



## An Alternative to Petroleum Fuel using Gas to Liquid Product

Ekerette E. Ezekiel<sup>1,2</sup> and Joseph O. Etim<sup>1</sup>

<sup>1</sup>Department of Chemical & Petroleum Engineering, University of Uyo, Uyo, Nigeria.

<sup>2</sup>Norwegian University of Science and Technology, Trondheim, Norway.

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### ABSTRACT

Following the large reserve of untapped natural gas in the world, the utilisation of gas reserve is a possible solution to increasing energy demand and a possible reduction in pollution and crude oil dependency. Due to its (Natural gas) lower hydrocarbon fraction it can be converted to higher petroleum products such as petrol (synthetic fuel), diesel, naphtha and aviation kerosene which are products on high demand. Emission performances of hydrocarbon products produce from gas are better than those from conventional crude oil cracking process. A process known as Fischer Tropsch (F-T) process, requiring an F-T plant is used for the conversion of natural gas into higher derivatives. The process involves three basic stages; Syngas Generation, Catalytic Synthesis to form petroleum products and Hydro-processing to convert into finished product. In an attempt to ensure a major step in utilising the large gas reserve in Nigeria, the setup of F-T plant in the Niger-Delta region is proposed. The choice of establishing the F-T plant in the Niger-Delta region is not political but an economic one; this is so because the feedstock (natural gas) is available in large quantity and transportation is less, thereby cutting cost. Investors will require reasonable model variables which includes a suitable depreciation evaluation, a profitable risk portfolio and a project fixed cost, which are the responsibilities of a petroleum economist. This paper addressed a comparative study of Gas to liquid fuel as an alternative to refined crude oil. Various parameters were evaluated: physical and chemical properties of the product, emission discharge, pollutants. The results obtained showed that gas to liquid products has environmental and efficient benefits over petroleum derived products (crude oil).

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### Introduction

When considering global energy challenges and a possible energy crisis emerging, experts have predicted an increase of 50% in energy demand by 2030, in the light of this possibility; traditional means of getting energy will have to be more efficient to meet up with rising energy demands. Over the past four decades, major steps have been taken to ensure that alternative means of generating energy were formulated and utilised to reduce pollution and crude oil dependency (Elsevier, 2005). Some of these steps include solar power generation, the use of hybrid machines, use of electric motor, utilising dams for generating electricity, power consumption enlightenment and more so, the proper utilisation of produced natural gas among others. Up until the past five decades where gas flaring became a major source of pollution concern; the possibility of utilising natural gas was not considered. With various alternative energy sources failing to rise up to expectations, hydrocarbon remains the keystone of energy production in the world. Efforts are currently directed toward converting gas to various liquid petroleum products such as petrol, kerosene, air kerosene, diesel and naphtha. Although this move reduces pollution to an extent, it will minimize the consumption of crude oil and give opportunities to explore the large reserve of natural gas in the world. Due to its large reserve, natural gas has emerged as a major force in global power generation market. Using GTL, natural gas is transformed into various liquid hydrocarbon products capable of meeting important and pressing needs of energy consumers, this form the basis of this research paper addressing a comparative alternative of utilizing natural gas

using GTLP in other to limit gas flaring into the atmosphere, (Fetkovich, 1975).

### Crude oil production

Akpan (2009) revealed that Nigeria's total annual crude oil production is accompanied by associated gas of about 40bcm per annum, of which 80% is flared with changes in government gas policies and introduction of various incentives to promote gas utilization coupled with the government's "flare-out" target of 2008, a number of domestic and export gas projects are at different stages of development in the country. The largest and then most successful of these gas project has been that of Nigerian Liquefied Natural Gas (NLNG) which the NNPC control 49% stake, Shell, Total LNG Nigeria Limited and Eni control 25.6%,15% and 10.4% stake respectively. Due to the variety of natural gas constituents, it finds wide application either as an energy source or as feedstock to the chemical and petrochemical industries:

(i) **As an energy source:** Natural gas competes with petroleum products, notably fuel oil, diesel and liquefied petroleum gas (LPG). It is less expensive, burns cleaner and is more abundant than all these other fuels.

