Incentive for Flare Reduction in Niger Delta – A Techno-economic Approach in the 2018 Reality

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Abstract: This study showcases the economic benefits of recovering flare gas in the Niger Delta region of Nigeria, using it to generate electricity. In this study, the cost of a natural gas processing plant simulated on ASPEN HYSYS version 8.6 was determined using equipment sizing by the Module Cost Technique. Thereafter a discounted cash flow (DCF) model was setup on Microsoft Excel with data obtained from reliable sources that reflects the 2018 fiscal reality of Nigeria in which discount rate and inflation rate stands at 14% and 14.33% respectively. Using a straight line depreciation covering a project life of 20 years, the DCF reveals a project payout time of 2.99 years, a net present value (NPV) of $128.79 and an internal rate of return (IRR) of 32.36%. The values of these economic indicators – Payout time, NPV and IRR shows that investing in electricity generation from a flare field in the Niger Delta region is economically worthwhile. This research also reveals that investing in this project is profitable provided the discount factor remains lower than 22.83% at an inflation rate of 14.33%. Similarly, the project is worth investing in if the inflation rate is higher than -1.51% at a discount rate of 14%.

Index Terms – Flare recovery, Niger Delta, Electricity generation, Investment, Net Present Value, Internal Rate of Return, Payout time.

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1. Introduction

Nigeria is blessed with a lot of primary energy resources including petroleum and Natural gas (NG). As at 2017, Nigeria's proven natural gas stands at approximately 198.7 trillion cubic feet which is known to be more than its oil reserve [19]. The Niger Delta which is the hub of exploration and production activities in Nigeria is the worse hit when it comes to the environmental, social and economic consequences of gas flaring with over 120 flare sites [23].

Top among other reasons why flaring is still popular is the concern that recovery of associated natural gas maybe uneconomical in the long run owing to its complexity and capital intensiveness of handling it [3].

Natural gas as a nonrenewable resource must be optimally utilized as an act of sustainable development particularly because it is a cleanest fossil fuel and has its use in electricity generation among others [31]. The Niger Delta region and Nigeria at large still suffers electricity problem and the flared gas can be the solution to this problem through the use of gas fired turbines.

It is true that gas to power projects are ongoing in Nigeria however, these projects are located mainly in popular gas provinces while flaring continues in locations where the gas is considered to be stranded.

The main objective of this study is to carry out an economic analysis of a gas to power project via electricity generation where a gas turbine will run on natural gas produced from a typical flare field in a bid to showcase the economic viability of such projects while presenting economic indicators

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which will guide investment decisions in the present economic reality of Nigeria.

Data on Nigerian oil and is available and can be obtained from the Nigeria National Petroleum Corporation (NNPC), Organization of Petroleum Exporting Countries (OPEC) and the Department of Petroleum Resources (DPR), that of Electricity tariff is obtainable from Power Holding Company of Nigeria (PHCN) while data on Nigeria fiscal policies is obtainable from the Central Bank of Nigeria. This study has therefore taken advantage of this to showcase incentives for flare reduction in Niger Delta.

2. Literature Review

Lack of infrastructure which is the major reason behind flaring in Niger Delta is directly linked with economics. For this reason, the attention of researchers has been drawn to revealing the economic feasibility of gas projects in a bid to reduce gas flaring to the barest minimum.

2.1 Economic Consequence of Gas Flaring

A total of 71 million cubic meters of associated gas from oil exploration is flared on daily basis [15]. Nigeria loses 2.5 billion dollars annually through gas flaring. According to Aregbe (2017), Nigeria has lost over 12.6 billion cubic feet of gas was flared. This is equivalent to 12,967.95x10^{12} Btu of energy that would have been used to generate power or converted to other forms of energy [5].

2.2 Options for Natural Gas Utilization in Nigeria

In February 3, 2008, the Nigerian Gas Master Plan was approved and the major aim of the plan was to the Nigerian Economy with gas by pursuing 3 key strategies one of which is to stimulate the multiplier effect of gas in the domestic economy with 3 key objectives which are; 1. Facilitate gas to power 2. Domestic Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) 3. Encourage emergence of natural gas based industry in the production of methanol, fertilizers, polymers etc [31].

Ahmed et al (2012) identified some of the numerous opportunities and prospects of Gas-to-Liquid technology for Nigeria with reference to the world existing GTL plants. These researchers opined that GTL has unlimited markets and offers a new way to unlock large gas reserves thereby making it an attractive option to commercialize abundant gas reserves [3].

