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A Techno-Economic Evaluation of Rice Straw-Based Power Generation in Bangladesh

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***Abstract*—The Availability of sufficient electrical energy is essential for a nation's economic growth to be steady. Bangladesh should, therefore, have enough electricity infrastructure to maintain its economic growth. Several kinds of agricultural waste are available in Bangladesh as an agricultural country. Therefore, Bangladesh may generate energy (such as electricity) from this enormous agricultural waste. One of the potential agricultural wastes for use as a source of energy is rice straw, but only if it is properly and methodically processed. This research investigates the technical potential of using filtered rice straw to produce energy in Bangladesh. Environmental risks are posed by the estimated 4 million tonnes annual burn of rice straw in an open field. Rice straws can produce a net annual electricity output of 217.21 GWh, corresponding to an input of 8640 tonnes of rice straw, according to simulation and full-scale experiments. But our country's available rice straw is almost 119.3 million tonnes/year. Notice that 17-tonne rice straw was used in the aspen simulator. The plant can reduce CO_2 emission by 0.03%. Total cost is $4,082,005 per year, and the per unit cost is $0.019. This research work aims to present a concept for producing electricity in Bangladesh's rural areas using rice straw. Small and medium-sized power plants based on rice straw are beneficial for producing and distributing electricity in rural areas. A comprehensive process model for biomass gasification in a twin-fire fixed-bed gasifier is developed using the ASPEN PLUS simulator. The chemical process industries primarily use the process modeling tool Aspen Plus for process monitoring, optimization, and conceptual design.**

Index Terms: **Rice Straw Technology, Gasification Analysis, Syn Gas, Rice Straw Power Plant, Techno-Economic Analysis.**

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I. Introduction

Bangladesh is both a highly populated and agricultural nation. The need for power in Bangladesh is rising. Bangladesh's government has declared that it aims to give power to all residents by the year 2020, despite the enormous lack of energy demand and growing at a rate of more than 8% yearly [1-3]. In Bangladesh, the power industry alone is responsible for 40% of all CO_2 emissions [4-7]. In specialized bio-digesters, animal waste such as dung and bird droppings are converted into biogas, a mixture of gases that contains CH_4 (40-70%) and CO_2 (30-60%) as well as other gases (1-5%) [8-11]. Using rice straw as a renewable source to produce electricity could be an alternative way for Bangladesh to do this. Renewable energy encompasses a wide range of energy sources. Although Bangladesh has a significant renewable energy potential, no systematic study has been undertaken to determine this potential's capacity for power generation [12]. Bangladesh's recognized commercial primary energy reserves are minimal compared to the needs of the nation for development [13]. In Bangladesh, the peak demand for electricity is 9268 MW, and by the year 2021, it was 18838 MW [14, 15]. Fossil fuels such as petroleum, natural gas, and coal continue to meet the majority of today's energy requirements [16]. In 1980, there was a very low primary energy demand of just 6557.131 million tonnes of oil equivalent (mtoe), but by 2005, that demand had increased to 11,429 mtoe. Fossil fuels supply approximately 80 percent of the world's energy, with nuclear power and renewable energy sources providing the remaining 20% [17]. From Banglades h's perspective, the rice straw used to generate electricit y can be a better, cost-effective alternative to conventio nal energy sources. The approximate production of rice straw globally is 725.748 million tonnes, with about 544.311 million tonnes per year produced in Asia [18]. The average caloric value of rice straw is 46.2 MJ/kg Cal/kg [19]. One tonne of rice paddy can produce 290 kg of rice straw, which generates 100 kwh of power [20-24]. How much electricity is generated per year depends on the Availability of raw materials and the technology used to convert rice straw to energy. According to this FAO, Bangladesh is ranked third in the world for producing rice, with a projected output of 38.4 million tonnes or 43981.48kg /day [25]. Production at 35.3 million tonnes (milled basis) [26]. Total rice production in Bangladesh is now about 38.17 million tonnes per year [27]. Global electricity production peaked in 1980 at 8027 TWh and increased to 17,363 TWh by 2005. From 1945 GW in 1980 to 3878 GW in 2005, power generation's installed capacity rose, with conventional fuels accounting for about 69% of that total [28]. Thailand built a rice straw power plant to reduce greenhouse gas emissions and generate electricity. Burning 8.5-14.3 Mt of rice straw annually reduced GHG emissions by 7.8-13.2 Mt CO_2-eq after converting to 786-1325 MW of electricity [29]. Savings in greenhouse gas emissions from a Malaysian rice straw-based power plant of roughly 1.79 kg CO_2-eq/kWh compared to coal-based and 1.05 kg CO_2-eq/kWh with natural gas-based power production are shown as an example of the use of Life Cycle Assessment for environmental analysis [30]. They estimate energy output and decrease power prices in several rice straw-rich areas. Average nominal and actual LCOE of various renewable energy technologies in Egypt, the simulation showed that the planned power plants had 10. 55 and 6.33 ¢/kWh, respectively [31].

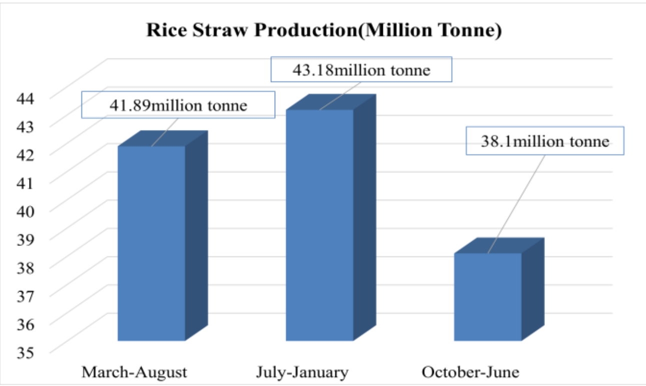


Fig. 1. Rice straw production in Bangladesh (three sessions).

