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Sustainability Impact Assessment Of Utilizing Synthesis Gas In Household Generators For Electricity Generation In Nigeria

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Abstract

Sustainability impact assessment (SIA) aims at determining if a project is worthwhile by subjecting it to different analysis. In this study, an SIA was conducted on utilizing syngas as an alternative to conventional fossil fuels, such as gasoline, for household power generation. The methods embarked on in the study includes the Life Cycle Analysis, Techno-Economic Assessment, and Cost Benefit Analysis. The global warming potential (GWP) of utilising syngas was assessed and it was gotten to be 0.111kgCO_2 equivalent, its acidification potential was 4.4E-4kgSO_2 equivalent and human toxicity potential was 8.86E-2. It showed promise of being an eco-friendly method of power generation. In regards to the economic assessment, it was found that the Levelized Cost of Electricity was ₦34.009/kWh and this is seen definitely as a cheaper option than the current electricity tariff offered by the Benin Electricity Distribution Company. The study shows that syngas holds great potential for power generation and availability in Nigeria. The results offer empirical proof for the development and implementation of hybrid technologies to bolster energy stability while mitigating carbon emissions

1. Introduction

A survey done by Stears and Sterling, estimated that over 40% of households in Nigeria own and use generators to meet their electricity requirements, showing that those households are incurring an annual expenditure of about $14bn [1]. Data accumulated by World Resources Institute's Climate Analysis Indicators Tool (WRI CAIT), revealed that Nigeria's Greenhouse Gas emissions grew by 25% (98.22 MtCO_2e) between 1990-2014 [2]. As of 2022, carbon emissions from the electricity industry in Nigeria totaled roughly 11.8 million metric tons of carbon dioxide equivalent [3]. Mba (2020), also conducted a study and it was seen that Nigeria generates 4.3 million units of 3000W, enough for just 10.75 percent of all households [4]. A report released by The International Renewable Energy Agency, IRENA, in conjunction with the Energy Commission of Nigeria, in 2023, it was revealed that Nigeria is the highest importer of Premium Motor Spirit (PMS) and diesel generators [5]. In concordance with this report, the India-based P&S Intelligence released a report in 2023, stating that the diesel generator market is projected to reach $806.8 million by the year 2030 [6]. The Nigerian market poses as a wonderful opportunity to generate revenue by providing affordable and renewable sources of electricity. There is a carbon emission problem in the world and it is vital to lower our carbon quota as a country by implementing greener solutions that boost the environment. The adoption of syngas in household generators for electricity generation is expected to provide a breakthrough in further decreasing the CO_2 emissions hurting the earth.

Syngas is a fuel gas mixture containing predominantly hydrogen, and carbon monoxide. This product can be obtained from various sources such as natural gas, coal, biomass, or any hydrocarbon feedstock. It is produced through endothermic reactions with steam, carbon dioxide, or oxygen. Previously, these mixtures were created through the reaction of steam with incandescent coke, resulting in a substance called "water gas" [7]. Through a thorough sustainability impact evaluation, this study explores the possibility of syngas as a competitive alternative to traditional fossil fuels for generating electricity for households in Nigeria. The downdraft biomass gasification system being analysed was developed by a study conducted by Akhator and Obanor (2024) [8]. This present study focuses on the Sustainability impact assessment (SIA) of utilizing the syngas in household generators for electricity generation in Nigeria.

Sustainability impact assessment is a systematic process for evaluating the potential environmental, social, and economic impacts of a proposed policy, program, project, or plan. This approach resembles a comprehensive analysis of the advantages and disadvantages, emphasizing long-term sustainability [9]. The study employs Life Cycle Analysis (LCA), Economic Assessment, and Cost Benefit Analysis (CBA) to evaluate the feasibility of employing syngas as an alternative to gasoline in household power generation.

In modern times, different articles have been published regarding the methods being utilized in this study, with regards to power generation. Yi Fang et al (2023) [10] conducted a life cycle assessment and cost benefit analysis on a concentrated solar thermal gasification of biomass. The net present worth of the system was determined to be -€0.7billion in the 30th year. Reduction in operation and maintenance (O&M) costs by 19% or improving the efficiency of the system by 20% were suggestions for enhancing the economic viability of the system, allowing for a payback period of less than 10 years. The system could save 787.7 kg of CO_2-eq/ton$_{waste-wood.}$ Tonini and Astrup (2012) [11] assessed the environmental impact of electricity production in Denmark, demonstrating significant reductions in greenhouse gas emissions through optimized residual biomass utilization. A comparison study by Varun et al. (2009) [12] revealed substantially lower carbon dioxide emissions from biomass-based electricity generation compared to coal-fired power plants. Cherubini and Stromman (2011) [13] conducted a comprehensive review of LCA studies on biomass-based bioenergy systems, concluding that net greenhouse gas emissions from biomass-generated electricity are typically 5-10% of those from fossil fuel-based systems.

The study's relevance is highlighted by Nigeria's pressing energy issues, where a significant portion of the population relies on expensive and polluting diesel and petrol generators. Transitioning to syngas could mitigate improper waste disposal, reduce carbon emissions, and promote sustainable energy practices. By examining the holistic impact of syngas, this research aims to support the development of cleaner, renewable energy solutions that enhance energy security and environmental sustainability.

2. Methodology

To assess the sustainable impact of using syngas on household generators for electricity power generation, several analyses were carried out. The analyses include: (i) a comprehensive lifecycle assessment employing a cradle-to-grave approach using the OpenLCA software, (ii) an economic analysis of the impacts of adopting the use of syngas in household generators, and (iii) a cost-benefit analysis of employing the technique.