Nigeria National Petroleum Corporation (NNPC) and joint venture partners are currently embarking on several gas utilization projects with some of them already executed. These include the following as reported by National Petroleum Investment Management Services (NAPIMS): a. Excravos Gas Project b. Oso NGL project c. LNG projects d. Ekpe Gas Compression Projects e. Oso 2Y2 projects f. Belema Gas injection project g. Odigbo node gas project h. Odidi AGG project i. Cawthrone channel gas injection project j. The West African gas pipeline project [18].

Gas turbine and steam turbine are two major turbine that generate electricity via a rotating shaft. Both turbines utilize natural gas as the primary fuel for energy input to the turbine. While gas turbine utilizes the heat energy generated from the combustion of the gas to drive the turbine shaft, steam turbine utilize the heat energy to generate super dry steam which drives the turbine shaft. In both cases, the continuous rotation of the shaft can be converted to electricity which is transmitted via high tension cable to the consumers [22].

2.3. Economic Analysis of Energy Projects

A well-conducted economic analysis should show that (i) a project is in line with the development context of a borrowing country (ii) There is strong rationale for the public sector (iii) the selected project represents the most efficient or least-cost option among all the feasible alternatives for achieving the intended project benefits and when benefits can be valued, it will generate a positive economic net present value (ENPV) using the minimum required economic internal rate of return (EIRR) as the discount rate, that is the project has an EIRR higher than the discount rate [6].

In energy finance, discounted cash flow (DCF) analysis is one of the main methods employed in valuing projects, companies and assets based upon their future cash flow forecasts [7]. DCF applies the long established concepts of the time value of money. All future cash flows are estimated and discounted to a particular point in time, usually close to the present day or the effective date of a transaction, give what is termed their present values (PVs). The sum of the PVs of all future cash flow values (FVs), both incoming and outgoing, is the net present value (NPV) which is taken as the value of the cash flows in question in present day terms [9].

Gopiechand (2016) used three economic indicators – Internal Rate of Return (IRR), Net Present Value (NPV) and Payback Time to perform an economic analysis of Landfill Gas to Energy projects in the Island of Trinidad and Tobago, taking into cognizance the electricity tariff in Trinidad and Tobago [13].

Adamu and Muttaqha (2017) used gas pipeline models that already exist in literature to analyze the investment cost, gas deliveries as well as cost and benefits if six possible gas pipeline route options in Nigeria. Economic indicators employed include IRR, NPV and Payback period. With this they were able to come to the conclusion that BSRO pipeline route option was found to be more viable and estimated to have an annual delivery of 37.25bcm, investment cost of $1.15billion, NPV of $2.43billion, IRR of 50.38%, Payback period of 2.60 years for forty years of operation [2].

So far these indicators have proven to be the most common in modern day research thus the decision to adopt it in this work.

Nagy et al (2017) carried out a techno-economic analysis of expander-based configuration for natural gas liquefaction. Here, the liquefaction process was modeled using ASPEN HYSYS simulation tool [17]. This team performed an economic analysis on the modeled liquefaction processes by developing a discounted cash flow model. The Total Capital Investment (TCI) for the liquefaction facility was determined using the Module Costing Technique, applying the cost correlations proposed by Turton et al [30]. The purchase cost C_p^0 of equipment as evaluated at some base conditions described by the expression

$\text{Log}_{10}\, C_p^0 = K_1 + K_2 \log_{10}(A) + K_3\, [\log_{10}(A)]^2$

The base cost was then adjusted for the actual working conditions of the equipment and for all the associated direct and indirect expenses with the Bare Module Cost Factor, F_{BM}.

$C_{BM} = C_p^0 \times F_{BM}$

The Bare Module Equipment Cost was actualized through the ratio of the Chemical Engineering Plant Cost Index, CEPCI for the given year to the CEPCI for the reference year and is increased by a particular percentage for contingencies and fees "X" [28]. The total TCI is then computed as:

$TCI = x \sum_{i=1}^{n} C_{BMi}$

The above methodology was applied for all major process equipment and is consistent with modern economic evaluation approach.

2.4. Literature Gap

Previously published research has revealed the potentials of harnessing flare gas, addressing the economic benefits and technological options to optimize the production of LNG and NGLs.

This research however, addresses the use of flare gas from a typical production field in Niger Delta to address the electricity problems in Niger Delta, imploring 2018 data that reflects the current economic reality of Nigeria and presenting a basis upon which informed investment decisions can be made.

