Volume 10, Issue 4, April – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

Economic Assessment of Electric Power Production in a Co-Gasification Combined Heat and Power Plant Using Nigerian and South African Coal, Biomass and Tyre as Fuel

M. Ozonoh[1*]

[1]Department of Chemical Engineering, Enugu State University of Science and Technology, P.M.B 01616, Enugu-Nigeria

Corresponding Author: M. Ozonoh[1*]

Publication Date: 2025/05/10

Abstract: Fossil fuels such as coal and petroleum are the major sources of fuel for energy generation. These two fuels produce gaseous pollutants that are dangerous to the environment. In this study, the economy of a 10 MW Combined Heat and Power (CHP) plant is assessed using Coal-to-solid waste ratios of 1:1 and 4:1 under two financial conditions namely: With Feedstock Costing (WFC) and Without Feedstock Costing (WOFC). The annual feedstock requirement of the plant and feed rate were estimated from the lower heating value of the fuel that was determined from a model equation, and the results were used for the assessment of the power plant. The Net present value (NPV), internal rate of return (IRR), and payback period (PBP) as investment tools, were used to evaluate the venture for 10th, 15th and 20th year. Coal + Pine saw-dust (PSD) mixed at a ratio of 1:1 was the optimum SA and Nigerian feedstocks, while the optimum year was at the 10th year. The annual profit WFC from the Nigerian and SA 1:1 Coal-to-PSD fuel ratio were NGN828,200,058.80 (USA517,625.04) and ZAR87,128,003.27 (USA5,125,176.67). The profits were 13.82 % and 28.40 % higher than that of solitary gasification of coal, respectively. A comparison of the Nigerian coal and Nigeria Coal + PSD WFC, revealed that about 5,106,875.44 kg/Yr of feedstock was saved from Coal + PSD (1:1) which resulted to an increase in the profit by 43.24 % per annum, whereas 3,737,610.81kg/Yr was saved from the South African Coal + PSD which resulted to about 13.82 % compared to solitary gasification of the South African coal. The 1:1 Coal-to-Solid Waste ratio was the optimum blend for all the feedstocks investigated.

Keywords: *Biomass; Coal; Co-Gasification; Electricity and Heat; Economic Assessment.*

How to Cite: M. Ozonoh (2025). Economic Assessment of Electric Power Production in a Co-Gasification Combined Heat and Power Plant Using Nigerian and South African Coal, Biomass and Tyre as Fuel. *International Journal of Innovative Science and Research Technology*, 10(4), 3147-3154. https://doi.org/10.38124/ijisrt/25apr518

I. INTRODUCTION

There are global energy challenges for domestic and industrial operations, but researchers have continued to carryout studies aimed at addressing the problem. The increase in the quest for energy has resulted to fast depletion of the available sources of fuel. Coal and petroleum are globally considered as the two major sources of fuels for power production, but unfortunately, both fuels emit a lot of gases that endangers the environment.

Nigeria and South Africa are the two African countries with large deposits of coal, and according to [1], both countries have the largest economy in the African continent. In South Africa (SA), coal is the major source of fuel for power production, covering about 95 % of the electric power generation in the country. The estimated coal reserve in SA is around 32 million tons, and it may last for about a century [2], while Nigeria has an estimated coal reserve of about 2.8 billion metric tons, but still depend on petroleum for power generation.

The local availability of coal in South Africa has resulted in the low electricity tariff in the country of about $0.1408 c/kWh [3], and the tariff is one of the lowest around the world. On the other hand, Nigeria is faced with poor electric power supplies that could be attributed to the kind of energy systems and sources available in the country as well as ineffective management in the power Sector. The cost of electric energy in South Africa maybe considered low when compared to that of Nigeria because of enormous use of coal for energy generation in the country, but gaseous emissions

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

arising from the production pose huge environmental threat. This also, applies to Nigeria, due to its over-dependency on the use of petroleum for power production.

Agro-waste and other solid waste are in abundant in Nigeria and SA, and can be blended with coal to produce electricity. According to the International Energy Agency (IEA), one-fifth of the global climate change are from the waste sector, and that about 140 billion metric tons of waste produces GHG which leads to climate change [4], but the wastes could be for energy production. Power production from biomass is not cost effective, and besides that, biomass produces high amounts of tar that causes operational difficulties in the gasifiers and end use facilities. Similarly, the Solitary gasification of coal produces a lot of gaseous emissions, whereas co-gasification process will reduce emissions, cost of feedstock, tar production, and as well be instrumental to waste management in both Nigeria and South Africa [5].

Researchers including [6,7,] have carried out some works on pyrolysis, combustion and gasification processes, and reported that a 5 MW of electrical power capacity are feasible for most fluidized bed systems. Other researchers including; [6,8,9] have also reported that biomass integrated gasification and combined gas-steam power cycle (IGCC) is an attractive technology providing about 40 % - 50 % total conversion efficiency.

