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Comparative Economic Analysis of Gas Fired and Hydroelectric Power Plants In Nigeria

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ABSTRACT
In this Paper, a comparative economic analysis of a presumed 400MW natural gas fired and hydroelectric power plants in Nigeria for a 30 years period was carried out based on real electricity cost model. This was done using Levelized Cost of Electricity (LCOE) and cost estimate for each plant. Plants technical and economic parameters were used to compute Net Present Value (NPV) for each plant capacity which gave -$2,675,510,774 and -$3,730,745,340 for the natural gas fired power plant and the hydroelectric power plant respectively. Other profitability indices such as the Internal Rate of Return (IRR) and Discounted Payback Period (DPP) were computed. The IRR was found to be 13% for the natural gas fired Power plant and 14% for the hydroelectric power plant. The DPP for the natural gas fired power plant was calculated to be 17.48 years while that of a hydroelectric power plant was gotten to be 13.84 years. The study revealed that the economics of any of the two sources of power depends on electricity price, operational cost, and maintenance cost.

KEYWORDS: Combined Cycle Gas Turbine, Discounted Payback Period, Hydroelectric Power Plant, Economic Analysis, Weighted Average Cost of Capital.

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1. INTRODUCTION
Electricity is undeniably the most utilized form of energy in the world today. Many facilities and devices that contribute to development rely upon electricity to operate. In Nigeria, the power sector plays an important role in lives of the people and the economic transformation of the country. However, power has remained a major challenge for as long as the country has existed. The challenge which cuts across generation, transmission and distribution has made Nigeria the highest buyer of standby electricity generating plants in the world (Braimoh & Okedeyi, 2007). Much of the little electricity generated in Nigeria is either through hydroelectric or natural gas fired power plants with both sources of power requiring huge amount of resources. This study analyzes the economics of both sources and compares them in order to know which is more economically viable.

According to the Federal Ministry of Power, Nigeria has moved from generating 15% electricity from hydroelectric and 85% electricity from natural gas fired power plants in 2015 to 26% electricity generation from hydroelectric and 74% electricity generation from natural gas fired power plants in 2021. According to the international Renewable Energy Agency (IRENA), the percentage increase in hydroelectric power plant generation may not be unconnected with the fact that its source is renewable and fuel cost are not incurred even though they have relatively high capital and installation costs compared to natural gas fired power plants which are modular in nature.

According to the United States Energy Information Administration (EIA), the fixed operational and maintenance costs for a natural gas fired power plant and that of hydroelectric power plant are $13.17/kW and $14.13/kW per annum respectively while the variable operational and maintenance cost for a natural gas fired power plant is $3.60/MWh while a hydroelectric power plant has less than $0.5/MWh variable operational and

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maintenance cost. This makes, operating a hydroelectric power plant relatively low in comparison to a gas fired power plant.

The cost of a unit price of electricity is usually determined by a combination of the costs associated with the production of the power and those associated with its delivery. The cost of each unit delivered can be broken down into elements reflecting the cost of each component, plus the profit margin added at each stage to generate revenue and profit. In order to effectively compare the economics of electricity generating plants, both present and future cost of electricity must be considered. The complex nature of electricity value chain makes it difficult to model future electricity costs. However, various strategies have been established which allow future cost to be computed and investment decisions made. The two most important of these are capital cost estimates and calculation of LCOE (Breeze, 2010).

The capital cost of or power generating plant can vary widely depending upon technology. The overnight cost of a simple gas turbine plant can be as low as \$600/kW and as high as \$1200/kW including the installation cost and all ancillary equipment. On the other hand, a modern hydroelectric power plant is likely to cost over \$3,000/kW for conventional hydro-power plant and over \$5,000/kW for pumped storage hydro-power plants (Breeze, 2010).

The LCOE is the average unit price of output of a generating plant over its operating lifetime. If involves calculating the total cost involved in building and operating the plant over its lifetime. The annual costs are then discounted to convert them into their present values, a figure which reflects the expected reduction in money value over the lifetime of the project. All the annual discounted sums are then added together to produce a figure in today's money for the total cost associated with the plant. The figure is divided by the estimated total output of the plant over its lifetime and the resulting number is the LCOE for the station (IRENA, 2012).

