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Economic Evaluation of Virtual Pipeline Transport of Natural Gas to the University of Port Harcourt

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Abstract
The University of Port Harcourt (UNIPORT), Choba, in partnership with Total Support Energy Limited (TSEL), commissioned a virtual pipeline transport project in an effort to address the problem of power generation and supply within the institution and its environs. In this work, we present a comparative evaluation of the economics of substituting a CNG-based virtual pipeline transport technology with a liquefied natural gas (LNG)-based technology. In order to accomplish this, a proprietary Visual Basic Application model (@Risk) integrated with an excel spreadsheet is used for the purpose of executing the comparative analysis. The results obtained from the analysis show that deploying the CNG-based technology is more viable at relatively shorter distances between the fuel producing location and fuel consumption location. The profitability index (PI) for both virtual pipeline technology routes were found to be 1.58 and 1.07 for CNG technology and LNG technology, respectively. Thus, with a relatively higher profit investment ratio (PIR), the CNG transport route is more economically valuable. To assure the sustainability of the virtual pipeline project at UNIPORT, key challenges hampering the success of the project are identified including: politics, financial constraints, poor decision making, and poor transmission/distribution network.

Keywords: *Virtual pipeline transportation of natural gas, CNG technology, LNG technology, Economic evaluation*

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1. Introduction

Virtual pipeline transport permits the transport of natural gas via conversion to compressed natural gas (CNG) or liquefied natural gas (LNG) (Hafner and Lucian, 2022; Princewill and Ikiensikimama, 2016; Adamu and Darmy, 2017; Udaeta et al, 2012; Black 1986; Campbell 2004; Burns 1982; De Sa Neto et al, 2005; Osokogwu et al, 2011; Rajnauth and Barrufer, 2008; Thomas and Dawe, 2003). These technologies involve the use of gas transportation modules (GTM) connected to mobile platforms which are then conveyed by trucks, ferry boats, boats and/or rail platforms. In order to find the most economically viable means of moving this gas, a comparative evaluation of both CNG and LNG technologies are investigated in this study. The objective is to examine the economic advantages of one over the other. Technical and economic variables were used to perform sensitivity analysis. The University of Port Harcourt (Uniport), Nigeria, and Total Support Energy Limited (TSEL) which is a producer and supplier of both CNG and LNG will be used as a case study. Uniport in her efforts to alleviate its poor access to electricity signed an agreement with TSEL that mandates the later to generate and supply electricity to UNIPORT and its environs using virtual pipeline transport technology. At some point in Nigeria, the total power generation capacity installed is about 12,522 megawatts (MW); of which about 1,930MW is hydro powered while 10,592MW is powered by gas. It is worthy of note that out of the total installed capacity which is 12,522MW, the highest peak generation by power plants as at February 13, 2018 was 4,083.34MW which is a far cry from the target capacity of 40GW by 2020, thus making the issue of private generation a necessity. The installed capacity for the University's project as at the time of this research was 1MW which was fueled using CNG-based virtual pipeline as its mode of transportation. The virtual pipeline transport technology successfully started at Uniport but faced serious challenge that culminated in the premature demise of the project. The current study will extend the virtual technology to LNG in order to make an informed comparative analysis of both technologies and establish the viability of one technology relative to the other. In addition, the study will examine the circumstances that could have led to the premature end of the virtual pipeline project as well as proffer pragmatic remedy that could have prevented its occurrence at the time.

2. Materials and methods

A comparative approach was used in the study of virtual transport of natural gas, and this was guided by the following procedures: (1) proprietary software, Excel and VBA were used for economic model development (@RISK©, 2011); (2) price, distance and turbine capacity were used as system and independent parameters characterizing fuel consumption ratio, and number of trucks used; (3) prices, distance and turbine capacities were varied at specific intervals to determine and tabulate the (net present value (NPV), internal rate of return (IRR), payout period (POP), profitability index (PI) and payout years (POY); (4)Other relevant fiscal data were sourced from literature; and (5) Microsoft Excel was used to plot the sensitivity of gas price against the NPVs (plus other relevant economic variables) of CNG and LNG.

2.1 Data acquisition

There is a VBA interface used for developing the application and it contains various features that will aid the developer. Real time data was obtained from the gas processing and delivery company (TSEL). These data which range from the price of the gas, distance to delivery point, quantity of gas delivered per day, the number of days the gas is delivered per year, the cost of delivery (operational expenditure), and the cost of procuring the module. The application was successfully built with the aid of the obtained data.

2.2 Gas turbine location, capacity and energy consumption rate

The gas turbine considered in this is situated on the Choba axis of East-West Road of Port Harcourt. It has a total installed capacity of 2MW. This information helped to ascertain the daily amount of gas to be delivered to the plant as well as assist in determining the number of facilities and the overall cost of executing the project. First, estimated Energy Produced per cubic meter of gas (M^3) which is to be 1000 KJ/Kwh with corresponding calorific value of the gas estimated as 35.2 MJ/M³. This will, therefore, give the energy produced per cubic meter as 3.52 Kwh/M³. Hence, the total gas consumption rate gives 568.18 M³/hr. Therefore, in 1 hour, it burns 568 M³, whereas in 24 hours it will burn 568 X 24 or 13636.36 M³ of gas. Table 1 indicates turbine capacity and its consumption rate. The distance from the loading point which is the mother station to the delivery point (daughter station) is also considered. This is done to quantify the amount of fuel (diesel) required to fire the trucks to and fro the station in a day. After careful measurement, the distance was approximately 19.8km (7.83 miles).

Table 1: Turbine capacity and its consumption rate.