Gasification behaviors of selected South African bituminous coals used in fluidized bed gasification have been investigated by Oboirien et al. [10], and it was observed that fuel characteristics have a very big influence on the gasification products. Thermo-chemical energy conversion processes such as pyrolysis, combustion and gasification have been reported by Bridgwater et al. [6] and Caputo et al. [7], and they explained that a 5 – MW capacity electricity and heat production can be achieved with most fluidized bed gasifier. The authors obtained some promising results, though the report lacked the most viable feedstock for the energy generation in terms of emission reduction and profit earnings in the power plant.

A 10 MW biomass fired steam power plant was used by Malek et al. [11] to evaluate the techno-economic analysis of the plant and it focused on the viability of using different fuels to produce energy. The results obtained by the authors were also promising, although it could not provide information on the different blends of fuels. There are other gasification facilities reported by some authors [6, 8, 9] as being very effective for power production such as the biomass integrated gasification and combined gas-steam power cycle (IGCC), which could deliver total energy conversion efficiency of around 40 % - 50 %. Achieving about 40 % energy conversion efficiency using a biomass integrated gasification combined cycle (BIGCC) plant delivering 20 MWe capacity [12], is feasible, but the fuels that may remain viable to achieving the aforementioned efficiencies for an investment period of time was not considered.

According to Ahmadi et al [13], the overall system efficiency of a typical co-generation system is within the range of 35 % - 40 %. It is important to understand the necessary process conditions and fuel that could allow for the achievement of the efficiencies.

Interestingly, some relevant information on 5, 10, 20 MW CHP plants for electricity and heat generations are in the literature but with limitations on blends of coal and biomass, and tyre. Ozonoh et al. [5] reported on the blends of these fuels, and categorized the energy contents of these wastes and coal, and the optimum operating conditions, but without coal sample from different geographical locations such as South Africa and Nigeria. The Time value of money also, was not considered in the economic analysis. In this study, an assessment of electric power production in a 10 MW co-gasification power plant using SA and Nigerian coal, biomass and tyre is carried to close the aforementioned research gaps. This will provide useful data to the scientific community for further research in this area. It will equally assist stakeholders in decision making.

II. MATERIALS AND METHOD

- *Materials*

Sugarcane bagasse (SCB), corn cob (CC) pine saw-dust (PSD) and waste tyre (WT) were the solid wastes used in the study. The SA coal and Nigerian coal were obtained from the Matla mine and Onyeama mine, Enugu, respectively. The size of the waste biomass before and after processing was 6.0 – 10.0 mm and 0.5 – 2.0 mm respectively. The Retsch biomass cutter (SM 200 Rostire) was used for the size reduction. The coal samples were equally milled from the initial size of 6.0 – 10.0 mm on collection to around 0.2 – 2.0 mm with milling machine situated at the coal laboratory of the School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Johannesburg. The size of the WT was 0.5 -3.0 mm. The same processing procedure given to the SA feedstocks was applied to the Nigerian feedstocks at the Project Development Institute (PRODA), Enugu.

- *Method*

The Economic parameter assessment of the CHP Plant was investigated. An empirical model equation reported in Ozonoh et al. [5] was used to determine the LHV of the feedstocks, and the results obtained were used to estimate the annual feedstock requirements and feed rates for the Nigerian and South African energy plants, respectively. Coal-to-solid waste ratios of 1:1 and 4:1 was used in the assessment and two financial conditions namely With Feedstocks Costing (WFC) and Without Feedstocks Costing (WOFC) were considered. The WFC considers the actual costs of the feedstocks together with cost of bagging and transportation of the feedstocks, while WOFC considers only the cost of bagging and transportation of feedstocks from the production site to the plant room. Finally, project evaluation and management tools such as NPV, IRR, and PBP were used to evaluate the viability of the venture at the 10th, 15th, and 20th year investment plan of the power plants. The project assessment model equations are contained in our

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

previous report [5]. The economic assessment considered is on solitary gasification of coal and co-gasification of blends of coal and solid wastes from both countries.

III. RESULTS AND DISCUSSION

➢ *Characterization of the Feedstocks*

The characterization result of the feedstocks is presented in Table 1. It is important to mention that the result presented in Table 1 was equally used in our current report on comparative study of Nigerian and SA Gas Emissions because the same feedstocks were used. From Table 1, it can be observed that the heating values of the fuels from both countries varied with a very wide margin, hence affecting the feedstock requirements at the power plants. Also, the ash content of the South African coal was very high when compared to the Nigerian coal, while the carbon content of the Nigerian coal is higher than that of the South African coal.

