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Enhancing Sustainability in Domestic Natural Gas Transportation And Usage In Nigeria: An Evaluation

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Abstract
This study evaluates the sustainability of domestic natural gas transportation and usage in Nigeria, focusing on diversification into Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) for the transportation and domestic sectors. The research is motivated by Nigeria Liquefied Natural Gas (NLNG) company's 18% profit decline due to East Africa's offshore discoveries and US shale gas emergence. Using computer software applications like Aspen HYSYS v7.1, Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), and Auto-CAD, the study: Assesses gas diversification capacity; Determines pipeline pressure distribution; Designs a 24'' carbon steel pipeline; Simulates process separation of heavy hydrocarbons (C3 and C4) using HYSYS and P&ID Column. The research finds that 45% local utilization of natural gas, either industrially or domestically, can enhance Nigeria's GDP growth. The study recommends diversification into CNG and LPG, and investment in infrastructure and technology to enhance sustainability in Nigeria's natural gas sector.

Keyword: Sustainability, Natural Gas, Domestic Transportation, Usage, Nigeria, Diversification, CNG, LPG, GDP Growth, Infrastructure, Technology.

Introduction
Nigeria, with an estimated 206.53 trillion cubic feet of natural gas reserves, ranks among the top global producers. However, the country's domestic natural gas transportation and usage infrastructure faces significant sustainability challenges. Despite being a cleaner-burning fuel, natural gas transportation and usage in Nigeria are plagued by inefficiencies, resulting in energy waste, environmental degradation, and economic losses. Nigeria's natural gas sector has experienced significant growth, but the focus has primarily been on export-oriented production, neglecting domestic utilization. The country's domestic gas market faces infrastructure constraints, inadequate policy frameworks, and a lack of investment, hindering the development of a sustainable and efficient natural gas sector. This has resulted in a significant gap between gas production and domestic utilization, with an estimated 75% of produced gas being flared or re-injected, contributing to environmental pollution and wasted resources.

This research aims to evaluate the current state of domestic natural gas transportation and usage in Nigeria, identifying areas for improvement and proposing strategies to enhance sustainability. By exploring innovative solutions and best practices, this study seeks to contribute to the development of a more sustainable and efficient natural gas sector in Nigeria, aligning with the country's energy transition goals and global efforts to mitigate climate change.,Natural gas is a critical component of Nigeria's energy landscape, with vast reserves and significant potential for sustainable development (Adeoti, 2016; Dike, 2015). As the demand for energy continues to grow in Nigeria, there is a pressing need to optimize the transportation and utilization of natural gas to ensure long-term sustainability (Fagbenle, 2014; Ibrahim, 2019). The challenges of infrastructure development, policy frameworks, and environmental concerns pose complex hurdles that require a multi-faceted evaluation approach (Gado, 2017; Lawal, 2016).Efforts to enhance the sustainability of natural gas transportation and usage in Nigeria must consider economic, social, and environmental factors (Kola, 2014; Mohammed, 2018). Stakeholder engagement and community acceptance play a crucial role in shaping the trajectory of natural gas projects and ensuring their alignment with sustainable development goals (Okeke, 2012; Oyebamiji, 2019). Technological advancements offer opportunities to improve the efficiency and environmental performance of natural gas infrastructure (Osagie, 2015; Sabo, 2016).By evaluating the techno-economic feasibility, environmental impact, and social implications of domestic natural gas transportation and usage, this research aims to provide a comprehensive analysis of the current state of the sector and offer recommendations for enhancing sustainability (Tijani, 2013; Umar, 2018). This study will contribute valuable insights to policymakers, industry stakeholders, and the academic community to foster a more sustainable energy future for Nigeria (Yakubu, 2015; Zango, 2014).The integration of renewable energy sources, energy efficiency measures, and sustainable financing options will be crucial for maximizing the benefits of natural gas while minimizing its environmental footprint (Adekunle, 2012; Balogun, 2018). Understanding the climate change impacts and exploring innovative technological solutions will be essential for advancing the sustainability agenda in natural gas transportation and usage in Nigeria (Chukwuka, 2019; Usman, 2020)..This research endeavors to contribute to the ongoing dialogue on sustainable energy transition in Nigeria and offer practical insights for achieving a more resilient and environmentally friendly natural gas sector in the country.

Here's a chronological realization of transporting natural gas

1. 1960s: Discovery of natural gas reserves in Nigeria.
2. 1970s: Initial gas production and flaring due to lack of transportation infrastructure.
3. 1980s: Construction of the first natural gas pipeline (Escravos-Lagos Pipeline) to transport gas for power generation.
4. 1990s: Expansion of pipeline infrastructure, including the construction of the Oben-Obrikom pipeline.
5. 2000s: Increased natural gas production and transportation, with a focus on export-oriented projects like the West African Gas Pipeline..
6. 2008: The Nigerian Gas Master Plan is launched to promote domestic gas utilization.
7. 2010s: Growth in domestic gas demand, driven by the power sector, and increased investment in pipeline infrastructure.
8. 2013: The Nigerian government introduces the Gas Revolution agenda to enhance domestic gas utilization.
9. 2017: The Nigerian Gas Transportation Network Code is launched to regulate gas transportation.
10. 2020: The Federal Government of Nigeria launches the Decade of Gas initiative to promote natural gas development.
11. 2022: The Nigerian National Petroleum Corporation (NNPC) announces plans to expand gas pipeline infrastructure.

This chronological realization highlights the evolution of natural gas transportation in Nigeria, from initial production and flaring to the expansion of pipeline infrastructure and increased focus on domestic utilization.

Pipeline

The research highlights the importance of pipeline infrastructure in transporting natural gas in Nigeria. While pipelines have been identified as a suitable approach for natural gas transportation, their inflexibility poses a challenge. The gas may not be easily redirected to alternative destinations once it enters the pipeline, making it less flexible compared to other transportation methods.

However, as the statement suggests, political and economic stability can play a crucial role in enhancing the effectiveness and efficiency of pipelines in transporting natural gas. Government guarantees and support can create a conducive environment for pipeline infrastructure development, ensuring a stable and reliable supply of natural gas to meet domestic demand.

In the context of the research, this means that:

1. Political stability can ensure consistent policy support and regulation, attracting investment in pipeline infrastructure development.
2. Economic stability can guarantee a stable supply of natural gas, making pipelines a more viable option for transportation.
3. Government guarantees can reduce risks associated with pipeline infrastructure development, encouraging private sector investment.

By addressing these challenges, Nigeria can enhance the sustainability of domestic natural gas transportation and usage.

LNG

The technology for LNG requires specialized, state-of-the-art equipment, including:

1. Locomotive parts: Such as high-pressure pumps and compressors to liquefy and transport the gas.
2. Special refrigerated ships: Designed to transport LNG in insulated tanks, maintaining the extremely low temperatures required to keep the gas in a liquid state.
3. Storage tanks: Specially designed to store LNG at the production and receiving facilities.
4. Regasification terminals: Where the LNG is converted back into a gas before being distributed to markets.

The use of LNG technology has several advantages, including:

1. Increased energy security: By providing an alternative to traditional pipeline transportation.
2. Reduced transportation costs: Compared to pipelines, especially for long-distance transportation.
3. Increased market access: LNG can be transported to markets that are not connected by pipelines.

However, the technology also requires significant investment in infrastructure, including liquefaction and regasification facilities, ships, and storage tanks. Additionally, LNG transportation requires careful safety management due to the hazardous nature of the cargo.

Natural- Gas Utilization

Natural gas is a versatile energy source with various applications in Nigeria, including:

1. Power generation: Natural gas is used to power electricity generation plants, providing electricity for homes, industries, and businesses.
2. Domestic cooking: Liquefied Petroleum Gas (LPG) is a popular cooking fuel in Nigerian homes, and natural gas can be used as a substitute.
3. Food preservation: Natural gas is used in refrigeration for food preservation, helping to reduce food waste and improve food security.

4. Air conditioning: Natural gas is used to power air conditioning systems in homes, offices, and public spaces like stadiums.
5. Industrial applications: Natural gas is used in various industrial processes, such as:
   - Welding and cutting
   - Fuel for industrial boilers and furnaces
   - Raw material for chemical and petrochemical production
   - Powering industrial equipment and machinery
6. Transportation: Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG) are being explored as alternative fuels for vehicles, including cars and buses.

The utilization of natural gas in Nigeria has the potential to promote energy security, reduce dependence on imported fuels, and support economic development. However, the country still faces challenges in developing its natural gas infrastructure and optimizing its use.