Gas Turbine Capacity	**2 MW**	
Quantity of Gas Required to Run the Turbine		
Gas Calorific Value (KWh/M³)	9.8	35.2 MJ/M³
Net Heat Rate (KJ/KWh)	1000	10 MJ/KWh
Energy Produced per M³ of Gas (KWh/M³)	3.52	
Gas Consumption Rate (M³/MWh)	284.09	
Total Gas Consumption Rate (M³/h)	568.18	
Total Gas Consumption Rate in a Day (M³)	13,636.36	202.1359562 MMBTU

2.3 Required number of trucks

The number of trucks required (T_n) to deliver an approximate quantity of gas to the gas power station is also important in setting up the cash flow model and could be deduced by: (1) knowing the amount (volume) of gas required; (2) the capacity of the module, and (3) the load factor of the module determined as 75%. The total number of trucks (T_n) required is given as:

$$T_{n} = \left(X/_{(D \times Z)} \right) \quad (1)$$

where X is the volume of gas required, D is the capacity of the module (7000scm), and Z the load factor for the module received from the company used as case study.

2.4 Fiscal terms and capital expenditure

These are economic systems employed to build the cash flow model and they include: (1) Royalty Rate; 25%; and (2) Tax Rate; 12.5% (see Table 2). For this work, the CAPEX includes the procurement of a compressor (compressors), land space for compressor station and other clearances/permits required to begin a gas compression station since there is an existing gas compression system(s). Therefore, the CAPEX for this study is concerned with the procurement of the Kelley's gas transport modules (KGTM), suspensions, truck heads and other accessories which will aid the smooth running of these modules. The facilities are tabulated in Table 3 and Table 4 for CNG and LNG, respectively.

Table 2: Economic data used for the study

Economic Data		
Start of Project	**2014**	**Years**
Project Location	Eleme Junct. PH	
First Gas	2018	Years
Gas Load Factor	75%	
Reserves (Gas Volume)	200,000,000,000	SCF
Gas Price in Naira	135.00	Per SCM
Gas Price in Dollars	50.37	Per SCM
Expensed CAPEX	30%	
Depreciated CAPEX	70%	
Tax Rate	12.5%	
Discount Rate	15%	
Distance to Delivery	19.6	km
On-Time Period	365	days/year
Depreciation Length	5	Years
Royalty	25%	
Variable OPEX (%Cumm. Gross Rev.)	5%	
Number of Months in 1 Year	12	Months
Number of Days in 1 Month	30.42	Days
Price of LNG	$10.20	DGE
Hours in a Day	24	hrs
Minutes in 1 Hour	60	Minutes
Seconds in a Minute	60	Seconds

Table 3: CAPEX for CNG technology

Project Facilities	**Cost ($)**
Dispenser	518, 550.00
Pressure Reducing Metering System (PRMS)	150.25
Import Duties	653.36
Compressors, Cat Engine 3408, Intermech Compressors, Trucks…	1, 102, 417.05
Line Heaters	15, 250.50
Engineering and Construction	65, 556.90
Manifold, Meter and Valve Skids	15,000.50
Contingency	1, 550, 000.00
Total Project Cost	**2,767, 578.50**

Table 4: CAPEX for LNG technology

Peakshaving Facilities	**Cost**
Common/Inlet Facilities	$50, 000.00
Acid Gas Removal Unit (Amines)	$25,000.00
Dehydration Unit	$32,000.00
Mercury Removal Unit (Molecular Sieves)	$62,000.00
Linde LIMUN^{TM} (Mixed Refrigerant) Liquefaction Unit	$4,900,000.00
Line Heaters	$500,000.00

Manifold, Meter and Valve Skids	$50,000.00
Dispenser	$150,000.00
BOG Handling	$39,550.00
Coil Wound	$500,000.00
Vaporizer Unit	$80,000.00
Storage (Vertical Cylinder Flat Bottom Tanks) 30 MSCM	$24,000,000.00
Unloading Facilities	$250,000.00
Associate Utilities	$450,000.00
Import Duties	$1,250,000.00
Contingency	$1,525,000.00
Total	$33,863,550.00
$800.00	Per M^3
$24,000,000.00	
Project Closing	$15,000.00

2.5 Operating expenditure and loading rate

Operating expenditure consist of the cost that are made to ensure the smooth (effective) running of these modules and they include; hydro-testing, road permits, truck driver's salary, spare tyres, truck fuel, lubricating oil, and fire extinguisher (see Table 5). This is also a key aspect in formulating the cash flow model.

Table 5: Operating expenditure for both CNG and LNG technologies

Project Facilities	**Cost**
Insurance Liability	$5,000.00
Insurance Trailer etc	$55,250.00
Certificate of Incorporation	$753.42
Nipex (Nigerian Petroleum Exchange Commision)	69.28
ITF	$136.99
Other Local Taxes	$3,500.00
Hydro, Gunfire, etc. Testing	$15,000.00
HSE Supervisor	$3,616.44
Field Engineer/Supervisor	$16,438.36
Technician(s)	$5,260.27
Truck Drivers	$7,232.88
Fuel (L/km)	$1,125.97
Office Maintenance	$10,000.00
Truck (Pick-Up) X2	$100,000.00
Maintenance (Compressor, Trucks, Trailer)	$30,000.00
Communications, Rentals	$65,550.00
Road Permits	$438.36
Compressor Operator(s)	$9,863.01
Total OPEX	$329,234.88
OPEX for LNG	
Fixed OPEX (% of CAPEX)	5%
Variable OPEX (% of Gross Revenue)	10%

The loading rate per day (LR_{Day}) could be obtained by multiplying the capacity of the transport module by the loading factor (NB: the loading factor (Z) = 0.75 or 75%). The model configuration consists of two Kelley Packs connected in series (247,212 scft of CNG) and mounted on a heavy-duty trailer equipped with air ride suspension. Each Kelley Pack has a capacity of approximately 123,606 scft (3,500 scm) at a service pressure of 3,250 psig. Let the capacity of the module be equal to C_m = 247,212 scft (7000 scm). Therefore, amount of gas in 1 KGTM (Am_{KGTM}) is given by the product of loading factor and module capacity. Thus, the cumulative annual delivery is the sum of all daily deliveries done in a year.

