Project Report

Carbon and Energy Balance in the Gasifier
&
Regression Analysis of Gasifier's Methane Output

Name: Chaitanya Kumar

Branch: Chemical Engineering

Department: Coal Gasification Plant (CGP)

College: Indian Institute of Technology Hyderabad (IITH)

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Preface

In a coal gasification plant, the purpose of conducting a carbon and energy balance is to ensure efficient and optimal operation. Monitoring carbon input and output helps in assessing the amount of carbon dioxide and other carbon-based emissions released into the atmosphere. Whereas energy balance helps in determining the overall thermal efficiency of the plant. By comparing the energy input (coal and other inputs) with the energy output (syngas, heat, and by-products), we can manage the efficiency of the gasification process. Energy balance is essential for controlling operating costs. Continuous energy balance calculations allow to monitor the performance of the gasification process in real-time, facilitating timely interventions and adjustments to maintain optimal performance

Company Overview

About JSP

JSPL (Jindal Steel and Power Limited) is a leading Indian steel manufacturer known for its integrated steel plants and advanced technology. With operations in steel, power, mining, and infrastructure, JSPL is committed to sustainable practices and community development. The company's facilities, including the major plant in Angul, Odisha, contribute significantly to the local economy through job creation and support for ancillary industries. JSPL focuses on innovation, efficiency, and environmental responsibility in its operations.

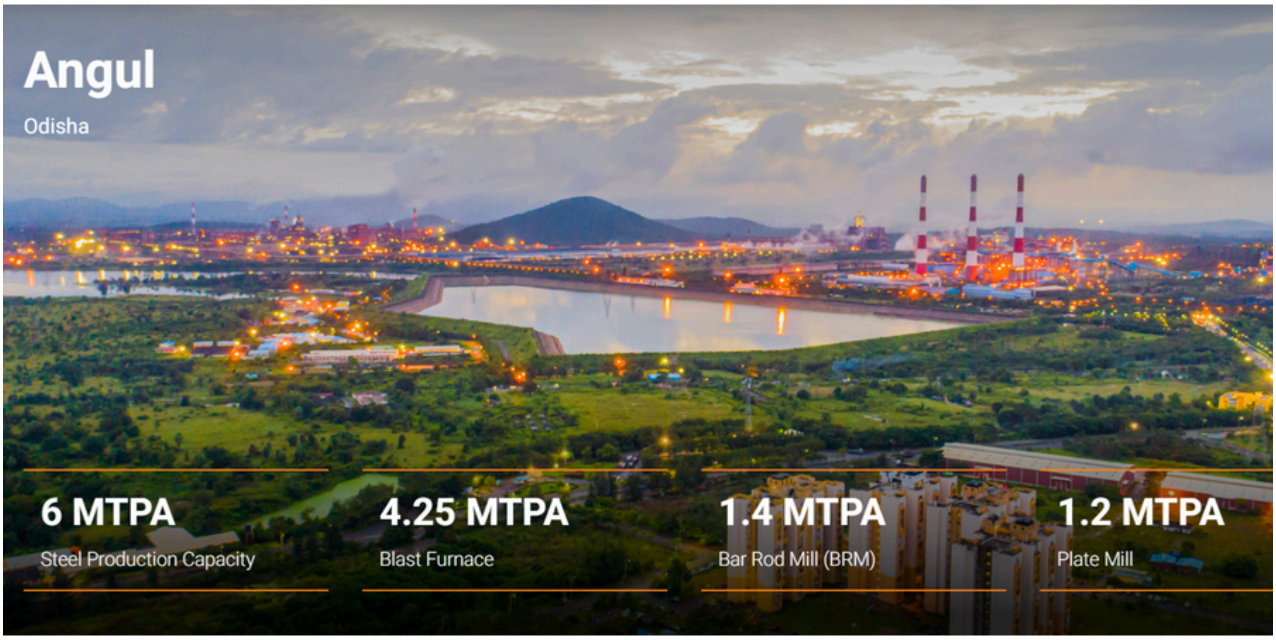
About JSP Angul

Jindal Steel and Power (JSP) Angul is a major industrial facility in Odisha, India, renowned for its steel and power production. It utilizes advanced technology, emphasizing sustainability and innovation, contributing significantly to India's industrial growth.

Future of JSP Angul

The future of JSP Angul is promising, driven by strategic expansions in steel production and power generation, adoption of green technologies, and a strong focus on sustainability. With supportive policies and increasing infrastructure development in India, JSPL is well-positioned for growth and continued success in both domestic and international markets.

History



Origin

JSP operates a pioneering coal gasification plant at its Angul, Odisha, steel complex. Commissioned in April 2015, this plant converts high-ash Indian coal into synthetic gas (syngas), used in the Direct Reduced Iron (DRI) process. The utilization of syn gas reduces reliability on imported natural gas, enhances cost efficiency, and minimizes environmental impact. The coal gasification plant at Angul underscores JSPL's commitment to leveraging domestic resources and sustainable steel production practices, setting a benchmark in the Indian steel industry.

Current Developmental status

JSPL's future development plans for its coal gasification plant in Angul include increasing production capacity and enhancing the efficiency of the gasification process. The company aims to leverage this technology to produce additional steel and reduce costs further. Emphasis will be on ensuring a stable supply of coal and possibly expanding the use of syngas in other industrial processes. This aligns with JSPL’s broader goals of sustainability and innovation in steel manufacturing. The successful operation of this plant is critical to JSPL's strategy for self-reliance and environmental stewardship.

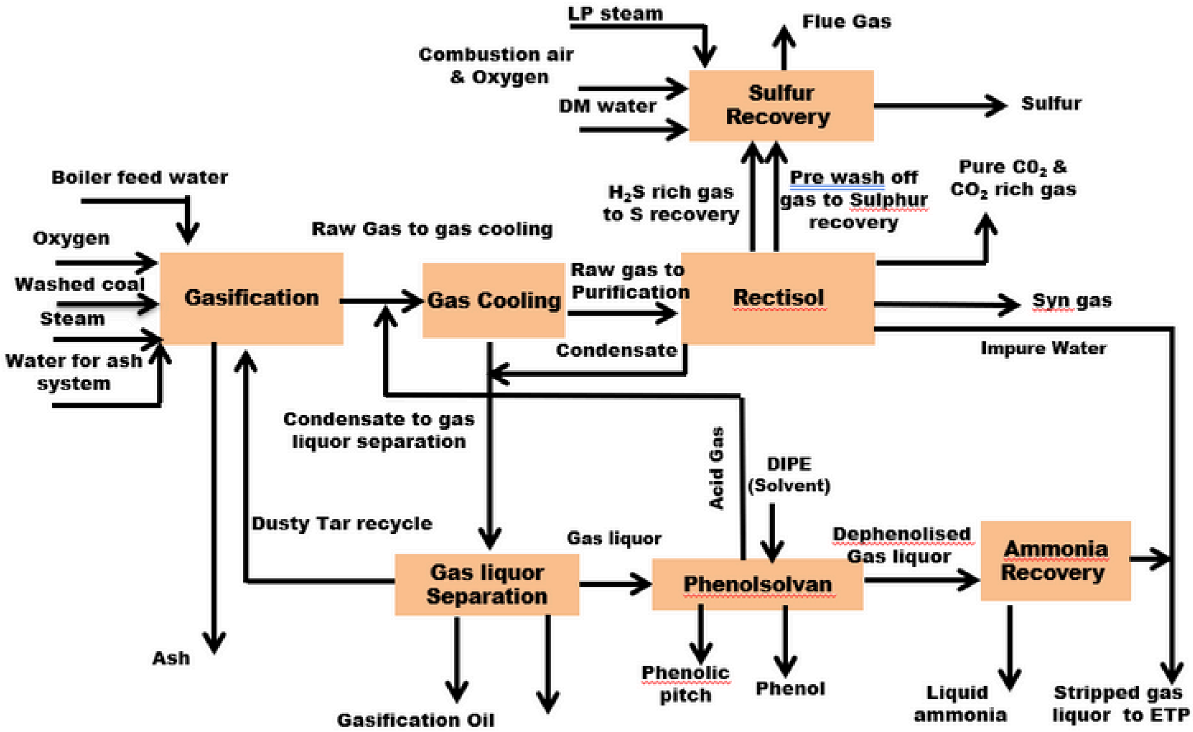
Introduction

This research examines carbon and energy balance calculations for coal gasification, with a focus on system efficiency.