3. Materials and Method

3.1 Overview

To achieve the set objective, it is necessary to simulate a typical flare gas recovery system, using data from a typical Niger Delta flare field, where water, natural gas liquids, sulphur, mercury and other impurities are removed or at least reduced to acceptable range suitable as feed for a gas turbine. Then an economic evaluation can be carried out since the cost of investment can now be determined.

3.2 Procedural Algorithm

A stepwise approach was adopted in this study and is shown below:

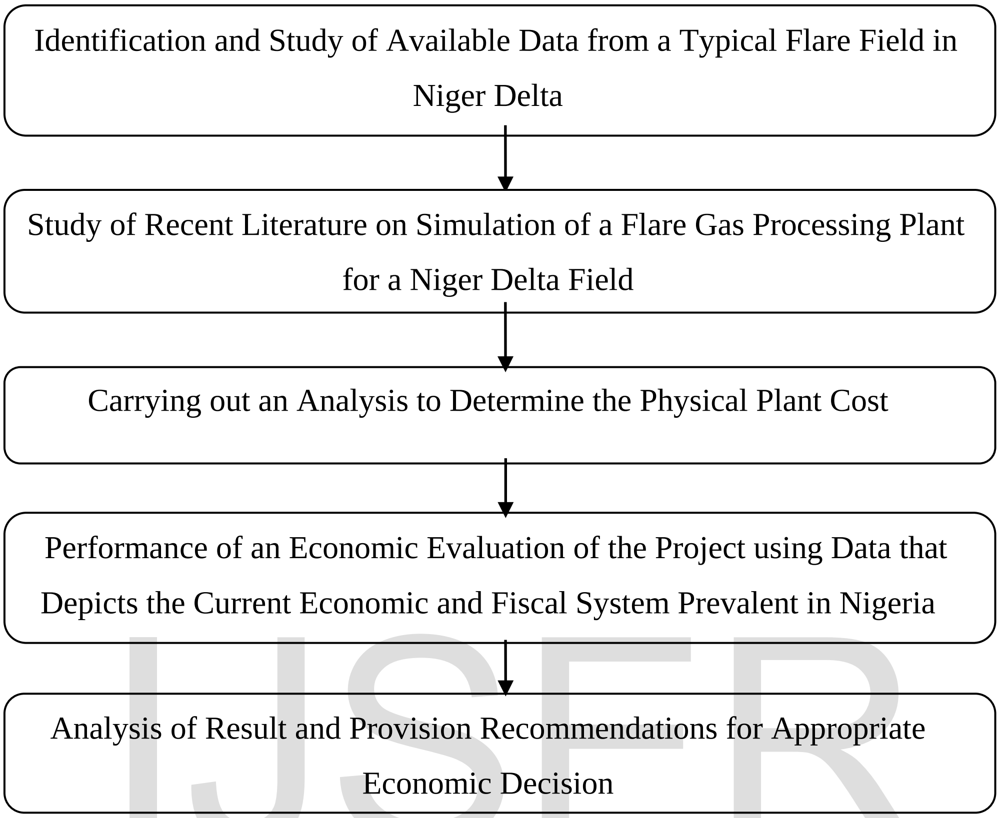
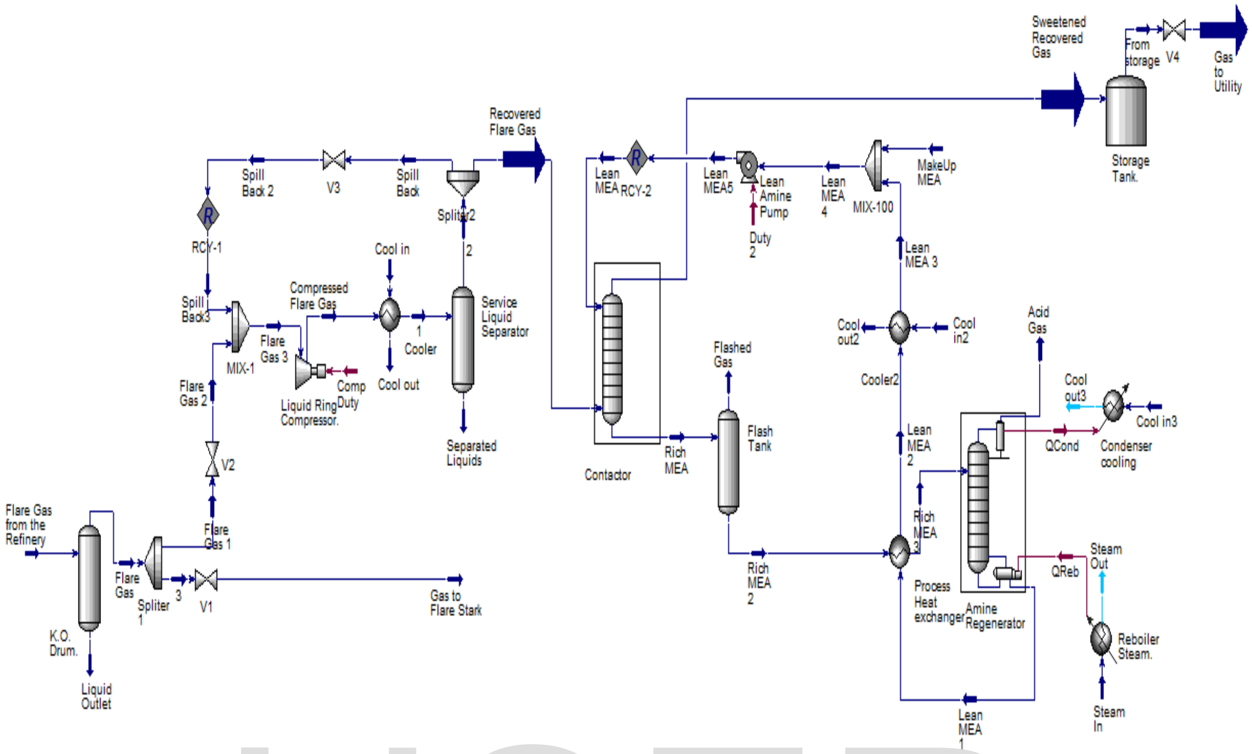