2.6 Deployed model and simulation runs

To create a financial model of a discounted cash flow, the following steps were taken: (1) Develop Model Logic; (2) Designate @RISK Outputs; (3) Define Input Distributions; (4) Set Number of Iterations; (5) Run Simulation; and (6) Analyse Results

Step 1: Develop model logic

First, develop the model logic in Excel. In this model, when evaluating an investment project; there is an initial investment (capital expenditure), operating expenditure (OPEX), followed by future years of revenue as well as variable costs and fixed costs. Cash flows are being projected or forecasted for the next '***n***' years to calculate the key measures of the project performance which are: the NPV, IRR, and the others. The NPV is based on the cash flows, initial investment and discount rate. However, there is a considerable uncertainty about the cost in future revenues. Thus, the values of the NPV, IRR, etc. cannot be ascertained, therefore the @RISK is introduced. @RISK helps to assess the probability of negative NPV and positive NPV, regardless of bonus. It will also help to uncover which of the uncertain inputs contribute most to the NPV- an information that might help us choose a more profitable strategy.

Step 2: Designate @RISK output cells

As mentioned in step1, outputs are the cells of interest, in analyzing-the bottom-line cells. In this model, the output cells are the NPV, IRR, and distance cells. @RISK do not tell the exact values from the outputs. This is impossible because the future cannot be predicted with uncertainty. However, as will be seen in the result step, @RISK can record the probability of different values occurring for each output and this information will help to make a more informed decision. @RISK cannot guess which cells are output cells, it has to be designated as such. To define the output cells in @RISK, we select the value we want such as NPV and IRR, then click the "add output" button, and type in the name of the output which is used in the reports. It is important to note that the formula in the output cells will change; thus, include the @RISK output function and a plus sign which is the '@RISK' way of indicating that this is a @RISK output cell.

Step 3: Define input distributions

@RISK is not the same as our normal traditional analysis, therefore, we cannot guess which values to try. Instead, @RISK allows us to earn a probability distribution in uncertain cells. The probability distributions indicate the possible values and how ugly they are. The corresponding output cells are called input cells. There are many different probability distributions one can use for @RISK inputs. The two most commonly used are triangular and normal distributions. It is important to note that all distributions require us to provide parameters. Parameters are values that describe the two probability distributions such as its central location, its variability and its shape. In a triangular distribution, the parameters are the minimum value, the most likely value and the maximum value. No value below the minimum or above the maximum are possible. In the normal distribution, the parameters are the mean and the standard deviation. The mean is the average or most likely value, the standard deviation is the measure of variability around the mean. Normal distributions are symmetric- values above the mean.

Step 4: Set Number of Iterations

Once there are designated output cells and enough probability distributions for input cells, the simulation is almost ready to run. However, before doing so, it is imperative to change at least one simulation setting, the "number of iterations". The number of iterations indicates how many random scenarios @RISK will generate. The more iterations used, the more accurate the result will be. The only downside is that more iteration requires more computing time which can be an issue with models such as this. For most models, it is advised to use between 1000-5000 iterations but open to further experiment. To change the number of iterations, enter a number in the iterations box of @RISK. For this work, 1000 iterations are used.

Step 5: Run the simulation

This is the easiest step of all and it is done by clicking on the "start simulation" button. However, before doing so, be aware of what is called "the simulation runs". First, a progress indicator will appear. Normally, the simulation will run very quickly but if the progress is too slow, stop the simulation from the progress window and perhaps, reduce the output cells being built as the simulation proceeds.

Step 6: Analyzing results

This is the step where the power of @RISK is appreciated. From the simulation run, @RISK keeps track of the 1000 values in the input cells and output cells and then it presents these in a variety of ways. The quickest way to see the distribution of an output is to select its cells and click in the browse results button. A chart of the output appears on a histogram and this helps to analyse the output in a number of ways. The two sliders are moved to see the` probability percentiles of these distributions. For example; to get the probability of a negative NPV, one can enter zero (0) above a left slider. The probability obtained is close to 21%, therefore, the company has to think twice before getting into such an investment. Alternatively, to get the 90th percentile, one can enter 10 above a right slider. There is only a 10% chance of having an NPV greater than the value that will appear, therefore the company might look at such percentiles to make a go or a no-go decision.

3. Results and discussion

Results focusing on gas price, turbine capacity, the distance, the respective NPV's, IRR's, POP's and probability indices of the risks involved in setting up such virtual pipeline gas transport projects are presented. For a project that requires gas to be transported from a source point which is 26.6 kilometers away from the demand point (power generation plant) at a gas consumption rate of at least 13.64 MSCM/day, a number of economic indicators are considered to determine the most viable alternative

3.1 Profitability indicators

Sensitivity studies carried out on the NPV and the changes that occurred when the gas price and turbine capacity were alternated were monitored. Also, the changes that occur when the distances between source and consumption points were altered was observed to a maximum distance of 1000 kilometers, to ascertain which technology option (CNG or LNG) will be more viable for the investor.

A. Profitability index (P.I.)

Profitability index (PI) is a measure of the economic viability of a project and this was analyzed for both projects. For the CNG-based project, the profitability index is 1.58. Since the PI for the CNG project is greater than 1, the project generates value and therefore should be executed by the company. Also, the PI of the LNG option was calculated and its value was 1.07, which also adds economic value and the investor or company is advised to continue with the project. However, the CNG option adds more economic value than the LNG option since its PI value is 0.51 greater than that of the LNG option. Therefore, with a CNG-based Profit Investment Ratio (PIR) of 0.58, a CNG project is more economically valuable than the LNG project with a relatively smaller PIR of 0.07.