2.1 Life Cycle Assessment (Lca)

Life Cycle Assessment (LCA) is a widely used method for evaluating the environmental effects of a process, technology, system, or service from start to finish. The ISO 14000 series of international standards provides a comprehensive framework for conducting Life Cycle Assessment (LCA). It includes principles and a framework (ISO 14040), goal and scope definition and inventory analysis (ISO 14041), life cycle impact assessment (ISO 14042), life cycle interpretation (ISO 14043), and requirements and guidelines (ISO 14044).

2.1.1 Goal

The goal of this Life Cycle Assessment is to evaluate the ecological consequences of the project, starting from the collection of the wood chips and encompassing all the intermediate processes leading up to energy generation in order to see the viability of this project.

2.1.2 Scope

The scope encompasses the analysis of energy generation, the release of pollutants, and the potential environmental impacts to provide information for decision-making aimed at promoting more sustainable alternatives.

2.1.2.1 System Boundary

This study utilized the cradle-to-gate technique to evaluate the power generated from the syngas produced by the downdraft gasifier. It covers the following processes:

- Collection and treatment of the feedstock which in this case are wood chips.
- Transportation of the feedstock to the gasification site.
- Gasification of the feedstock to produce syngas.
- Generation of electricity from the syngas.

2.1.2.2 Functional Unit

In accordance with the relevant ISO standards, any product system within the realm of LCA must conform to a function that signifies the performance characteristics of the system [14]. Functional unit precisely determines the product's size and type, the life cycle of which is being analysed by the function quantitative definition that it delivers [15]. The functional unit considered for this study was 1kWh of electricity generated.

2.1.3 Data Aqcuisition and Inventory

Primary data was collected from the operation of the developed downdraft gasifier (Akhator and Obanor, 2024). As said earlier in the system boundary, the feedstock was wood chips obtained from sawmills across Benin City. Characterization of the wood chips revealed a moisture content of 9.84% and an energy content of 19.78 MJ/kg [16].

The values of the different input and output flows for the different processes were calculated manually first, and then the system was modelled using the OpenLCA software. The ecoinvent version 3.10 Allocation at Point of Substitution (APOS) unit processes database was used to provide additional data and processes for this research. The impact method used for the calculation was the Centrum voor Milieukunde Leiden (CML) version 2001, and the allocation method of choice was physical. It was chosen because it contained the three environmental impact categories to be analysed:

- Global warming potential
- Acidification potential
- Human Toxicity Potential

An inventory of the various input and output data, except for those from the ecoinvent database, is shown in Table 1 below

Table 1. Life Cycle Inventory Table

INPUT	**AMOUNT**	**UNIT**
Wood Chips (10% moisture content)	1.287	kg
Air (for gasification)	1.866	kg
Syngas	2.6	kg
Air (for combustion)	4.13	kg
Diesel (additional for transport)	0.005	kg
Transport (for wood)	260	Kg/km
Generator, 5KVA	1	pcs
OUTPUT		
Electricity	2	K Wh
Carbon dioxide	1.7517	Kg
Nitrogen	4.5552	Kg
Water Vapour	0.4219	Kg
Particulate Matter	0.0012	kg

2.1.4 Assumptions

The assumptions taken to carry out this LCA are presented in Table 2.

Generator Transportation	Generator is already on-site
Mass of Char	10% of the mass of biomass consumed
Emission reduction factor (E.R.)	25%
Energy Generated by Generator	2 kWh.
Air/Wood Mass Ratio for consumption	5.8kg air per 1kg wood.

1 kg of wood = 2.02 kg of syngas
Distance of wood waste to syngas production site = 100 km.
Gasification reaction: CHaObNcSdAsh + yH2O + x (O2 + 3.76N2) => z1H2 + z2CO + z3CH4 + z4CO2 + z5N2 + z6H2O + char + Ash + impurities (tars, H2S, dust).
Mole fraction of syngas = 16.642% H2, 28.15% CO, 2.538% CH4, 6.132% CO2, 45.418% N2.
When the syngas combusts with air in the generator, the oxygen in the air reacts with the various constituents of the syngas except N_2 and CO_2.

2.2 Economic Assessment

The system's economic performance is initially proved by many common economic indicators, such as the levelized cost of energy (LCOE), internal rate of return (IRR), and net present costs (NPC). The LCOE stands for the unit electricity cost in systems generated during the complete life cycle of the system. The computation for LCOE is illustrated in equation (1) as stated by Evans et al. (2009) [17].

$$LCOE = \frac{\sum_{n=0}^{N} C_n (1+r)^{-n}}{\sum_{n=0}^{N} E_n (1+r)^{-n}} \quad \text{-----------------------------------(1)}$$

An economic sensitivity analysis was undertaken to evaluate how uncertainty in capital and operating cost predictions can influence fuel prices. The capacity estimated for the gasification unit is 2kW input, based on the biomass lower heating value of 19.78MJ/kg. This guarantees the fuel synthesis facility makes use of the benefits of scale while being unrestricted by feedstock availability.

where

$\sum_{n=0}^{N} C_n (1+r)^{-n}$ represents the total cost of the year, C_{NY};

$\sum_{n=0}^{N} E_n (1+r)^{-n}$ represents the total Power consumption in kWh; and r is the discount rate. The above formula can be further simplified to:

$$LCOE = I_{t,e} + F_{c,e} + O\&M_{c,e} \quad \text{- -------------------------------------(2)}$$

The present value of all the expenses a system incurs over its lifespan less the present value of all the money it generates is the system's total net present cost (NPC). Costs include fuel costs, pollution fines, replacement costs, O&M costs, capital expenditures, and grid power purchase costs. Salvage value and grid sales revenue are examples of revenues.