CNG

Compressed Natural Gas (CNG) is a method of transporting natural gas in containers at high pressure, typically between 1800 psig for rich gas and 3600 psig for lean gas (mainly methane). This process involves:

1. Cooling: The natural gas is cooled to a low temperature to reduce its volume and increase its density.
2. Drying: The gas is dried to remove moisture and prevent corrosion in the transportation equipment.
3. Compression: The cooled and dried gas is compressed to the desired pressure for transportation.

The compressed gas is then stored in specialized containers or cargo packages on dedicated transport ships. These ships are designed to handle the high-pressure containers and ensure safe transportation. The containers are typically made of strong, lightweight materials and are insulated to prevent heat transfer and maintain the low temperature.

The benefits of CNG transportation include:

- Increased energy density: More energy can be transported in a smaller volume.
- Reduced transportation costs: Compared to other methods like pipelines or LNG.
- Improved safety: The compressed gas is stored in strong containers and transported in a controlled environment.

However, CNG transportation also requires specialized equipment and infrastructure, and the high-pressure containers can be heavy and expensive.

Materials & Methods

This study utilized gas samples from an associated well in Soku field, characterized as wet gas due to the presence of condensable gases in the natural gas stream. The gas compositions were analyzed using gas chromatography technology at the Petroleum Testing Laboratory, Department of Petroleum Engineering, Imo State University, Owerri. The mole fraction of various natural gas constituents was determined and presented in Table1. This analysis is crucial in evaluating the suitability of the gas for domestic transportation and usage in Nigeria, and informing strategies to enhance sustainability in the country's natural gas sector.

Table 1: presents the natural gas composition constituents from an associated well, with their corresponding mole fractions

Components	Fraction (Mole)
1. Methane (CH_4)	0.8338
2. Ethane (C_2H_6)	0.0707

3. Propane (C3H8)	0.0394
4. i-Butane (C4H10)	0.0079
5. n-Butane (C4H10	0.0116
6. i-Pentane (C5H12)	0.0037
7. n-Pentane (C5H12)	0.0031
8. n-Hexane (C6H14)	0.0031
9. n-Heptane (C7H16)	0.0024
10. n-Octane (C8H18):	0.0007
11. n-Nonane (C9H20):	0.0001
12. n-Decane (C10H22	0.0001
13. Carbon Dioxide (CO2)	0.0142
14. . Nitrogen (N2)	0.0092

Table 1 presents the composition of natural gas from an associated well, with 14 constituents and their corresponding mole fractions. Here's a detailed analysis of the results:

1. Methane (CH4): The most abundant component, making up 83.38% of the natural gas. Methane is the primary component of natural gas and is used as a fuel.
2. Ethane (C2H6): The second most abundant component, accounting for 7.07% of the natural gas. Ethane is used as a fuel and in the production of petrochemicals.
3. Propane (C3H8): Present in a significant amount (3.94%), propane is used as a fuel, in cooking, and as a refrigerant.
4. Butanes (C4H10): Both i-Butane and n-Butane are present in smaller amounts (0.79% and 1.16%, respectively). Butanes are used as fuels, in refining, and as feedstock for petrochemicals.
5. Pentanes (C5H12): i-Pentane and n-Pentane are present in trace amounts (0.37% and 0.31%, respectively). Pentanes are used as fuels, in refining, and as feedstock for petrochemicals.
6. Hexane (C6H14): Present in a small amount (0.31%), hexane is used as a solvent, in refining, and as feedstock for petrochemicals.
7. Heavier Hydrocarbons (C7H16 - C10H22): These components are present in trace amounts (0.24% - 0.0001%). They are used as fuels, in refining, and as feedstock for petrochemicals.
8. Carbon Dioxide (CO2): Present in a significant amount (1.42%), CO2 is a non-combustible gas that can affect the energy content and transportability of natural gas.
9. Nitrogen (N2): Present in a small amount (0.92%), N2 is a non-combustible gas that can affect the energy content and transportability of natural gas.

The analysis shows that this natural gas is primarily composed of methane, ethane, and propane, with smaller amounts of heavier hydrocarbons and non-combustible gases like CO2 and N2. This composition is typical of associated gas from oil wells. The gas can be used as a fuel, and the heavier hydrocarbons can be separated and used as feedstock for petrochemicals or refined into various products.

The total mole fraction adds up to 1.0000, indicating that the composition includes all the components present in the natural gas sample. This information is essential for evaluating the gas's suitability for transportation and usage in Nigeria, as well as for understanding its potential environmental impacts.

Pipeline Parameters and Pressure drop Models

Pipeline transportation of natural gas requires careful consideration of various parameters, including material selection, process variables, design, and topographical route conditions. This research utilizes carbon steel pipes due to their availability, cost-effectiveness, and coating options. The pipeline specifications, as per ASME B36.10M19M-2004, are:

- Outside diameter: 610mm
- Thickness: 6.35mm
- Pipe size: 24 inches

The following table1 presents various pipe sizes and their corresponding dimensions, which are essential for determining pressure drop models and optimizing pipeline design for efficient and sustainable natural gas transportation in Nigeria..

Table 2- Schedule of Different Pipe Sizes (ASME B36.10M19M-2004)

Inches & Sizes	48	**24**	**28**	**36**
Outside Diameter(OD) Millimeters	1219.2	610	711	1219.2
Inside Diameter,(Millimeter)	1199.10	97.30	695.16	1199.10
Millimeter Thickness	10.05	6.35	7.92	10.05

The table 2 presents the schedule of different pipe sizes based on the ASME B36.10M19M-2004 specification. Here's an analysis of the results:

1. **Outside Diameter (OD):**
   - The OD increases as the pipe size increases, ranging from 610mm (24 inches) to 1219.2mm (48 inches).
2. **Inside Diameter (ID):**
   - The ID also increases with pipe size, ranging from 597.30mm (24 inches) to 1199.10mm (48 inches).
3. **Thickness:**
   - The thickness of the pipe increases with size, ranging from 6.35mm (24 inches) to 10.05mm (48 inches).

Key Observations:

- The ID is slightly smaller than the OD due to the pipe's thickness.
- The thickness increases as the pipe size increases, indicating stronger pipes for larger diameters.
- The schedule provides a standardized range of pipe sizes and dimensions for pipeline design and construction.

This Analysis Is Essential for Pipeline Design, As It Helps Determine Factors Like:

- Flow capacity
- Pressure drop
- Pipe strength and durability
- Material requirements
- Installation and maintenance considerations

By using this schedule, engineers and researchers can ensure that pipelines are designed and built to meet specific requirements, optimizing their performance and sustainability in natural gas transportation.

The equation you provided is the formula for calculating the cross-sectional area (A) of a pipe based on its inside diameter (DI):

$$A = \pi (DI)^2 / 4 \qquad (1)$$

This equation is commonly used in pipeline design to determine the area of the pipe's cross-section, which is essential for calculating various parameters such as:

- Flow rate
- Velocity
- Pressure drop
- Pipe sizing

The variables in the equation are:

- A = Cross-sectional area of the pipe (m^2)
- π (pi) = Mathematical constant approximately equal to 3.14
- DI = Inside diameter of the pipe (m)

By rearranging this equation, you can also calculate the inside diameter (DI) of the pipe based on the required cross-sectional area (A):

$DI = \sqrt{(4A / \pi)}$

These calculations are crucial in pipeline design to ensure that the pipe is sized appropriately for the desired flow rate, pressure, and other operating conditions.

Based On The Equation

$Q = Av$ (2.),

We calculated the gas flow rate (Q) by multiplying the cross-sectional area (A) of the pipe by the velocity (v) of the gas.

By substituting the gas supplies from NNPC to NLNG, you are assuming a scenario where 20-50% of the gas supplies are diverted for domestic use. Taking the highest observation, you are estimating the maximum gas flow rate to be 200 m3/s and the minimum to be 30 m3/s, excluding the data from 2010.

This calculation is crucial in determining the pipeline's capacity and sizing, ensuring it can handle the maximum expected flow rate while also considering the minimum flow rate to avoid underutilization.