B. Net Present Value (N.P.V)

(i) Sensitivity with respect to gas price

An increase in the price for both CNG and LNG projects, will lead to a corresponding increase in their NPV's. From Table 6, it is observed that, as the prices of the gas increased, the various IRR's were affected too. Fixing the price at $3 led to a 17% increase in the IRR of the CNG-based project while the LNG-based option registered an IRR of zero. Subsequently, when the price was increased to $25, the LNG attained its highest IRR value, though still relatively lower than the IRR for the CNG option.

Table 6: Effects of price increase/decrease on NPV

Price ($)	CNG NPV ($MM)	CNG IRR (%)	LNG NPV ($MM)	LNG 1RR (%)
0.37	2.154	22	-36.55	-
1.00	14.237	48	-33.91	-
2.00	33.565	73	-29.72	-10
3.00	52.588	90	-21.82	0
4.00	71.763	104	-17.87	4
5.00	90.938	116	-13.92	6
6.00	110.113	126	-9.97	8
7.00	129.288	136	-6.02	10%
8.00	148.463	144	-2.07	12
9.00	167.639	151	-1.87	14
10.00	186.814	158	-0.02	16
15.00	282.689	187	21.62	24
20.00	378.565	210	41.37	31
25.00	474.441	229	61.12	37

based project.

In addition, as distance increases, there is also a corresponding decrease in the IRR's for both the CNG and the LNG projects. At a distance of 10km, the IRR for the CNG project is 22.03% while that of the LNG is 16.16%. As the distance increased to 20km, the IRR for the CNG project reduced to 21.95% while the IRR for the LNG project is 16.15%. At a distance of 1000km, the IRR for the CNG option decreased to 12.98% but the IRR for the LBG option increased to 594%.

(i) Sensitivity with respect to distance

Table 7 and Fig. 1 show that as the distances between source and consumption location increases, there is also a corresponding decrease in the NPV for both CNG and LNG projects. At a distance of 10 km, the NPV for the CNG option is 2.13 (MM$) while that of the LNG is 2.64 (MM$). When the distance is increased to 500km, the LNG option's NPV is still 0.52 (MM$) higher than that of the CNG option. This is even higher at an increased distance of 1000km. Hence, the LNG project is seen to be more valuable and thus, preferred to the CNG-based project.

Table 7: NPV's for CNG and LNG options in respect of distance between source and consumption locations

Distance (km)	CNG NPV ($MM)	CNG IRR (%)	LNG NPV ($MM)	LNG IRR (%)
10.00	2.13	22.03	2.64	16.11
20.00	2.11	21.95	2.62	16.15
26.60	2.09	21.90	2.60	16.14
30.00	2.08	21.87	2.59	16.14
40.00	2.05	21.79	2.56	16.12
50.00	2.03	21.71	2.54	16.11
60.00	2.00	21.63	2.51	16.10
70.00	1.97	21.55	2.48	16.09
80.00	1.95	21.47	2.46	16.08
90.00	1.92	21.39	2.43	16.07
100.00	1.90	21.31	2.40	16.05
500.00	0.82	17.92	1.34	15.59
1000.00	-0.51	12.98	0.002	15.00

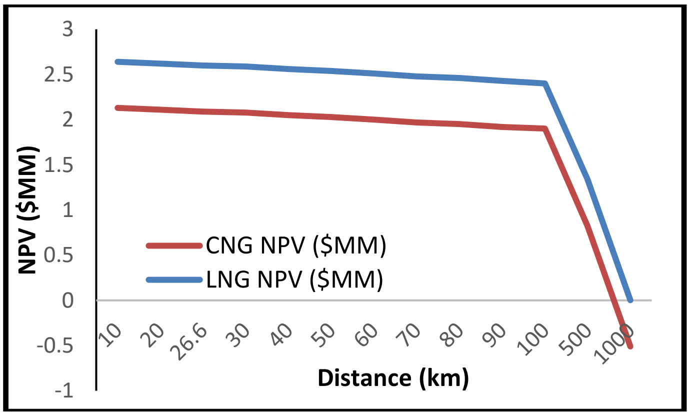

Fig. 1: Sensitivity of NPV on distance

(i) Sensitivity with respect to turbine capacity

Table 8 and Fig. 2 show that, as their (CNG and LNG projects) turbine capacities increase, there is also a corresponding decrease of the NPV's for both the CNG and the LNG projects. For a turbine capacity of 1MW, the NPV for the CNG is negative 0.94(MM$) while that of the LNG is negative 17.51(MM$), making both projects not to be valuable. But when the capacity is increased to 2MW, their various NPV's became 2.09($MM) and 2.60($MM), respectively. This shows an improvement from their previous NPV's. Comparing both NPV's, the NPV of the LNG project is seen to be 0.51 (MM$) higher than the NPV for the CNG. When the turbine capacity is increased to 500MW, the NPV of the LNG is seen to be about 8,929.46(MM$) higher than that of the CNG. Also, at a distance of 1000km, the NPV for the LNG is still seen to be much higher than that of the CNG. Therefore, in terms of NPV for both projects, the LNG project is seen to be more valuable and thus, preferred to the CNG. Hence, the LNG project should be executed by the investor. Observing the figures, it is seen that as the capacity increased to 2MW, the IRR for the CNG project rose to 22% while the IRR for the LNG project is 16%. At a capacity of 1000MW, the IRR for the CNG increased to 54%, while the IRR for LNG project increased to 594%. With a capacity of 2MW, the IRR for the CNG project is 22% which is better when compared to the 16% for the LNG option. However, at a capacity of 5MW and above, the IRR of the LNG project outperforms that of the CNG, thus indicating a clear preference for the LNG option.