The research involves quantifying carbon at different phases of the operation and calculating total efficiency. The process starts with raw gas data and converts volumes to moles to determine carbon content in each component. Carbon content in coal is calculated using a fixed carbon percentage, but carbon in ash is calculated using a predetermined proportion. The volatile stuff in coal is also calculated. Efficiency is measured by comparing carbon output to carbon input from coal. Energy calculations begin with the total heat from coal gasification, which is calculated by multiplying coal mass by its gross calorific value. The latent heat of high-pressure steam is computed similarly.

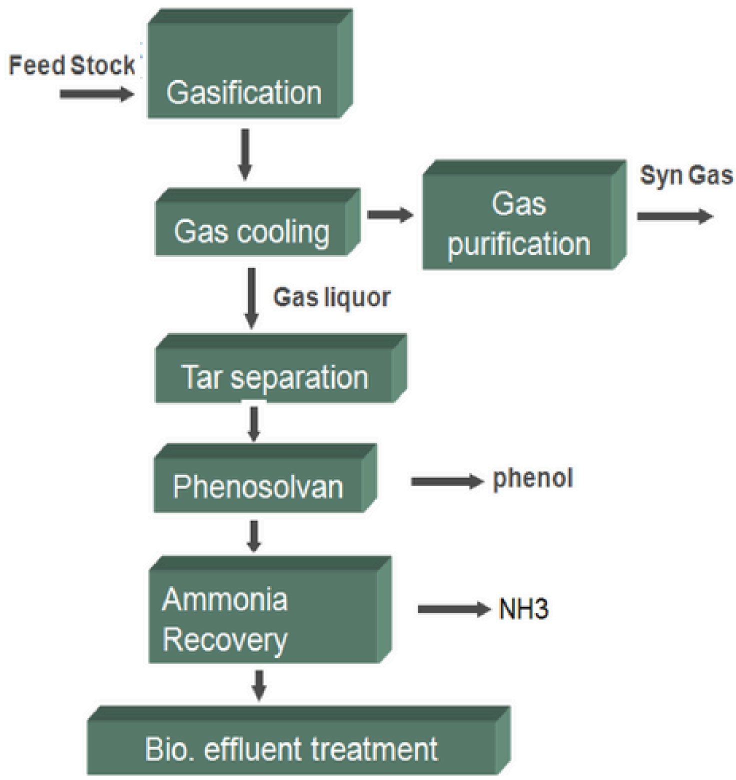
The total heat energy of raw gas is calculated by combining the mixture's density and the ideal gas equation, as well as its calorific value. Efficiency is calculated by comparing raw gas output to total energy input from coal and steam.

CGP Overview



CGP consists of multiple units that work together to achieve the required production of syn gas:

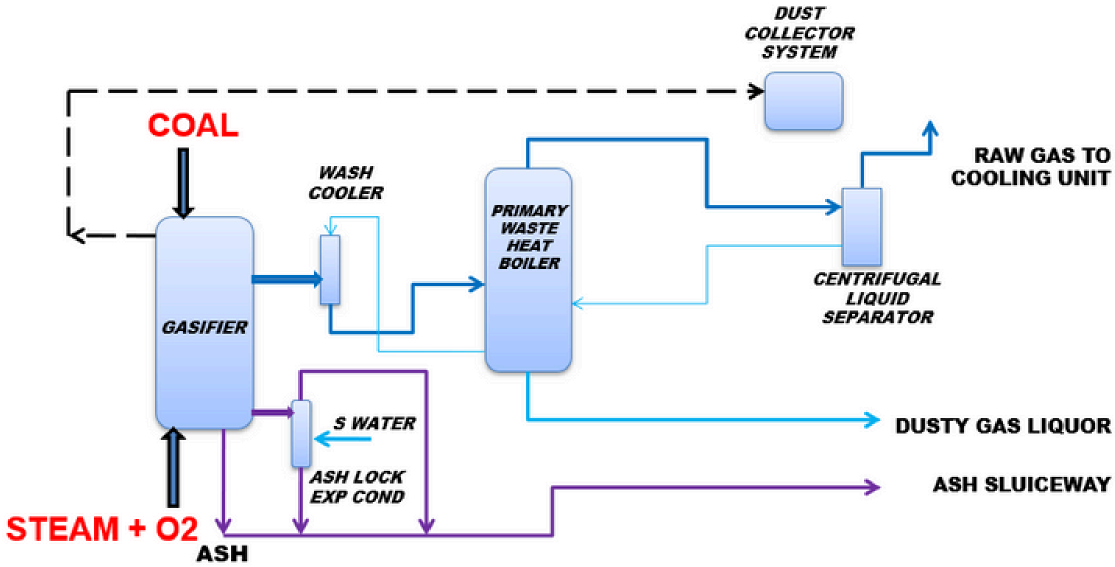
Unit 3: Gasification Unit
Unit 4: Gas Cooling Unit
Unit 5: Gas Liquor Separation Unit
Unit 6: Phenosolvan Unit
Unit 7: Ammonia Recovery Unit
Unit 8: Rectisol Unit
Unit 9: Sulfur Recovery Unit



Gasifier Unit

Objective:

The Gasification unit aims to convert coal into raw gas using seven Sasol-Lurgi FBDB Mark IV gasifiers. The process utilizes high pressure steam and pure oxygen. These gasifiers can operate independently, ensuring continuous production even during maintenance.



Process Description:

Gasifier Design: The gasifier is a double-walled vessel with boiler feed water maintained between the outer shell and inner wall to protect against high temperatures.

Coal Feeding: Lump coal (5-50mm) is fed batch-wise into the gasifier.

Temperature Control: The combustion zone temperature is controlled to prevent clinker formation and ensure smooth ash discharge.