Table 1 Feedstocks Ultimate and Proximate Analysis

Nigerian Feedstocks						South African Feedstocks				
Ultimate Analysis [%]										
Feedstock	C	H	N	S	O	C	H	N	S	O
CC	22.91	4.86	0.62	0.00	71.60	24.82	3.94	0.97	0.00	70.27
SCB	39.45	7.16	0.41	0.00	52.98	38.67	6.40	0.23	0.00	54.70
PSD	48.73	6.82	0.21	0.33	43.91	50.54	7.08	0.15	0.57	41.66
WT	86.50	6.64	0.40	2.00	1.10	87.60	8.03	0.33	3.12	0.92
Coal	75.80	5.30	1.90	0.50	16.80	39.09	2.90	0.92	0.66	8.63
Proximate Analysis [%]										
Feedstock	MC	VM	Ash	FC	MC	VM	Ash	FC		
CC	8.01	70.58	0.45	20.96	5.87	72.50	0.29	21.34		
SCB	7.95	73.01	0.38	18.66	8.80	71.50	0.49	19.12		
PSD	9.60	69.98	0.57	19.85	8.55	71.80	0.59	19.06		
WT	0.51	63.54	7.60	28.35	0.32	63.29	9.92	26.47		
Coal	3.03	35.00	13.40	48.60	3.80	19.90	44.00	32.30		
Heating value [MJ/Kg]										
Parameters	CC	SCB	PSD	WT	Coal	CC	SCB	PSD	WT	Coal
HHV	17.14	19.05	19.73	28.15	33.3	17.42	18.85	21.50	30.95	18.60
LHV	16.73	18.73	19.11	27.88	32.10	17.15	17.58	19.72	23.57	17.89

CC: Corn cob; SCB: sugarcane bagasse; PSD: pine saw-dust; WT: Waste-tyre; LHV: lower heating value; HHV: higher heating value

➢ *Assessment of Solitary Coal Gasification: South African and Nigerian Coal*

An evaluation of energy production from gasification of South African coal (Matla coal mine) and Nigerian coal (Onyeama coal mine, Enugu) was carried out in the CHP Plant with 10 MW and 11MW electric and thermal power capacity. The results obtained are presented in fig. 2a and fig. 2b, respectively.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

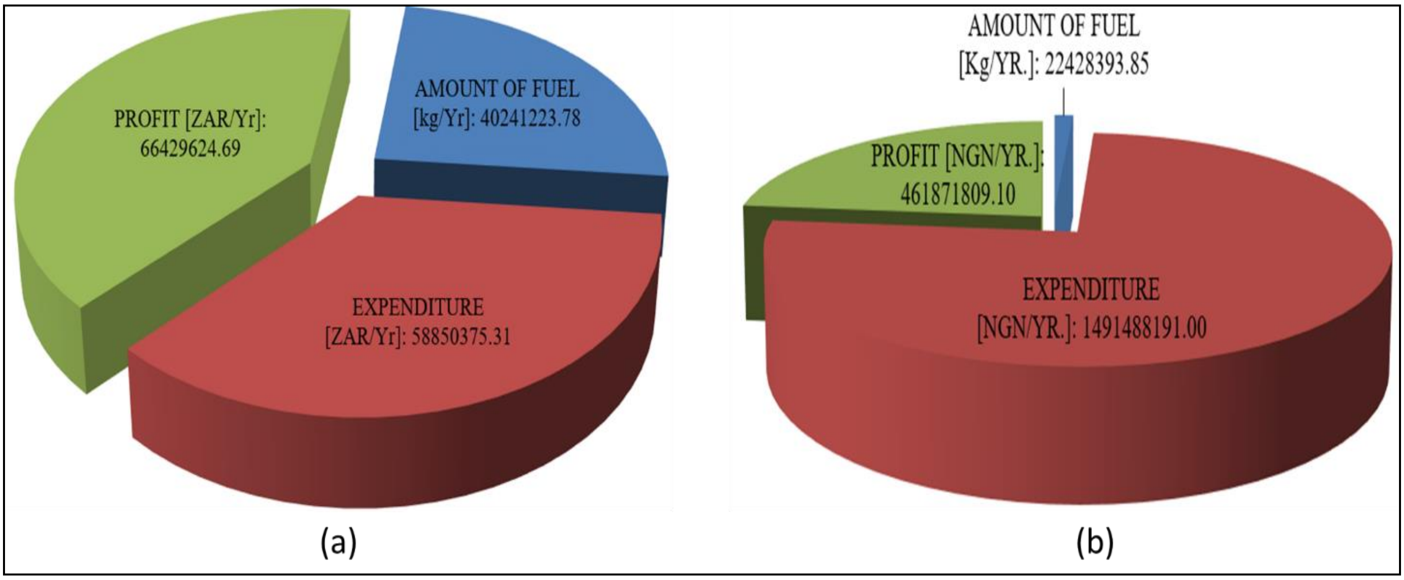

Fig 1 (a): 100% South African Coal (Matla Mine) (b): 100 % Nigerian Coal (Onyeama Mine).

