 105240 ton per year with purity of 99.99%.

2- The CO2 capacity produced is 266768 ton per year with purity of 99.9 %

3- Capture rate of CO2 is 65786 kg/h which is consider 99% of the inlet CO2

4- Our price for H2 is 12 $/Kmol

5- The amount of H2 supplied is 70160 ton per year

6- The conversion of methane is 99.96

Forecasting

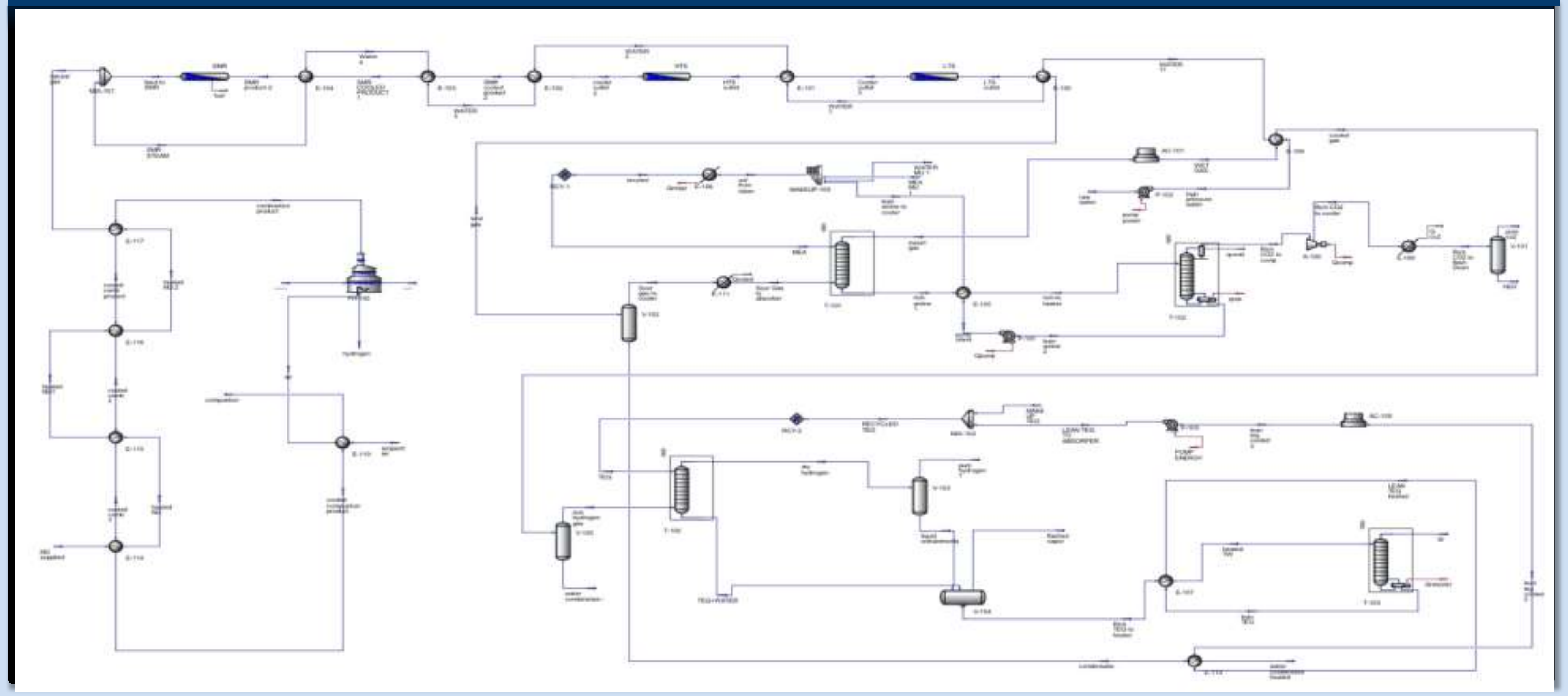
OLS Regression Results

Dep. Variable:	Next Year Production	R-squared:	0.948
Model:	OLS	Adj. R-squared:	0.865
Method:	Least Squares	F-statistic:	11.42
Date:	Wed, 25 Oct 2023	Prob (F-statistic):	0.00791
Time:	12:16:48	Log-Likelihood:	-44.485
No. Observations:	14	AIC:	107.0
Df Residuals:	5	BIC:	112.7
Df Model:	8		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
intercept	-4992.5138	2958.548	-1.687	0.152	-1.26e+04	2612.677
Hydrogen Production (MW)	0.9186	0.377	2.437	0.059	-0.051	1.888
CO2 Emissions	-33.1220	15.720	-2.107	0.089	-73.533	7.289
Average Global Temperature	427.6326	237.437	1.801	0.132	-182.719	1037.984
Gas Prices Index (Global)	0.3035	0.332	0.913	0.403	-0.551	1.158
gdppercapita_k	0.0309	1.049	0.029	0.978	-2.665	2.727
gdpgrowth_p	-11.7312	6.396	-1.834	0.126	-28.173	4.710
inflation_p	-2.8812	9.051	-0.318	0.763	-26.147	20.384
industrialgrowth_p	12.9071	6.643	1.943	0.110	-4.168	29.982

	Coefficients	2023 Data
intercept	-4992.513803	1
Hydrogen Production (MW)	0.918615	250
CO2 Emissions	-33.122009	37.2
Average Global Temperature	427.632614	15
Gas Prices Index (Global)	0.303535	180
gdppercapita_k	0.0309	21.07
gdpgrowth_p	-11.731182	0.03
inflation_p	-2.881231	2.3
industrialgrowth_p	12.907055	-2
Hydrogen Demand 2024	441.98	

Final prototype design



Optimization model

Objective functions:

Objective 1: Maximize Hydrogen Production (Z_1)
Maximize Z_1: $Z_1 = RH_2 * H_2$
Objective 2: Maximize Carbon Dioxide Capture (Z_2)
Maximize Z_2: $Z_2 = RCO_2 * CO_2$
Objective 3: Maximize Profit (Z_3)
Maximize Z_3: $Z_3 = RH_2 * H_2 + RCO_2 * CO_2 - (CH_2*H_2 + CCH_4 *CH_4 + CCO_2 * CO_2 + CT * (Tmax-T) + CP * (Pmax-P) + CTEG * FTEG + CMEA * FMEA + CTHTS * (THTS-T) + CTLTS * (T-TLTS))$

Results

H2t: 5994	FMEA: 15680	Objective Function Values:
CH4: 1490	THTS: 400	Z1: 71928.0
CO2: 1494	TLTS: 205	Z2: 2988.0
T: 900	TTEG: 35	Z3 (Profit):
P: 7.0	TABS: 50	63834.1
FTEG: 580	PABS: 5	

Conclusion

70080 Tons Annually

H2 price is 12 $/Kmol

266768 Tons Annually

Low CO2 emission

H2 and CO2 production will support local industry