Table 8: NPV's for CNG and LNG options in respect of turbine capacity

Turbine Capacity (MW)	CNG NPV ($MM)	CNG IRR (%)	LNG NPV ($MM)	LNG 1RR (%)
1.00	-0.94	11	-17.51	6
2.00	2.09	22	2.60	16
5.00	10.14	37	62.93	38
10.00	22.08	46	163.47	62
20.00	44.51	51	364.56	96
30.00	65.37	51	565.65	121
40.00	88.51	54	766.74	141
50.00	105.08	51	967.83	159
60.00	129.90	51	1168.91	174
70.00	148.73	52	1370	188
80.00	170.56	52	1571.09	200
90.00	192.39	53	1772.18	212
100.00	214.22	53	1973.27	223
200.00	432.50	54	3984.15	305
250.00	541.64	54	4989.60	336
500.00	1078.76	55	10016.81	450
1000.00	2178.76	55	20071.24	594

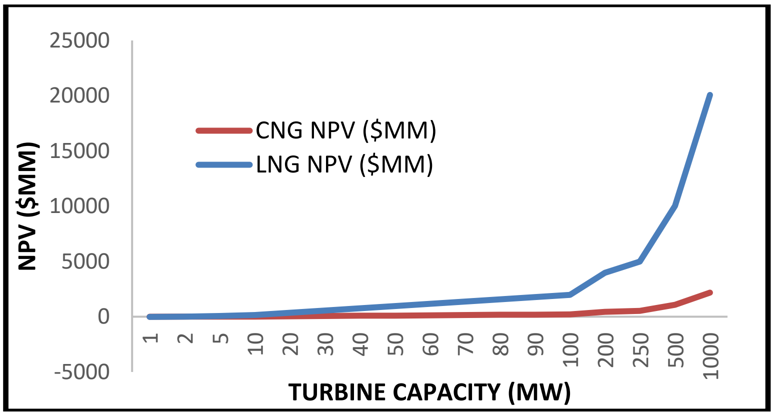

Fig. 2: Sensitivity of NPV on turbine capacity

(i) Payback period

Payback period can refer to the capital budgeting tool used to determine the number of years it takes for the project to pay for itself; the number of years it takes to recover the funds invested in a project. In this work, it took the CNG-based project 9.39 years to pay for itself while that of the LNG-based project took 20.49 years (Fig. 3a) to pay for itself (see Fig. 3b). In capital budgeting, projects that take longer period of time are considered to be less desirable than projects that take a shorter time period. Since the length of time it took the CNG project to recover the cost of investment is 9.39 years, the CNG project is preferred to that of the LNG.

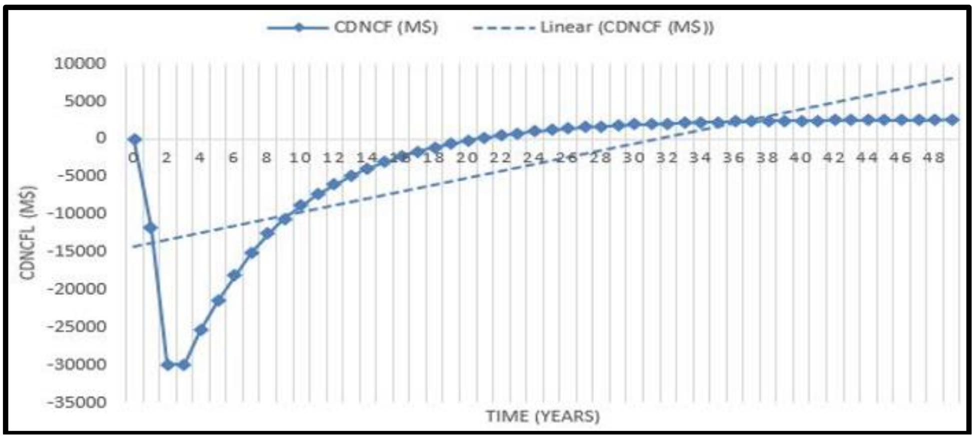

Fig. 3a: Payback period for LNG

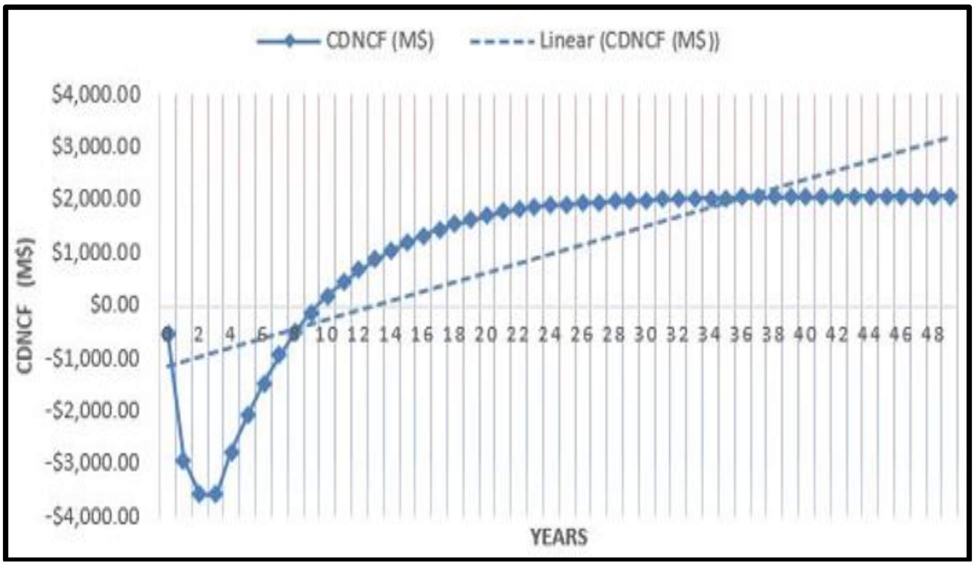

Fig. 3b: Payback period for CNG

However, comparing the various trends in the graphs for the POP's of both projects, it was observed that the changes in gas price, turbine capacity and distance can either affect the payout years positively or negatively. From Table 9 and Fig. 4, payback (pay-out) period for each project is seen to be affected by the change in distance to the delivery point. As their distances increased, the pay-out period also increased, thus extending the years for the project to be profitable. Observe that as the distance increased from 10 km to 1000 km, the CNG project became less valuable since its pay-out years couldn't be ascertained from the model due to a negative NPV but the LNG project paid-out at 48.76 years. Apparently, the CNG-based project appears more valuable for shorter distances between source and consumption locations while the LNG option is considered more economically profitable at relatively longer distances.