(ii) **As a feedstock to chemical/petrochemical industries:** Natural gas and natural gas liquids are used to manufacture a gamut of intermediate chemicals and finished products such as ammonia, Oxo alcohol, chloromethane, methanol, fertilizers, etc.

(iii) **As a residential fuel:** In temperate countries, because of the climatic conditions, a sizeable gas market exists in the distribution of natural gas for domestic heating, cooking and for refrigeration and air conditioning.

### The Genesis of Gas-Liquid-Technology

According to (Matheaus and Osamu, 1995) the term Gas -to-Liquid technology (GTL) refers to a number of technologies designed to convert natural gas to liquid fuels as an alternative to the traditional refining of crude oil and other natural gas commercialisation routes. The Fischer-Tropsch technique developed in the early 20<sup>th</sup> century were widely deployed to create synthetic fuel in World War II, the process steps consist mainly of treatment of natural gas to remove water and impurities, reforming of the natural gas to produce syngas, Fischer-Tropsch conversion to produce hydrocarbon waxes and upgrading to produce finished products. Gas flaring is a major contributor to air pollution; the major problem associated with it includes global warming and ozone layer depletion. These events are of great environmental consequences such as melting of ice cap region of the northern hemisphere thereby increasing water level in the ocean resulting in flooding and damages to crop production due to acidic rainfall. These problems have led to some question as stated below, is the adopted method feasible? , What roles can be played by public and private sector? , Are there strict measures against gas flaring? , Are these measures followed? , Should there be a system of gas flaring limits imposed on industries?

### The effective use of gas/liquid technology

(Alleman and Commick ,2003) studied GTL processes trends in recent times, and made the following conclusions that; GLT offers an effective means to use untapped natural gas resources and a diversification of fuel resources by ensuring substitutes for crude oil. GTL not only add value but is capable of producing products that could be sold or blended into refinery stock as superior products with clean-burning properties. Diesel fuels produced by the process have an energy density comparable to conventional diesel, but with higher cetane number. This should be considered the most significant advantage of GTL process.

GTL process needs low-cost natural gas as a feed stock; less than \$1.0 per million Btu to compete with traditional diesel fuels. Some sources of remote natural gas called "stranded gas", that are not otherwise economically available will be ideally suited for this process. Examples are Alaska and Qatar. GTL in operation today, converts 10,000 cubic feet (286 cubic meters) of natural gas into slightly more than one barrel of liquid (Burton, 2011).

While the cost of producing GLT fuel has been declining as a result of using better catalysts, scale up and plant design, the transport and distribution costs are slightly higher compared to refinery-produced fuels. Research and development is focused on reducing costs further. Examples are cited for Cobalt catalysts as follows: Increasing the catalyst life by making it more resistant to irreversible sulphur poisoning. Changing the selectivity dependency on the hydrogen/Carbon (ii) oxide ratio to such an extent that high diesel yields can be obtained at hydrogen/Carbon (ii) oxide ratios similar to the usage ratio.

(Bulter, 1994) made the following contributions from his research on Gas to Liquid fuel:

i. Converting natural gas to liquid fuel benefits the environment in producing clean fuels, Fischer-Tropsch process manufactures diesel with zero sulphur. In addition, GTL encourages oil producers to utilize the associated gas produced in the oil fields and not to be flared.

ii. Associated natural gas could be converted to petroleum fuels and blended with heavy crude oils. This will upgrade the quality of the crude and cut, at the same time, the expenses incurred in collecting and transporting the associated gas.

iii. The composition of the hydrocarbon feed stock sets the preferred conversion routes for the production of liquid transportation fuels, for example, Gasoline or Middle Distillate Fuels (kerosene/gas oil).When the Carbon/Hydrogen ratio of feed stocks and products are well matched; as with the case: coal aromatic gasoline, and with natural gas middle distillates, then a relatively high theoretical efficiency is possible. If the Carbon/Hydrogen ratio of the feed/products differs substantially, rejection of Carbon or Hydrogen as the case may be is inevitable and lower conversion efficiencies are the result.