It can be observed from Fig. 2a that the annual feedstock requirement in the plant was higher than that of Fig. 2b (Nigerian Coal). It was attributed to the higher quality of the Nigerian coal (mainly the HHV) as against the South African coal with high ash content.

Meanwhile, about the sum of USA3,907,624.98 (ZAR66,429,624.69) profit was earned from South African fuel, while USA288,669.88 (NGN461,871,809.10) was obtaied from the Nigerian fuel by generating a 10 MW capacity electric and thermal power. The implication is that around 56.48 % higher profit was made from South Afriacan feedstock when compared to the Nigerian feedstock.

➢ *Economic Assessment of the Power Plants at the 10th Year*

The economic assessment of SA and Nigerian power plants at the 10th Year, are shown in Fig. 3 (a) and Fig. 3 (b) respectively.

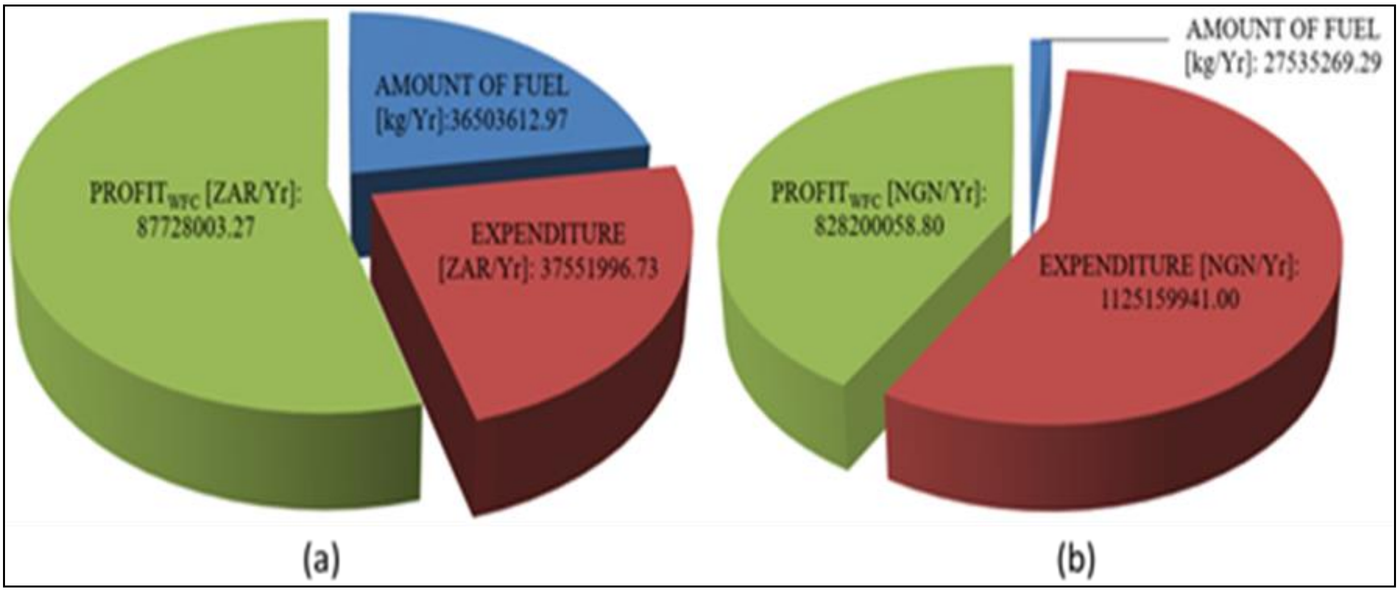

Fig 2 (a): South African Coal (Matla Mine): Coal + PSD [1:1, WFC] (b): Nigerian Coal (Onyeama Mine, Enugu): Coal + PSD [1:1, WFC]

It can be observed from Fig. 3a and Fig. 3b that the annual profits generated from the 10 MW power plant were ZAR87,128,003.27 (USA5,125,176.67) and NGN828,200,058.80 (USA517,625.04) for South African and Nigerian fuels at the exchange rate of ZAR17.00 and NGN1600.00 per USA1.00, respectively. It implies that about USA4,607,551.63 profit was earned from the plant using South African feedstock for producing a 10 MW electricity and heat (around 38.83 % higher than profit from Nigerian feedstock). The physio-chemical properties of Nigerian feedstocks are higher than that of the South African feedstock, and were expected to generate a higher profit, but because of the higher capital cost investment (mainly from the price of Nigerian coal), reverse was the case hence; resulted to non-viability of the feedstocks at the 10th year, as presented in Table 2 and Table 3.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