Figure 3.1: Procedural Algorithm

3.3 Data Source

This study leveraged on a research already existing in literature where ASPEN HYSYS version 8.6 was used to simulate a Natural Gas Processing facility taking its feed from a flare stack [12]. The economic evaluation was conducted using current data from reliable sources including the Central Bank of Nigeria and the Nigeria National Petroleum Corporation [8], [19]. Evaluation was guided by the Guidelines of the Department of Petroleum Resources [10].



Source: Evbuomwan et al (2017) [12]

3.4 Simulation Tool

There are several simulation tools that are available, but ASPEN HYSYS provides one of the best process modeling environments for conceptual design and operations improvement of petroleum and natural gas process [21]. Microsoft excel was used to set up the Discounted Cash Flow (DCF) model.

3.5 Computational Approach

3.5.1 Capital Cost

The capital cost of the simulated plant was obtained using the module costing technique. The bare module cost, C_{BM}, for all the equipment used in the process was calculated using Equation 3.1 (Turton et.al, 2012). The sum of the estimate of each equipment as taken as the estimated fixed capital cost.

$$C_{BM} = C_p^0 \times F_{BM} \qquad \text{Equation 3.1}$$

Where C_p^0 is the equipment purchase cost and evaluated from Equation 3.2 below and F_{BM}, the cost factor was evaluated from Equation 3.3.

$$\text{Log}_{10} C_p^0 = K_1 + K_2 \log_{10}(A) + K_3 [\log_{10}(A)]^2 \qquad \text{Equation 3.2}$$

$$F_{BM} = (B_1 + B_2 \cdot F_M \cdot F_P) \qquad \text{Equation 3.3}$$

K_1, K_2 and K_3 are item specific constants whose values are obtained from Table A.1 in the fourth edition of the book – Analysis, Synthesis and Design of Chemical Processes by Richard Turton et.al while A is a capacity measure for given equipment specified in the same book by Richard Turton et.al. In the same vein, B_1, B_2 are item specific constants whose values are obtained from Table A.4 in Turton et.al. F_M and F_P are correction factors for material and pressure respectively.

The cost estimate for the valve is not available and so the cost was obtained online from FLOMATIC® VALVES at www.flomatic.com. Also, not all units in the model needed for the costing was available on ASPEN HYSYS hence the decision to use similar units for the costing. To estimate costs of equipment that are outside range with respect to their power, capacities, ratings etc are scaled up/scaled down using the Six-Tenths Factor

Equation 3.4 as provided by Coulson and Richardson, 2005 [27].

$C_2 = C_1 \left(\frac{S2}{S1}\right)^n$ Equation 3.4

Where C represents costs and S represents the capacity measure.

In cases where the cost data used is not in the present year, typical of most of the data used in this work, the Chemical Engineering Plant Cost Index, CEPCI is used as seen in Equation 3.5.