Fig. 1 shows that rice straw production, on average, is 38.1 million tonnes from October to June. From July to January, it is almost 43.18 million tonnes. From March to August, it is nearly 41.89 million tonnes. So, vast amounts of rice straw are produced in Bangladesh as an agricultural country, which is almost 10.26 million tonnes per month.

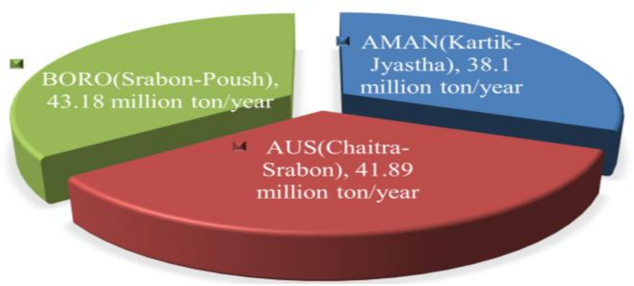


Fig. 2. Annual rice straw production in Bangladesh.

Bangladesh produces an annual amount of rice straw, as shown in Fig. 2. Rice may be farmed in Bangladesh throughout the year in the same vein as Aush, Aman, or Boro. Typically, December and January are used for cultivating Aman (both broadcast and transplanted), March through May for Boro, and July and August for Aus. Aush, Indonesia's rice straw producer, produces a total of over 41,89,000,000 tonnes every year. The annual output from Aman is 38.1 million tons, while the production from Boro is 43.18 million tonnes [32]. Rice straw is a byproduct of the rice industry and is often harvested together with rice. Rice straw is either heaped or strewn out on the field after harvesting, depending on whether it was gathered manually or mechanically. Straw-to-paddy ratios change from variation to variety and from growth to growth. According to Fig. 3, Asia produces 91% of the world's rice straw, between 800 and 1000 million metric tons annually [18].

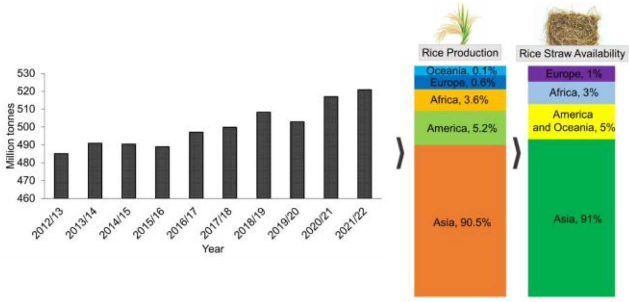


Fig. 3. Production of annual rice straw on a global scale [33].

Rice straw has not been the topic of significant study for the development of renewable energy; nevertheless, there has been some work on rice straw for power production in Bangladesh. Rice straw is a byproduct of the rice crop and may be found in large quantities. One of the projects that allows us to contribute our work is named "In Bangladesh: A techno-economic evaluation of rice straw-based power generation." Working towards "rice straw-based power generation" in the future will make it possible to effect significant change. This transition will be possible to achieve. As a result, Enthusiasm surrounds the prospect of rice straw being used in electricity production in Bangladesh.

To find an economical and easy solution for sustainable and climate-friendly power generation from rice straw, the objectives of this research are given below:

- To generate power using rice straw in Bangladesh.
- To reduce the unavailability of input and gas transport costs, improve power generation, gas purification costs, gas lifting costs, etc.
- To apply the gasification method in the power generation system.

II. Rice Straw Characteristic and Electricity Generation

This section investigates rice straw availability and characteristics depending on site selection and calculates the power generation.

A. Rice straw characteristic and Availability

Evaluating farmer practices for managing straw is crucial in creating fertilizer recommendations. The soil K balance is the main area where the removal of straw has an impact.

Complete removal of straw over several crop seasons without replacing the soil's K content with mineral fertilizer is likely to result in a rise in K deficiency cases [34]. Burning causes atmospheric pollution and results in nutrient loss [35]. As a lignocellulosic biomass, rice straw is used. Cellulose, hemicellulose, and lignin make up 38%, 25%, and 12%, respectively (Japan Institute of Energy 2002). Rice straw's biomass is comparable to softwood, with lesser cellulose and lignin and greater hemicellulose Barmina and colleagues (2013). Electricity can be generated from rice straw by using its characteristics & and chemical composition, making it easy to use for electricity generation. Annual rice straw production in Southeast Asia is 520 million t/year [19].

B. Electricity generation capacity based on rice straw availability

TABLE I
RICE STRAW VIABILITY IN MAJOR CROPS RESIDUES IN BANGLADESH [20,32].

	Production Rice Straw (million tonne/year)	Current usages	Unutilized amount Rice Straw (million tonne/year)
Aus	41.89	A small quantity for composting and animal feed.	40.5
Aman	38.1		37.3
Boro	43.18		41.5
Total	123.17		119.3

Table I shows that to collect more rice straw from Boro rice than from other rice, such as Aus rice and Aman rice. Rice straw production 41.89, 38.1, 43.14 million tonne/year from Aus, Aman, Boro. The total production of rice straw is 123.17 million tonnes/year. Without usage (like A small quantity for composting and animal feed), it is almost 119.3. And in the table II, electricity generation capacity based on rice straw availability.

TABLE II
ELECTRICITY GENERATION CAPACITY BASED ON RICE STRAW AVAILABILITY [32].

	Rice (million tonne)	Rice Straw (million tonne/year)	Potential of electricity generation (GWh/y)
Aus	13190163	40.5	1018.17×10^3
Aman	10887870	37.5	942.75×10^3
Boro	19192164	41.5	1043.31×10^3
Total	34270197	119.3	2999.202×10^3

III. PERFORMANCE INVESTIGATION

Direct combustion, gasification, and pyrolysis are three thermal processes that break down organic waste into diverse solid, liquid, and gaseous components by subjecting the biomass to heat (usually over 300 °C). A wide range of process variables include pressure, temperature, catalyst use, heating rate, oxygen availability, and reaction time. A variety of process parameters influence product quality and distribution. These include temperature, reaction time, heating rate, oxygen concentration, catalysts, and pressure [36].