Table 2 Nigerian Coal and Solid Wastes: Economic Assessment at the 10th Year

Nigerian Coal [Onyeama Mine, Enugu]							
Feedstocks [-]	Capital Cost Investment [δ] [ZAR/Yr.]	Cash Flow [μ] [ZAR/Yr.]	Net Present Value [NPV] [ZAR/Yr.]	Internal Rate of Return [IRR] (%)		Payback Period [PBP] (Yr.)	
10th Year Blending Ratio: [1:1], Interest Rate: [5 %]: WFC				WFC	WOFC	WFC	WOFC
Coal + SCB	1231469512	721890487	-788291374	0.00	16.17	1.71	0.22
Coal + CC	1271136881	682223119	-852311065	0.00	17.67	1.86	0.23
Coal + PSD	787508701	1165851298	-71777137	0.00	19.63	0.68	0.21
Coal + WT	1147518552	805841447	-652801807	0.00	23.78	1.42	0.16
Blending Ratio: [4:1], Interest Rate: [5 %] -WFC							
Coal+ SCB	1403285504	550074495	-1065587481	0.00	19.43	2.55	0.16
Coal + CC	1418177861	535182138	-1089622453	0.00	19.29	2.65	0.17
Coal + PSD	1376507661	576852339	-1022370364	0.00	19.83	2.39	0.16
Coal + WT	1361047196	592312804	-997418515	0.00	21.90	2.30	0.14

WFC: with feedstock costing; WOFC: without feedstock costing; CC: corn cob; SCB: sugarcane bagasse; PSD: pine saw-dust; WT; waste-tyre.

From the WFC investment condition and Coal-to-Solid Waste ratio of 1:1, the NPV was negative, and the IRR was also zero for the feedstocks studied, implying that the venture is not viable. From Table 2, all the operating conditions considered using the Nigerian feedstocks at the 10th Year, demonstrated loss of investment, while a sufficient profit higher than that of Nigeria plant was achieved using the South African feedstocks at the same 10th year investment, WFC. It can also be observed that all the feedstocks studied at the 10th year using Coal-to-Solid Waste ratios of 1:1 were viable (SA), whereas; the 4:1 mixture was not an encouraging venture, WFC. The investment carried out WOFC, and for all the conditions investigated at the 10th year were promising. A comprehensive analysis for the South African feedstocks at the 10th year is presented in table 3.

Table 3 South African Coal and Solid Wastes: Economic Assessment at the 10th Year

South African Coal [Matla Mine]							
Feedstocks [-]	Capital Cost Investment [δ][ZAR/Yr.]	Cash Flow [μ] [ZAR/Yr.]	Net Present Value [NPV] [ZAR/Yr.]	Internal Rate of Return [IRR] (%)		Payback Period [PBP] (Yr.)	
10th Year Blending Ratio: [1:1], Interest Rate: [5 %], WFC				WFC	WOFC	WFC	WOFC
Coal + SCB	44476116.37	80803883.63	5130458.73	6.16	18.02	0.55	0.16
Coal + CC	45801214.65	79478785.44	2991865.14	5.66	17.67	0.58	0.19
Coal + PSD	37551996.73	87728003.27	16305387.18	8.85	19.63	0.43	0.20
Coal + WT	38350790.02	86929209.98	15016204.11	8.52	23.78	0.44	0.12
Blending Ratio: [4:1], Interest Rate: [5 %], WFC							
Coal + SCB	53160538.67	72119461.33	-8885445.55	3.14	19.43	0.74	0.17
Coal + CC	53762028.57	71517971.43	-9856198.04	2.90	19.29	0.75	0.17
Coal + PSD	50474593.28	74805406.72	-4550562.65	3.99	19.83	0.67	0.16
Coal + WT	49265992.25	76014007.75	-2599985.44	4.43	2.19	0.65	0.14

WFC: With Feedstock Costing; WOFC: Without Feedstock Costing; CC: corn cob; SCB: sugarcane bagasse; PSD: pine saw-dust; WT; waste-tyre

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

➢ *Effect of Feedstock Blending Ratio: Nigerian and South African Feedstocks*

The annual fuel requirement, expenditure and the profit accrued using feedstocks from both countries in the power plant are shown in Fig. 4 (a) and Fig. 4 (b), respectively.