The following equation, equation (3) calculates NPC:

$$NPC = \frac{C_{ann,tot}}{CRF_{(r,\, R_{proj})}} \quad \text{--------------------------------(3)}$$

where $C_{ann,tot}$, is the total yearly cost; $CRF_{(r,\, R_{proj})}$ is the capital recovery factor ; r, interest rate, %; R_{proj} represents the project lifetime. The capital recovery factor is a ratio that can be used to assess the present value of a sequence of equal annual cash payments. The formula is stated using equation 4:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad \text{----------------------------------(4)}$$

Internal rate of return (IRR) is the discount rate when the net present cost (NPC) is zero in the life of the system, which is calculated by equation (5).

$$\sum_{t=0}^{n} (CI - CO)_t \left(\frac{P}{F}, IRR, t\right) = 0 \quad \text{---------------------------------(5)}$$

where $(CI – CO)_t$ represents the net cash flow of the n-th year; P is the principal, and F is the end value.

The reliable operation of a power plant over its lifetime strongly relies on regular maintenance. However, the duration of maintenance periods is directly connected to the plant's annual operational hours. The operation and maintenance (O&M) cost requires specific information on maintenance personnel expenses, replacement parts, and repairs, which can be tough to collect. Nevertheless, according to renewable power generation costs [18], gasifiers typically incur an O&M cost of 3-6% of the entire plant cost per year. For this computation, an average O&M cost of 4.5% of the total plant investment cost (I_{tot}) was employed, as stated in Equation 6

$$O\&M_{c,a} = 0.045 \times C_{ann,tot} \qquad (6)$$

The specific O&M cost is obtained from equation 7,

$$O\&M_{c,e} = \frac{O\&M_{c,a}}{E_t} \qquad (7)$$

Annual cost of biomass ($F_{c,a}$ in N/yr) was calculated by multiplying the biomass consumption rate (kg/h), biomass specific cost (Fc,s in N/kg), and annual operation time ($t_{o,\,yr}$) together as shown in equation 8.

$$F_{c,a} = m_f \times F_{c,s} \times t_{yr} \qquad (8)$$

The annual specific cost of biomass F(c, e) was determined by relating annual cost of biomass with the energy generated per year using equation 9.

$$F_{c,e} = F_{c,a} \times E_t \qquad (9)$$

The reliable operation of a power plant over its lifetime depends immensely on adequate maintenance.

For the economic analysis, the net present value of the plant and the breakeven selling price are calculated using the discounted cash flow rate of return methodology. The values for the economic parameters and cost parameters used in the economic analysis are presented in Table 3 and Table 4 respectively. The variable costs shown in Table 5 are costs that can change in the production process due to factors such as inflation.

Table 3: Economic Parameters

Plant Operation Time	
Daily (hrs/day)	14
Yearly (days/year)	360
Generator Power Output (kW)	2 kW
Daily Generator Power Output (kWh)	28
Annual Generator Power Output (kWh/year)	10,080

Fuel	
Biomass Consumption Rate	3.704 kg/hr
Efficiency of Generator	21%
Specific Biomass Rate	₦3.00/kg
Gasoline Consumption Rate	1.11L/hr
Specific Cost of Gasoline (Market Value)	₦600.00/L

TABLE 4 Cost Parameters

Cost Parameters	
Capital Expenditure Cost (CapEX) (₦)	966,600.00
Annual Fuel Cost (₦)	56,004.40
Operation & Maintenance Cost (₦)	20,347.00
Discount Rate (%)	18.75

For the variable costs, the maintenance and repair costs are estimated at *4.5% of the total capital investment*.

TABLE 5 Variable Costs

Variable Costs	
Operation & Maintenance Costs	₦20,347.47
Biomass Cost/year	₦56,004.48
Total	₦76,351.95

2.3 Cost-Benefit Analysis

The steps indicated below were done to accomplish the analysis in this study:

- Collation of general performance data of several gasification methods in small-scale production.
- Performing down selection process with specified criteria to determine the most suited technology.
- Sizing and pricing of equipment
- Determining the cost of syngas production
- Determining capital investment and doing discounted cash flow analysis
- Discerning the payback period for the system in order to check its economic viability
- Performing sensitivity analysis on process and economic aspects.

The Net Present Value (NPV) approach was used to examine the economic viability of the proposed Downdraft Gasifier Generator (DGG) technology. All cash flows of the proposed Downdraft Gasifier Generator (DGG) system are studied over 20 years and resolved to their equivalent present worth (PW) cash flow. Revenues were thought to represent positive cash flows while costs were seen as negative. The NPV of the DGG system was computed using equation 10:

NPV = CAPEX + PW(O&M) + PW(BCT) – PW(ES) - SV -------------------------------(10)

where CAPEX is the capital cost that included the initial investment cost of constructing of the Downdraft Gasifier Generator system (DGG), BCT is the cost of procuring the biomass, ES is the income from selling electricity to customers and SF is the salvage value of the project after its useful life. The PW is the present value, which is determined with annual value (AW).