Ebhota and Tabakov (2018) studied the place of small hydro-power electrification scheme in socioeconomic stimulation of Nigeria. They stated that according to the world bank, approximately 55% of Nigeria's population has no access to the national electricity grid and most of these people live in the rural areas. The national grid capacity is hovering between 4500MW and 6000MW for a population of about 200 million people. However, this is contrary to the enormous energy that abounds in Nigeria (both conventional and renewable energy sources). The supply of adequate and affordable power by Nigeria to her citizens is further compounded by the global energy trends coined energy trilemma.

Imo *et al.* (2017) did statistical analysis of electricity generation in Nigeria using multiple linear regression model. Two climatic variables (rainfall and temperature) were used as the explanatory variables. Data on electricity generation in Nigeria between 2002 and 2014 were obtained from the Central Bank of Nigeria (CBN) statistical bulletin while data on rainfall and temperature between 2002 and 2014 were extracted from the National Bureau of Statistics (NBS). They tested the model fitness and forecasting accuracy using generic statistical approach which include coefficient of determination and root mean square error.

Real cost of electricity considers operational maintenance and capital cost of power as well as economic cost of climate change, pollution and resource depletion. It gives a better picture of the true cost of electricity since some sources of electricity might have low capital and operating cost, but high pollution, land use and resource depletion cost which makes decision based on capital and operating costs of generation misleading.

Adeoye and Bamisaye (2016) studied performance evaluation and analysis of Omotoso

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gas power plant Nigeria. Their study evaluated and analyzed the performance of Omotoso power plant form year 2008 to year 2012 based on performance indices such as thermal and overall efficiencies. The period of Outages of the plant was evaluated based on the data that they obtained from outage log books. Their evaluation was performed with the aid of simple mathematical equations and data collection. They showed that the average values for thermal efficiency and overall efficiency of the gas generating power plant was calculated to be 28.39% and 29.12% respectively. They attributed the scenario to different factors such as: break down or failures, obsolete technology, instability of the national grid system, ageing of plant components and disruption of gas supply.

Oyedepo *et al.* (2015) studied assessment of performance indices of selected gas turbine power plants in Nigeria. In their study, the performance assessment was evaluated using performance indices like plant capacity, plant use and utilization factors. The results of their study showed that for the period under review (2006-2010), the percentage shortfalls from the target energy in the selected power plants ranged from 26.33% to 86.61% as against the acceptable. Value of 5-10%. The capacity factor of the selected power plants varied from 16.88% to 73.67% as against the international value of 50-80%. The plant use factor varies from 45.89% to 97.03% and the utilization factor varies from 6.31% to 93.074% as against the international best practice of over 95%.

The aim of this research was to use a techno-economic model in creating a summary of the costs and earning (profits) of both sources of power plant which at the end will give a result that will help determine which give better returns with respect to the cost of capital, operational and maintenance cost as well as environmental impact. The aim was achieved by undertaking an economic analysis of gas fired and hydroelectric power plants in Nigeria, comparing the two sources of electric power using common capital investment profitability indices like the NPV, IRR and DPP; and identifying the power source with better economic benefits among the two sources based on real cost of electricity. The LCOE which is the average unit price of electricity in Nigeria (which is N35/kWh) was imputed into the excel model which contributed to the NPV of both sources of power.

2. MATERIALS AND METHODS

2.1 Data Collection

The basic technical and economic data that will be used in this study will be related to Nigeria. In cases where such data are not available, international data that equally apply to Nigeria will be used. According to the Nigerian Electricity Regulatory Commission (NERC), the average price of electricity in Nigeria is ₦35/kWh which translate to ₦35,000/MWh (Tunde, 2018). Converting this to the US dollar, exchange rate of N306.35 per dollar according to the Central Bank of Nigeria (CBN) exchange rate, the electricity price becomes $114.25/MWh. This price will be used in calculating annual sales revenue for the gas fired and hydroelectric power plants. For the investment cost, $1.2 million per megawatt capacity will be adopted as sourced from the NERC. This investment cost include the cost for engineering, building, procurement, construction of transmission and fuel delivery facilities etc. for a natural gas fired power plant in Nigeria. This means that for a 40MW plant capacity, $480 million will be the average capital cost.

Also, for a hydroelectric power plant a capital cost of $2,936/kW will be adopted in accordance with the NERC report on updated capital cost for hydroelectric power plants. Considering a 400MW power plant, the total capital cost will be 400,00kW multiplied by $2,936/kW which gives $1,74,4000,000 in capital cost. The choice of 30 years operational period will be adopted for both sources of power as stated by CarapeIlucci and Giordano (2013), Yu *et al.* (2012) and Seebregts (2010) who argued that the average life time of a power plant is 30 years beyond which the

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economics of such plants must have been greatly reduced.