Cost in present year = $\text{Cost}_{\text{reference year}}$ x ($\text{CEPIC}_{\text{present year}}$/$\text{Cost}_{\text{reference year}}$) Equation 3.5

3.5.2 Operational Cost

Operational cost was taken as 21% of the total capital expenditure. This is a realistic but very general estimate. They were designed for engineers to carryout preliminary design and process specification sheets. (Engineering Design Guideline- KLM Technology Group, 2014) [14]. This percentage is taken to be a near accurate estimate of OPEX which covers raw materials, waste treatment, utilities, labour, direct supervision, maintenance and repairs, operating supplies, patents and royalties and laboratory charges.

3.5.3 Product

The products from the storage tank in the flare gas processing model developed are within specification range for its use in power generation.

3.5.4 Cost per Product

The total annual cost TAC, and total production per annum was calculated as a step to calculating the cost per barrel produced. The mathematical formula for calculating TAC and the annual capital charge ratio, ACCR is shown in Equation 3.6 and 3.7 respectively.

TAC = Annual operating cost + ACCR x Total capital cost

Equation 3.6

$\text{ACCR} = \frac{[i(1+i)n]}{[(1+i)n - 1]}$ Equation 3.7

3.5.5 Project Evaluation

An Excel spreadsheet for the proposed project cash flow was prepared and payout time, net present value (NPV) and internal rate of return (IRR) for the project was calculated and a sensitivity analysis was done also to provide a better framework for investment decisions. The following assumptions were made based:

Five year Straight line depreciation

Salvage value is 16.7% on the total capital expenditure

As at 2018, the Discount Rate and Inflation factor in Nigeria stands at – 14% and 12.69 % respectively [8].

4. Results and Discussion

4.1 Simulation Result

The model was run to obtain convergence on all streams, equipment and the entire flowsheet.

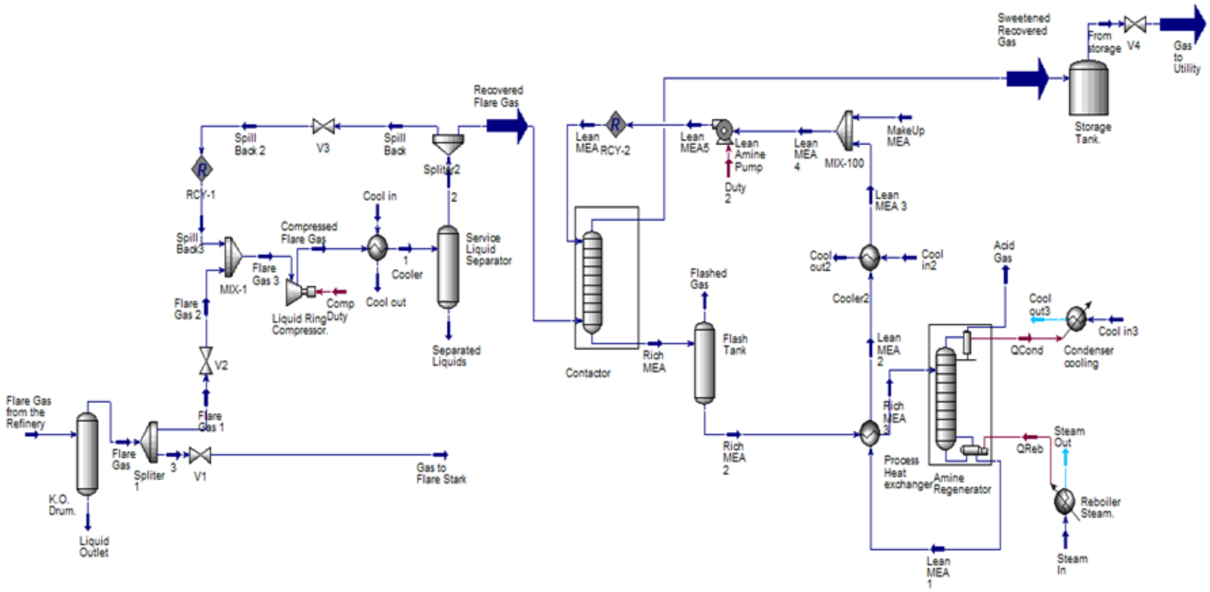


Figure 4.1: Process flow diagram of the simulated a flare gas recovery system
Source: Evbuomwan et al (2018) [12].

4.2 Mass Balance and Energy Balance

When using ASPEN HYSYS simulation tool, convergence is only possible when there is mass and energy balance. This is a proof that conservation was maintained in the simulation undertaken.