Heat Exchange: Heat is exchanged in two ways:

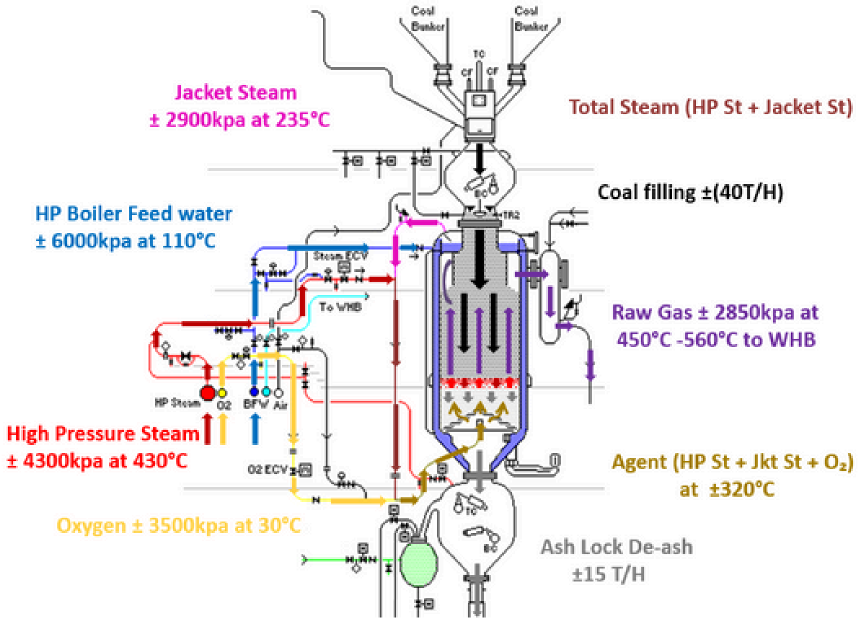
a. Between high-temperature ash and the gasification agent.
b. Between high-temperature raw gas and low-temperature coal.

Raw Gas Cooling: Raw gas exits the gasifier at 450-550°C and is quenched to 198°C in the wash cooler, then further cooled in the waste heat boiler.

Gasifier

The **coal bunker** serves as a storage container for coal before it is fed into the gasifier. It acts as a reserve for storage feeding and buffering operations.

The **coal lock** transfers coal from atmospheric pressure to the high-pressure gasifier while maintaining a pressure seal, ensuring safe and controlled feeding.



The **gasifier** converts coal into Raw gas through a process of partial oxidation at high temperatures. It facilitates the breakdown of coal into gaseous components, enhancing energy extraction efficiency.

The **Ash lock** removes ash and other solid residues from the gasifier while maintaining a pressure seal to prevent gas escape. It ensures the continuous operation of the gasifier by periodically discharging ash without disrupting the high-pressure environment.

An **Ash sluiceway** facilitates the removal of ash generated during the gasification process. It directs the ash slurry away from the gasifier, ensuring continuous operation by preventing buildup that could hinder efficiency or damage equipment.

Reaction Zones

1.Ash Bed: Superheats the gasification agent.
2.Combustion Zone: Main reactions occur, raising temperatures to ~1500°C.
3. Gasification Zone: Key reactions produce CO and H2, with minor influences from other reactions.
4.Carbonization Zone: Drives out coal volatiles and cracks recycled tar.
5.Drying and Preheating Zone: Dries and heats wet screened coal.

Carbon and Energy Balance

Carbon Balance Calculations

Control Room Data (Sample for 24 Hours):

1. Raw Gas (Nm3) = 3162094
2. Coal (kg) = 2925000
3. Ash Produced (kg) = 821930
4. Volatile Matter in Coal (%) = 33.72
5. Raw gas Data:
   a. CO (Vol%) = 21.61
   b. CO2 (Vol%) = 27.99
   c. CH4 (Vol%) = 10.94
   d. OHC (Vol%) = 0.91

Assumptions:

1. Percentage of Carbon in Ash: 3%
2. Percentage of Carbon in Volatile Matter: 15%
3. Percentage Of Fixed Carbon in Coal: 47.47%

Calculations Based on Sample Data:

Step 1: Volume of each component of Raw Gas

Raw gas (liter) = Raw gas (Nm3) * 1000 = 3162094000

Volume of CO (liter) = (21.61 * 3162094000)/100= 683328513.4

Volume Of CO2 (liter) = (27.99 * 3162094000)/100 = 885070110.6

Volume Of CH4 (liter) = (10.94 * 3162094000)/100 = 345933083.6

Volume Of OHC (liter) = (0.91 * 3162094000)/100 = 28775055.4

Step 2: Moles of each component of Raw Gas

Moles Of CO = Total Volume of CO / 22.4 = 683328513.4 / 22.4 =30505737.205

Moles Of CO2 = Total Volume of CO2 / 22.4 = 885070110.6 / 22.4 = 39512058.509

Moles Of CH4 = Total Volume of CH4 / 22.4 = 345933083.6 / 22.4 = 15443441.232

Moles Of OHC = Total Volume of OHC / 22.4 = 28775055.4 / 22.4 = 1284600.688

Step 3: Amount Of Carbon in each component of Raw Gas

Carbon in CO = (Moles * 12) / 1000 = (30505737.205 * 12)/1000 = 366068.8465

Carbon in CO2 = (Moles * 12) / 1000 = (39512058.509 * 12)/1000 = 474144.7021

Carbon in CH4 = (Moles * 12) / 1000 = (15443441.232 * 12)/1000 = 185321.2948

Carbon in OHC = (Moles * 12) / 1000 = (1284600.688 * 12)/1000 = 15415.20825

Total Carbon from Raw Gas = 1040950.052 Kg

Step 4: Amount Of Carbon in Coal

Carbon in Coal = (47.47 * Coal) / 100 = 1388497.5 Kg

Step 5: Amount Of Carbon in Ash

Carbon in Ash = (3 * Ash) / 100 = 24657.9 Kg

Step 6: Volatile Matter in Coal

Mass Of Volatile Matter = (2925000 * 33.72)/100=986310*0.15=147946.5 Kg

Step 7: Efficiency Calculation

Efficiency = Carbon (Out)/ Carbon (In) * 100

= (Carbon (ash) + Carbon (raw gas) + Volatile Matter (coal) / (Carbon (coal))

= (24657.9 + 1040950.52 + 147946.5) / (1388497.5) = 87.40054999 %

Energy Balance Calculations

Control Room Data (Sample):

1. Raw Gas (Nm3) = 3162094
2. HP Steam (Kg) = 2651000
3. Coal (kg) - 2925000
4. Ash(kg) - Energy loss due to temp change

Assumptions:

1. Heat from Raw Gas: 3111 Kcal/Kg
2. Net Calorific Value of Coal: 4900 Kcal/Kg
3. Heat from HP Steam: 700 Kcal/Kg

Calculations Based on Sample Data:

Step 1: Heat from Coal Gasification

Total Heat from Coal = Mass of Coal * NCV Of Coal

= 2925000 (Kg) * 4900(Kcal/Kg)

= 14332500000 Kcal

Step 2: Latent Heat from HP Steam

Total Latent Heat from HP Steam = Mass of HP Steam * Latent Heat from HP Steam

= 2651000 (Kg) *700(Kcal/Kg)

= 1855700000 Kcal

Step 3: Raw Gas Density Calculation:

Using Ideal Gas Equation at STP Conditions

Taking into account major components and their density:

Raw Gas Density Calculations				
Raw Gas Components	Compositions(Vol %)	Density(kg/m3)	Molecular Mass(g/mol)	Xi*Mi
CH4	10.04	0.668	16	1.6064
H2	41.14	0.0899	2	0.8228
CO2	26.76	1.842	44	11.7744
O2	0.1	1.331	32	0.032
CO	20.25	1.165	38	7.695
N2	0.35	1.165	28	0.098
H2S	0.21	1.434	34	0.0714
			Average Molecular Mass	22.1

$$PM = \rho RT$$

$$\Rightarrow \rho = PM/RT = 1(atm) * 22.1(g/mol) / 0.0821 (atm\, L\, mol^{-1}K^{-1}) * 298 (K)$$

$$\Rightarrow \rho = 0.90\, g/L = 0.9\, Kg/m^3$$

Step 4: Accounting for Energy loss because of temperature change due to cooling:

The Cp of the mixture is calculated using this formula:

$$C_{p\,mixture} = \left(\frac{m_1}{m_{mixture}}\right)C_{p\,1} + \left(\frac{m_2}{m_{mixture}}\right)C_{p\,2}$$

Where:

C_p = Heat Capacity

m = Mass

$m_{mixture}$ is $m_1 + m_2$

Raw Gas Specific Heat Calculations						
Raw Gas Components	Compositions(Vol %)	Density(kg/m3)	Mass Percent	Mass Fraction	Cpi	Mi*Cpi
CH4	10.04	0.668	0.0670672	0.07971818404	0.533	0.04248979209
H2	41.14	0.0899	0.03698486	0.04396136824	3.4	0.149468652
CO2	26.76	1.842	0.4929192	0.5858992697	0.81	0.4745784085
O2	0.1	1.331	0.001331	0.001582068477	0.22	0.000348055064
CO	20.25	1.165	0.2359125	0.28041302	1.04	0.2916295408
N2	0.35	1.165	0.0040775	0.004846644789	0.25	0.001211661197
H2S	0.21	1.434	0.0030114	0.003579444787	0.24	0.000859066748
Summation			0.84130366		Average Cp	0.9605851763

Cp=0.96 Kcal/kg.K

The Cp thus calculated is added to the Raw gas calorific value so as to inculcate energy loss because of temperature change.

Cp (dT) = 0.96* (dT) =0.96119 * 400 = 384.23 Kcal/Kg

Raw gas heat value = 3111 + 384.23 = 3495.23 Kcal/Kg

Step 5: Heat From Raw Gas:

Heat from raw gas = raw gas heat(Kcal/Kg) * density (Kg/m3) * Volume of raw gas(m3)

= 3495(Kcal/Kg) * 0.90(Kg/m3) *3162094(m3)

= 9947021230 Kcal

Step 6: Efficiency Calculation:

Efficiency = Energy(Out) / Energy(In) * 100

= Energy (raw gas)/(Energy (Coal) + Energy (HP Steam))

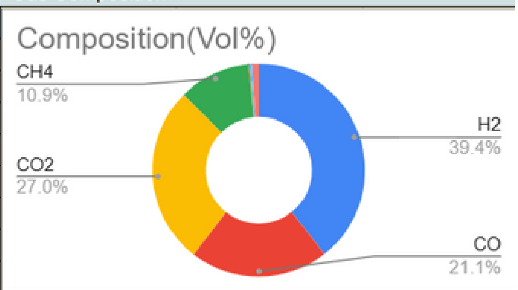
= 9947021230 (Kcal) /(14332500000 (Kcal)+1855700000 (Kcal)

= 61.4461226 %

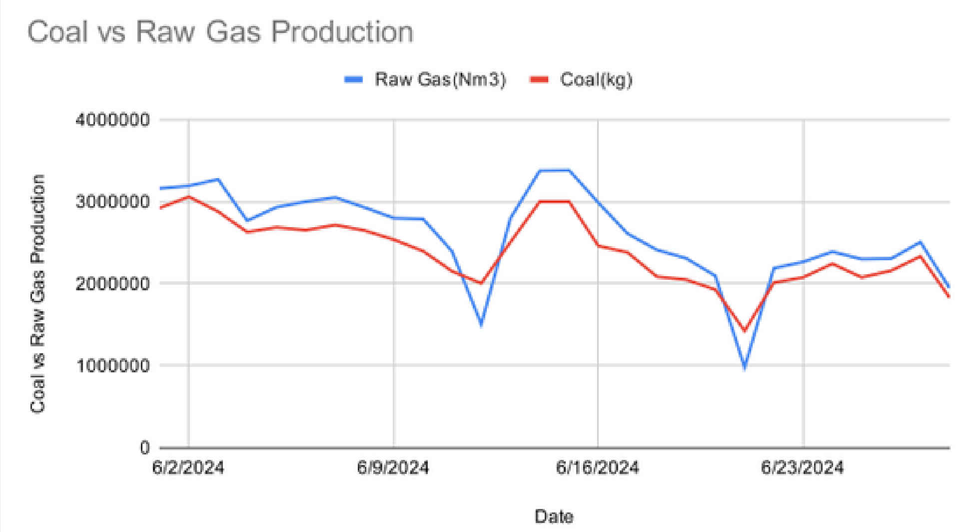
Carbon Balance Data

One Month Data(24-Hour-Basis)												
	INPUT		OUTPUT									
Date	Coal(kg)	VM%	Raw Gas (Nm3)	H2 (Vol%)	CO (Vol%)	CO2 (Vol%)	CH4 (Vol%)	O2 (Vol%)	N2 (Vol%)	H2S (Vol%)	Other HCs (Vol%)	Ash (kg)
6/1/2024	2,925,000.00	33.72	3,162,094.00	38.12	21.61	27.99	10.94	0.07	0.16	0.2	0.91	821930
6/2/2024	3,061,000.00	32.4	3,194,007.00	37.98	21.86	27.75	10.87	0.11	0.17	0.2	1.06	903810
6/3/2024	2,880,000.00	33.03	3,272,797.00	38.51	21.29	28.25	10.2	0.13	0.45	0.16	1	831900
6/4/2024	2,631,000.00	34	2,769,730.00	38.22	21.7	28.06	10.39	0.09	0.18	0.21	1.16	699320
6/5/2024	2,688,000.00	33.53	2,933,680.00	39.67	21.57	26.86	10.34	0.14	0.33	0.21	0.88	711240
6/6/2024	2,654,000.00	33.58	3,001,231.00	39.13	22.57	27.57	9.17	0.19	0.28	0.22	0.86	680670
6/7/2024	2,718,000.00	33.13	3,052,871.00	39.08	21.59	27.48	10.33	0.12	0.16	0.2	1.03	719500
6/8/2024	2,650,000.00	31.71	2,931,219.00	41.72	20.73	26.09	9.74	0.13	0.27	0.2	1.11	755460
6/9/2024	2,539,000.00	32.04	2,801,329.00	41.14	20.25	26.76	10.04	0.1	0.35	0.21	1.15	662170
6/10/2024	2,399,000.00	34.37	2,790,345.00	39.51	21.23	26.58	10.79	0.12	0.47	0.2	1.1	618180
6/11/2024	2,153,000.00	35.38	2,395,683.00	40.65	20.55	26.55	10.67	0.06	0.25	0.23	1.04	518870
6/12/2024	2,006,000.00	34.79	1,509,849.00	40.24	20.76	26.5	10.79	0.07	0.35	0.23	1.05	458370
6/13/2024	2,510,000.00	34.99	2,801,768.00	39.75	21.02	26.71	11.03	0.08	0.15	0.23	1.04	621440
6/14/2024	3,002,000.00	35.26	3,378,980.00	39.34	21.33	26.85	11.03	0.11	0.12	0.25	0.97	694.96
6/15/2024	3,002,000.00	35.73	3,385,001.00	39.84	21.71	26.28	10.68	0.12	0.15	0.25	0.98	672.45
6/16/2024	2,463,000.00	36.01	2,988,753.00	39.67	21.14	26.12	11.51	0.13	0.54	0.25	1.03	557.13
6/17/2024	2,382,000.00	35.89	2,611,857.00	39.92	21.01	26.28	11.29	0.11	0.13	0.28	0.98	536.19
6/18/2024	2,088,000.00	36.31	2,413,551.00	39.57	20.87	26.25	11.84	0.04	0.12	0.3	1	462.7
6/19/2024	2,051,000.00	36.31	2,311,527.00	39.49	20.08	26.75	12.14	0.12	0.12	0.29	1	439.12
6/20/2024	1,930,000.00	36.22	2,097,389.00	39.68	19.93	27.04	11.73	0.14	0.16	0.28	1.04	416.11
6/21/2024	1,426,000.00	36.15	981,078.00	38.6	19.5	28.23	12.08	0.1	0.2	0.22	1.1	295.61
6/22/2024	2,015,000.00	35.4	2,190,756.00	38.99	19.12	28.3	12	0.08	0.15	0.26	1.11	464.46
6/23/2024	2,079,000.00	34.68	2,267,406.00	38.98	20.08	27.8	11.36	0.08	0.26	0.26	1.18	514.14
6/24/2024	2,245,000.00	34.52	2,391,240.00	38.75	21.03	27.79	10.79	0.12	0.23	0.23	1.06	619.17
6/25/2024	2,079,000.00	35.42	2,300,943.00	39.24	20.73	27.63	10.7	0.12	0.23	0.27	1.07	499.38
6/26/2024	2,160,000.00	35.04	2,306,127.00	39.18	22.94	25.75	10.73	0.04	0.11	0.27	0.99	501.34
6/27/2024	2,335,000.00	35.23	2,508,641.00	38.94	22.21	26.58	10.86	0.05	0.11	0.26	0.98	573.48
6/28/2024	1,831,000.00	34.77	1,946,925.00	39.36	21.95	26.32	10.89	0.08	0.13	0.28	0.99	473.86