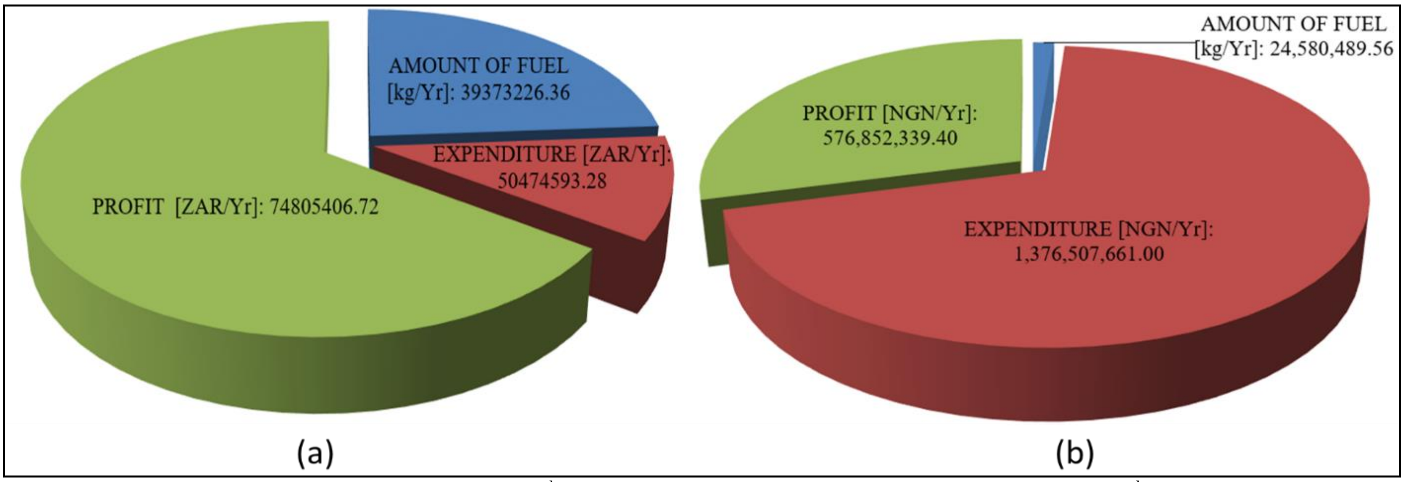

Fig 3 (a) South African Coal + PSD at the 10th Year: [4:1, WFC] (b): Nigerian Coal + PSD at the 10th Year: [4:1, WFC]

A compare of the transactions with respect to blend ratios was carried out. From the result, the use of Nigerian Coal-to-Solid Waste ratio of 1:1 as against 4:1, resulted to savings of NGN588,998,958.60 which is around 33.80 % increase in profit generated per annum, WFC. The 1:1 Coal-to-Solid Waste ratio was the optimum blend for all the feedstocks investigated. Similarly, larger amounts of fuel were consumed in the plant that used South African Coal-to-Solid Waste ratio of 4:1 than 1:1, thus; resulting to a loss in the annual feedstock of about 3.78 %, which then resulted to a decrease in the annual profit earnings of around 7.97 % (Coal + PSD), WFC. The results were attributed to the physio-chemical properties of the fuels which affected the energy value of the fuel. A comparison of the Nigerian coal and Nigeria Coal + PSD WFC, revealed that about 5,106,875.44 kg/Yr of feedstock was saved from Coal + PSD (1:1), hence; resulted to an increase in the profit by 43.24 % per annum, whereas, the South African Coal + PSD indicated a savings in the annual feedstock requirement of the plant of around 3,737,610.81kg/Yr, hence; resulted to an increase in the annual profit by 13.82 % compared to the South African coal. More so, around 703,979,489.10 kg/Yr and 2669613.39 kg/Yr of feedstocks were saved in the South African and Nigerian power plants by using Coal-to-Solid Waste ratio of 1:1 as against 4:1, thus; resulted to an increase in the profit made per annum by 32.18 % and 7.88 % respectively.

Although Nigerian feedstocks indicated a 33.80 % increase in profit due to the use of Coal-to-Solid Waste ratio of 1:1, the results obtained in using the NPV, IRR, PBP tools revealed that the investments were not worth pursuing at the 10th year due to the high cost of coal in Nigeria. Generally, Coal + PSD was the most promising feedstock for all the feedstocks studied for all ratios, WFC, and for both countries.

➢ *Economic Assessment at the 15th and 20th Year: South Africa and Nigerian Feedstocks*

The time/future value of money was considered at the 15th and 20th year of the investment as shown in Fig. 5a and Fig. 5b as well as Fig. 6a and Fig. 6b, respectively. From Fig. 5a, it can be observed that only Coal + PSD and Coal + WT were viable for all the feedstocks investigated, whereas; at the 20th year (Fig. 5b), none of the feedstocks were lucrative for electric power generation. Using Coal-to-Solid Waste ratio of 4:1 was not encouraging at the 15th and 20th year, WFC whereas; WOFC, it worth investing**.**