PW = AW1+iN-1i1+iN ---(11)

where i signifies the interest rate (an interest rate of 18.75% was utilised based on Central Bank of Nigeria (CBN) Monetary Policy Rate, January 2024), and N denotes the estimated operation years (N = 20 years in this study). Table 6 below illustrates the cost of engineering measurements and evaluation for the gasification system.

The payback period is defined as the amount of time it will take to recover the cost of investment. It can also be termed as the point to breakeven. The payback values are the cumulative values of the net present values with each year passing, i.e.,

$PB = NPV_{y_0} + NPV_{y_1} + \cdots NPV_{y_{19}}$--(12)

Where PB refers to payback and NPV_y refers to Net Present Value with respect to its year.

2.3.1 Capex And Operation and Maintenance (O&M) Cost

The capital cost (CAPEX) was determined by the Bills of Engineering & Materials which was meticulously drafted out. The Downdraft Gasifier Generator has been fabricated and the cost of production for the fabrication process was determined to be ₦551,600. O&M cost refers to the cost it will take for operation and maintenance of running the device.

It has been determined that a 5kVA generator will be required to produce the required power and that has been determined from market prices to be ₦415,000 which brings up the capital cost to a sum of ₦966,600. Following IRENA standards on O&M, an average value of 4.5% was taken for the operation and maintenance cost.

2.3.2 Electricity Units Sales Revenue (Es) and Salvage Value

The parameter, ES, refers to the benefits gotten by the producer from selling units of electricity gasifier. The electricity selling price was obtained through the LCOE (Levelized Cost of Electricity). The DGG has been rated to produce 2000W per hour. The salvage value has been taken to be 10% of the initial investment cost.

2.3.3 Biomass Cost

The availability of wood waste in Benin City was 335,460.04 tons per year [19]. It has been determined that the specific biomass cost was N6.00/kg after adjustment for inflation. This helps determine the biomass cost.

3.0 Results And Discussion

3.1 Economic Analysis Results

The following data were calculated using the methods and equations described in Section 2.2 and they are shown in Table 6 and Figure 1.

TABLE 6 Economic Analysis

Cost Parameters	Generator with Biomass Gasifier	Gasoline Generator
CAPEX cost (₦/kWh)	18.577	7.976
Annual Fuel Cost (₦/kWh)	11.112	357.5
O&M Cost (₦/kWh)	4.315	1.852
LCOE (₦/kWh)	34.009	367.028
WACC (%)	18.75	18.75
IRR (%)	16%	

This pie chart below represents the fractions of the cost that influence the value of the Levelized Cost of Electricity (LCOE), it can be seen that the capital expenditure had the most bearing in determining the cost of electricity units.

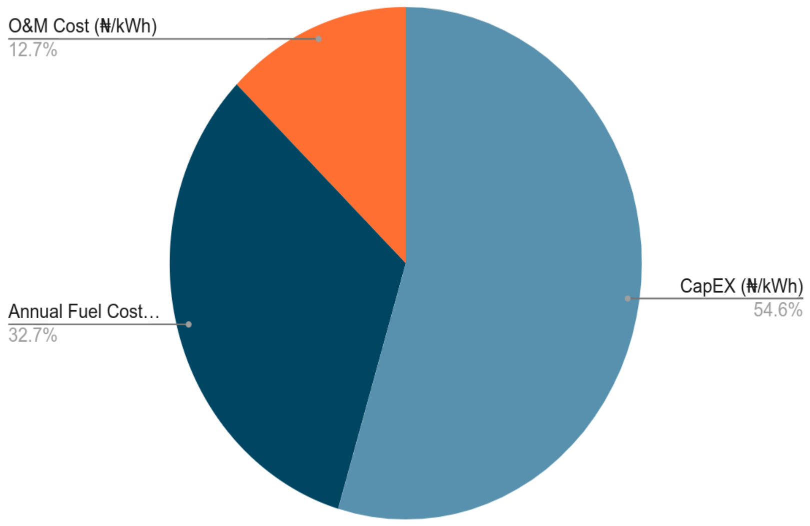

FIGURE 1 Composition of the Lcoe

3.1.1 Effect of Biomass Cost on LCOE

The analysis shows that the price of biomass fuel and the Levelized Cost of Energy (LCOE) are directly correlated. Biomass accounts for a sizable portion of total operating costs, changes in its cost have a direct impact on the LCOE. This sensitivity emphasizes the importance of reliable and affordable fuel sources to maintain long-term economic sustainability. Fluctuations in the price of biomass can strongly impact the competitiveness of syngas generation among alternative energy sources. The figure below is an effect of biomass cost variation on the LCOE

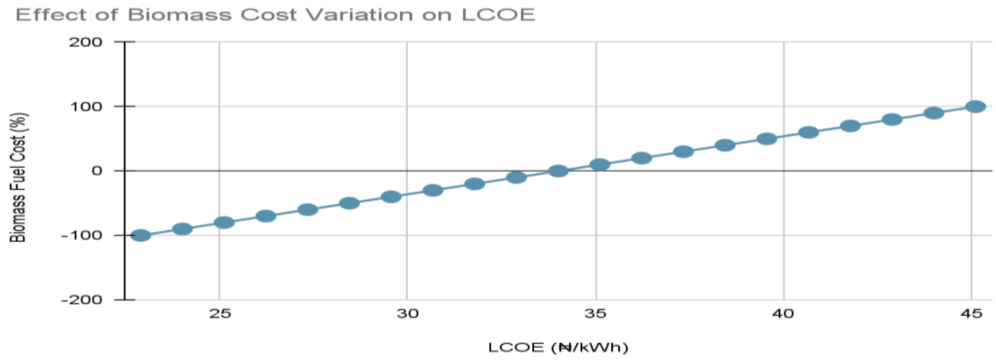

FIGURE 2 The Effect of Biomass Cost Variation on LCOE

3.1.2 Effect of Operating Hours on LCOE

As the operation time decreases, The LCOE of the system increases and vice-versa. Hence, while reducing operation time might seem like a cost-saving measure initially, the effect leads to an increase in the LCOE of the system thus potentially impacting the economic viability of the system. The effect of the number of operating hours on the LCOE is shown in the figure below.