Average Raw Gas Composition	
Components	Avg Composition(Vol%)
H2	39.4025
CO	21.08428571
CO2	27.04
CH4	10.89035714
O2	0.1017857143
N2	0.2260714286
H2S	0.2375
OHC	1.031071429



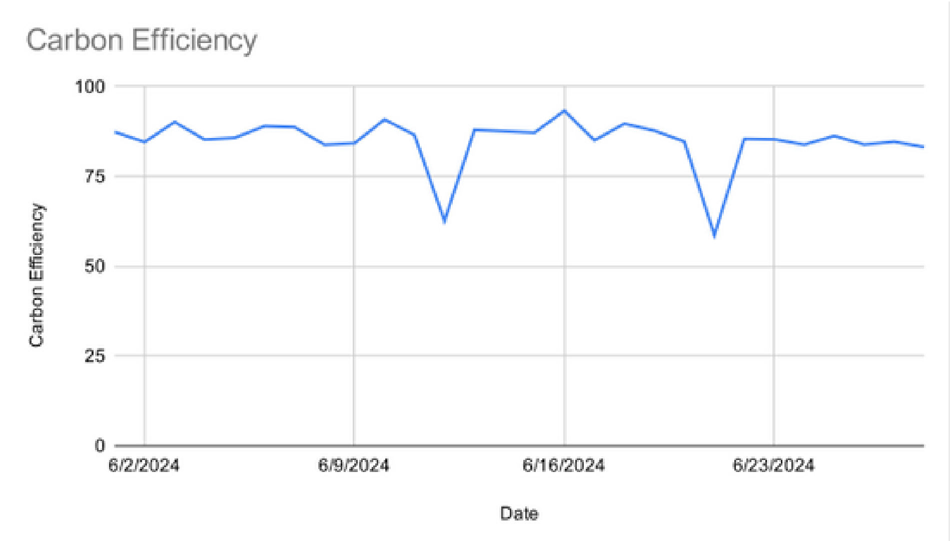
Average Composition of the Raw Gas over the month of observations



Coal vs Raw Gas Trends over the month of observations

Carbon Balance Calculations

	INPUT	OUTPUT			
Date	Input Carbon (in Coal)	Total Carbon in Raw Gas	Carbon in VM	Carbon in Ash	Carbon Efficiency
6/1/2024	1388497.5	1,040,950.05	147946.5	24657.9	87.40054999
6/2/2024	1453056.7	1,052,995.66	148764.6	27114.3	84.57168704
6/3/2024	1367136	1,064,944.77	142689.6	24957	90.1586504
6/4/2024	1248935.7	909,707.93	134181	20979.6	85.26207767
6/5/2024	1275993.6	937,467.92	135192.96	21337.2	85.73695679
6/6/2024	1259853.8	967,414.66	133681.98	20420.1	89.01959392
6/7/2024	1290234.6	988,312.47	135071.01	21585	88.74110807
6/8/2024	1257955	905,589.64	126047.25	22663.8	83.81068412
6/9/2024	1205263.3	873,414.36	122024.34	19865.1	84.23917025
6/10/2024	1138805.3	892,412.12	123680.445	18545.4	90.85292886
6/11/2024	1022029.1	754,768.49	114259.71	15566.1	86.55275032
6/12/2024	952248.2	478,028.98	104683.11	13751.1	62.63736577
6/13/2024	1191497	897,566.39	131737.35	18643.2	87.95212589
6/14/2024	1425049.4	1,089,359.02	158775.78	20.8488	87.5868335
6/15/2024	1425049.4	1,081,689.16	160892.19	20.1735	87.197084
6/16/2024	1169186.1	957,468.37	133038.945	16.7139	93.27206599
6/17/2024	1130735.4	833,368.94	128234.97	16.0857	85.04376885
6/18/2024	991173.6	775,267.06	113722.92	13.881	89.69204401
6/19/2024	973609.7	742,619.33	111707.715	13.1736	87.74976406
6/20/2024	916171	671,239.39	104856.9	12.4833	84.71221748
6/21/2024	676922.2	320,129.26	77324.85	8.8683	58.71619716
6/22/2024	956520.5	710,391.75	106996.5	13.9338	85.45579394
6/23/2024	986901.3	733,910.73	108149.58	15.4242	85.32522342
6/24/2024	1065701.5	777,195.70	116246.1	18.5751	83.83777032
6/25/2024	986901.3	741,191.26	110457.27	14.9814	86.29672646
6/26/2024	1025352	746,320.35	113529.6	15.0402	83.86046846
6/27/2024	1108424.5	814,815.56	123393.075	17.2044	84.64499257
6/28/2024	869175.7	627,361.81	95495.805	14.2158	83.16751556
Average	1134227.836	835,210.75	123670.7877	9654.192964	84.76764696