4.3 Throughput Calculation

This simulated plant was repeated but this time, the feed gas parameters were changed to that of a typical flare field which had nearly similar composition with that used by Evbuomwan et al (2018) but differs in feed gas rate and temperature and pressure.

$$Throughput\ Efficiency = \frac{Discharge\ gas\ flowrate}{Feed\ gas\ flowrate} \times 100\%$$

$$= \frac{9.124 m^3/h}{9.180 m^3/h} \times 100\% \quad = 99.39\%$$

Less than 0.1% of the amine solution used is lost in the process. This is an indication that the plant is one of high efficiency.

4.4 Discharge Gas Quality

The quality of gas at the discharge stream is shown in Table 4.1

Table 4.1: The discharge stream properties

Property	**Value**	
Temperature	56°C	
Pressure	5.4 atm	
Gas flowrate	9.124 m^3/h	
Component composition of the product stream		
Component	**Mass composition**	**Mole composition**
Methane	0.782349	0.873524
Ethane	0.069909	0.041645
Propane	0.046828	0.019022
n-Butane	0.013646	0.004205
i-Butane	0.008123	0.002503
n-Pentane	0.000000	0.000000
i-Pentane	0.000000	0.000000
n-Hexane	0.000000	0.000000
CO	0.000000	0.000000
CO_2	0.000437	0.000178
H_2S	0.000002	0.000001
Oxygen	0.000000	0.000000
Nitrogen	0.052613	0.033643
H_2O	0.025144	0.025001
MEAmine	0.000947	0.000278
Total	**1.000000**	**1.000000**

The product meets pipeline specification as described by Kidnay and Parish (2006) in Table 4.2

Table 4.2 Pipeline Specification for Natural Gas

Parts	**Minimum**	**Maximum**
Methane	75 mol %	None
Ethane	None	10mol %
Propane	None	5mol %
Butane	None	2mol %
Pentane and heavier	None	0.5mol %
Nitrogen and other inerts	None	3mol %
Carbon dioxide	None	2-3mol %
Hydrogen sulfide	None	0.3g/100scf
Water vapor	None	7 lb/MM scf
Oxygen	None	1.0 %

Source: Kidnay and Parish (2006) Fundamentals of Natural Gas Processing

4.5 Plant Cost

Applying Equations 3.1, 3.2 and 3.3 gave the bare module cost of the plant. Coulson and Richardson's Six-Tenths Factor Equation (Equation 3.4) was applied to scale up the cost as Evbuomwan et al (2018) designed the plant based on a flow rate of 5.7 m^3/h, against 9.18 m^3/h under consideration, which affected the equipment cost which was found using equipment sizing. Also, the consolidated CEPCI for 2018 is not available but comparing the CEPCI for January 2017 and that of January 2018, we see that the latter is greater than the former by 4.2% [24].

Table 4.3: Summary of the Equipment Purchase Costs Updated to 2018

Equipment	Cost ($)
Liquid-Ring-Compressor	734,583.68
Cooler	1,079,419.64
Service Liquid Separator	422,993.83
Absorber (Contactor)	214,710.164
Flash Tank	422,993.83
Process Heat Exchanger	268,992.96
Stripper (Regenerator)	114,881.45
Trays	77,879.71
Reboiler	1,156,960.94
Condenser	287,802.69
Cooler 2	612,152.65
Pump	115,635.38
Storage tank	1,032,716.31
Gas Turbine	2,714,028.00
Total Equipment Purchase Cost (EPC)	**$9,255,775.71**

Based on the percentages offered by Turton et al and Coulson and Richardson for the estimation of the cost of items and projects, the Physical Plant Cost and Fixed Capital Cost are presented in Table 4.4 and 4.5 below:

Table 4.4: The Physical Plant Cost (PPC) Estimate from the Major Plant Items

Items	**Cost fraction from Equipment Purchase Cost (EPC)**	**Cost of items ($)**
Equipment Purchase Cost (EPC)	1	9,255,775.71
Equipment erection	0.4	3,702,310.284
Piping	0.7	6,479,042.997
Instrumentation	0.2	1,851,155.142
Electrical wiring	0.1	925,577.571
Buildings, process	0.15	1,388,366.357
Total Physical Plant Cost (PPC) =		**23,602,228.06**

Table 4.5: The Fixed Capital Cost (FCC) Estimate from Other Plant Items

Item	**Cost fraction from the Physical Plant Cost (PPC)**	**Cost of items ($)**
The Physical Plant Cost (PPC)	1	23,602,228.06
Design and engineering	0.3	7,080,668.418
Contractor's fee	0.05	1,180,111.403
Contingency	0.1	2,360,222.806
The Fixed Capital Cost (FCC) = Total		**34,223,230.69**

Al-Saadon (2005) (4) gave the Operating Expenditure, OPEX for large projects to be in the range of 5-7% of the capital expenditure, CAPEX. For the purpose of this work, the OPEX is placed at 7% of the CAPEX. Therefore the OPEX is calculated thus:

OPEX = 7% of CAPEX

= 0.07 * $34,223,230.69

= ***$2,395,626.148***

4.6 Revenue Estimation

Scholars [11],[12],[16],[25] have advocated that electricity generation is one of the most economically effective ways of utilizing flared gas. This recommendation is considered and thus evaluated below.