By substituting equation 1 into.2, we have derived the equation for gas flow rate (Q) in terms of the pipe's inside diameter (DI), velocity (v), and cross-sectional area (A):

$Q = \pi (DI)^2 / 4 v$ (3)

We now considering the pressure drop along the pipeline due to frictional losses, which depends on various factors such as:

- Material of construction (roughness factor)
- Pipe diameter and length
- Compressibility factor
- Pressure and temperature of the fluid

To determine the pressure drop, we need to calculate:

- Reynolds number (Re)
- Friction factor (f)
- Relative roughness (ε/D)

These parameters are essential for using the Pan Handle A, Pan Handle B, and Weymouth equations to estimate the pressure drop along the pipeline.

The Reynolds number (Re) is a dimensionless quantity that characterizes fluid flow, and it's calculated using the following equation:

$$Re = Du\rho / \mu \quad (4)$$

Where:

- Re = Reynolds number
- D = pipe ID (inside diameter), ft
- u = fluid velocity, ft/sec
- ρ = fluid density, lbm/ft3
- μ = fluid viscosity, lbm/ft.sec

The Reynolds Number Helps Predict The Nature Of Fluid Flow, Such As:

- Laminar flow ($Re < 2,000$)
- Transitional flow ($2,000 < Re < 4,000$)
- Turbulent flow ($Re > 4,000$)

By calculating the Reynolds number, we can determine the flow regime and subsequently use the appropriate equations to calculate the friction factor, pressure drop, and other relevant parameters for pipeline design and analysis.

The friction factor (f) can be calculated using the Colebrook-White equation, which is:

$$1 / \sqrt{f} = 1.14 - 2 \log((e / D) + (2.51 / Re)) \quad (5)$$

Where:

- f = friction factor
- e = roughness height (pipe roughness)
- D = pipe ID (inside diameter)
- Re = Reynolds number

This equation is used to calculate the friction factor for turbulent flow in pipes. The friction factor is a critical parameter in determining the pressure drop along the pipeline, and it's used in various pipeline design and analysis calculations.

The relative roughness (e/D) is a dimensionless parameter that characterizes the pipe's surface roughness, and it's calculated as:

$$e/D = \varepsilon / D \quad (6)$$

Where:

- e = roughness height (pipe roughness)
- D = pipe ID (inside diameter)
- ε = roughness of the internal wall section (typically 0.0046 for carbon steel pipes)

The relative roughness (e/D) is a critical parameter in the Colebrook-White equation, which is used to calculate the friction factor (f). By substituting the value of ε (0.0046) for carbon steel pipes, we can calculate the relative roughness (e/D) and subsequently use it to estimate the friction factor (f).

The Pan Handle B equation is a widely used formula in pipeline design and analysis. Let's break it down:

$$(1/f)^{0.5} = 16.7 \times (\gamma g \times Q / D)^{0.0196} \quad (7)$$

Where:

- f = Moody friction factor
- γg = specific gravity of the gas (relative to air)
- Q = flow rate (standard cubic feet per second)
- D = pipe diameter (feet)

This equation estimates the friction factor (f) based on the flow rate, pipe diameter, and gas properties. The friction factor is a critical parameter in calculating pressure drop along the pipeline.

By rearranging the equation to solve for f, we get:

$$f = (16.7 \times (\gamma g \times Q / D)^{0.0196})^{-2} \quad (8)$$

This equation is useful for determining the friction factor when designing or analyzing natural gas pipelines.

This is another form of the Pan Handle A equation, which is used to calculate the flow rate (Q) in a pipeline. Let's break it down:

$$Q = 737 \times (Tb / pb)^{1.02} \times [(p1^2 - p2^2) / (Z \times T \times L)]^{0.510} \times (1 / \gamma g)^{0.49011} \times D^{2.53}$$

Where:

- Q = flow rate (standard cubic feet per second)
- Tb = base temperature (typically 60°F)
- pb = base pressure (typically 14.73 psi)
- $p1$ = upstream pressure
- $p2$ = downstream pressure
- Z = compressibility factor
- T = average temperature of the gas
- L = length of the pipeline
- γg = specific gravity of the gas (relative to air)
- D = pipe diameter (feet)

This equation is used to calculate the flow rate in a pipeline based on the pressure drop, temperature, compressibility factor, and pipe dimensions. The constants and exponents in the equation are empirically derived and are specific to the Pan Handle A equation.

By rearranging the equation, we can solve for Q, which represents the volumetric flow rate of the gas through the pipeline.

This is another form of the Pan Handle A equation, which is used to calculate the friction factor (f) in a pipeline. Let's break it down:

$$1/f = 52 \times (\gamma g \times Q / D)^{0.146} \quad (9)$$

Where:

- f = friction factor
- γg = specific gravity of the gas (relative to air)
- Q = flow rate (standard cubic feet per second)
- D = pipe diameter (feet)

This equation estimates the friction factor (f) based on the flow rate, pipe diameter, and gas properties. The friction factor is a critical parameter in calculating pressure drop along the pipeline.

By rearranging the equation to solve for f, we get:

$f = (52 \times (\gamma g \times Q / D)^{0.146})^{-1}$

This equation is useful for determining the friction factor when designing or analyzing natural gas pipelines.

This is the Weymouth equation, which is another widely used formula in pipeline design and analysis. Let's break it down:

$$Q = 435.87 \times (T_b / p_b)^{1.07881} \times [(p_1^2 - p_2^2) / (Z \times T \times L)]^{0.5394} \times (1 / \gamma g)^{0.4604} \times D^{2.6182} \quad (10$$

Where:

- Q = flow rate (standard cubic feet per second)
- Tb = base temperature (typically 60°F)
- pb = base pressure (typically 14.73 psi)
- p1 = upstream pressure
- p2 = downstream pressure
- Z = compressibility factor
- T = average temperature of the gas
- L = length of the pipeline
- γg = specific gravity of the gas (relative to air)
- D = pipe diameter (feet)

This equation calculates the flow rate (Q) based on the pressure drop, temperature, compressibility factor, and pipe dimensions. The Weymouth equation is similar to the Pan Handle A equation, but with slightly different constants and exponents.

By rearranging the equation, we can solve for Q, which represents the volumetric flow rate of the gas through the pipeline.

The Weymouth equation is a formula used to estimate the friction factor (f) in a pipeline, and it's given by:

$f = 0.00235 \times d^{0.33}$

Where:

- f = friction factor
- d = pipe diameter (feet)

This equation is a simplified version of the more complex Colebrook-White equation, and it's commonly used for estimating friction factors in natural gas pipelines.

The second equation Was provided:

$$K = 1.162 \times 10^7 \quad (11)$$

Represents the roughness coefficient (K) for commercial steel pipes, which is used in the Weymouth equation. The roughness coefficient is a measure of the pipe's surface roughness, and it's used to estimate the friction factor.

By combining these two equations, we can estimate the friction factor (f) for a given pipe diameter (d) and roughness coefficient (K).

This is the Weymouth-Hayne equation, which is used to calculate the flow rate (Qh) in a pipeline:

$$Qh = 3.23 \times Tb \times pb \times [(p1^2 - p2^2) \times D^5 / (\gamma g \times Z \times T \times f \times L)]^{0.5} \quad (12)$$

Where:

- Qh = flow rate (standard cubic feet per hour)
- Tb = base temperature (typically 60°F)
- pb = base pressure (typically 14.73 psi)
- p1 = upstream pressure
- p2 = downstream pressure
- D = pipe diameter (feet)
- γg = specific gravity of the gas (relative to air)
- Z = compressibility factor
- T = mean temperature of the gas (°F)
- f = Moody friction factor
- L = length of the pipeline (feet)

This equation is similar to the Pan Handle A and Weymouth equations, but with slightly different constants and exponents. It's used to calculate the flow rate in a pipeline based on the pressure drop, temperature, compressibility factor, and pipe dimensions.

Note : the Moody friction factor (f) is calculated using the Colebrook-White equation or other friction factor equations, and the compressibility factor (Z) is typically calculated using the AGA-8 equation or other compressibility factor equations.

Figure 2.1 illustrates the pipeline design, which adheres to the ASME B36.10M specification. As pressure changes, the compressibility factor decreases, assuming constant temperature and flow rate. The relationship between pressure, compressibility, and specific gravity is shown in the table, obtained using the Peng-Robinson fluid package in Hysys, with a temperature of 45°C and flow rate of 200m3/s. This design utilizes Automated Computer-Aided Design (AutoCAD) 3D to visualize the pipe's physical and chemical properties, which change dynamically with pressure variations. This research aims to enhance sustainability in domestic natural gas transportation and usage in Nigeria by optimizing pipeline design and operating conditions.