There is a different method of generating electricity from rice straw. Among some effective ways are where the gas is used to generate electricity, straw power systems employ the rice straw gasification method and the system designed would simply clean the synthesis gas (SNG) flowing through the pipes using a filter. It eventually reaches the engine of the straw power system, and electricity is generated from crop waste. This process has produced CO_2, but a re-fire will start; this is where the straw is put into the gasifier. The gas from the burning process is fed through the turbine, resulting in almost zero carbon emission.

A typical analysis of the chemical composition of given in the table:

TABLE III
CHEMICAL COMPOSITION OF RICE STRAW.

Property	Approximate value
Ash [%] [37]	14.32
Carbon [%] [19]	44.4
Hydrogen [%] [19]	7.4
Nitrogen [%] [19]	1.13
Moisture Content [%] [38]	9.1
Higher Heating Value (HHV) [MJ/kg] [19]	15.03

Table III provides almost all chemical compositions of rice straw in percentages found in Bangladesh. Where ash is nearly 14.32%, the second one is Carbon, which is 44.4%, then Hydrogen is 7.4%, and the fourth is Nitrogen, which is 1.13%. The second is moisture content, 9.1% and the last is HHV, 15.03%. These are the chemical properties of rice straw.

TABLE IV
CHEMICAL REACTION [39].

Reaction Name	Chemical Reaction	ΔH
Partial oxidation:	$C + ½ O_2 \rightarrow CO$	ΔH=-268MJ/kmol
Complete oxidation:	$C + O_2 \rightarrow CO$	ΔH=-406MJ/kmol
Water gas reaction:	$C+H_2O \rightarrow CO+H_2$	ΔH=+118MJ/kmol
Water gas shift reaction:	$CO + H_2O \rightarrow CO_2 + H_2$	ΔH=-42MJ/kmol
Steam methane reforming:	$CH_4+H_2O \rightarrow CO + 3H_2$	ΔH=+88MJ/kmol
Hydrocarbon reactions:	$C_nH_m+nH_2O \rightarrow CO+(n+m/2)H_2$	(Endothermic)

All chemical reactions listed in the table IV with ΔH.

IV. PROPOSED OPERATING PRINCIPLE

The system consists of blocks representing components and signal lines connecting them and shown in Fig. 4.

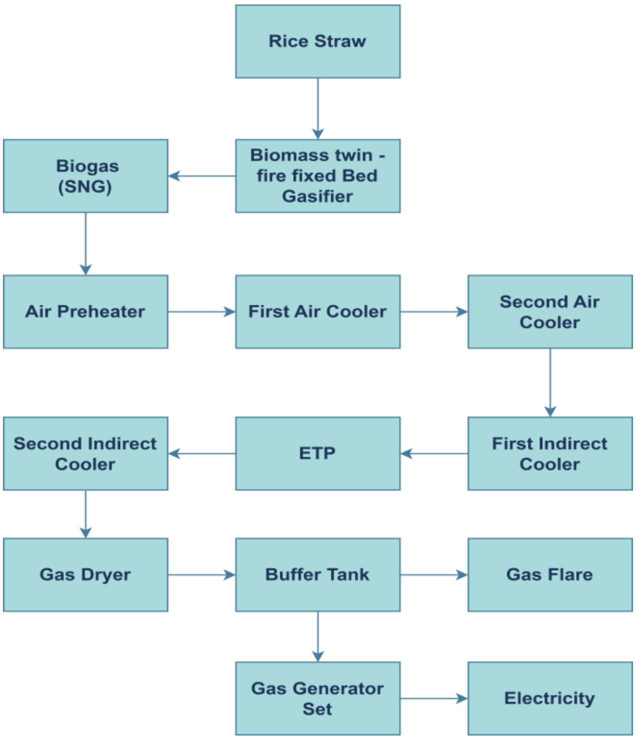


Fig. 4. Block diagram of a rice straw to electricity production unit.

The fundamental premise of a biomass gasification system is to transform rice straw processing residue into combustible gas. There are three steps to the biomass gasification process. The first process involves biomass gasification, which converts biomass into syngas. The second stage is to purify syngas. The gasifier's production gas typically contains impurities such as dust, coke and tar. The purification system will eliminate the pollutants to ensure the gas engine's regular operation. The third step is to generate power using a gas engine.

Biomass-fire fixed Bed Gasifiers convert biomass to high-temperature combustible gas syngas. The high-temperature air produced by the air preheater is used as a gasification agent, and a booster fan purifies the combustible gas produced to meet the requirements of gas-fired internal combustion generator sets.

The main components of syn gas include combustible gases (CO, H_2, CH_2) and N_2, CO_2, H_2O as well as minimal particles and tar, etc.

Air Preheater: The normal-temperature air heated by the high-temperature combustible gas from the gasifier is used as a gasifying agent considering air temperature.

First Air Cooler: The external normal temperature environment is used to cool the gas passing through the pipe while playing the role of gravity dust collector. In this section considering gas temperature.

Second Air Cooler: Consider gas temperature, The external normal temperature environment is used to cool the gas passing through the pipe and at the same time, it plays the role of a gravity dust collector.

First Indirect Cooler: The biomass combustible gas is cooled to 80-100°C by indirect heat exchange between high temperature biomass combustible gas and circulating cooling water. In this section, temperature controlled to consider gas temperature.

Electrostatic Tar Precipitator: Separating tar droplets and small particles by high voltage direct current electric field. Tar condensate and dust particles in the gas will gather on the anode tube of the Electrostatic tar precipitator under the action of the electromagnetic field after carrying electrons [40]. The depending parameters for the Electrostatic Tar Precipitator include:

1. **High voltage direct current electric field**: This is the primary force used to separate tar droplets and small particles.
2. **Tar condensate and dust particles**: These are the substances being collected.
3. **Anode tube**: The location where tar condensate and dust particles gather.
4. **Electromagnetic field**: The field that influences the movement and collection of particles.