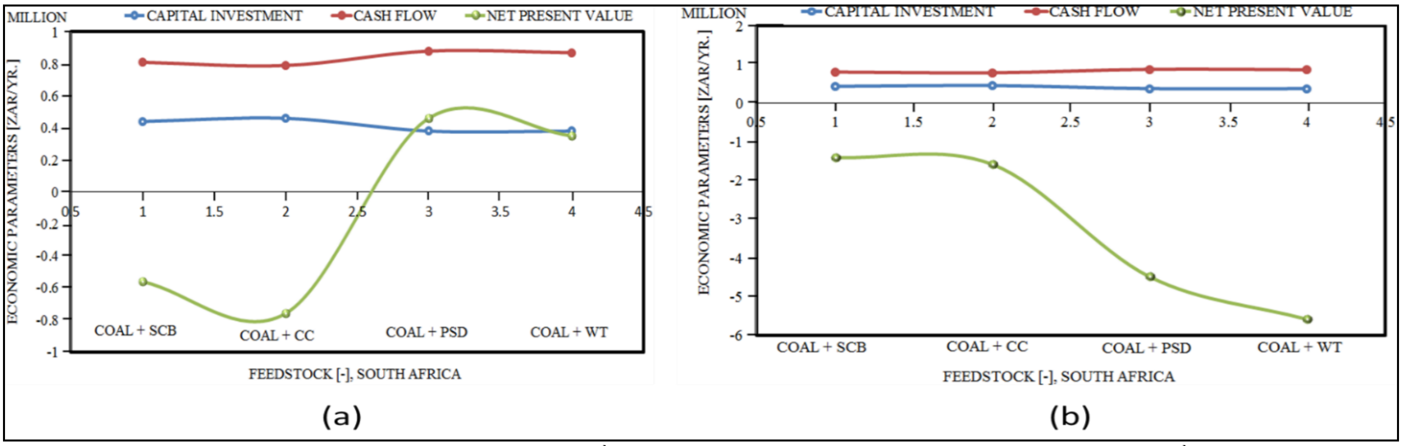

Fig 4 (a): South African Coal (Matla Mine): 15th Year [1:1] (b): South African Coal (Matla Mine): 20th Year [1:1]

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

Similarly, the Nigerian fuels shows that no feedstock was viable at the 15th and 20th year, because of the investment cost as shown in figures 6a and 6b, respectively, and the same trend of result was observed using the 1:1 Coal-to-Solid Waste ratio (Nigerian feedstocks).

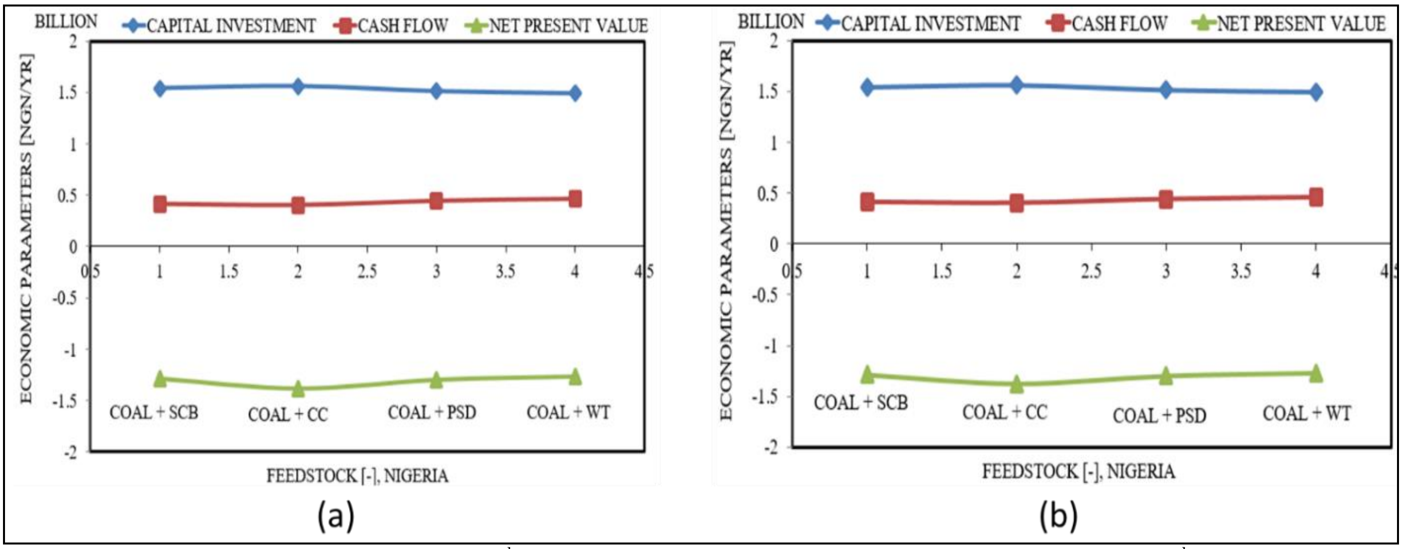

Fig 5 (a): Nigerian Coal (Onyeama Mine): 15th Year, WFC [4:1] (b): 6b: Nigerian Coal (Onyeama Mine): 20th Year, WFC [4:1].