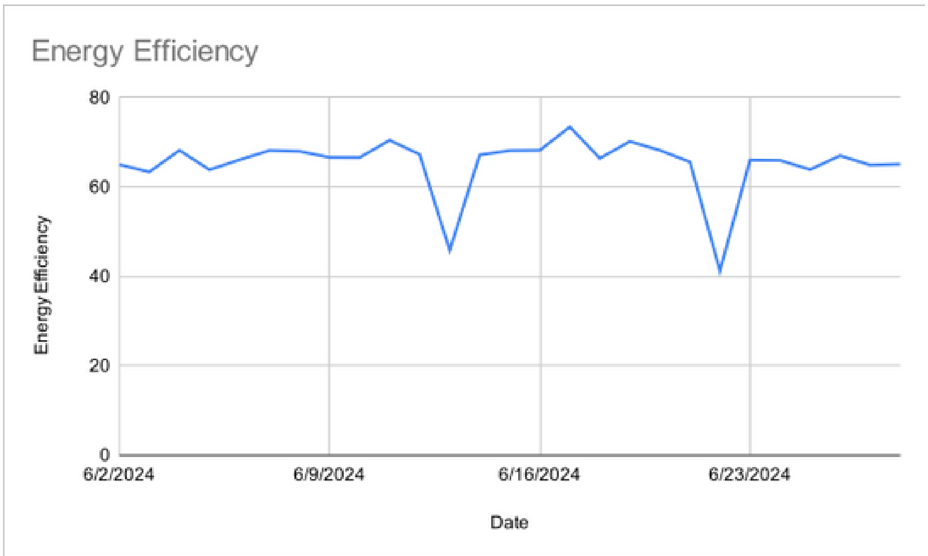


Coal vs Raw Gas Trends over the month of observations

[Link for the Carbon balance Sheet]

Energy Balance Calculations

	Input Energy			Output Energy	
Date	Heat from Coal (Kcal)	Heat from HP Steam (Kcal)	Input Energy (Kcal)	Heat in Raw Gas (Kcal)	Energy Efficiency
6/1/2024	13455000000	1855700000	15310700000	9947021230	64.96777568
6/2/2024	14080600000	1781500000	15862100000	10047410178	63.34224458
6/3/2024	13248000000	1855000000	15103000000	10295260432	68.16698955
6/4/2024	12102600000	1547000000	13649600000	8712759049	63.83160715
6/5/2024	12364800000	1609300000	13974100000	9228497712	66.04001483
6/6/2024	12208400000	1647800000	13856200000	9440993365	68.13551598
6/7/2024	12502800000	1632400000	14135200000	9603437675	67.93987828
6/8/2024	12190000000	1657600000	13847600000	9220756127	66.58739512
6/9/2024	11679400000	1560300000	13239700000	8812160245	66.55860967
6/10/2024	11035400000	1430100000	12465500000	8777607799	70.41520837
6/11/2024	9903800000	1300600000	11204400000	7536116783	67.26033329
6/12/2024	9227600000	1138900000	10366500000	4749542568	45.81625976
6/13/2024	11546000000	1581300000	13127300000	8813541210	67.13902486
6/14/2024	13809200000	1796900000	15606100000	10629281039	68.10978424
6/15/2024	13809200000	1810200000	15619400000	10648221341	68.1730498
6/16/2024	11329800000	1477000000	12806800000	9401741233	73.41210321
6/17/2024	10957200000	1417500000	12374700000	8216136848	66.3946346
6/18/2024	9604800000	1218000000	10822800000	7592324276	70.15120187
6/19/2024	9434600000	1232700000	10667300000	7271386665	68.16520267
6/20/2024	8878000000	1183000000	10061000000	6597771259	65.57768869
6/21/2024	6559600000	926100000	7485700000	3086183932	41.22772663
6/22/2024	9269000000	1171800000	10440800000	6891476484	66.00525328
6/23/2024	9563400000	1257200000	10820600000	7132594926	65.91681539
6/24/2024	10327000000	1449700000	11776700000	7522140407	63.87307486
6/25/2024	9563400000	1244600000	10808000000	7238092502	66.96976778
6/26/2024	9936000000	1246000000	11182000000	7254399847	64.87569171
6/27/2024	10741000000	1386700000	12127700000	7891449554	65.0696303
6/28/2024	8422600000	1204000000	9626600000	6124455601	63.62013173
Average	10991042857	1450675000	12441717857	8167241439	65.13366478



Energy efficiency over the month of the observations

[Link for the Energy balance Sheet]

Findings

93.23%
Maximum Carbon Efficiency (on 16th June)

69.40%
Maximum Energy Efficiency (on 16th June)

84.76%
Average Carbon Efficiency (for June)

61.58%
Average Energy Efficiency (for June)

58.7%
Minimum Carbon Efficiency (on 21st June)

38.99%
Minimum Energy Efficiency (on 21st June)

Conclusion

This project has identified key areas for improvement in the gasification process, such as enhancing conversion efficiencies, reducing energy losses, and implementing advanced carbon capture and storage technologies. Addressing these aspects can lead to substantial improvements in the economic and environmental performance of the coal gasification plant.

this project underscores the importance of integrating advanced technologies and sustainable practices in industrial processes. The insights gained from the carbon and energy balance analysis not only enhance the operational efficiency of the coal gasification plant but also support the global transition towards a low-carbon economy.

Regression Analysis of Gasifier's Methane Output

Problem Statement:

The objective of this project is to predict the methane output (CH4_hr avg) of gasifiers used in a coal gasification plant. Understanding and predicting methane production is essential for optimizing plant operations and ensuring efficient resource utilization.

Data:

Average of TR5_0i_max	Outlet Temperature of 'i'th gasifier
Average of 03_TIC_1i08.DACA.PV	Ash lock Temperature of 'i'th gasifier
Average of 03_fi_1i08.DACA.PV	HP BFW Flow of 'i'th gasifier
Average of 08_PIC_1104.DACA.PV	Syngas Header Pressure
CO2_GG-0i	CO2 composition produced per hour by 'i'th gasifier
Load_GG-10i	HP O2 Flow in 'i'th gasifier
Count	Number of Gasifiers in Operation
VM(wt%)	Volatile Matter percentage
ASH(wt%)	Ash percentage
FC(wt%) :	Fixed Carbon percentage
CH4_hr avg :	Average Methane composition produced per hour

The dataset used includes operational parameters of gasifiers such as outlet temperatures, flow rates, pressures, and composition percentages of gases produced (CO_2 and CH_4). Additionally, parameters like volatile matter (VM), ash content (ASH), and fixed carbon (FC) percentages are considered, which influence gasification reactions and methane production.

Data Preprocessing:

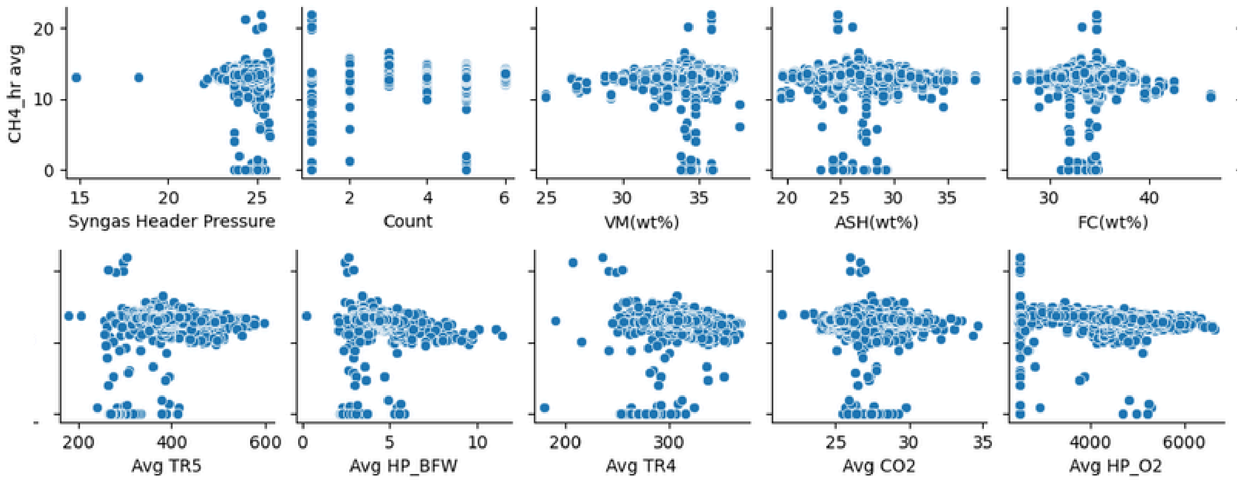
Calculated weighted averages of relevant parameters to better represent overall gasifier performance.