Second Indirect Cooler: The biomass combustible gas is cooled to 40-50°C by indirect heat exchange between high temperature biomass combustible gas and circulating cooling water. In this section, temperature controlled to consider gas temperature.

Gas Dryer: To remove moisture from biomass gas increasing gas temperature.

Gas Flare: When the gasifier is started or stopped, a high voltage electric spark ignites biomass combustible gas, tar-free gas- blue flame [41].

Buffer Tank: Stabilize gas pressure and deliver the combustible gas to several generating units on average.

Gas Generator Set: Using biomass gas or synthesis gas to generate electricity for users can also be exported to the state Grid but also can generate hot water or stream. The average is that it can start and stop at any time and Run 24*7.

Our proposed model 3D diagram shown in Fig.5 represents to all sections of this research study.

Components of the proposed power plant:

1.Elevator	2.Gasifier	3.Cyclone
4.Air Cooler	5.Indirect Cooler	6.ESP
7.Isolation Seal	8.Booster Fan	9.Indirect Cooler
10.Water Drop Catcher	11.Water Drop Bleeding	12.Gas Flare
13.Buffer Tank	14.Gas Generator sets	15.Air Blower
16.Water Cooling Tower	17.Water Pump	18.Water Pooling
19.Condensate Pool	20.Tank	21.Air Cooler

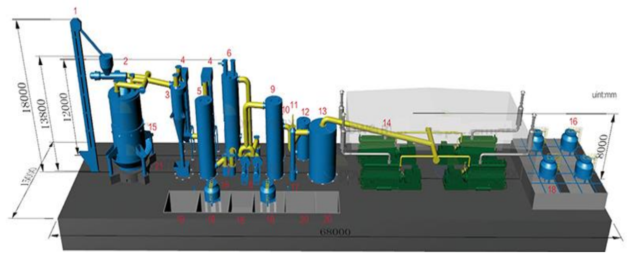


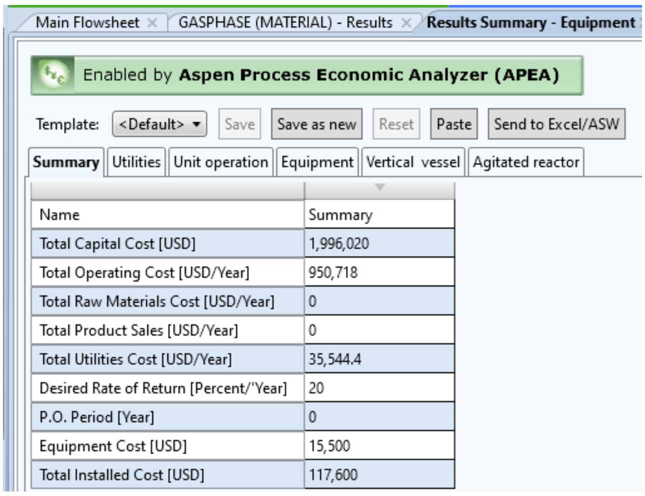
Fig. 5. Proposed rice straw-based Power Plant Model [42].

V. Generation & Economic Analysis

According to simulation data calculated generation and given below: So, $V = \frac{\frac{n}{m}RT}{P}$

$or, V = 10127.27711\ Nm^3/tonne.$

So, the generation of electricity is 25.14 MWh/tonne according to Table X. From BARI data, 1 tonne of rice straw per bigha. And from one bigha of land, each farmer has received between $93.23 and $111.88 [43, 44]. According to this, Rice straw costs $805,519 to $966,623 annually. As per aspen Process economic analyzer total capital costs of straw are estimated per year at $1,996,020, operating costs $950,718, and utilities costs $35,544.4. Step-by-step ash (750) and equipment cost $15,500, and total installation cost $117600. The overall total cost almost 4,082,005 USD/year. Per unit cost is $0.019, depending on a number of variables including fuel prices, plant performance, and operating costs.



Name	Summary
Total Capital Cost [USD]	1,996,020
Total Operating Cost [USD/Year]	950,718
Total Raw Materials Cost [USD/Year]	0
Total Product Sales [USD/Year]	0
Total Utilities Cost [USD/Year]	35,544.4
Desired Rate of Return [Percent/'Year]	20
P.O. Period [Year]	0
Equipment Cost [USD]	15,500
Total Installed Cost [USD]	117,600

Fig. 6. Aspen Process Economic Analyzer Interface.

TABLE V
ASPEN PROCESS ECONOMIC ANALYZER.

Name	Summary
Total Capital cost [USD/Y]	1,996,020
Total operating cost [USD/Y]	950,718
Total Raw materials Cost [USD/Y]	805,519-966,623
Total Utilities cost [USD/Y]	35,544.4
Total Installed cost + Equipment cost [USD]	117,600+15,500
Over all Total cost [USD]	4,082,005
Desired Rate of Return[percent/Y]	20

In Table V, aspen process economic analyzer with include rest of almost others cost.

Exist other power plant per Unit cost:

Natural Gas: Natural gas can be used to generate electricity for between $0.03 and $0.07 per kWh, depending on a number of variables including fuel prices, plant performance, and operating costs [14,16].

Coal: The cost of coal-fired power facilities typically ranges from $0.05 to $0.10 per kWh. The price of coal and the cost of transportation can affect this cost [45,46].

Oil: Because of the high cost and volatility of oil, power generation utilizing it is typically more expensive, ranging from $0.10 to $0.20 per kWh [28, 47].

Renewables: The price of renewable energy sources, such as wind and solar power, can differ greatly. The cost per kWh for solar electricity can range from $0.05 to $0.15, whereas the cost of wind power may be slightly higher based on location and technology [48,49].

Different types of fuel price in table VI. And shown comparison between syn gas vs others fuel price. The investigation shows that the suggested model performs better than alternative renewable energy facilities. The information shows that the suggested model delivers increased cost-effectiveness and reliability in addition to increased efficiency. Due to these benefits, it is a more practical choice for producing energy sustainably.

TABLE VI
COMPARISON BETWEEN SYN GAS VS OTHERS FUEL PRICE [51].