### Materials and Methodology

**Material/Data requirement:** Gas -To liquid Diesel (GTL diesel), European diesel (EU diesel), Emission discharge data, Viscosity data, Heating value data, Cetane number data, Total sulphur data, Excel spreadshee

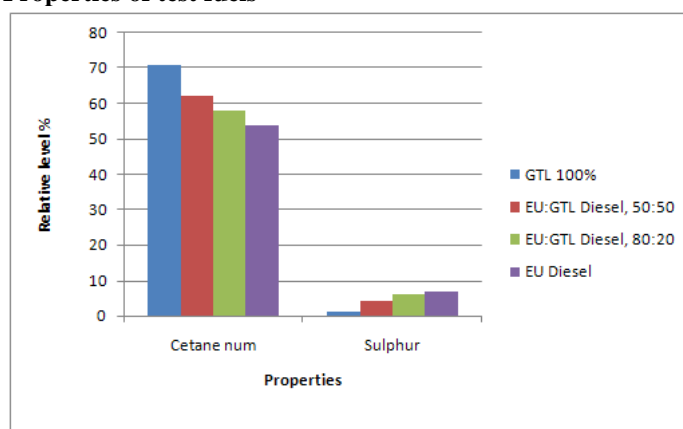
### Method: Comparative Analysis

A comparative analysis was deployed in analyzing the fuel products obtained from GTL diesel, EU: GTL diesel and EU diesel. This analysis is limited to four products such as GTL diesel, EU diesel, EU and GTL diesel at a ratio of 50:50 and EU and GTL diesel at a ratio of 80:20. The analysis was aided by excel tool. To determine how

commercially preferable the GTL diesel could be used as an alternative to crude oil refined diesel, the physical and chemical properties of the products of GTL diesel, EU diesel, EU:GTL (50:50) diesel and EU:GTL(80:20) diesel was analyzed based on; Environmental emission, Pollutants of different diesel, Total sulphur, Cetane number, Viscosity and Heating value. The Research data used for the analysis are; The GTL diesel, EU diesel, EU: GTL (50:50) diesel, EU: GTL (80:20) diesel. The physical and chemical properties of the product was studied, the different emission discharge and the different pollutants was compared to determine whether GTL diesel could comfortably replace or be as an alternative to refine crude oil products based on the United States standard of effluent discharge. The results was extensively analysed by the Excel tool and presented with tables, histogram and graph

### Results and discussion

#### Properties of test fuels



**Figure 1. Physical Properties of GTL Diesel, EU: GTL Diesel and GTL diesel**

From Figure1, It can be seen that the viscosity of GTL diesel is the better of all the diesel in terms of its quality because it has the lowest viscosity, thus, making the diesel to have an excellent combustion efficiency as compared to the other diesel. The blend of EU: GTL diesel at a ratio of 50:50 seems to be a good diesel but not as good as the GTL diesel because of its low viscosity thus making it a good quality diesel with good combustion efficiency.

The blend of EU: GTL diesel at a ratio of 80:20 also is a quality diesel because of its low viscosity which also makes the diesel to possess fair combustion efficiency. The EU diesel has the highest viscosity which means the diesel is a low quality diesel in terms of its combustion efficiency. Thus, making the EU diesel the least quality diesel. In order of its increasing quality; EU diesel > EU: GTL 80:20 diesel > EU: GTL 50:50 > GTL diesel. (Lee et al, 1998) Heating value is referred as the amount of heat released during combustion of a specified amount of it. The higher the heating value the better the diesel because the fuel can easily burn substances. From FIG 4.1, The GTL diesel has the highest heating value >74 thus making the diesel to have a high combustion efficiency. The diesel blending of EU: GTL at a ratio of 50:50, diesel blending of EU: GTL at a ratio of 80:20, and EU diesel all have the same heating value. From Figure1, indicated that in terms of heating value quality GTL is a better diesel than the blended diesel at different ratios and the EU diesel.