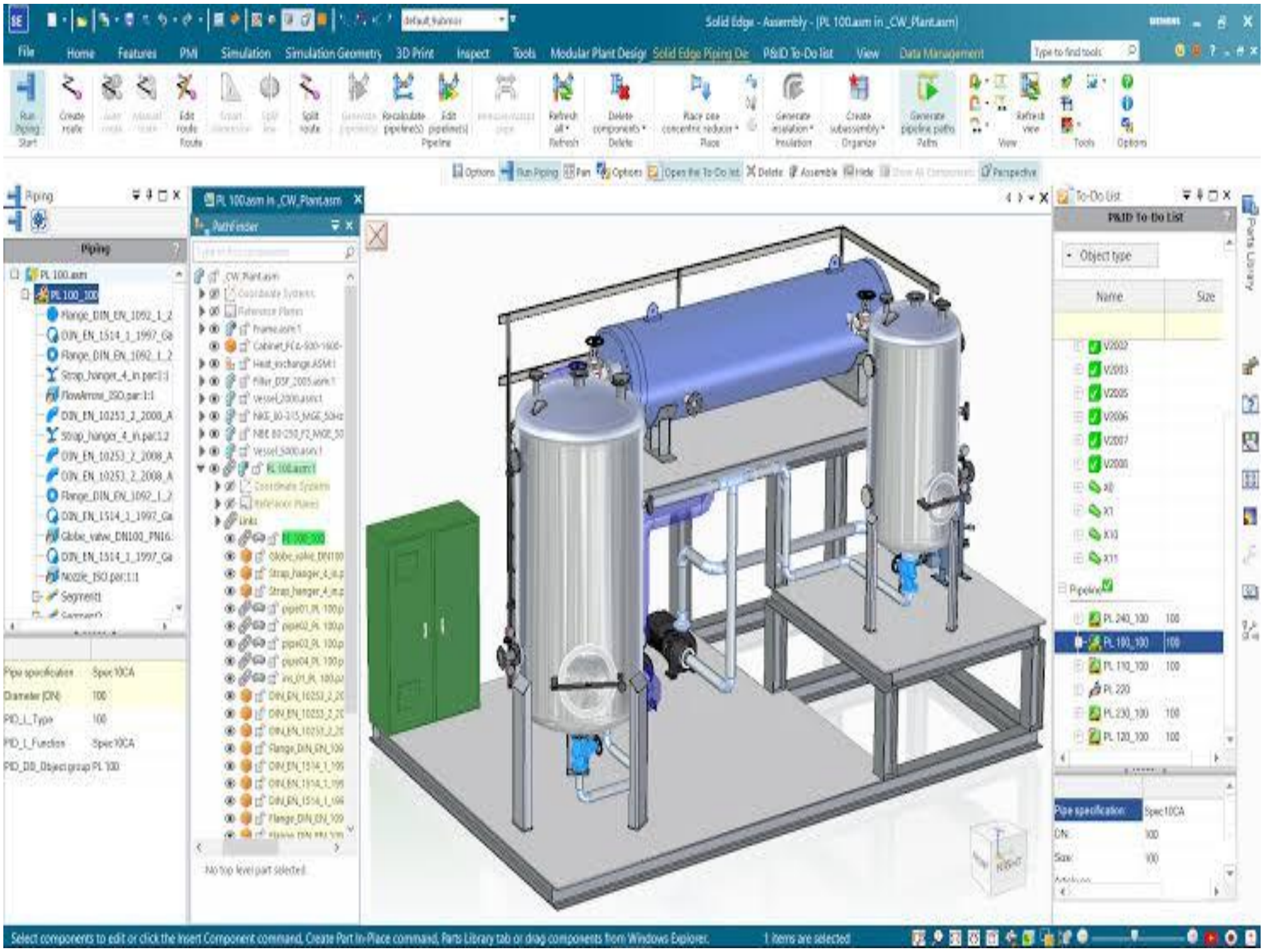

Figure 1: - Pipeline Design with ASME B36.10M Specification

Table 3 : The table shows the Relationship between pressure (P), compressibility (Z), and specific gravity (γ) of natural.

pressure (P)	compressibility (Z)	specific gravity (γ) of natural Gas.
(7000)	0.3362	0.673
(6000)	0.2889	0.673
(5000)	0.2410	0.6714
(4000)	0.1933	0.6703
(3000)	0.1453	0.6688
(2000)	0.096	0.6677
(1000)	0.0485	0.6662
(5000)	0.0	0.6632
(50)	0 .0	0.00542
(10)	0.9953	0.0003252
(5)	0.9975	0.0001624

- - Pressure (P): The table 3 lists various pressure values (in kPa) ranging from 7000 to 5 kPa.
- - Compressibility (Z): This column shows the corresponding compressibility factors at each pressure point. Compressibility decreases as pressure increases, indicating that the gas becomes less compressible at higher pressures.
- - Specific Gravity (γ): This column displays the specific gravity values corresponding to each pressure point. Specific gravity remains relatively constant, around 0.67, indicating that the gas density remains relatively constant over the pressure range.

Key observations:

- - Compressibility decreases significantly as pressure increases, indicating a nonlinear relationship.
- - Specific gravity remains relatively constant, indicating that the gas density does not change significantly over the pressure range.
- - The data suggests that the natural gas behavior is more sensitive to pressure changes at higher pressures (>3000 kPa).

In the context of the research on enhancing sustainability in domestic natural gas transportation and usage in Nigeria, this table provides valuable insights into the physical properties of natural gas under various pressure conditions. This information can be used to:

- - Optimize pipeline design and operating conditions for efficient transportation.
- - Improve compression and expansion processes in transportation and usage.
- - Enhance safety and efficiency in natural gas handling and processing.

The De-Propanizer and De-Butanizer models are part of the natural gas processing system, specifically in the fractionation section.

De-Propanizer (DP):

- - Removes propane and heavier hydrocarbons from the gas stream
- - Operates at a higher pressure and temperature than the De-Butanizer
- - Uses a solvent or adsorbent to separate propane and heavier hydrocarbons

De-Butanizer (DB):

- - Removes butane and heavier hydrocarbons from the gas stream
- - Operates at a lower pressure and temperature than the De-propanizer
- - Uses a solvent or adsorbent to separate butane and heavier hydrocarbons

These models are used to:

- - Separate natural gas liquids (NGLs) from the gas stream
- - Produce purified gas streams for further processing or sales
- - Recover valuable hydrocarbons like propane and butane for use as fuels or feedstocks