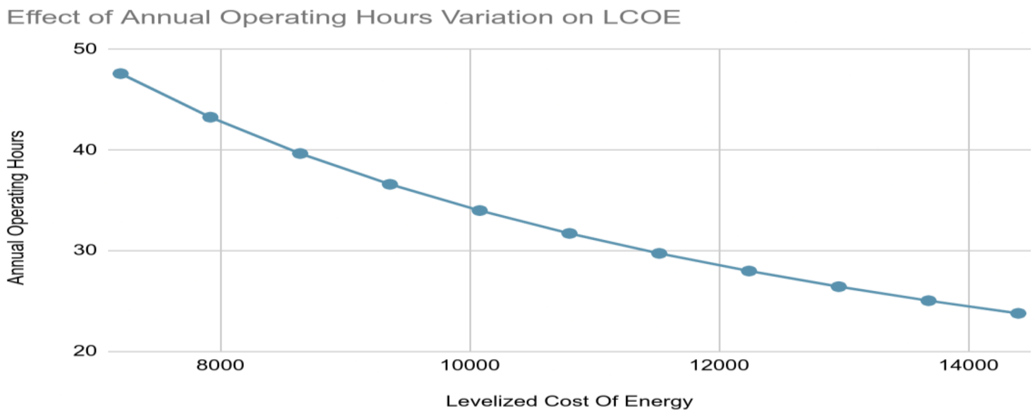

FIGURE 3 The Effects of Operating Hours on LCOE

3.1.3 Effect of O&M Cost Variation on LCOE

The variation of the operation and maintenance costs has a linear effect on the LCOE value as shown in Fig 4 below. It shows that as the operation and maintenance costs increase it increases the LCOE value.

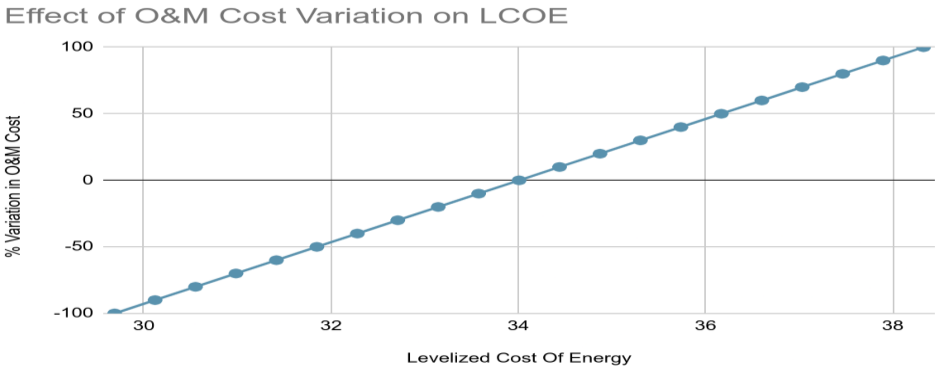

FIGURE 4: Effect of O&M Cost Variation on LCOE

The LCOE was obtained as 34.009 (₦/kWh) for the fixed bed downdraft gasifier fuelled by wood waste and 367.028 (₦/kWh) for the gasoline generator. The results showed that the small-scale downdraft gasifier is more beneficial economically.

It was observed that the LCOE of the biomass system was less than the current electricity tariff of Maximum Demand (MD1 and MD2) areas which have an electricity tariff range of 45.29 (₦/kWh) to 225 (₦/kWh) across all bands. It is also less than non-MD areas across Band A to Band C which are 45.80 (₦/kWh) to 225 (₦/kWh). The tariff rates of non-MD areas in Band D and Band E are higher than the LCOE.

Tariff Class	A	B	C	D	E
Min. Supply Hrs	20	16	12	8	4
(Tariff) Non MD N/KWh	225	68.56	56.91	41.2	41.21
(Tariff) MD 1 N/KWh	225	63.88	54.98	46.64	46.64
(Tariff) MD 2 N/KWh	225	63.88	54.98	46.64	46.64

FIGURE 5 Tariff Rates According To Benin Electric Distribution Company [20]

3.2 Cba Analysis

3.2.1 Present Worth Analysis

The following results were obtained after running an extensive cost-benefit analysis for the Downdraft Gasifier Generator system, these results are displayed in Figure 6. It was found from economic evaluation that the Levelized Cost of Electricity was ₦34.009kWh. The total NPV as at year 20 was -₦157,606.95. The cumulative present worth of the O&M cost in year 20 was ₦3,217,667.08. The PW of the biomass cost was ₦574,493.956 in year 20. The sources of revenue for the DGG system were the ES and salvage value at the end of its total lifespan with the cumulative PW value of electricity selling revenue being ₦25,359,080.26. A chart representing the present worth analysis of the different economic parameters is shown below.