Table 9: POP due to changes in price, distance and capacity

Capacity (MW)	CNG (Yrs.)	LNG (Yrs.)	Price ($)	CNG (Yrs.)	LNG (Yrs.)	Distance (km)	CNG (Yrs.)	LNG (Yrs.)
1	-	-	0.37	9.39	-	10.00	9.3	20.38
2	9.39	20.49	1.00	4,49	-	20.00	9.35	20.45
5	5.34	5.59	2.00	3.68	-	26.60	9.39	20.49
10	4.55	4.13	3.00	3.45	-	30.00	9.41	20.51
20	4.20	3.55	4.00	3.34	-	40.00	9.46	20.58

30	4.11	3.36	5.00	3.27	-	50.00	9.52	20.65
40	4.04	3.27	6.00	3.22	-	60.00	9.57	20.72
50	4.41	3.22	7.00	3.19	-	70.00	9.63	20.78
60	4.38	3.18	8.00	3.17	-	80.00	9.68	20.85
70	4.36	3.15	9.00	3.15	-	90.00	9.74	20.92
80	4.34	3.13	10.00	3.13	22.85	100.00	9.8	20.98
90	4.33	3.12	10.20	3.13	20.49	200.00	10.47	21.76
100	4.32	3.11	15.00	3.09	8.75	250.00	10.84	22.18
200	4.27	3.05	20.00	3.07	6.60	500.00	13.65	24.85
250	4.26	3.04	25.00	3.05	5.66	1000.00		48.76
500	4.24	3.02						
1000	4.23	3.01						

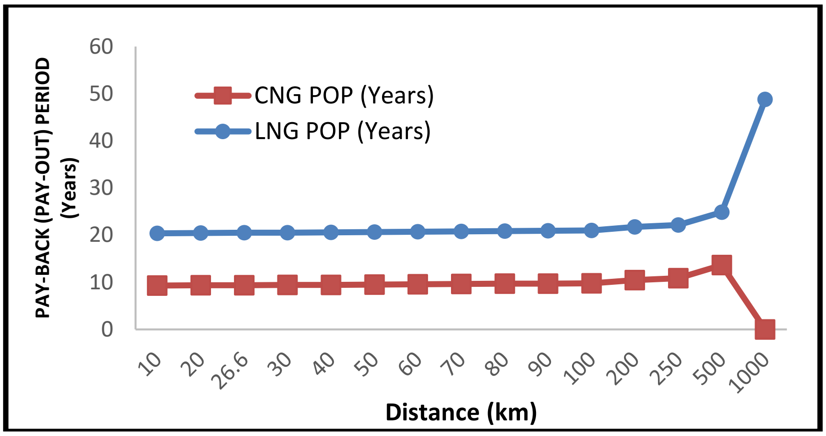

Fig. 4: Changes in POP due to distance from source to consumption locations.

From Table 9 and Fig. 5, it is shown that the payback (pay-out) period for each project is affected by the changes in price of the gas. As prices increase, the pay-out period reduces. As price increased to $10.20, the CNG project paid out quickly at 3.13 years while the LNG project paid out at 20.49 years. At a price of $25, the CNG option was seen to payout faster in 3.05 years while that of the LNG also paid out within the first six years (5.66years).

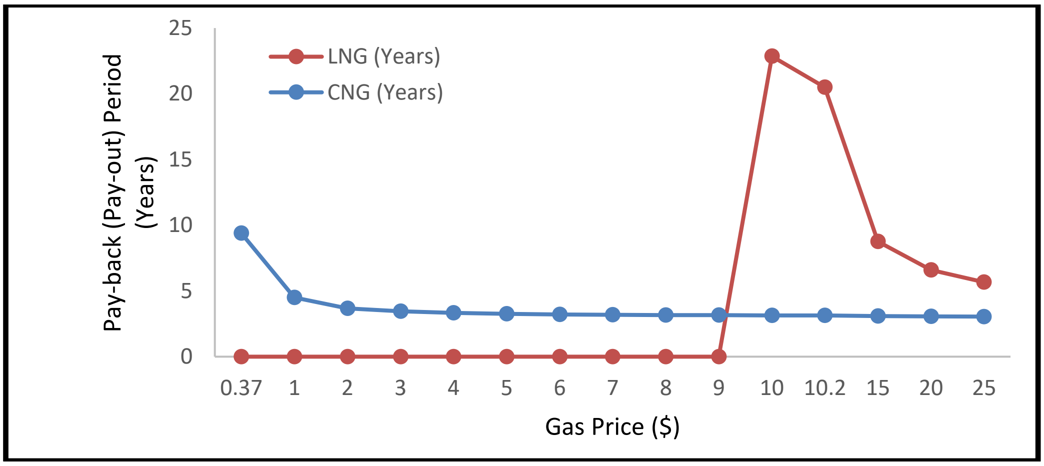

Fig. 5: Changes in POP due to distance

From Table 9 and Fig. 6, we observe that the payback (pay-out) period for each project is affected by the change in turbine capacity. As the turbine capacity increased, the pay-out period also reduced correspondingly. For a 1MW turbine capacity, both the CNG project and the LNG project are seen to be less valuable and/or inconclusive since the payout period couldn't be ascertained from the model. But as the turbine capacity increased, the pay-out years decreased. At 2MW, the CNG project paid out in 9.39 years while the LNG project paid out at 20.49 years. At a capacity of 1000MW, the CNG was seen to payout in 4.23years while that of the LNG also paid out within the first four years (3.01years). Therefore, at a capacity of 2MW, the CNG project was seen to payout faster and is preferred; At 1000MW, the CNG payout reduced to 4.23 years with the LNG project paying out at 3.01years. It can deduce that the LNG project is now more economically profitable at this turbine capacity.