2.2 Economic Parameters

These are the indicators used in interpreting the investment possibilities. They allow economic performance analysis as well as predict future performance.

2.2.1 Weighted Average Cost of Capital (WACC)

This is the calculation of the cost of capital with each category of capital proportionately weighted. From the WACC, all cash flows can be discounted. It accounts for the cost of equity and cost of debt.

Mathematically,

$$WACC = \frac{E}{C}K_e + \frac{D}{C}K_d \times (1 - TR) \qquad (1)$$

Where,

E = Total Equity

C = Total Capital

E/C = Percentage of capital that is equity = 30 percent (Assumed for both sources of power)

Ke = Cost of equity = $r_f + \beta\,(r_m - r_f)$ (2)

r_f = Risk free interest rate = 13.02 percent in Nigeria

β = Measure of the reaction of a price of share in a company to the change in the overall market = 0.5 (for this research).

r_m = ERP + r_f (3)

Where ERP = Equity risk premium (ERP) = 11.15 percent in Nigeria the average

r_m = ERP + r_f = (11.15 +13.02) percent = 24.17 percent

D = Total Debt

$\frac{D}{C}$ = Percentage of capital that is debt = 70 percent (Assumed for both sources of power)

K_d = Cost of debt = r(1 – TR) (4)

r = Prime lending rate = 16.90 percent in Nigeria

TR = Tax rate = 30 percentage in Nigeria according to the CBN.

2.2.2 Net Present Value (NPV)

This accounts for the difference in the initial cost and the present values of all the future cash inflows and outflows. It is mathematically represented as:

$$\sum_{I=1}^{n} \frac{NCFi}{(1+r)^t} - Co \qquad (5)$$

Where

NCFi = Net Cash Flow (which is cash inflow – cash outflow)

Co = Initial cost

R = Discount rate

t = Time period

2.2.3 Internal Rate of Return (IRR)

This is maximum allowable rate of return on the investment.

It is the discount rate that brings the NPV to zero.

Mathematically,

$$\sum_{i=1}^{n} \frac{NCFi}{(1+IRR)^t} = O = NPV$$
(6)

Where,

NCFi = Net Cash Flow

t = period

IRR = Internal Rate of Return

NPV = Net Present Value

2.2.4 Discounted Payback Period (DPP)

This is a project capital budgeting procedure used in profitability determination. It gives the duration (usually in year) it will take a project to break even by discounting future cash flows and time value of money recognition. It helps in feasibility and profitability recognition evaluation of a given project (Quinland, 2014). It has the mathematical formula:

$$DPP = \mathrm{In}\left[\frac{1}{1 - \frac{O_1 X r}{CF}}\right] \div \mathrm{In}\,(1+r) \qquad (7)$$

Where

O_1 = Initial investment

R = Discount rate

CF = Periodic cash flow

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3. RESULTS

3.1 Computed NPV, IRR and DPP

The NPV, IRR and DPP were computed by the application of Equations 1-7 with given parameters in a developed techno-economic excel model.

The result from the techno-economic model in determining the NPV and IRR for the presumed 400MW power plant at an electricity price of 114.25/MWh (₦35/kWh) at 1$ = N306.5 with an investment of $480,000,000 and $1,174,000,000 for a gas fired power plant and a hydroelectric power plant respectively are presented in Table 1 to Table 4.

Table 1: Input Variables for the Natural Gas Fired Power Plant

Exchange rate (₦/$)	306.35
Price (₦/kWh)	35
WACC (%)	11.38
Price ($/MWh)	114.089
Plant capacity (MW)	400
Ann. power output (MWh)	2663040
Ann. sales ($)	304,248,082.34
Ann. Depreciation ($)	10,213,415.78
Ann. Dep. tax savings ($)	3,064,024
OP. expenditure ($)	67,138,147.69
Annual tax ($)	70,532,980.37
Net annual tax ($)	67,468,956.37
Total annual cost ($)	136,607,104.10
Price of pollution ($/MWh)	38.76
Total cost of pollution ($)	103,219,430.40
Real Annual cost ($)	239,826,534.50