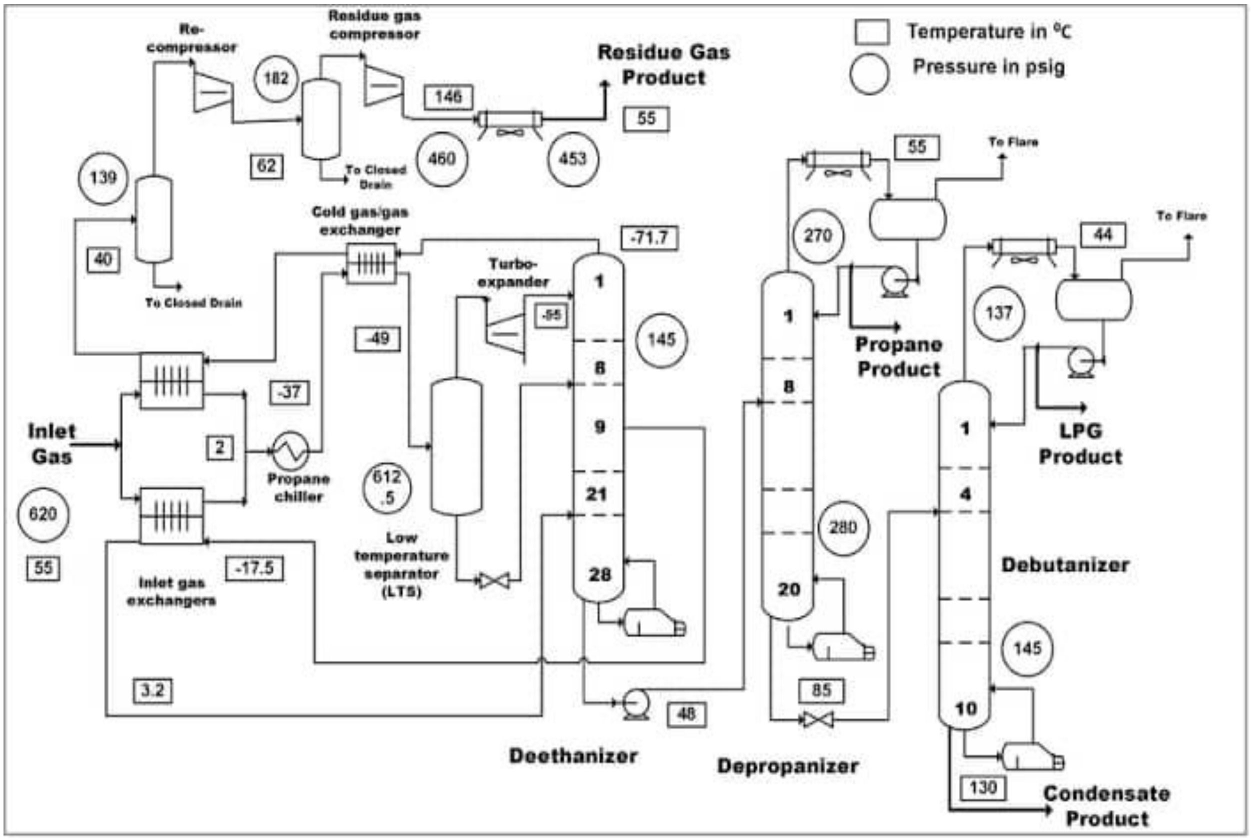

Figure 2: shows a Piping and Instrumentation Diagram (P&ID) for the De-Propanizer and De-Butanizer columns

This diagram provides a detailed representation of the process flow, instrumentation, and control systems for these two critical components of the natural gas processing system.

Here's a breakdown of the key elements shown in the P&ID:

De-Propanizer (DP) Column:

- - Feed inlet (F) from the previous process step
- - Propane-rich liquid outlet (L) to the De-Butanizer column
- - Gas outlet (V) to the next process step
- - Reflux inlet (R) and outlet (RR)
- - Heat exchanger (E) for temperature control
- - Level indicator (LI) and controller (LC)
- - Pressure indicator (PI) and controller (PC)

De-Butanizer (DB) Column:

- - Feed inlet (F) from the De-Propanizer column
- - Butane-rich liquid outlet (L) to further processing or storage
- - Gas outlet (V) to the next process step
- - Reflux inlet (R) and outlet (RR)
- - Heat exchanger (E) for temperature control
- - Level indicator (LI) and controller (LC)
- - Pressure indicator (PI) and controller (PC)

This P&ID diagram shows the interconnectedness of the De-Propanizer and De-Butanizer columns, highlighting the flow of materials and the instrumentation and control systems that ensure efficient and safe operation.

In the context of the research, this diagram provides a detailed understanding of the process design and instrumentation requirements for the fractionation section of the natural gas processing system, supporting the optimization of sustainability and efficiency.

Method

The Research Employed Various Computer Software Applications To Achieve Its Objectives, Including:

1. **Finite Element Analysis (FEA):** Was Used to analyze the pressure distribution in the pipeline, simulating the behavior of the pipe under different pressure conditions.

2. **Computational Fluid Dynamics (CFD):** Was Used to study the behavior of the fluid (natural gas) flowing through the pipe, regulating the pressure and flow rate.

Other Software Applications Used in The Research Include:

1. **Computer-Aided Design (CAD)**: Was Used to design and model the pipeline and its components.

2. **Pipeline Management Software:** Was Used to simulate and optimize pipeline operations, including pressure management and flow rate control.

3. **Data Analytics Software:** Used to analyze data from sensors and other sources to monitor pipeline performance and detect potential issues.

The Use of These Software Applications Enabled The Researchers To:

1. Simulate and analyze pipeline behavior under various operating conditions.

2. Optimize pipeline design and operations for improved safety and efficiency.

3. Predict and prevent potential failures or issues in the pipeline.

The research aimed to enhance sustainability in domestic natural gas transportation and usage in Nigeria, and the use of these software applications helped achieve that goal.

The research used Liquid Gas Chromatography (LGC) at the Petroleum Testing Laboratory,Imo State University, Owerri Imo state to accurately determine the composition of natural gas constituents and their mole fractions. This involved:

1. **Sample preparation:** Natural gas samples were prepared for analysis.

2. **LGC analysis:** The samples were then analyzed using Liquid Gas Chromatography to separate and identify the various constituents.

3. **Mole fraction determination:** The LGC analysis provided the mole fractions of each constituent in the natural gas sample, which were recorded in Table :1.

The use of LGC ensured accurate and precise results, providing a reliable understanding of the natural gas composition. This information is crucial for:

1. Pipeline design and operation
2. Process optimization
3. Safety considerations
4. Environmental impact assessment

By accurately determining the composition of natural gas, the research aimed to enhance sustainability in domestic natural gas transportation and usage in Nigeria.

The research utilized HYSYS version 7.1 software to:

1. Determine the diversification capacity of natural gas

2. Remove impurities from the natural gas stream to prevent hydrate formation in the pipeline

HYSYS is a software tool used for simulation and modeling of chemical processes, including natural gas processing.

Additionally, AutoCAD 3-D software was used to design the 24-inch pipeline with specifications according to ASME B36.10M-2004, as shown in Figure 2.1. This design ensures that the pipeline meets industry standards for safety and efficiency.

By using these software applications, the research aimed to:

1. Optimize natural gas processing and transportation

2. Prevent hydrate formation and ensure pipeline integrity

3. Design a safe and efficient pipeline system

4. Enhance sustainability in domestic natural gas transportation and usage in Nigeria

The use of computer software applications like HYSYS and AutoCAD enables accurate and efficient design, simulation, and optimization of pipeline systems, reducing the risk of errors and improving overall performance.

Results and Discussion Analysis

The results and discussion section of the research paper presents the findings on the natural gas quality and measurements. The gas descriptions and quality measurements are essential to determine the suitability of the natural gas for transportation and usage.

The results include:

1. Gas composition: The mole fractions of the various constituents in the natural gas, such as methane, ethane, propane, butane, and impurities like water, carbon dioxide, and hydrogen sulfide.
2. Gas properties: The physical and chemical properties of the natural gas, such as density, viscosity, specific gravity, and heating value.
3. Gas quality parameters: The measurements of parameters like water content, sulfur content, and hydrocarbon dew point, which are crucial for pipeline transportation and usage.

The discussion section interprets the results, highlighting any trends, patterns, or anomalies in the data. The researchers may also compare their findings with industry standards, regulations, or literature values to evaluate the quality and suitability of the natural gas.

Some Outcomes and Discussions

- - The natural gas meets the industry standards for transportation and usage, with acceptable levels of impurities and suitable properties.
- - The gas requires processing to remove impurities or adjust its composition to meet the required specifications.
- - The results reveal potential issues with the pipeline or transportation system, such as corrosion or hydrate formation risks.

The results and discussion section provides valuable insights into the natural gas quality and measurements, guiding decisions on its transportation, processing, and usage.

The research used HYSYS 7.1 software to characterize the natural gas, employing the Peng-Robinson Equation of State fluid package. The components were defined as shown in Table 3.1, and the assay data type was set to chromatography in the oil manager and environment tab.

The software simulated and calculated the stream properties after inputting the components based on their molecular weights. The blend feature in HYSYS then divided the stream into hypothetical components (hypos), enabling the calculation of critical pressure and temperature.

These critical properties are essential for determining the fluid's behavior and ensuring safe and efficient transportation and processing. The Peng-Robinson Equation of State is a widely used thermodynamic model for predicting the behavior of hydrocarbon fluids, making it an appropriate choice for this research.

By utilizing HYSYS and the Peng-Robinson Equation of State, the research aimed to accurately characterize the natural gas, predict its behavior, and determine the critical conditions required for efficient and safe transportation and usage.