$$\text{weighted\_average}_i = \frac{1}{\text{Count}[i]} \sum_{j=1}^{\text{Count}[i]} \text{top\_values}_{ij}$$

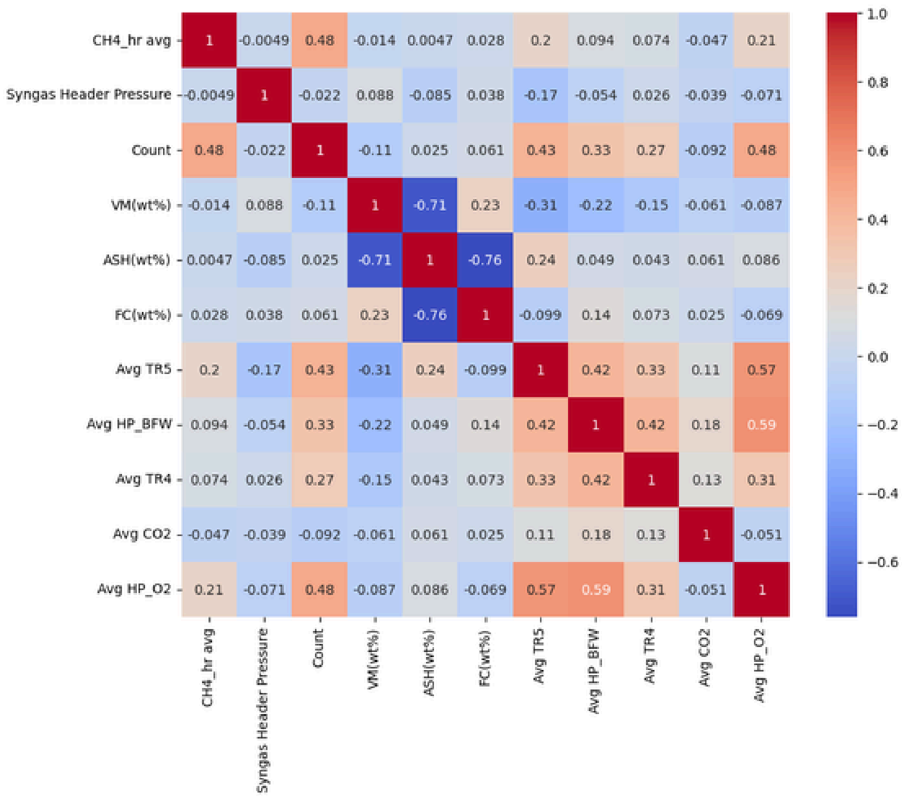
Data after pre-processing

	CH4_hr avg	Syngas Header Pressure	Count	VM(wt%)	ASH(wt%)	FC(wt%)	Avg TR5	Avg HP_BFW	Avg TR4	Avg CO2	Avg HP_O2
0	12.688833	22.193833	4.0	35.15	26.75	32.28	511.852167	6.230333	301.898833	27.135292	5697.218333
1	12.171667	21.966167	5.0	35.15	26.75	32.28	498.310067	5.630733	280.516933	28.675533	5372.799200
2	12.344333	24.495500	5.0	35.15	26.75	32.28	491.921533	5.510900	301.432733	26.369967	5130.564100
3	13.030000	24.680500	5.0	35.15	26.75	32.28	487.500133	5.471733	294.388567	27.072800	4926.512900
4	13.169333	24.084833	5.0	33.30	28.54	32.28	509.515333	5.785400	293.165333	27.593433	5045.142400
...	...	...	...	...	...	...	...	...	...	...	...
2752	13.553059	24.708252	5.0	35.66	25.92	33.45	414.695686	4.038034	300.599136	29.387188	4612.633206
2753	13.735909	24.994046	5.0	35.66	25.92	33.45	392.961530	4.421848	308.032909	28.911742	4321.878770
2754	13.452631	25.141703	5.0	32.15	29.39	31.20	386.366665	4.432533	300.522528	28.803951	4439.261580
2755	13.253233	24.670947	5.0	32.15	29.39	31.20	374.363907	4.634457	301.644080	29.255461	4383.122669
2756	13.143982	24.490545	5.0	32.15	29.39	31.20	369.870351	4.423925	308.096948	29.424167	4537.422454

Pair plot to check the relationship among the different parameters



Correlation Heatmap



Most Important parameters according to correlation

```
Count                     0.483044
Avg HP_O2                 0.210596
Avg TR5                   0.197118
Avg HP_BFW                0.094127
Avg TR4                   0.073779
Avg CO2                   0.046686
FC(wt%)                   0.028311
VM(wt%)                   0.014011
Syngas Header Pressure    0.004919
ASH(wt%)                  0.004734
```

Modeling

Linear Regression:

$$\log(y+1) = \beta_0 + \beta_1 \log(x_1+1) + \beta_2 \log(x_2+1) + \cdots + \beta_p \log(x_p+1)$$

y: Target variable (methane production).

$x_1, x_2, \ldots, x_p$: Predictor variables (e.g., `Syngas Header Pressure`, `Avg TR5`, etc.).

β_0: Intercept.

$\beta_1, \beta_2, \ldots, \beta_p$: Coefficients of predictor variables.

The Linear regression function in log-transformed space is:

log(y+1) = -2.51950 + (-0.23523*log(Syngas Header Pressure+1)) + (0.86743*log(Count+1)) + (0.65019*log(VM(wt%)+1)) + (0.34590*log(ASH(wt%)+1)) + (0.39486*log(FC(wt%)+1)) + (0.10683*log(Avg TR5+1)) + (0.02699*log(Avg HP_BFW+1)) + (-0.18181*log(Avg TR4+1)) + (0.11390*log(Avg CO2+1)) + (-0.06056*log(Avg HP_O2+1))

```
RMSE: 0.19288490196196537
R2 Score: 0.765241007061623
```

Support Vector Machine(SVR):

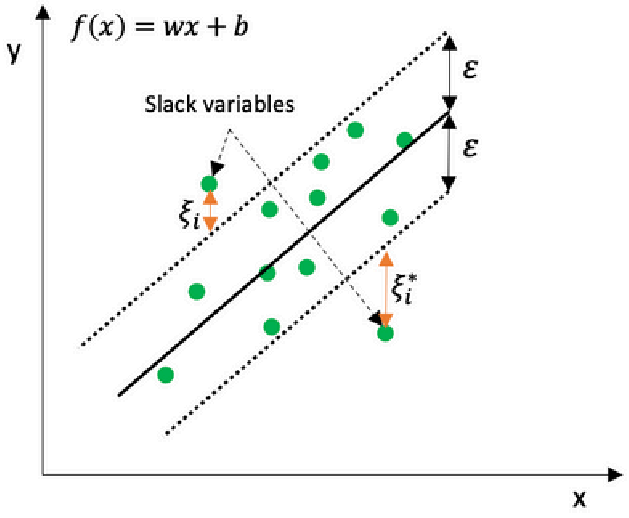
$$f(x) = \langle w, \phi(x) \rangle + b$$

$\langle w, \phi(x) \rangle$: Dot product of the weight vector w and the transformed feature vector $\phi(x)$.