With a discharge rate of 0.8360kg/s, the flare gas recovery system best fits to serve a Siemens® Gas Turbine model version SGT-400 capable of generating 13MW of electricity (26).

With the current electricity tariff of the Port Harcourt (in Niger Delta region of Nigeria) of ₦50.81/KWh for commercial and residential tariff class (20), the project have an hourly yield of ₦660,530 a daily yield of ₦15,582,720 and an annual yield of ₦5,786,242,800 which is equal to $15,852,720 at the current Naira to Dollar exchange rate of ₦365/$ (1).

4.7 Project Evaluation

Table 4.6: Simple Payback Estimation of the Project

Capital Cost Investment	$34,223,230.69
Revenue/ Year	$15,852,720
Operating Cost	$2,395,626.148
Annual Savings	$13,457,093.852
Payback Period	**2.54 years**

Judging from the value of the simple pay-back period, it can be deduced that the project is capable of paying back the invested capital after 2 years and 6months and 3 days of electricity production. This proves the viability of the project as it comes within the interval of 2-5 years suggested by Towler and Sinnott (2009) (29) for most typical viable process plants.

4.8 Cash Flow Projection and Economic Indicators

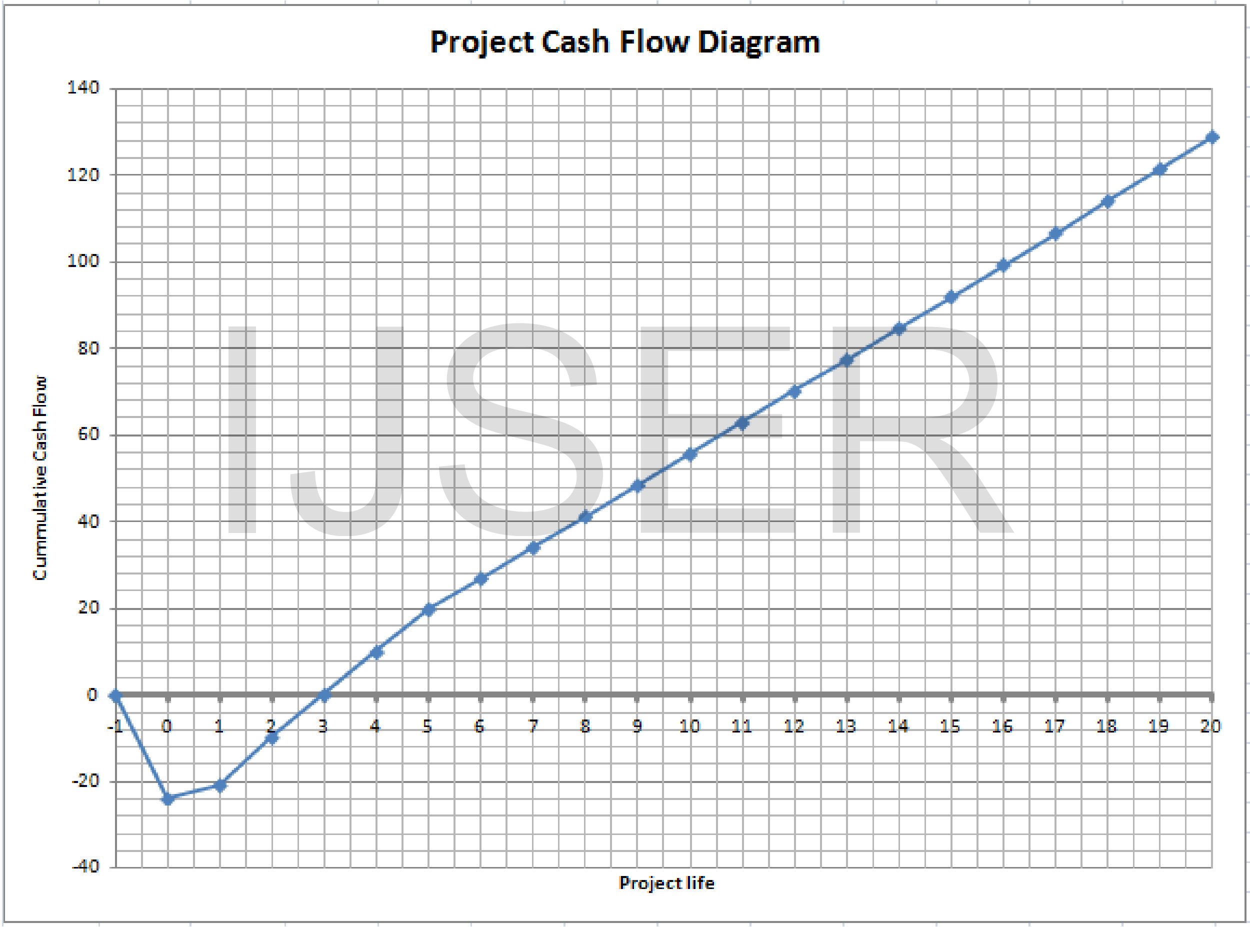


Figure 4.2: Cash Flow Diagram for the Proposed Project

With the 2018 discount rate of 14% and inflation factor of 14.33%, using a straight line depreciation of 5 years covering a project life of 20 years, the discounted cash flow (DCF) reveals a project payout time of 2.99 years (approximately 3 years). Just after the payout time, we expect a continuous increase in profit.

Also calculated from the DCF model was the net present value (NPV) which stood at $128.79. This value is a far deviation from zero thus affirming that the project is profitable.

The internal rate of return (IRR) of the proposed project was calculated and found to be 32.36%.IRR greater than the current discount rate of 14% indicates that the project is economically worthwhile.

4.9 Sensitivity Analysis

The result of the sensitivity analysis carried out using the spreadsheet prepared for the DCF analysis is shown in Table 4.7 and Table 4.8.

Table 4.7: Effect of changing Discount rate (or interest rate) on project profitability at inflation rate of 14.33%

Discount rates (%)	NPV (Million $)	IRR (%)	REMARK
1	646.57	49.39	INVEST
5	373.00	43.70	INVEST
10	201.09	37.17	INVEST
15	115.88	31.21	INVEST
20	70.28	25.74	INVEST