#### Properties of test fuels

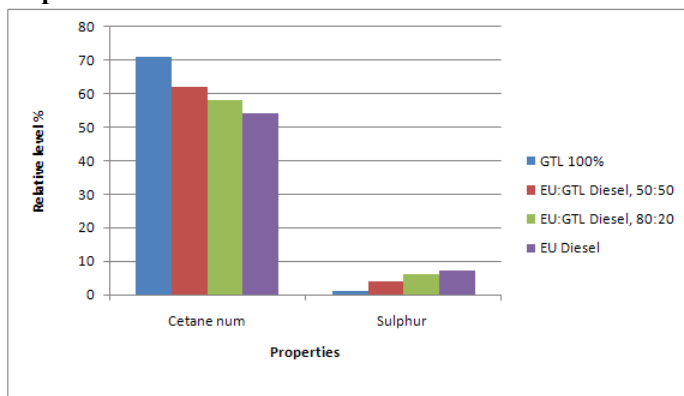


Figure 2. Chemical properties of GTL Diesel, EU: GTL Diesel, EU diesel

From Figure 2: It is evident that the higher the cetane number, the more easily the fuel will combust in a compression engine. GTL Diesel has a cetane number of > 65, thus making the diesel to have shorter ignition delay which causes an engine to run more smoothly and quietly. While the blending of EU:GTL diesel at a 50:50 ratio yielded a cetane number of about 60 also making the diesel to have a short ignition delay. Also the blending of EU: GTL diesel at a 80:20 ratio yielded a cetane number of about 58 making the diesel to have a short ignition delay. Furthermore, EU diesel has the lowest cetane number of about 52 making the diesel to have a long ignition delay. Comparing the cetane numbers of the different diesel in order of their quality, GTL Diesel > EU: GTL 50:50 > EU: GTL 80:20 > EU Diesel. Sulphur in diesel fuel contributes to increased acid levels in the engine and causes serious damage on engine. The presence of sulphur minimizes the durability of engine and also has a negative impact on the environment. (Bond, 2011) GTL diesel is virtually free of sulfur and aromatic compounds, cleaner-burning than conventional diesel with equivalent or lower greenhouse gas emissions. Its use for transportation especially in older vehicles without advanced exhaust after treatment systems – reduces emissions of particulates and other pollutants, helping to improve ambient air quality. GTL diesel has the least sulphur content and less pollutant compared to other diesel. The blend of EU: GTL diesel at a ratio of 50:50 also has a low sulphur content which in some ways has a negative impact on the environment though it might be negligible.

The blend of EU: GTL diesel at a ratio of 80:20 has low sulphur content, its impact on engines and the environment is

pronounced. Finally, the effect of EU diesel on the environment and engine is worrisome because of its negative impact. In other of diesel quality, GTL > EU: GTL 50:50 > EU: GTL 80:20 > EU Diesel.