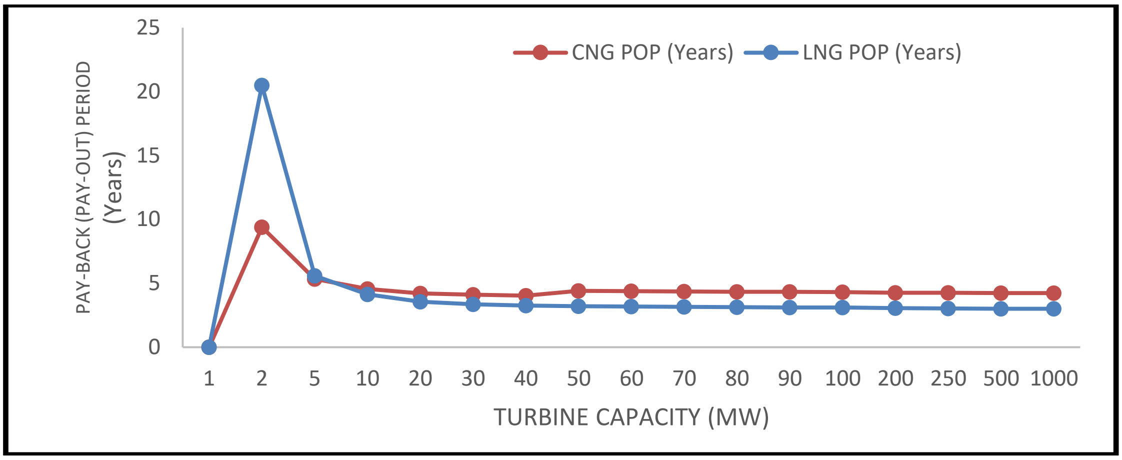

Fig. 6: Changes in POP due to capacity

D. Virtual pipeline project challenges at Uniport

A decision to assess the problems associated with the virtual pipeline project at the University of Port Harcourt (UNIPORT) was made. A research questionnaire was prepared and from data obtained and analyzed from various respondents which included; students, operators, administrative staff and passersby, some key problems that hampered the virtual pipeline project can be established which are: 1) Political 2) Financial; 3) Decision making; 4) Bad transmission/distribution systems; and 5) Poor/inadequate administrative policy.

(1) Problem of politics

Institutional Politics can either make or mar any organization when it is unhealthy but brings out the best in everyone when it is healthy. There is some unhealthy politics played by stakeholders within the institution which negatively affected the sustenance of the virtual pipeline project. There should be caution in electing new leadership in universities. There should not be any form of interference from Government or any other external political force. The role of governments in universities should be to oversee and also help put intervention funds in place not to dictate or interfere in the politics and policies of the school. Government interference in who to run the institution and how to run the institution most times does not bode well for the university due to the non-pressurized working environment thus making the administrators lazy and not willing to explore but focus on witch-hunting and other illegalities. These attitudes and illegalities will prevent delivery of meaningful projects and may not be willing to sustain existing projects since they are only accountable to the government that propelled them to power. For example, in February 2016 when a newly inaugurated Federal Government sacked some of the VC's that were appointed by former president Goodluck Ebele Jonathan. This drastic change in leadership led to the immediate revocation of some projects including the collapse of the virtual pipeline project at UNIPORT. To solve this kind of issues, the political structure of the institution should change and the processes of choosing a vice chancellor (VC), who is the overall administrative head of the university should be left to the institution alone, with no external interference. This will go a long way to enthrone leaders that are accountable since the position of the VC will be open to all qualified candidates within the confines of the university – and such a healthy competition brings out the best in people. If at all the government of the day wants to appoint or disengage any VC, there are procedures laid down by the constitution and they should be strictly followed. in the appointment and disengagement of Vice Chancellors.

(2) Problem of financing

Financing is a factor that led to the collapse of the CNG-based virtual pipeline project at

UNIPORT. It is understandable that financing a project of such magnitude by a single university is a big challenge. Universities suffer from paucity of funds and mostly depend on Government allocation to fund projects. University management and governing councils should learn partner with industry and other individuals/businesses to be able to fund these kinds of projects. Before the collapse of the virtual pipeline project, Uniport was able to afford further payments to the IPP, TSEL.

The University is not only a citadel of learning but also a very friendly environment where various businesses (small and medium scale) thrive. Majority of these businesses use power to service their businesses but with the persistent issue of inadequate power supply, almost 90% of them had resorted to generating their own power. They spend at least NGN1,000.00 on premium motor spirit (PMS) for their various petrol-powered power generating sets. As at the time of this research, at least 215 different business owners who do businesses that require electric power in the institution were captured. In addition to the 215 accounted for in this research, there are various commercial banks and other financial institutions domiciled in the university, namely: Access Bank PLC, Union Bank, U and C Micro Finance Bank Limited, United Bank for Africa (UBA) PLC, Fidelity Bank, First City Monument Bank (FCMB), and Eco Bank Nigeria PLC. These institutions require sufficient power to run their businesses, and hence spend so much funds for power generation. On average, each bank spends NGN200,000.00 every month for diesel. Aside these business owners, most offices also own at least one generating set which is powered by petrol. These offices spend at least a minimum of NGN 800.00 each day which amounts to NGN 16,800.00 every 21 working days of the month.