Also, from Fig. 6a and Fig. 6b, the capital investments for the individual feedstocks ran into billions of naira, and in this case, the future value of money is not commensurate with the cash-in-flow for the periods studied, and hence; resulted to negative NPV. However, the evaluation carried out WOFC has always indicated a viable venture for all the conditions studied.

IV. CONCLUSIONS

The economic assessment of a 10 MW co-gasification power plant has been carried out using SA and Nigerian coal mixed with SCB, CC, PSD, and WT in the ratio of 1:1 and 4:1 respectively. Two financial conditions including WFC and WOFC were studied. Investment evaluation tools including the NPV, IRR, and PBP were used to determine the potentials of the feedstocks for power production at the 10th, 15th and 20th year investments. The following conclusions were made:

- The Coal + PSD was the optimum feedstock, and the Nigerian Coal + PSD produced around 13.82 % profit, while the SA Coal + PSD produced about 28.40 % annual profit higher than the profit earned from solitary gasification of coal for power generation.
- The optimum investment year was at the 10th year, but the Nigerian feedstocks was not viable at the aforementioned year.
- A comparison of the Nigerian coal and Nigeria Coal + PSD WFC, revealed that about 5,106,875.44 kg/Yr of feedstock was saved from Coal + PSD (1:1) which resulted to an increase in the profit by 43.24 % per annum, whereas 3,737,610.81kg/Yr was saved from the South African Coal + PSD which resulted to about 13.82 % compared to solitary gasification of the South African coal.
- Higher amount of fuel was used/consumed in the South African power plant at Coal-to-Solid Waste ratio of 4:1 compared to the 1:1, hence resulted to a loss in the annual feedstock of about 3.78 %.

REFERENCES

[1]. L.M. Mohlala, M.O. Bodunrin, A.A. Awosusi, M.O. Daramola, N.P. Cele, and P.A. Olubambi, ‘‘Beneficiation of corncob and sugarcane bagasse for energy generation and materials development in Nigeria and South Africa: A short overview’’ Alexandria Engineering Journal 3, 3025-3036, 2016.
[2]. Stats SA: Electricity generated and available distribution (P4141). Retrieved from STATS SA (Statistics South Africa) website on 20-02-17: Available online at: http://.www.stats, 2015.
[3]. SA Power Network ‘‘South Africa Power Network’’ Retrieved from SA Power Network website on 22-03-17. Available online at: https://www.sapowernetworks.com.au/centric/industry/our_network/network_tariffs.jsp, 2015.
[4]. UNDP, ‘‘Converting waste Agricultural Biomass into Resources’’ Compedium of Technology, United Nations Environmental Programme, Japan, 2009.
[5]. M. Ozonoh, T.C. Aniokete, B.O. Oboirien and M.O. Daramola ‘‘Techno-economic analysis of electricity and heat production by co-gasification of coal, biomass and waste tyre in South Africa’’ Journal of Cleaner Production 201, 192 – 206, 2018.
[6]. A.V. Bridgwater, A.J. Toft, and J.G. Brammer ‘‘A techno-economic comparison of power production by biomass fast pyrolysis with gasification and combustion’’ Renew Sust Energ Rev, 6, 181-248, 2002.
[7]. A.C. Caputo, M. Palumbo, P.M. Pelaggage, and F. Scacchia ‘‘Economics of biomass energy utilization in combustion and gasification plants: effects on

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr518

logistic variables'' Biomass Bioenerg, 28, 35-51, 2005.
[8]. C.P. Mitchell, A.V. Bridgwater, D.J. Stevens, A.J. Toft, and M.P. ''Techno-economic assessment of biomass to energy'' Biomass Bioenerg, 9, 205-26, 1995.
[9]. E. Searcy and P.C. Flynn. A criterion for selecting renewable energy processes. Biomass Bioenerg 34, 798 – 804, 2010.
[10]. B.O. Oboirien, B.C. North, S.O. Obayopo, J.K. Odusote, and E.R. Sadiku ''Analysis of clean coal technology in Nigeria for energy generation'' Energy Strategy Reviews 20, 64-70, 2018.
[11]. A. Malek, A.B.M. Hasanuzzaman, M. Rahim, and Y.A.A Turki ''Techno-economic analysis and environmental impact assessment of a 10 MW biomass-based power plant in Malaysia'' Journal of Cleaner Production 141, 502-513, 2017.
[12]. A. Demirbas ''Biomass resource facilities and biomass conversion processing for fuels and chemicals'' Energy Conv. Manag. 42, 1357-1378, 2001.
[13]. F. Ahmadi, A.L Amin, A.Q. Hasanuzzaman, R. Saidur ''Alternative energy resources in Bangladesh and future prospect'' Renew. Sust. Energ. Rev. 25, 2013.