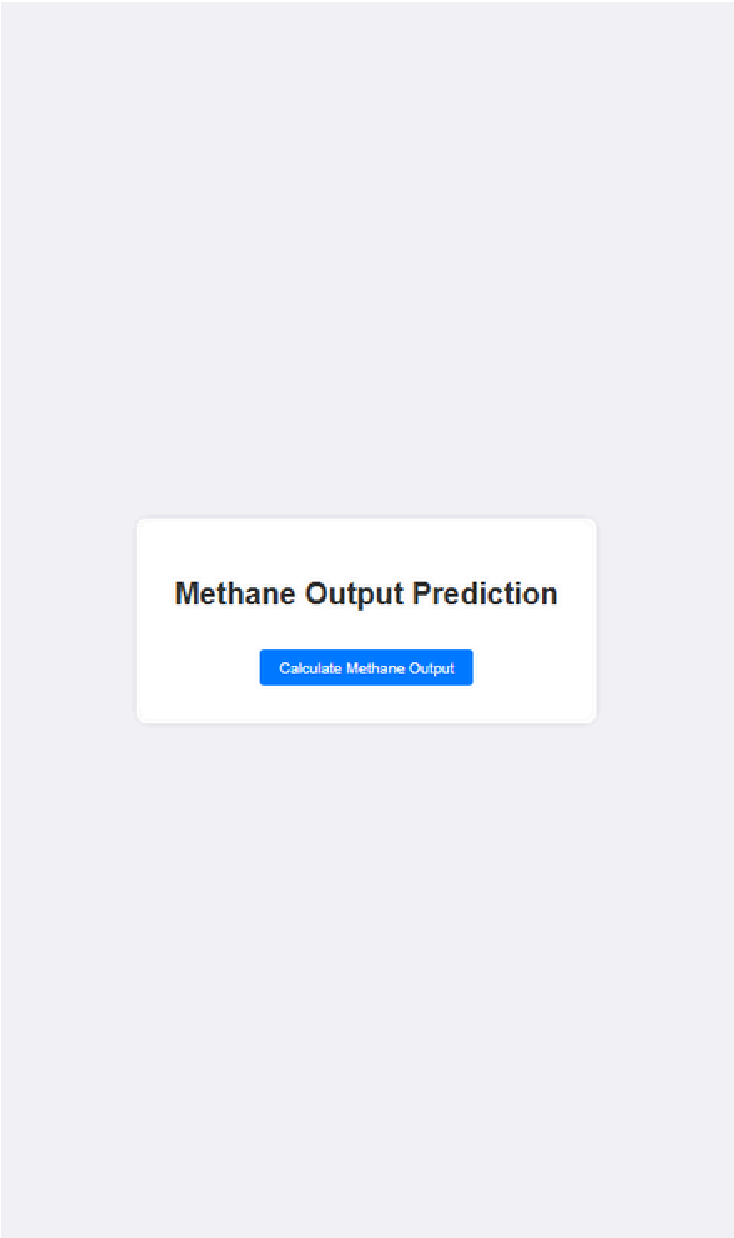
$\phi(x)$: Transformation function (often involving a kernel function) that maps the input features into a higher-dimensional space.

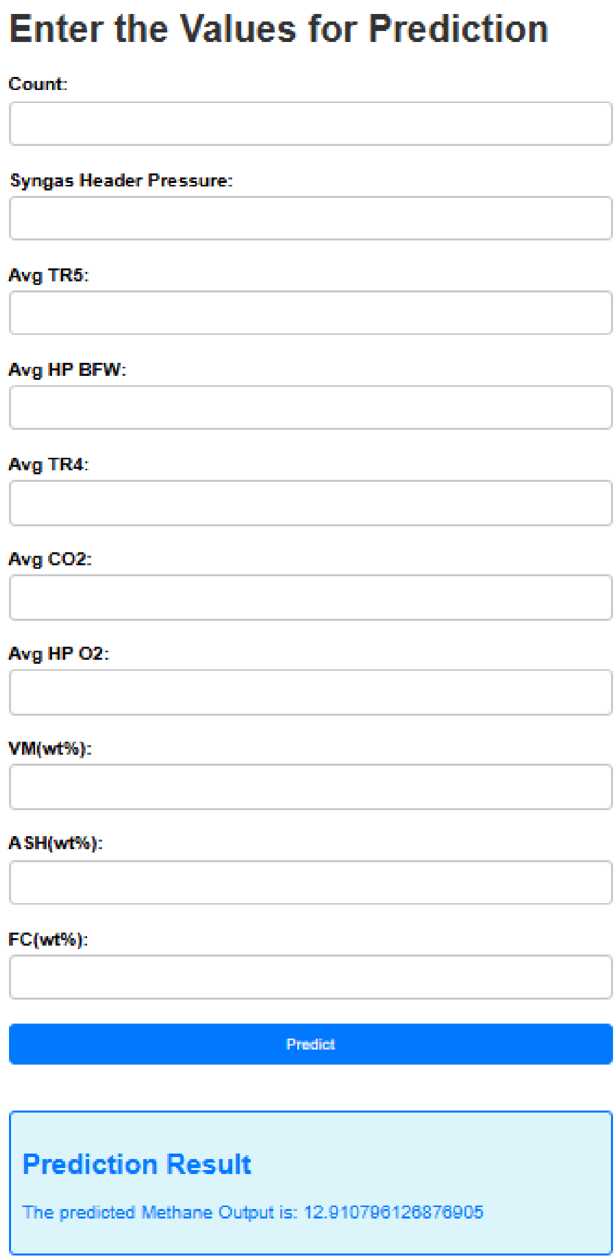
b: Bias term.

```
Mean Squared Error: 0.6593875885801205
R-squared: 0.858590953948575
```



User Interface for Methane Output Calculation





[Link for the website]

Conclusion

Dependencies:

The methane output depends positively on the parameters:

- Number of Gasifiers in Operation
- FC(wt%)
- Gasifier's Outlet Temperature
- Ash Lock Temperature
- HP BFW
- HP O2
- ASH(wt%)

The methane output depends negatively on the parameters:

- Raw Gas Header Pressure
- VM(wt%)
- CO2 Output

Suggestions

- **Model Refinement:** While the SVR model performs well, further refinement could involve experimenting with different kernel functions and hyperparameter settings to enhance performance even further.
- **Integration with Process Data:** Future work should focus on integrating the SVR model with real-time process data for continuous monitoring and optimization. Incorporating additional data sources and variables could further improve prediction accuracy.
- **Scalability and Implementation:** Consideration should be given to scaling the model for larger datasets and implementing it within industrial control systems. Validation of the model's performance in real-world scenarios is essential for successful deployment.

THANK YOU