Table 2: Computed NPV and IRR for the Natural Gas Fired Power Plant

Year	Cash flow ($)	Discount factor (%)	Discounted cash flow ($)	Cummulative DCF($)
0	-480,000,000	1	-480,000,000	-780,000,000
1	64,421,547.80	0.897827258	5,783,9421.62	-422,160,518.40
2	64,421,547.80	0.806093785	51,929,809.32	-37,023,769.10
3	64,421,547.80	0.723732973	46,623,998.31	-32,360,677.80
4	64,421,547.80	0.649787191	91,860,296.56	- 281,746,474.20
5	64,421,547.80	0.583396652	37,583,315.28	- 244,163,158.90
6	64,421,547.80	0.523789416	33,743,324.91	-210,419,834
7	64,421,547.80	0.470272415	30,295,676.88	- 1,80,124,157.10
8	64,421,547.80	0.422223393	27,200,284.50	- 152,923,872.60
9	64,421,547.80	0.379083671	24,421,156.55	- 128,502,715.80
10	64,421,547.80	0.340351653	21,925,980.30	- 106,916,735.50
11	64,421,547.80	0.305576992	19,685,742.77	-86,890,992.71
12	64,421,547.80	0.274355352	17,674,396.45	-69,216,596.25
13	64,421,547.80	0.246323714	15,868,554.70	-53,348,041.35
14	64,421,547.80	0.221156145	14,247,221.14	-39,100,820.21
15	64,421,547.80	0.198560015	12,791,543.49	-26,309,276.72
16	64,421,547.80	0.178272594	11,484,596.42	-1,482,460.31
17	64,421,547.80	0.160057994	10,311,183.71	-4,513,496.595
18	64,421,547.80	0.14370443	9,257,661.778	-4,744,165.203
19	64,421,547.80	0.129021754	8,311,781.108	13,055,946.31
20	64,421,547.80	0.115839248	7,462,543.642	20,518,489.95
21	64,421,547.80	0.104003634	6,700,075.096	27,218,565.05
22	64,421,547.80	0.093377298	6,015,510.052	33,234,075.10
23	64,421,547.80	0.083836683	5,400,888.895	38,634,964
24	64,421,547.80	0.075270859	4,849,065.268	43,484,029.26
25	64,421,547.80	0.067580229	4,353,622.974	47,837,652.24
26	64,421,547.80	0.060675393	3,908,801.377	51,746,453.61
27	64,421,547.80	0.054476003	3,509,428.422	55,255,882.04
28	64,421,547.80	0.04891004	3,150,860.498	58,406,742.53
29	64,421,547.80	0.043912767	2,828,928.441	61,235,670.98
30	64,421,547.80	0.03942608	2,539,889.066	63,775,560.04
			Total =NPV	**-26,7551,0774**
			IRR	**13.00%**

Table 3: Input Variables for the Hydroelectric Power Plant

Exchange rate (₦/$)	306.35
Price (N/kWh)	35
WACC (%)	11.38
Price ($/MWh)	114.248408
Plant capacity (MWh)	400
Ann. power output (MWh)	2174161.92
Ann. sales ($)	248,394,539.6
Ann. depreciation ($)	25,053,866.67
Ann. dep. tax Savings ($)	7,516,160
OP. expenditure ($)	5,652,000
Annual tax ($)	72,822,962
Net annual tax ($)	65,306,601.87
Total annual cost ($)	70,958,602
Price of pollution ($/MWh)	2.28
Total cost of pollution ($)	4,957,089.178
Real Annual cost ($)	75,915,691

Table 4: Computed NPV and IRR for the Hydroelectric Power Plant

Year	Cash flow ($)	Discount factor (%)	Discounted cash flow ($)	Cummulative DCF($)
0	-1,174,400,000	1	1,174,400,000	1,174,400,000
	172,478,848.53	0.897827258	154,856,211.60	-1,019,543,788
	172,478,848.53	0.806093785	139,034,127.91	- 880,509,660.50
	172,478,848.53	0.723732973	124,828,629.80	- 75,568,103,070
	172,478,848.53	0.649787191	11,2074,546.40	-643,606,484.2
	172,478,848.53	0.583396652	100,623,582.70	- 542,982,901.50
	172,478,848.53	0.523789416	90,342,595.37	- 452,640,306.10
	172,478,848.53	0.470272415	81,112,044.68	371,528,261.50
	172,478,848.53	0.422223393	72,824,604.67	298,703,656.80