Fuel Name	Price
Methanol	$2,049.00/T
Naphtha	$587.20/T
Syn Gas (Proposed model Production cost)	$0.047/$Nm3$
Coal	$135.10/T
Brent	$73.614/BbI
Crude Oil	$69.418/BbI
Fuel Name	Price
UK Gas	$58.29/thm
TTF Gas	$25.21/MWh
Gasoline	$2.4727/Gal
Ethanol	$2.44/Gal
Natural gas	$2.2994/MMBtu
Heating Oil	$2.2584/Gal
Propane	$0.65/Gal

To determine whether or not the proposed power plant is economically viable, calculate the LCOE using rice straw in the SAM economic system. Assuming that the power plant will run for 20 years, it is the period used to get the LCOE. To get the LCOE, to divide the sum of all expenditures incurred during the lifetime of the generation plant by the sum of all energy produced during that time. As a result, the Life Cost of Energy (LCOE) may be considered a lowered estimation of each unit of energy consumption over the lifetime of the electrical infrastructure. Pricing is often expressed in dollars per kilowatt-hour ($/kWh). The Lowest cost of ownership considers initial investment, gasoline prices, and ongoing operational and maintenance expenses. To determine the total cost of ownership (LCOE) of sustainable energy, it is possible to utilize a method known as (1) that is commonly used in numerous sources [50].

$$LCOE = \frac{\sum_{n}^{t-1} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{n}^{t-1} \frac{E_t}{(1+r)^t}} \quad (1)$$

$$E_t = E_o \left(1 - \frac{DR}{100}\right)^t \quad (2)$$

Where:
For t(Year) times,
- I_t = Investment costs;
- M_t = Operating expenses;
- F_t = Rice straw cost;
- E_t = Electricity production;
- E_o = Expenses of installation;
- When a nominal discount rate is used, the discount rate is denoted by the symbol r. The formula below calculates the nominal discount rate;

$$r_{nominal} = [(1 + inflation) * (1 + r_{real})] - 1 \quad (3)$$

- Lifespan of the biomass power plant, denoted by n;
- To estimate a 0.2 percent yearly drop in production for biomass energy systems (DR=Degradation factor).

VI. Results and Discussion

Rice straw-based power plant technology was created in this research to satisfy Bangladesh's energy needs at a lesser cost than other non-conventional sources. Rice straw produces no carbon emissions, and the analysis of the energy produced from rice straw showed that it has minimal carbon emissions. The specification of output data is shown in Table VII. And biomass gasifier generator simulation and gas phase properties are shown in fig. 7.-11. (Table VIII & IX). The calculation indicates that an amount of 1 tonne rice straw can produce an amount of 10127.27711 Nm^3 /h biofuel. From this fuel, 25.14 Mw of electricity will be produced. In addition to producing electricity amounting to 217.21 GWh/y. Gasification controls the simulation products of syn gas from rice straw, so the overall process for syngas production. The process has four sections; one section is a dryer in which width straw is dried, water is removed, then pyrolysis, a combustion reactor to the gasifier, and finally, to get syn gas. In the dryer, using for nitrogen to dry out potassium, and oxygen is used for the combustion, oxygen is used for the gasifier, and the cyclone is used to remove the ash from pyrolysis because get some ash.

TABLE VII
ELECTRICITY OUTPUT GENERATION FROM RICE STRAW.

Input		Output	
Rice Straw Quantity [Mt/y]	8640 (tonne/y)	Annual energy output [GWh/y]	217.21
	1tonne	Energy output [MWh]	25.14
Carbon [%]	44.40	Ash amount [tonne/y]	125.098kg/h
Oxygen [%]	47.07	Biomass	1000kg/h
Hydrogen [%]	7.40	HP Steam Generation	210.53kw
Nitrogen [%]	1.13	Average MV	25.14
Moisture [%]	15	Total Flow gas/fuel kg/h	47383.5

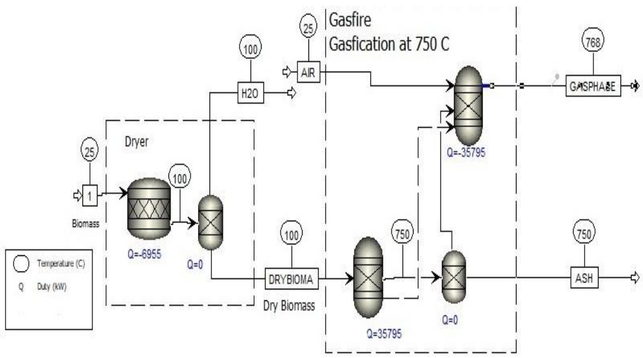


Fig. 7. Biomass Gasifier Schematic.

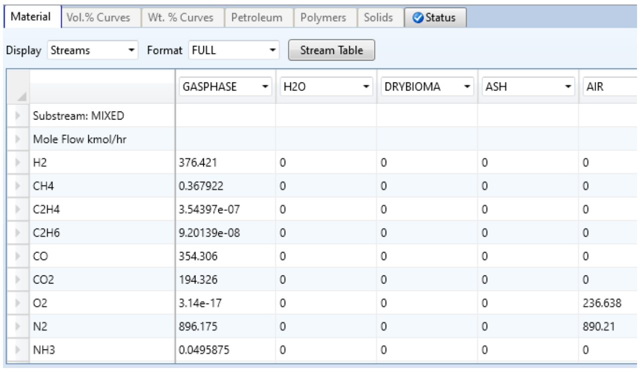
Using Aspen Plus software, a biomass gasification system's process flow diagram is shown in detail in Fig. 7. The Dryer and the Gasfire Gasification are its two primary parts. Here's a detailed explanation:

Dryer Section
RStoic Reactor: Evaluate the catalyst filter reaction by simulation. The biomass is dried in the RStoic reactor at the start of the procedure. To lower the moisture content of the biomass, stoichiometric reactions are carried out in this reactor [52,54].
Separator: The RStoic reactor's output is sent to a separator after drying. This part extracts the dried biomass from any moisture or char or contaminants that may still be present [53].
Gasfire Gasification Section
RYield Reactor: The RYield reactor is then filled with the dried biomass. Based on predetermined yield criteria, this reactor transforms biomass into gas at a high temperature of 750°C.
Separator: The separator separates the gas and solid byproducts in the output of the reactor yield. The ash is eliminated as a byproduct and the gas phase is focused on additional processing [54].
RGibbs Reactor: The separator's gas is introduced into the

RGibbs reactor. By minimizing the Gibbs free energy, this reactor determines the equilibrium composition of the gas and guarantees the production of the most stable mixture of gases [52,53,54].