#### Emission Discharge of Test Fuels

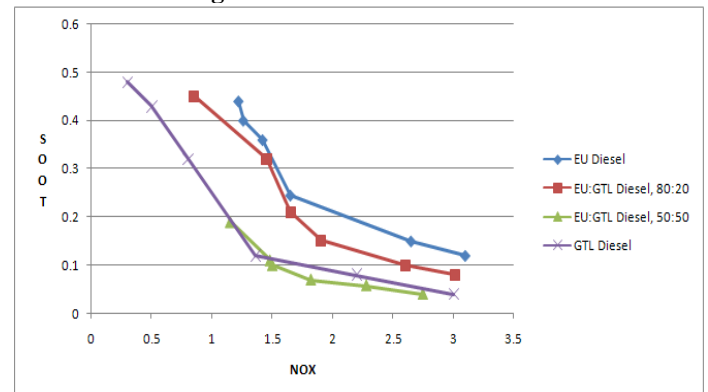


Figure 3. Emission discharge of different diesel

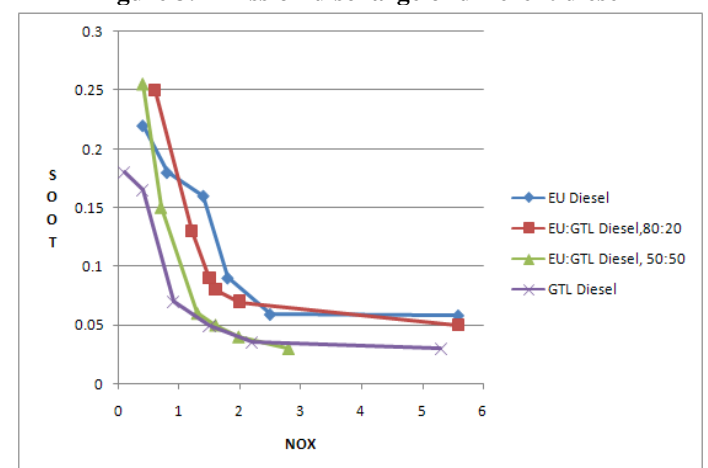


Figure 4. Emission discharge of different diesel

Figure 3 and Figure 4 showed two results obtained from the steady state test bench work. The figure depicts representative data for the effect of GTL diesel fuel and its blends on the soot and NOx trade-off characteristic at two operating points, namely 2000 rev/min and 5 bar bmep (brake mean effective pressure), and 1600 rev/min and 3.3 bar bmep. In this case, the EGR rate was varied, while the SOPI and SOMI were kept constant and equal to the reference values. Soot emission levels were calculated from exhaust smoke levels determined by FSN (Filter Smoke Number) measurements. It is evident that GTL diesel offers a significant reduction in terms of both soot emissions and NOx for all the EGR rates tested. The soot emission increase for decreasing NOx values follows the expected pattern. Surprisingly, the strong non-linear behavior of the EU50 blend is again evident; this fuel exhibits almost the same benefits as neat GTL diesel fuel.

Use of Gas-to-Liquid diesel fuel as a blend component for a diesel fuel composition which, when combusted in an engine, has reduced NO<sub>x</sub> and soot emissions, which comprises both crude oil derived diesel fuel meeting the European EN 590 specification for sulphur-free diesel fuel and Gas-to-Liquid (GTL) diesel fuel.

Reductions in both NO<sub>x</sub> and soot emissions may be obtained which are greater than indicated by the blending ratio of the GTL diesel in the crude oil derived diesel fuel. Thus, more than 70% of the reduction in both NO<sub>x</sub> and soot emissions which may be obtained with neat GTL diesel fuel, may be obtained with a 1:1 GTL: Crude derived diesel ratio.

**Table 1. Physical Properties of different diesel**

	UNITS	GTL Diesel 100%	EU:GTL Diesel 50:50	EU:GTL Diesel 80:20	EU Diesel
Viscosity@40°C	mm <sup>2</sup> /s	1.97	2.54	2.79	2.95
Heating Value	MJ/kg	73.8	43.5	43.2	43.1

**Table 2. Chemical Properties of different diesel**

	UNITS	GTL 100%	EU:GTL 50:50	EU:GTL 80:20	EU Diesel
Cetane number		71	62	58	54
Total sulphur	Mg/kg	1	4	6	7

**Table 3. Emission discharge of different diesels at 2000rpm and 5bar**

DIESELS	SOOT TEST						NOX TEST					
	1	2	3	4	5	6	1	2	3	4	5	6
EU Diesel	0.12	0.15	0.245	0.36	0.4	0.44	3.1	2.65	1.65	1.42	1.26	1.22
EU:GTL Diesel, 80:20	0.08	0.1	0.15	0.21	0.3	0.66	3.01	2.6	1.9	1.65	1.45	0.85
EU:GTL Diesel, 50:50	0.04	0.058	0.07	0.1	0.11	0.19	2.75	2.28	1.82	1.5	1.48	1.15
GTL Diesel	0.04	0.08	0.12	0.32	0.66	0.88	3	2.2	1.36	0.8	0.5	0.3