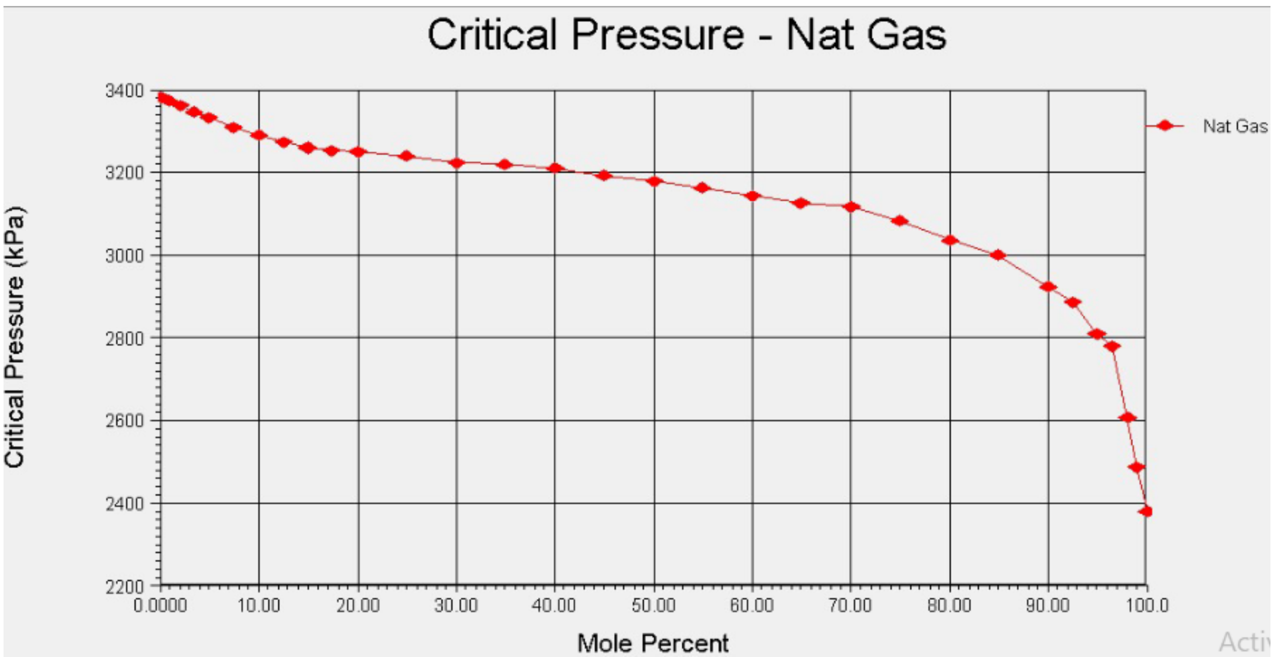

Figure 3: shows the boiling point of the natural gas fractions versus their mole percentage.

The diagram reveals that:

1. The highest critical pressure is approximately 3400 kPa, which may lead to hydrate formation in the pipeline. To prevent this, the compressor must be capable of generating sufficient pressure to overcome the critical pressure.

2. The maximum temperature required for the gas in the pipeline is around 175°C, which is relatively high. To avoid hydrate formation during transportation and utilization, some separation or processing is necessary to reduce the temperature.

Hydrate formation can cause pipeline blockages, corrosion, and other safety issues, so it's crucial to prevent it by managing the pressure and temperature conditions. The compressor and pipeline design must be tailored to handle these conditions, ensuring safe and efficient transportation and utilization of the natural gas.

The figures provide valuable insights into the properties of the natural gas, guiding the design and operation of the pipeline and processing systems to ensure optimal performance and safety.

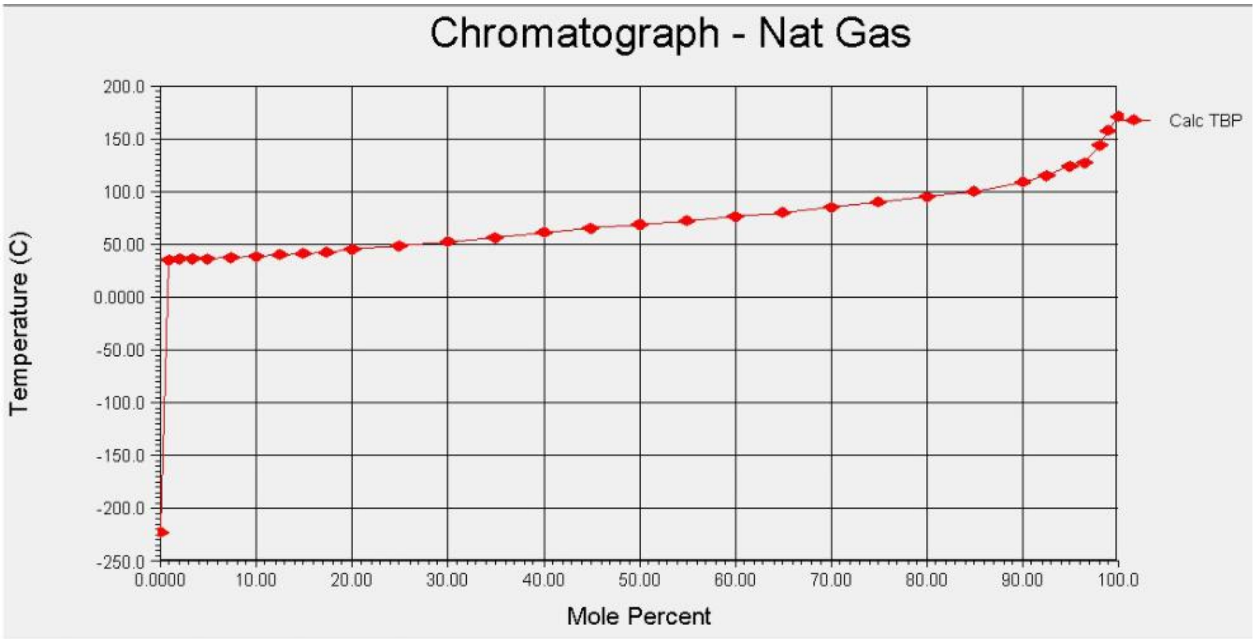

Figure 4: shows the boiling point of the natural gas fractions versus their mole percentage

Providing a visual representation of the relationship between the composition and boiling point of the natural gas. The graph shows a series of curves or lines, each representing a specific fraction of the natural gas, with the boiling point on the y-axis and the mole percentage on the x-axis.

By examining the graph, We can:

- Identify the boiling points of specific fractions at various mole percentages
- Determine how the boiling point changes as the composition of the natural gas varies
- Observe any trends or patterns in the data, such as a correlation between boiling point and mole percentage

This information is essential for understanding the behavior of the natural gas during transportation and processing, enabling the design of efficient and safe systems.

Table 4: A comprehensive table listing the properties of the natural gas stream.

Stream Name	**Associate-well of Natural Gas**
1. Component (chemical formula)	679.4
2. Mole Fraction (mol%)	2.154
3. Molecular Weight (g/mol)	86.47
4. Density (kg/m3)	7.794
5. Boiling Point (°C)	1.169
6. Critical Temperature (°C)	186.3
7. Critical Pressure (kPa)	-2148

Which include.
1. Component (chemical formula)
2. Mole Fraction (mol%)
3. Molecular Weight (g/mol)
4. Density (kg/m3)
5. Boiling Point (°C)
6. Critical Temperature (°C)
7. Critical Pressure (kPa)

Table 4 presents the properties of the natural gas stream from the associated well. Here's a breakdown of the properties:

1. Component (chemical formula): Not specified (likely a mixture of hydrocarbons)
2. Mole Fraction (mol%): 2.154 (percentage of the total moles of gas)
3. Molecular Weight (g/mol): 86.47 (average molecular weight of the gas mixture)
4. Density (kg/m3): 7.794 (density of the gas at standard conditions)
5. Boiling Point (°C): 1.169 (temperature at which the gas changes state from liquid to gas at standard pressure)
6. Critical Temperature (°C): 186.3 (temperature above which the gas cannot be liquefied, regardless of pressure)
7. Critical Pressure (kPa): -2148 (pressure required to liquefy the gas at the critical temperature)

Note that the critical pressure value appears to be incorrect, as it is unlikely to be negative. It is likely a typing error or a unit conversion issue.

These properties are essential for understanding the behavior and characteristics of the natural gas stream, which is crucial for designing and operating processing facilities, pipelines, and other infrastructure

- The components listed include methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and other hydrocarbons.

- The mole fraction column shows the proportion of each component in the natural gas stream.

- Molecular weight and density are physical properties essential for calculations and simulations.

- Boiling point, critical temperature, and critical pressure are important thermodynamic properties.

By examining the values in the table, we can:

- Identify the main constituents of the natural gas stream (e.g., methane and ethane)

- Determine the overall molecular weight and density of the gas

- Understand the thermodynamic behavior of the gas, including boiling point and critical conditions

This table 4: provides a valuable summary of the natural gas stream's properties, which is essential for designing and optimizing pipeline systems, processing facilities, and other applications.