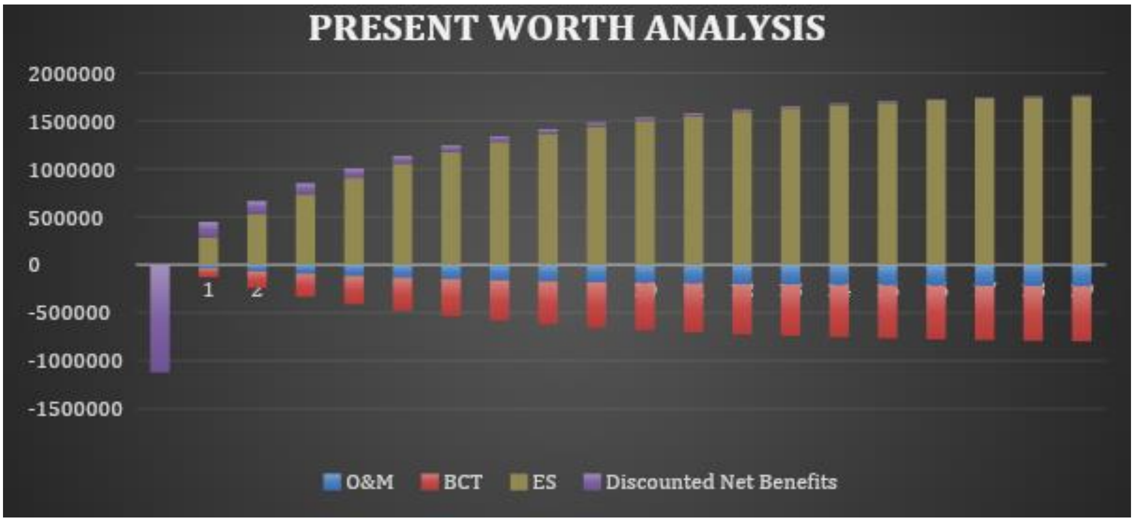

FIGURE 6 Present Worth Analysis

3.2.2 Payback Analysis

From analysis, it has been determined that the project will yield a negative net present value after the projected useful life. Data represented on the chart in Figure 7 showed that there was steady growth in the net present value. For the project to be economically viable, however, i.e., to produce a payback in 10 years, it has been determined that the following conditions should exist:

1. The O&M cost of the system needs to be reduced by 30%
2. The biomass cost needs to be decreased by 40%
3. The government should provide incentives such as tax and import duties breaks.

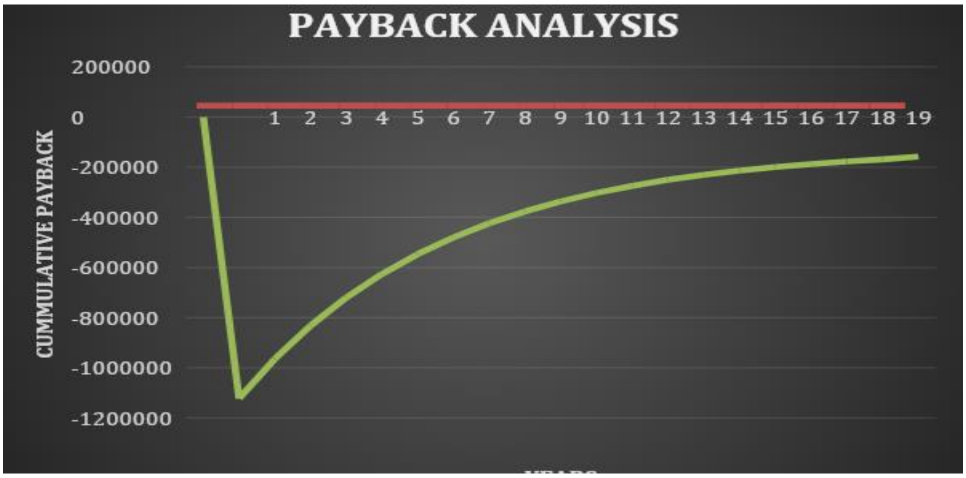

FIGURE 7 Payback Analysis Curve

3.2.3 Sensitivity Analysis

The impacts of Electricity Selling revenue, Operation and Maintenance Cost, Salvage Value after its useful life, and Biomass cost, on the Net Present Value (NPV) were studied via sensitivity analysis. and the results are presented on the chart given in Figure 8. It can be seen from the chart that the least sensitive parameter is the O&M cost as a large difference in it will impact the NPV. However, it can be observed that very little changes in the values of the other parameters can cause a change in the NPV of this project with the most sensitive parameter being the electricity selling revenue. From calculations, it has been determined that a 9% change in its value can have large effect on the success of the project. Hence, it can be said that the profitability of the project can be greatly increased with the sales revenue of electricity rising with costs such as O&M cost and Biomass cost being reduced.