**Table 4. Emission discharge of different diesel at 1600rpm and 3.3bar**

DIESELS	SOOT TEST						NOX TEST					
	1	2	3	4	5	6	1	2	3	4	5	6
EU Diesel	0.058	0.059	0.09	0.16	0.18	0.22	5.6	2.5	1.8	1.4	0.8	0.4
EU:GTL Diesel, 80:20	0.05	0.07	0.08	0.09	0.13	0.25	5.6	2	1.6	1.5	1.2	0.6
EU:GTL Diesel, 50:50	0.03	0.04	0.05	0.06	0.15	0.255	2.8	1.98	1.6	1.3	0.7	0.4
GTL Diesel	0.03	0.035	0.049	0.07	0.165	0.18	5.3	2.2	1.5	0.9	0.4	0.1

**Table 5. Test vehicle and engine data**

<b>Vehicle</b>	<b>Mercedes e 220 cdi</b>
Designation	Limousine
Model year	2003
Transmission	6- speed manual gearbox
Gross vehicle mass	2145kg
Engine designation	Mb om646, eu3 emission control
Displacement configuration	2,2 l, in-line 4 cylinder,4 valves cylinder
Compression ratio	18:1
Fuel management	Common rail fuel injection(peak pressure 1600 bar)
Air management	Turbocharged (vnt),intercooled
Emission control	Cooled egr,inlet swirl control,close coupled and underfloor oxidation catalyts
Rated torque	340nm at 2000rev/min
Rated power	110kw at 4200rev/min

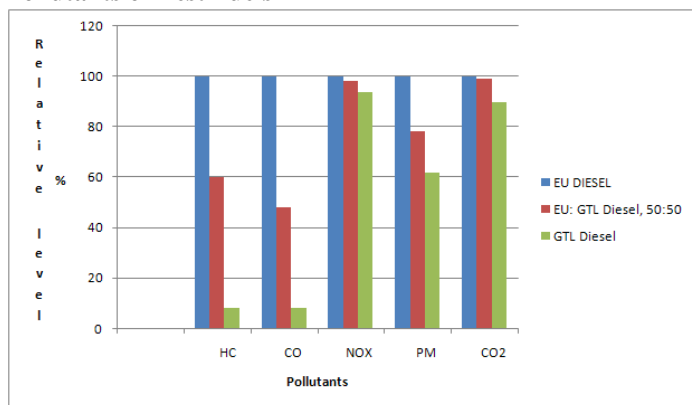
**Table 6. Pollutants of different diesel**

Different diesel	HC	CO	NOX	PM	CO2
EU DIESEL	100	100	100	100	100
EU: GTL Diesel, 50:50	60	48	98	78	99
GTL Diesel	8	8	94	62	90

More than 40% of the reduction in both NO<sub>x</sub> and soot emissions which may be obtained with neat GTL diesel, may be obtained with a 1:4 GTL derived diesel ratio.

However, in some embodiments the reduction in NO<sub>x</sub> emissions may be less than the reduction in soot emissions and vice versa. In some embodiments, the reduction in NO<sub>x</sub> may be minimal; however, the NO<sub>x</sub> will be reduced by the use of GTL diesel in accordance with the invention. Dynamometer tests was conducted with a Mercedes Benz<sup>TM</sup> E 220 CDI vehicle, using the New European Driving Cycle (NEDC) emission test, and without any changes to the basic EU3 emission level engine calibration or engine hardware. The vehicle was tested with its standard calibration without any adaptation, with EU diesel, the 1:1 blend and for the neat GTL fuel. The relevant test vehicle data are shown below in Table 4.5