TABLE VIII
COMPOSITION OF SNG.

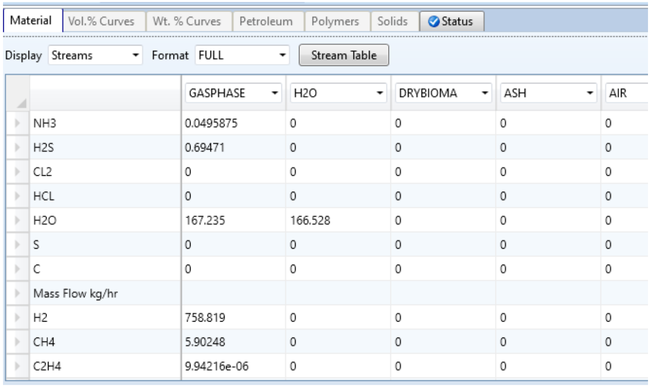
Composition of SNG	value	Unit
CO	354.306	kmol/h
CO_2	194.326	kmol/h
CH_4	0.367922	kmol/h
O_2	3.14E-17	kmol/h
N_2	896.175	kmol/h



Material | Vol.% Curves | Wt. % Curves | Petroleum | Polymers | Solids | Status
Display Streams | Format FULL | Stream Table

	GASPHASE	H2O	DRYBIOMA	ASH	AIR
Substream: MIXED					
Mole Flow kmol/hr					
H2	376.421	0	0	0	0
CH4	0.367922	0	0	0	0
C2H4	3.54397e-07	0	0	0	0
C2H6	9.20139e-08	0	0	0	0
CO	354.306	0	0	0	0
CO2	194.326	0	0	0	0
O2	3.14e-17	0	0	0	236.638
N2	896.175	0	0	0	890.21
NH3	0.0495875	0	0	0	0

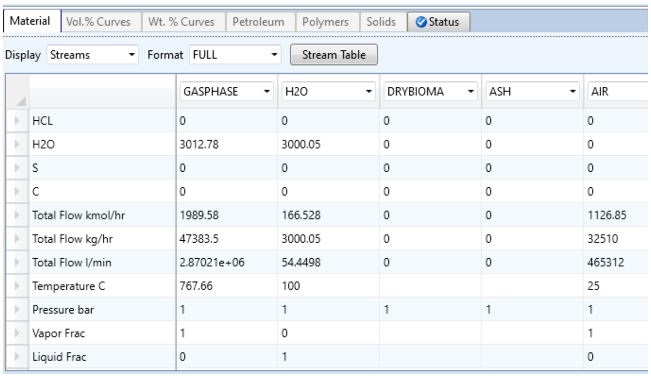
Fig. 8. SNG Gas Properties.



Material | Vol.% Curves | Wt. % Curves | Petroleum | Polymers | Solids | Status
Display Streams | Format FULL | Stream Table

	GASPHASE	H2O	DRYBIOMA	ASH	AIR
NH3	0.0495875	0	0	0	0
H2S	0.69471	0	0	0	0
CL2	0	0	0	0	0
HCL	0	0	0	0	0
H2O	167.235	166.528	0	0	0
S	0	0	0	0	0
C	0	0	0	0	0
Mass Flow kg/hr					
H2	758.819	0	0	0	0
CH4	5.90248	0	0	0	0
C2H4	9.94216e-06	0	0	0	0

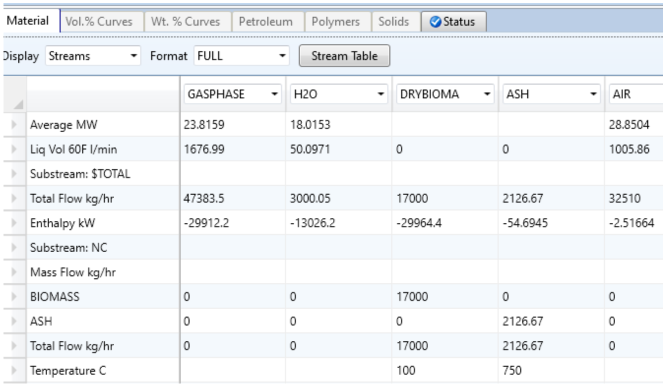
Fig. 9. Simulation Output (Aspen).



Material | Vol.% Curves | Wt. % Curves | Petroleum | Polymers | Solids | Status
Display Streams | Format FULL | Stream Table

	GASPHASE	H2O	DRYBIOMA	ASH	AIR
HCL	0	0	0	0	0
H2O	3012.78	3000.05	0	0	0
S	0	0	0	0	0
C	0	0	0	0	0
Total Flow kmol/hr	1989.58	166.528	0	0	1126.85
Total Flow kg/hr	47383.5	3000.05	0	0	32510
Total Flow l/min	2.87021e+06	54.4498	0	0	465312
Temperature C	767.66	100			25
Pressure bar	1	1	1	1	1
Vapor Frac	1	0			1
Liquid Frac	0	1			0

Fig. 10. SNG Output.