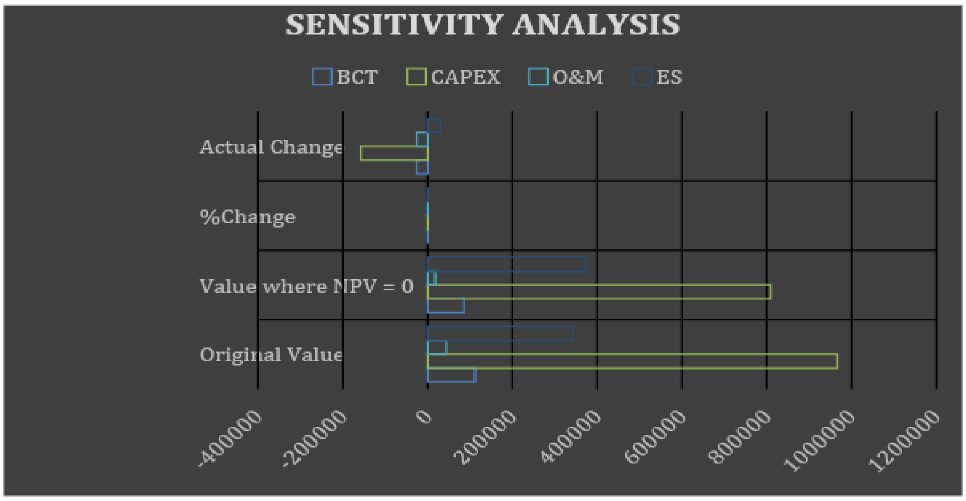

FIGURE 8 Sensitivity Analysis Chart

3.3 Lca Results

After modelling the lifecycle inventory using OpenLCA software, the LCIA was conducted using the CML method that was discussed in section 2.1.3. The impact categories measured are shown in the following subsections.

- Global Warming Potential 20: From this analysis, the GWP was found to be 0.111kg CO2/kWh of electricity generated. This means that the project doesn't have an adverse impact on the climate as can be seen in the comparison against other means of electricity generation.

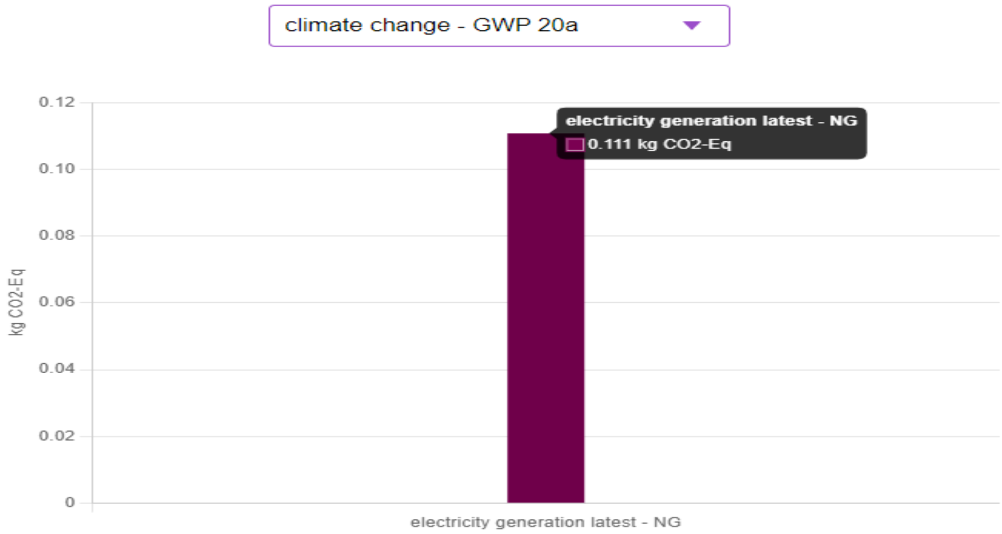

FIGURE 9 Global Warming Potential*20 (Kg Co_2/Kwh)

- Acidification Potential: The acidification potential was 0.00044kgSO2/kWh of electricity generated. Which is also acceptable when compared with that of alternatives such as the Integrated Gasification Combined Cycle Power Plant (IGCC), and a Natural Gas Combined Cycle Power Plant (NGCC).

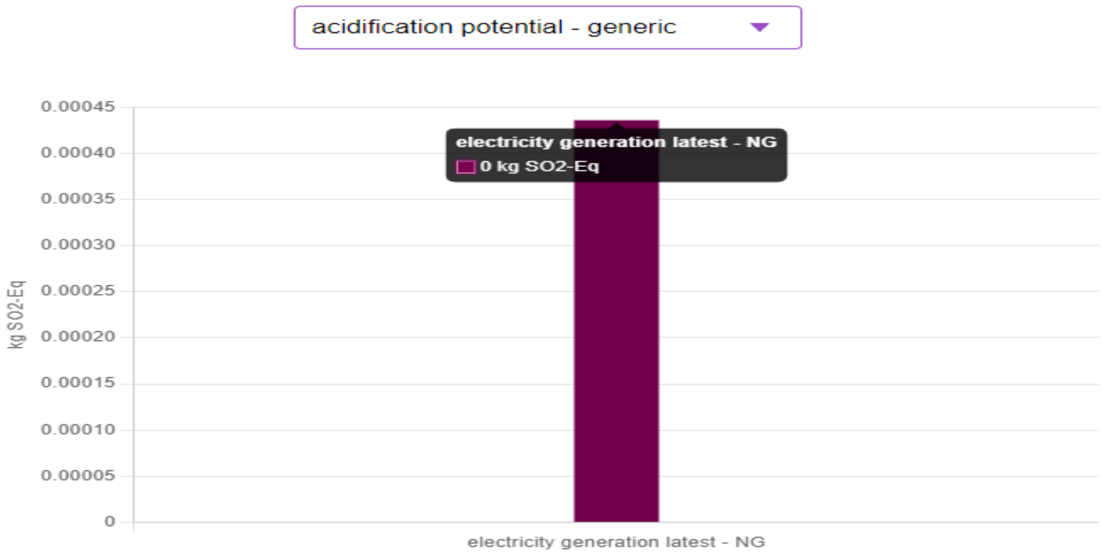

FIGURE 10 Acidification Potential (Kg So_2/Kwh)

- Human Toxicity Potential (HTP): The HTP gotten from the LCA is higher than those of compared power plants. This is due to lower efficiency of contaminant removal and incomplete combustion of the syngas.