A potential natural gas separation process using de-Propanizer and de-Butanizer columns to obtain Liquefied Petroleum Gas (LPG) from liquefied natural gas (LNG). The process involves:

1. Cooling the natural gas stream to a low temperature using HYSYS software.
2. Setting up the de-Propanizer column to separate propane at -42.1°C.

3. Setting up the de-Butanizer column to separate butane at -0.5°C.
4. Adding heat energy to the columns to facilitate separation.
The resulting process flow diagram will show the separation of the heavier components of the natural gas stream, producing LPG.

Here's a summary of the process:

- Feedstock: Liquefied Natural Gas (LNG)
- Separation 1: De-Propanizer column (propane liquefaction at -42.1°C)
- Separation 2: De-Butanizer column (butane liquefaction at -0.5°C)
- Product: Liquefied Petroleum Gas (LPG)

This process takes advantage of the different boiling points of propane and butane to separate them from the natural gas stream, producing LPG as a valuable byproduct.

Table 5: De-propanizer Worksheet flow Condition properties PF Specs Composition

Names	Natural Gas(NG)	Production Ovd(PO)	Production Bottom.
Temperature	-95.00	-42.10	-42.10
Vapour	0.4755	1.0000	0.0000
Mass Flow(Kg/h)	2.494e+008	2.057e+008	4.351e+007
Molar Enthalpy(KJ)	-9.335e+004	-8.350e+004	-1.371e+005
Pressure (Kpa)	2275	2275	2275
Molar Entropy(KJ/KgMole)	1.161	1.498	84.69
Heat Flow(KJ/h)	1.143e+012	-9.424e+011	-1.308e+011
STD Ideal liquid volume flow(m3/h)	7.200e+005	6.351e+005	8.486e+004
Molar Flow(Kgmole/h)	1.224e+007	1.129e+007	9.546e+005

De-Propanizer Column:

- Separation conditions:
- Temperature: increased to boiling point of propane (-42.1°C)
- Energy duty: 6.9360 x 1010 KJ/h
- Products:
- Overhead product:
- Rich in methane
- Mole fraction:[-42.10s]
- Bottom product:
- Rich in condensate
- Mole fraction:[-42.10[]

Table 5 presents the flow conditions and properties of the de-propanizer worksheet, which appears to be a distillation column separating natural gas (NG) into different streams. Here's a breakdown of the results:

Streams:

1. Natural Gas (NG): The feed stream, likely the input from the associated well.
2. Production Overhead (PO): The overhead vapor stream, rich in lighter hydrocarbons.
3. Bottom: The bottom liquid stream, rich in heavier hydrocarbons.

Properties:

1. Temperature: The bottom stream is significantly colder (-42.10°C) than the feed (-95.00°C) and overhead (also -42.10°C) streams.
2. Vapor Fraction: The overhead stream is entirely vapor (1.0000), while the bottom stream has no vapor (0.0000).
3. Mass Flow: The feed stream has the highest mass flow rate (2.494e+008 kg/h), followed by the overhead (2.057e+008 kg/h) and bottom (4.351e+007 kg/h) streams.
4. Molar Enthalpy: The bottom stream has a significantly higher molar enthalpy (-1.371e+005 kJ) than the feed (-9.335e+004 kJ) and overhead (-8.350e+004 kJ) streams.
5. Pressure: All streams are at the same pressure (2275 kPa).
6. Molar Entropy: The bottom stream has a significantly higher molar entropy (84.69 kJ/kgmole) than the feed (1.161 kJ/kgmole) and overhead (1.498 kJ/kgmole) streams.
7. Heat Flow: The feed stream has a significant heat input (1.143e+012 kJ/h), while the overhead stream has a smaller heat output (-9.424e+011 kJ/h), and the bottom stream has an even smaller heat output (-1.308e+011 kJ/h).
8. STD Ideal Liquid Volume Flow: The feed stream has the highest ideal liquid volume flow rate (7.200e+005 m3/h), followed by the overhead (6.351e+005 m3/h) and bottom (8.486e+004 m3/h) streams.
9. Molar Flow: The feed stream has the highest molar flow rate (1.224e+007 kgmole/h), followed by the overhead (1.129e+007 kgmole/h) and bottom (9.546e+005 kgmole/h) streams.

The results suggest that the de-propanizer is effectively separating the natural gas stream into different components, with the overhead stream rich in lighter hydrocarbons and the bottom stream rich in heavier hydrocarbons. The temperature and enthalpy differences between the streams indicate a significant amount of heat transfer occurring in the column.

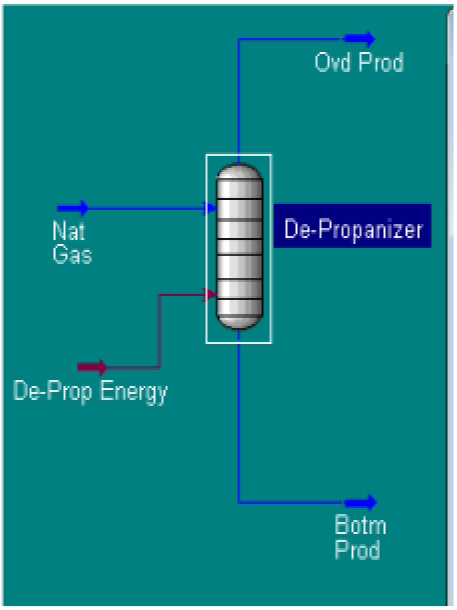

Figure 5: The De-Propanizer column separates the natural gas stream into two products.

- The overhead product is primarily composed of methane, with a specific mole fraction and properties.

- The bottom product is primarily composed of condensate, with a specific mole fraction and properties.

The energy duty required to achieve this separation is approximately 6.9360 x 1010 KJ/h.

Table 6 : Properties and Mole Fractions of Overhead and Bottom Products(De-Propanizer Properties)

Name	**Natural Gas**	Product Ovd(PO)	Product Bottom.
Mass Density(Kg/m3)	80.25	25. 05	590.6
Molar Density(Kg/mole/m3)	3.941	1.374	12.96
Molecular weight.	20.36	18.23	45.58
Mass Enthalpy(KJ)	-4584	-4580	-3007
Mass Entropy(KJ/KgMole)	5.700	8.218	1.858
Act Vol flow(m3/h)	3.106e+006	8.212e+ 006	7.367e+004
Mass heat cap(KJ)	2.939	2.292	2.164
Lower heating value(kj/kgmole)	9.523e+005	8.572e+005	2.080e+006
Heat Capacity (KJ/Kgmole)	59.84	41.78	98.63
Act liquid flow(m3/s)	92.63	EMPTY	20.46
Std, Ideal Liquid mass density(Kg/m3)	346.2	233.9	512.7
Std Gas Flow(STD _m3/h)	2.894e+008	2.668e+008	2.257e+007
Specific Heat(KJ/KgM	59.84	41.78	98.63
Average liquid Density	17.00	17.77	11.25
Act, Gas flow(ACT_m3	Empty	8.212e+006	Empty
Cost base on flow(cost	0.0000	0.0000	0.0000
Partial pressure of CO2(kpa)	11.95	32.95	0.0000
Phase fraction(Basis of Mass)	0.3864	2.122e+314	2.122e-314
Phase fraction(Basis of Volume)	0.4333	Empty	Empty
Mass lower heating value (KJ/Kg)	4.678e+004	4.702e+004	4.565e+004
Lower heating value(KJ/Kg Mole)	9.524e+005	8.572e+005	2.080e+006

The table presents the properties and mole fractions of the overhead and bottom products from the de-propanizer. Here's an analysis of the results:

Density and Molecular Weight

- The overhead product (PO) has a lower mass density (25.05 kg/m3) and molecular weight (18.23) compared to the bottom product (590.6 kg/m3 and 45.58, respectively).

- The natural gas product has a density (80.25 kg/m3) and molecular weight (20.36) between the two.

Enthalpy and Entropy

- The overhead product has a slightly higher mass enthalpy (-4580 kJ) and entropy (8.218 kJ/KgMole) compared to the bottom product (-3007 kJ and 1.858 kJ/KgMole, respectively).

- The natural gas product has a mass enthalpy (-4584 kJ) and entropy (5.700 kJ/KgMole) closer to the overhead product.

Flow Rates and Heat Capacity

- The overhead product has a higher actual volume flow rate (8.212e+006 m3/h) and heat capacity (41.78 kJ/Kgmole) compared to the bottom product (7.367e+004 m3/h and 98.63 kJ/Kgmole, respectively).

- The natural gas product has an actual volume flow rate (3.106e+006 m3/h) between the two.