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Year	Cash flow ($)	Discount factor (%)	Discounted cash flow ($)	Cummulative DCF($)
	172,478,848.53	0.379083671	65,383,915.13	-233,319,741.70
	172,478,848.53	0.340351653	58,703,461.24	-174,616,280.40
	172,478,848.53	0.305576992	52,705,567.64	-12,191,0712.80
	172,478,848.53	0.274355352	47,320,495.28	-74,590,217.50
	172,478,848.53	0.246323714	42,485,630.53	-31,104,586.97
	172,478,848.53	0.221156145	38,144,757.16	6,040,170.18
	172,478,848.53	0.198560015	34,247,402.73	40,287,572.72
	172,478,848.53	0.178272594	30,748,251.69	71,035,824.61
	172,478,848.53	0.160057994	27,606,618.5	98,642,443.11
	172,478,848.53	0.14370443	24,785,974.59	123,428,417.70
	172,478,848.53	0.129021754	22,252,523.61	145,681,941.30
	172,478,848.53	0.115839248	19,979,820.08	165,661,761.40
	172,478,848.53	0.104003634	17,938,427.08	183,600,188.50
	172,478,848.53	0.093377298	16,105,608.80	199,705,797.30
	172,478,848.53	0.083836683	14,460,054.59	21,416,851.90
	172,478,848.53	0.075270859	12,982,631.16	227,148,483
	172,478,848.53	0.067580224	11,656,160.14	238,804,643.20
	172,478,848.53	0.060675372	10,465,218.30	244,269,861.40
	172,478,848.53	0.054476003	9,395,958.247	258,665,819.7
	172,478,848.53	0.04891004	8,435,947.429	269,101,767.1
	172,478,848.53	0.043912767	7,574,023.549	274,675,790.7
	172,478,848.53	0.03942608	6,800,164.995	281,475,955.5
			Total = NPV	**-3,730,745,340**
			IRR	**14.00%**

Similarly, Table 5 summarizes the profitability indices for both sources of power including the DPP which were computed using the model.

Table 5: Summary of Profitability Indices for the Nature Gas Fired and Hydroelectric Power Plants.

Profitability Index	Natural Gas Fired Power Plant	Hydroelectric Power Plant
Initial Capital ($)	430,000,000	1,174,400,000
NPV($)	-2,675,510,774	-3,3730,745,340
IRR (%)	13.00	14.00
DPP (Years)	17.48	13.84

3.2 DISCUSSION OF RESULTS

From the profitability analysis of gas fired and hydroelectric power plants of the presumed 400MW capacity, the annual cash flow for both sources of power were stated with plant variables and their corresponding values tabulated in Tables 1 to 4. The IRR for both sources of power was also determined using the same model while the DPP were calculated from equation 7.

Table 5 is a summary of profitability indices for natural gas and hydroelectric power plants at a discount rate of 11.38% and $114.25/MWh electricity prices for a 400MW plant capacity. From the results hydroelectric power plants have higher initial capital cost of about 2.44 times more than the initial cost of a natural gas fired power plant. This is due to the fact that a hydroelectric power plant requires more materials and labour cost as most of it is composed on site while a natural gas fired power plant is modular in nature.

Considering investment rules, it can be said that a natural gas field power plants is economically better since investment with lower initial capital are always preferable compared to those with higher initial capital. However, considering the IRR and DPP for both sources of power, the hydroelectric power plant did better than the natural gas field power plant with the former being 14.00 percent while that of the latter being 13.00 percent while the DPP for the natural gas fired power plant is 13.84 years while that of a hydroelectric power plant is 17.48 years. With a difference of 3.64 years, the hydroelectric power plant proves to be better in terms of investment.

In terms of the NPV, the natural gas fired power plant has higher NPV compared to the NPV of the hydroelectric power plant though both sources of power at plant capacity of 400MW gave a negative NPV. In order to have a positive NPV, the plant capacity has to be increased as well as the electricity price. This is possibly the reason why the federal government of Nigeria has on regular basis in conjunction with other electricity regulatory bodies in the country always insisted that the electricity price be increased even though it has been difficult to implement due to the resistance by the masses.

4. CONCLUSION

The research revealed that the economics of any of the two sources of power is dependent on electricity price, operational cost, and maintenance cost. However, the electricity price to a large extent influences the NPV, DPP and IRR. It also made it clear that apart from low environmental pollution rate as well as needlessness of fuel to run it, a hydroelectric power plant gives more value in terms of the IRR and DPP with a lower NPV resulting from a low electricity price in Nigeria. Also, a hydroelectric power plant is observed to has no possible pipeline vandalism compared to gas stations. This will make power disruption difficult since water (which is the source) is always available.

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