Furthermore, the University is surrounded by other well-known businesses like; Kilimanjaro, Sammies fast food, Genesis fast food, Dreams fast food, FCMB and First Bank of Nigeria PLC. These businesses and financial institutions spend large amounts of money on generating power each day to service their businesses. One finding confirmed that First Bank of Nigeria spend NGN 1,150,000.00 every month on power generation (excluding national grid electricity bills). Kilimanjaro on the other hand spend about NGN 450,000.00 every month (also excluding national grid electricity bills) while Sammies and Genesis spend NGN 385,000.00 on average to service their respective businesses. The commercial bank, FCMB, spends NGN 708,000.00 every month. The university itself, as at the time of this research, spends NGN 73,500,000.00 for diesel every month to service the various campuses of the institution. Table 10 lists some of the findings. With array of businesses at the University and its environs, the university should be able to finance such a small virtual pipeline project by introducing a small levy to be paid by all users of the electricity generated by the CNG-based power plant. This efforts in addition to strategic and productive industry partnership can help sustain such a beneficial virtual pipeline project. Table 10 shows that UNIPORT and the businesses within the school and its surroundings spend about NGN 76,843,000.00, excluding the amount spent by the other institutions on national grid generated utility bills.

Table 10: Summary of expenditure per establishment per month

S/No	Institutions/Business	Amount Spent (NGN)
1.	University of Port Harcourt	73,500,000.00
2.	Small Businesses within	215,000.00
3.	First Bank of Nigeria	1,150,000.00
4.	FCMB	708,000.00
5.	U and C Micro F. Bank	200,000.00
6.	UBA	200,000.00
7.	Access Bank	200,000.00
8.	Fidelity Bank	200,000.00
9.	Union Bank	200,000.00
10.	Eco Bank	200,000.00
11.	Kilimanjaro Fast-Food	450,000.00
12.	Genesis Fast Food	385,000.00
13.	Sammies Fast Food	385,000.00
	Total	**NGN76,843,000.00**

(3) Problem of decision making

The university decision making process sometime exclude all stakeholders. For a virtual pipeline project like the one started at UNIPORT, decision-making should be collective with all qualified stakeholder contributing. It is understood that the vice-chancellor is the principal officer here but such projects should look beyond the tenure of current VC. This prevents the quick or gradual shutdown of excellent projects when a new VC takes office. Thus, decision making in such projects should be all inclusive, with heads/representatives of all bodies that are domiciled in the institution attending. The key issues to be discussed and addressed should include:

- The terms of agreement,
- The amount agreed,
- How the payments (funds) are to be generated, and
- How the payments are to be made.

The above issues as agreed and resolved should be the yardstick for continuation and/or termination of contractual agreements. Such decision-making strategy will help educate and inform all stakeholders, thus bringing a sense of belonging to all stakeholders. During and after consultative meetings with all stakeholders, stakeholders should be allowed time to study the contract terms and also do their own findings to evaluate the project costs, terms of contracts and also the method (terms) of payments and report back to university management. This will put the institution in good stead to ensure a healthy and sustainable relationship between the management and stakeholders, foster a good working relationship and also help to hasten the decision-making process in the future. This healthy relationship will also help to instill confidence and avoid the following issues that can arise:

- Insecurity/suspicion of insincerity on the part of project initiators and promoters.
- Embezzlement/misappropriation of fund.
- Curbing continuity in governance/political instability issues.

(4) Transmission/distribution systems

Findings include the observation that the transmission of the generated power seems be a troubling issue. This is due to the state of the transmission systems in place. They are considered obsolete and are illegally tapped into by university residents, leading to the overload of the turbine. To prevent the problem of overload, power losses and emergency shutdown, there is need for a total overhaul (revitalization) of the system. Repairing and replacing equipment and accessories where necessary as well as introducing a new system like the one being used by one of TSEL's major client (Ariaria market in Abia State) will go a long way in solving this type of problem.

In the Ariaria market, The TSEL introduced the "Pay As You Use" also known as "Pay As You Go" (PAYGo) to prevent power wastage and illegal tapings (connections) by others within the vicinity. With this system, consumers pay for what they use, therefore disallowing anyone from illegally tapping or connecting illegally. If this system was introduced at Uniport, it would have instilled discipline in students, business owners, and other residents within and around the University and also help to protect the power generator from overloading. Often times, students leave their hostels for classes and other engagements without turning off their appliances thereby wasting scarce energy resources. This would not be the case if the PAYGo is implemented. Also, some students/residents within the school environment allow business owners/residents in close proximity to connect illegally to the system leading to breakdown of the power plant but with the introduction of the PAYGo system and a total overhaul of the transmission and distribution system, this will be checkmated as no one would like to pay for another man's comfort.

(5) Poor/inadequate administrative policy

The university is not only a citadel of learning but a socio-cultural and socio-economic environment and thus may need some administrative, developmental policy that can bring positive development to the community. One example is to introduce new technologies connected with the project that can, for instance, enable use of available local materials. Also, the university management should push for every aspiring vice chancellor to introduce a project that is seen to be sustainable and that will positively impact the community.

4. Conclusion

The application developed in this work is dynamic and with little tweaking, can be used for selecting a preferred virtual pipeline project for power generation. Factor affecting project profitability include: distance between fuel source and consumption locations, gas price, and turbine capacity. The contribution made by each variable to the profitability of the project were investigated. From the analysis of results, the following conclusions were reached: (1) in terms of NPV for each mode of transportation, CNG option at US$2.09 million and LNG option at US$2.6 million, indicates a preference for the deployment of an LNG technology-based project; (2) Considering relatively longer distances between source and consumption locations, an LNG project is seen to be more valuable and thus, preferred to the CNG option, judging by their NPV values; (3) Considering the turbine capacity factor, an LNG project is more valuable; and (4) In terms of gas price, CNG project is more valuable at a uniform price of $0.37 and thus, preferred to the LNG option. From the above considerations and taking into consideration the two key items considered by an investor which are CAPEX and also the price that will be favourable to consumers, CNG option is preferred for this UNIPORT project since it is less costly and still profitable even at the relatively low price of $0.37.

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