Material | Vol.% Curves | Wt. % Curves | Petroleum | Polymers | Solids | Status
Display Streams | Format FULL | Stream Table

	GASPHASE	H2O	DRYBIOMA	ASH	AIR
Average MW	23.8159	18.0153			28.8504
Liq Vol 60F l/min	1676.99	50.0971	0	0	1005.86
Substream: $TOTAL					
Total Flow kg/hr	47383.5	3000.05	17000	2126.67	32510
Enthalpy kW	-29912.2	-13026.2	-29964.4	-54.6945	-2.51664
Substream: NC					
Mass Flow kg/hr					
BIOMASS	0	0	17000	0	0
ASH	0	0	0	2126.67	0
Total Flow kg/hr	0	0	17000	2126.67	0
Temperature C			100	750	

Fig. 11. Simulation Output (Aspen).

TABLE IX
SYNTHESIS GAS PROPERTIES ACCORDING TO FIG. 8, FIG.9, FIG. 10 & FIG. 11.

Material					
Display: Streams	Format: Full				Stream Table
	Gasphase	H_2O	Dry Bioma	Ash	Air
Sub stream: MIXED					
Mole Flow kmol/hr					
H_2	376.421	0	0	0	0
CH_4	0.367922	0	0		0
C_2H_4	3.54397e-07	0	0	0	0
C_2H_6	9.20139e-08	0	0	0	0
CO	354.306	0	0	0	0
CO_2	194.326	0	0	0	0
O_2	3.14e-17	0	0	0	236.638
N_2	896.175	0	0	0	890.21
NH_3	0.0495875	0	0	0	0
H_2S	0.69471	0	0	0	0
CL_2	0	0	0	0	0
HCL	0	0	0	0	0
H_2O	167.235	166.528	0	0	0
S	0	0	0	0	0
C	0	0	0	0	0
Mass Flow kg/hr					
H_2	758.819	0	0	0	0
CH_4	5.90248	0	0	0	0
C_2H_4	9.94216e-06	0	0	0	0
HCL	0	0	0	0	0
H_2O	3012.78	3000.05	0	0	0
S	0	0	0	0	0
C	0	0	0	0	0
Total Flow kmol/hr	1989.58	166.528	0	0	1126.85
Total Flow kg/hr	47383.5	3000.05	0	0	32510
Total Flow l/min	2.87021e+06	54.4498	0	0	465312
Temperat	767.66	100			25

ure C					
Pressure Bar	1	1	1	1	1
Vapor Frac	1	0			1
Liquid Frac	0	1			0
Average MW	23.8159	18.0153			28.8504
Liq Vol 60F Vmin	1676.99	50.0971	0	0	1005.86
Sub stream: $Total					
Total Flow kg/hr	47383.5	3000.05	17000	2126.67	32510
Enthalpy kw	-29912.2	-13026.2	-29964.4	-54.6945	-2.51664
Sub stream: NC					
Mass Flow Kg/hr					
Biomass	0	0	17000	0	0
Ash	0	0	0	2126.67	0
Total Flow kg/hr	0	0	17000	2126.67	0
Temperature C			100	750	

TABLE X
SYSTEM FOR GENERATING ELECTRICITY THROUGH BIOFUEL GASIFICATION, MODEL CFBG.

Model [42]	200CFBG	400CFBG	500CFBG
Rated [42] Power(kw)	200	400	500
Rated [42] Voltage(V)	220 / 400 / 440(50Hz)		
Model of Gasifier [42]	CFBG 200	CFBG 400	CFBG 500
	From Aspen Simulation		
Gasifier Type	Circulating Fluidized Bed Gasifier (CFBG)		
Biomass Moisture	⩽15% (wet basis)	Biomass Size	⩽8-15mm
Biomass (Kg/h)	200-360	400-720	500-900
Gas Production (Nm^3/h)	566.8-1020.2	1133.6-2040.4	1417-2550
Ash Discharge Type	Dry Ash Type		
Type of Gas Purification	Semi Dry Type Gas Purification System		
Heat Value of Gas	1000-1200Kcal/Nm^3		
Gas Composition	CO-10~16%, CO_2 -11~17%, CH_4 -4~9%, H_2 -3~ 8%, C_nH_m-.9~1.4%, O_2 -.5~1.3%, N_2 -55~60%		
Model of Genest	100GFLS	400GFLS	500GFLS
Qty of Genset	2	1	1

VII. PARAMETRIC ANALYSES

Using a parametric analysis, cost-of-ownership (LCOE) and yearly energy output were measured over a larger parameter space. The correlation between rice straw moisture content, flue gas production, and energy output is depicted in Fig. 12.-16. According to the findings, the amount of output energy is susceptible to the values of the various input parameters within the investigated range. When input variables are kept at their lowest possible levels, output increases and LCOE drops. The most important takeaway is that these operational parameter settings significantly impact the proposed system's efficiency. More study is needed to determine these operating parameter settings' primary effects and interactions on energy output and LCOE and improve system performance.

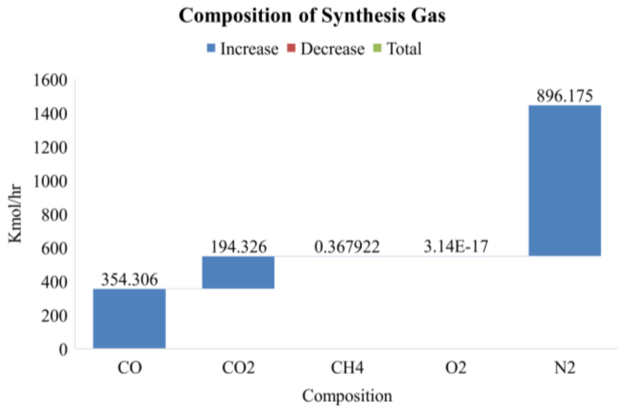


Fig. 12. Composition of Synthesis Gas bar graph.

Fig. 12. is a gas composition and value (Kmol/h) bar graph. From this bar graph, the lowest value of O_2 was 3.14E-17 Kmol/hr. The second last values of CH_4 are 0.367922 Kmol/h. The maximum value of N_2 is 896.175 Kmol/hr. The second carbon monoxide (CO) value was 354.306 Kmol/hr. The third one is CO_2, whose value was 194.326 Kmol/hr.