#### Pollutants of Test Fuels



**Figure 5. Combustible contaminant of different diesel**

The results of the unadapted vehicle emission tests as depicted in figure5 for the EU diesel, EU50, and GTL diesel fuel. The averaged results for the test runs are presented as the percentages relative to the EU diesel reference fuel. FC indicates the volumetric fuel consumption. For neat GTL diesel fuel, an unexpectedly high reduction of >90% for HC and CO emissions was observed. The CO and HC reductions for the 50% blend scale roughly with the blending ratio. The NO<sub>x</sub> emissions were reduced marginally, with the 50% blend again showing about half the reduction of the neat GTL diesel fuel. The same applies for the HC, NO<sub>x</sub> data. PM emissions were reduced by up to 30% with the GTL diesel. Surprisingly, a strong non-linear characteristic was evident with the 50% blend (EU50), which showed a reduction of approximately 22%. Thus, with these result as depicted in FIG 4.5, It is evident that GTL diesel is a better fuel to EU diesel in terms of its pollutants.

#### Conclusion

With an expected global population increase of over two billion and increasing development, particularly in the expansion of affordable transport, per capita energy use by 2030 is set to increase by 50%. Natural gas has emerged as a major force in the global power generation market but, until recently, it lacked the versatility to address other pressing energy needs. Originally developed to reduce flaring, GTL is designed to take what has been historically a waste product in Nigeria and turn it into high value products with the potential to access export markets anywhere in the world. With Gas-to-Liquids (GTL) technology, natural gas can be transformed into a range of high quality energy and chemical products, including transport fuels, base oils, waxes, paraffins and naphtha. GTL offers gas owners the opportunity to diversify gas monetization to a degree considered impossible just a decade ago, achieving a product value significantly above that of a feedstock for power generation.

GTL technology permits the large-scale use of natural gas for motor fuel production, in particular diesel, and is of primary strategic interest for all of the for all of the major oil companies, making it possible to reduce fuel production costs, reduce the environmental impact of the process and valorize natural gas reserves that would otherwise be difficult to exploit.

From the evaluation and analysis carried out in this research work, the following conclusion could be drawn:

- GTL diesel physical properties is better than the physical properties of GTL diesel blends and refined diesel ( Figure 1).
- GTL diesel chemical properties is better than the chemical properties of GTL diesel blends and refined diesel ( Figure 2)
- GTL diesel emission discharge is low compared to its GTL blend diesels and refined diesel (Figure 3 and Figure 4).
- GTL diesel has the least combustible contaminants compared to GTL blend diesel and refined diesel (figure.5).

#### Recommendation

From the outcome of the literature lessons and the results obtained from the analysis of GTLP as an alternative to petroleum fuel product; the following recommendations are made:

- Diesel fuels made with Gas-To-Liquids technology have environmental and efficiency benefits over petroleum-derived diesel
- It will aid in the effective use of untapped natural gas resources, and diversification of fuel resources by ensuring substitutes for crude oil.
- GTL diesel will promote the diffusion of highly efficient diesel powered vehicles (with low pollutant discharge) compared to petroleum-derived diesel.
- GTL technology will help in the reduction and effective use of associated gases (flaring) in oil and gas producing countries.
- GTL technology will help to diversify the economy through the involvement in the most abundant hydrocarbon in Nigeria.
- There is viability in job creation through efficient and appropriate development of the petroleum industries in the area of GTLP.
- GTL will provides option for gas producing nations to diversify into the transportation of fuel markets as the process yields various liquid products like diesel and jet fuel

#### Nomenclature

Bmep	=	brake mean effective pressure
EU	=	European diesel
F-T	=	Tropsch process
FSN	=	filter smoke number
GLT	=	Gas to Liquid technology
GTL	=	Gas to liquid
GTLP	=	Gas to liquid product
LPG	=	Liquefied petroleum Gas
LNG	=	Liquefied natural Gas
MJ/kg	=	million joules per kilogramme
MM <sup>2</sup> /S	=	millimeter square per second
NEDC	=	New European drilling circle
NLNG	=	Nigerian Liquefied gas
NNPC	=	Nigerian National Petroleum Cooperation

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