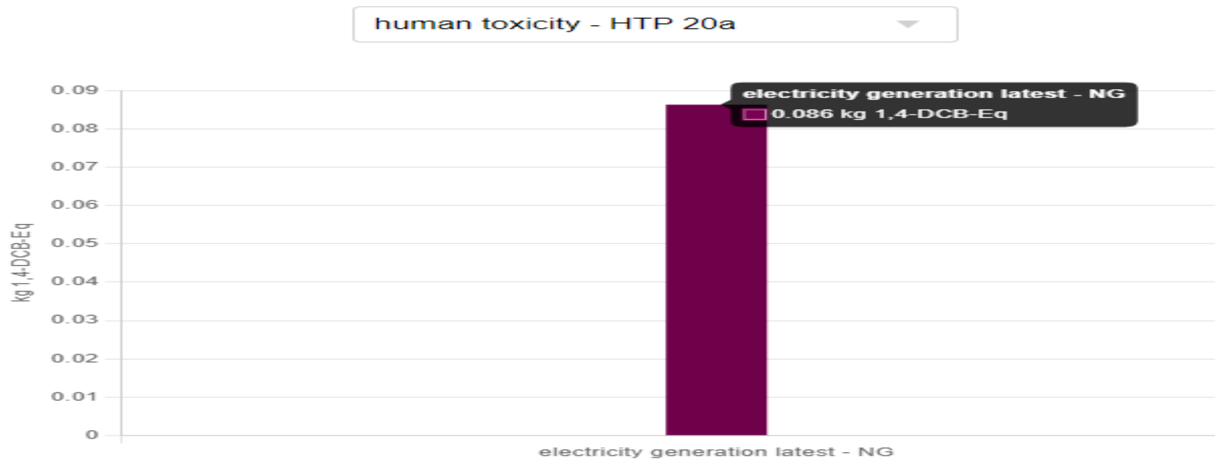

FIGURE 11 Human Toxicity Potential (Kg 1-4 Dcb/Kwh)

3.3.1 Impact Categories Results Against other Energy Sources

Table 7 shows a comparison between the syngas power plant, an Integrated Gasification Combined Cycle Power Plant (IGCC), and a Natural Gas Combined Cycle Power Plant (NGCC) [21], another biomass gasification power plant and a natural gas power plant [22].

TABLE 7 Impact Results Comparison Against other Alternatives

	Unit	Syngas	IGCC	NGCC	Biomass Gasification	Natural Gas
Energy Efficiency	%	21	42	64	22	39
Global Warming Potential	kg CO_2 eq	0.111	0.813	0.459	0.0839	0.423
Acidification Potential	kg SO_2 eq	4.4E-4	3.79E-4	4.53E-4	3.36E-4	3.33E-4
Human Toxicity Potential	kg, 1-4 DB eq	8.86E-2	2.87E-3	1.39E-3	3.31E-2	4.83E-2

From Table 7 above, the syngas power plant is compared against other power plants, including another power plant that utilizes biomass gasification. The comparison is spread across the 3 impact categories as mentioned in section 2.1.3. As expected, the GWP of the syngas power plant is a lot lower than most of the systems included in the comparison, with the exception being the biomass gasification power plant. The difference between both GWPs is 0.0271 kg CO2/kWh. This can be attributed to the fact that the feedstock could be different, leading to different gas products after gasification, and there is no Carbon Capture System (CCS) technology in the syngas power plant.

On the other hand, the acidification potential is similarly minute across the different power plants, with the highest being the NGCC, which is closely followed by the syngas power plant. On the other end of the relatively short scale, the power plant with the least acidification potential is the Natural Gas power plant, while the biomass gasification power plant has a slightly higher value.
As for the human toxicity potential impact category, the syngas power plant being analysed had the highest value, while the NGCC and IGCC had the lowest values, although the former had a HTP value of less than half of that of the latter. The high HTP of the syngas power plant can be attributed to the large amounts of nitrogen gas that gets released during the electricity distribution process. This is due to the fact that large quantity of air is used to combust the syngas, resulting in large amounts of nitrogen gas.

4. Conclusion

A sustainability impact assessment of using syngas in household generators for electricity generation in Nigeria was carried out in this study. Results show that the Downdraft Gasifier Generator plant has the capacity to be a game changer in the energy generation sector in Nigeria. However, the LCA identifies a few areas which can be improved before it can reach its full potential, while also showing how promising this technology is. As this technology is in its early stages in the country, further research and development are crucial. This will determine its viability as a large-scale contributor to the energy grid. While the initial assessment is encouraging, focused efforts are required to address current limitations. Overcoming these challenges will pave the way for its successful integration into the energy sector as a substantial and sustainable fuel source. The analysis has shown that this system can be a major player in the energy market but with a touch of increased revenue parameters, it can yield even greater returns and the payback period can be attained at a closer time. The sensitivity analysis showed that reducing capital investment, sourcing for cheaper biomass options, and increasing operation hours while reducing downtimes will increase the LCOE and achieve higher revenues from selling electricity from the plant. It also showed that the electricity selling revenue is the most sensitive parameter for the plant's success.

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