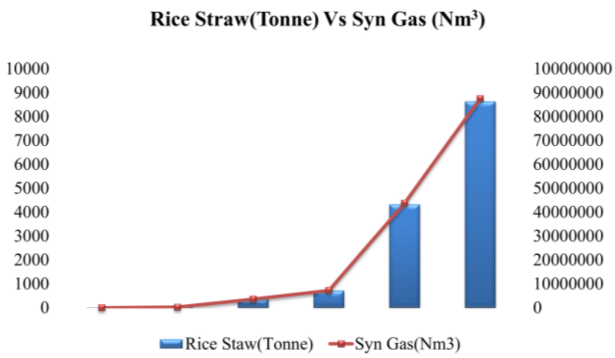


Fig. 13. Rice Straw (Tonne) Vs Syn Gas (Nm^3) bar & line Graph.

Fig. 13. is the Biomass (Tonne) and Gas Production bar and line graph. This graph shows that Biomass (Tonne) is directly

proportional to Gas Production (Nm^3). When input, biomass increases at a maximum point according to boiler and biomass availability and increases gas production at a time. When expanding, input and output also increase. But at a certain point, the output is an error because of boiler capacity error. For example, the input biomass was 1 Tonne, and the output was 10127.28 Nm3, and when the input biomass was 8640 kg/h, the output was 87499673 Nm^3.

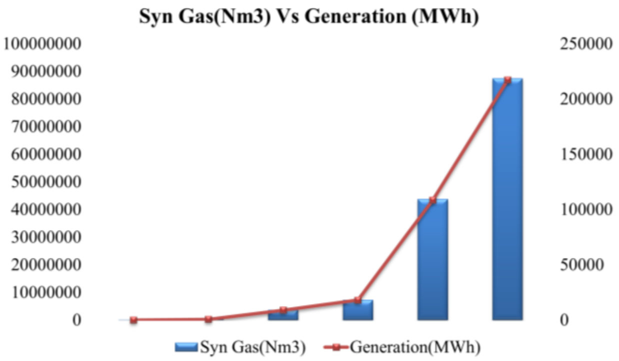


Fig. 14. Syn Gas (Nm^3) Vs Generation (MWh) Line-Bar Graph.

Fig. 14. is Syn Gas (Nm^3) Vs Generation (MWh) bar and line graph.

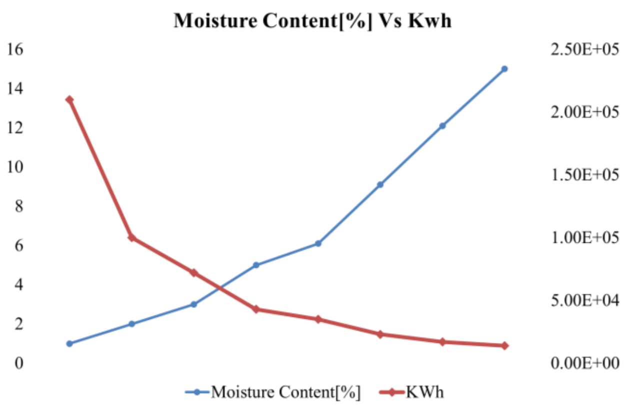


Fig. 15. Moisture Content Vs kWh Lines Graph.

Fig. 15. is moisture content [%] Vs kwh line graph. This graph shows moisture content [%] is inversely proportional to kwh. When moisture content [%] increases, output kwh decreases. That means moisture content [%] is inversely proportional to rice straw or biomass power plant efficiency. To analyzed eight samples. When moisture content [%] increases, output efficiency or kwh decreases. From this line graph to see when moisture content [%] was minimum, and at this point, output kwh was maximum. When moisture content [%] was maximum, and at this point, output kwh was minimum.

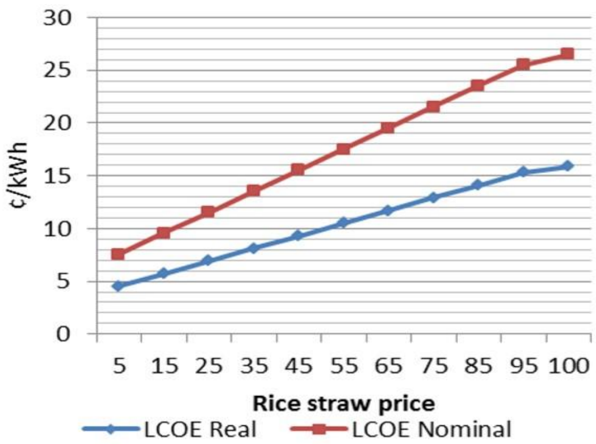


Fig. 16. Rice straw Price Vs CkWh Lines Graph.

Fig. 16. is rice straw price Vs c/kwh line graph. From this graph shown that rice straw price is directly proportional to c/kwh.

VIII. Conclusion

This study discusses a power generation system using rice straw, which has been examined using various gasification metrics. This process was also tested and compared in the presence of energy recovery and without. This observation demonstrates the effects on system efficiency depending on the different process parameters such as syn gas yield, temperature, process integration, and energy recovery. The system developed in this study produces an amount of 10127.27711 Nm^3/h biofuel, which can be used to generate 25.14 MWh of electricity. In addition, it produces electricity amounting to 217.21 GWh/y. Rice straw power plants will contribute to Bangladesh's electricity production. Using the GDP power approach, enough power can be generated from rice straws to satisfy future demand by the target year of 2041, which is 51000MW. It will be possible to bring about a significant change by producing electricity from rice straws in the future. Energy from biomass sources is becoming essential for this nation.

The future of the research is to produce cement with the ash that can be obtained from rice straw. In that case, the rice straw ash deposited in the gas flare will pass through the rotary ash gate into the water jacket cooling conveyor and output as cement. With this, structural development can be applied to boost power plants' economic growth. Furthermore, the power plant's high-temperature exhaust gas can be utilized by a waste heat boiler to generate steam or hot water for civic or industrial use. Steam turbines may also be used to create a gas-steam combined cycle power plant, increasing overall efficiency.

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