25	44.02	20.71	DON'T INVEST
30	27.83	16.07	DON'T INVEST
35	17.22	11.77	DON'T INVEST
40	9.89	7.78	DON'T INVEST
45	4.59	4.06	DON'T INVEST
50	0.60	0.59	DON'T INVEST
55	-2.48	-2.65	DON'T INVEST

From Table 4.7 above, it can be seen that from varying discount rates at the current inflation rate of 14.33%, the project remains profitable provided the discount rate remains lower than 22.83%. At a discount rate of 22.83%, IRR= discount rate. At discount rates above 22.83%, the IRR of the project becomes less than the discount rate thus not economically wise to invest even if the NPV is positive.

Table 4.8: Effect of Changing Inflation Rate on Project Profitability at a Discount Rate of 14%

Inflation rates (%)	NPV (Million $)	IRR (%)	REMARK
25	410.85	50.50	INVEST
20	236.95	38.92	INVEST
15	138.31	33.13	INVEST
10	81.40	27.34	INVEST
5	47.69	21.56	INVEST
1	30.39	16.93	INVEST
0	26.98	15.77	INVEST
-5	13.67	9.98	DON'T INVEST
-10	4.76	4.19	DON'T INVEST
-15	-1.54	-1.60	DON'T INVEST

The result from the sensitivity analysis of varying inflation rate while keeping discount rate at 14%, shows that investment in the proposed project is only profitable when the inflation rate is higher than -1.51% because inflation rates less than -1.51% will result in the IRR being less than the discount rate. Thus unwise to invest even if the NPV is positive.

5. Conclusion

The results from this study shows that the gases flared within the Niger Delta region of Nigeria can be optimally recovered and used for electricity generation thereby solving the power problem currently being faced by the populace and also serves as a medium of curbing the adverse environmental, social and economic impact on gas flaring in this region.

An investment in this venture is viable going by the current fiscal policies in Nigeria. The sensitivity analysis carried out shows that in the foreseeable future, investment in electricity generation from flare gas remains worthwhile.

6. Recommendation

1. The government and all stake holders should consider a zero-flare policy as this is not only possible but also economically advantageous.

2. This study should be advanced by setting up and running a pilot plant, then an economic analysis should be carried out. This will reduce the error margin as real equipment are being used thereby coming up with more precise with which better informed investment decisions can be made.

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