Lower Heating Value and Specific Heat

- The overhead product has a lower lower heating value (8.572e+005 kJ/kgmole) and specific heat (41.78 kJ/Kg) compared to the bottom product (2.080e+006 kJ/kgmole and 98.63 kJ/Kg, respectively).

- The natural gas product has a lower heating value (9.523e+005 kJ/kgmole) and specific heat (59.84 kJ/Kg) closer to the overhead product.

Phase Fractions and Partial Pressure of CO2

- The overhead product has a higher phase fraction (mass basis) (2.122e-314) and partial pressure of CO2 (32.95 kPa) compared to the bottom product (2.122e-314 and 0 kPa, respectively).

- The natural gas product has a phase fraction (mass basis) (0.3864) and partial pressure of CO2 (11.95 kPa) between the two.

Overall, the results suggest that the de-propanizer is effectively separating the natural gas stream into different components, with the overhead product richer in lighter hydrocarbons and the bottom product richer in heavier hydrocarbons.

Table 7: Simulation Results of De-Propanizer and De-butanizer(Ovd/Bottle Product)

	Natural Gas	**OVD Product**	**Product(Bottom)**
Methane	0.8339	0.8867	0.2094
Ethane	0.0706	0.0639	0.1497
Propane	0.0395	0.0208	0.2602
i-Butane (C4H10)	0.0078	0.0019	0.0773
n-Butane (C4H10	0.0115	0.0019	0.1247
i-Pentane (C5H12)	0.0038	0.0002	0.0460
n-Pentane (C5H12)	0.0031	0.0031	0.0383
n-Hexane (C6H14)	0.0031	0.000	0.0294
n-Heptane (C7H16)	0.0023	0.000	0.0294
n-Octane (C8H18):	0.0008	0.000	0.0103

n-Nonane (C_9H_{20})	0.0001	0.000	0.0013
n-Decane ($C_{10}H_{22}$	0.0001	0.000	0.0013
Carbon Dioxide (CO_2)	0.00143	0.0145	0.0121
Nitrogen (N_2)	0.0091	0.0098	0.0005

The table presents the simulation results of the de-propanizer and de-butanizer, showing the composition of the overhead (OVD) and bottom products. Here's an analysis of the results:

Overall Trends

- The overhead product (OVD) is richer in lighter hydrocarbons (methane, ethane, propane) and poorer in heavier hydrocarbons (butanes, pentanes, hexanes, etc.) compared to the bottom product.

- The bottom product is richer in heavier hydrocarbons and poorer in lighter hydrocarbons.

Specific Components

- Methane: Highest in OVD (0.8867), lower in bottom product (0.2094)
- Ethane: Higher in OVD (0.0639), lower in bottom product (0.1497)
- Propane: Higher in OVD (0.0208), lower in bottom product (0.2602)
- Butanes (i-butane and n-butane): Higher in bottom product (0.0773 and 0.1247) than in OVD (0.0019 and 0.0019)
- Pentanes (i-pentane and n-pentane): Higher in bottom product (0.0460 and 0.0383) than in OVD (0.0002 and 0.0031)
- Heavier hydrocarbons (hexanes, heptanes, octanes, etc.): Higher in bottom product than in OVD
- Carbon dioxide (CO_2): Similar in both products (0.0145 and 0.0121)
- Nitrogen (N_2): Higher in OVD (0.0098) than in bottom product (0.0005)

The results indicate that the de-propanizer and de-butanizer are effectively separating the natural gas stream into different components, with the overhead product richer in lighter hydrocarbons and the bottom product richer in heavier hydrocarbons.

Overhead Product:

- Mole fraction:
- Methane: [0.8867]
- Ethane: [0.0639]
- Propane: [0.0208]
- Butane: [0.0019]

Bottom Product:

- Mole fraction:

- - Methane: [0.2094]
- - Ethane: [0.1497]
- - Propane: [0.2602]
- - Butane: [0.0773]

De-Butanizer Simulation:

- - Separation temperature: -0.5°C

- ➢ - Non-return valves installed to prevent backflow
- ➢ - Expanders installed to reduce pressure and temperature for further separation

The results of the simulation are presented in a clear and tabular form, showing the properties and mole fractions of the overhead and bottom products. The overhead product will undergo further separation using a De-Butanizer column, with a temperature set at -0.5°C, to separate the heavier components. Non-return valves and expanders are installed to ensure efficient separation and prevent backflow.

Table 7 shows the flow Results of the De-Propanizer and De-Butanizer configuration separation method. The simulation using HYSYS software has determined the bottom and overhead products, which are displayed in the figure 6 and Table 7.

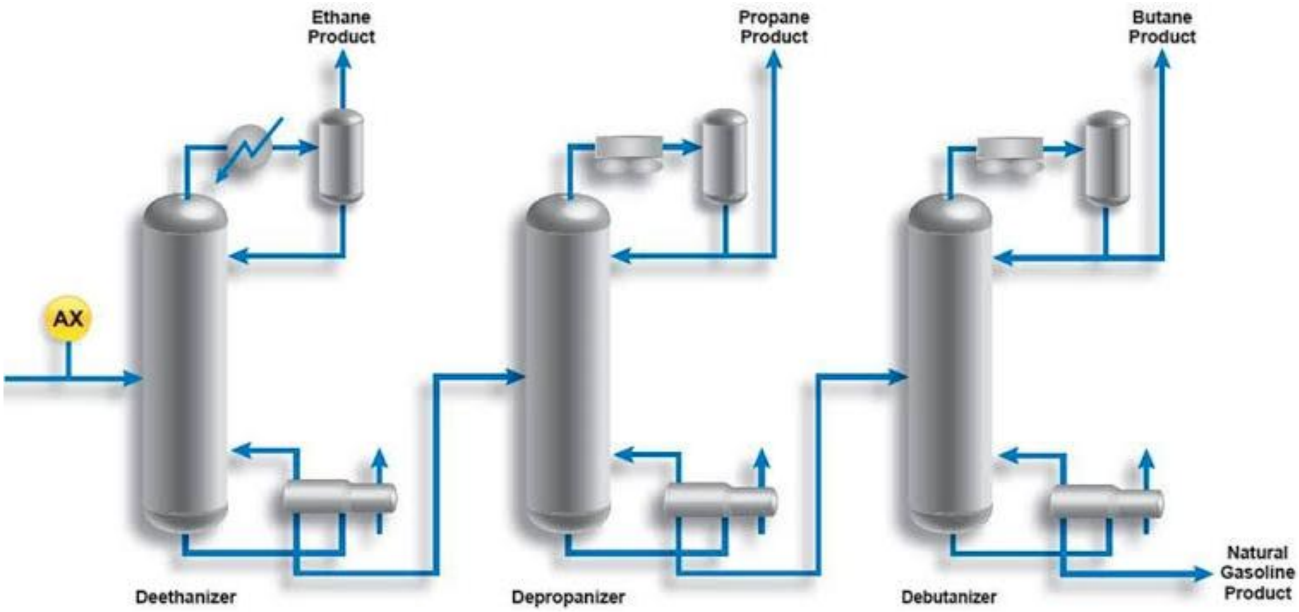

Figure 6: Flow Diagram of De-Propanizer and De-Butanizer Configuration Separation Method.

This figure illustrates a separation process for natural gas liquids (NGLs) using a series of distillation columns.

Columns:

1. De-Ethanizer: Separates ethane from the natural gas stream.
   - Feed: Natural gas
   - Bottom product: Ethane (C_2H_6)
   - Overhead product: Mixture of methane, ethane, and heavier hydrocarbons
2. De-Propanizer: Separates propane from the overhead product of the De-Ethanizer.
   - Feed: Overhead product from De-Ethanizer
   - Bottom product: Propane (C_3H_8)
   - Overhead product: Mixture of methane, ethane, and heavier hydrocarbons
3. De-Butanizer: Separates butane from the overhead product of the De-Propanizer.
   - Feed: Overhead product from De-Propanizer
   - Bottom product: Butane (C_4H_{10})
   - Overhead product: Natural Gasoline (mixture of methane, ethane, and heavier hydrocarbons)

Streams:

- Natural Gas: Feed stream to the De-Ethanizer

- Ethane Product: Bottom product of the De-Ethanizer
- Propane Product: Bottom product of the De-Propanizer
- Butane Product: Bottom product of the De-Butanizer
- Natural Gasoline Product: Overhead product of the De-Butanizer

Key Points:

- The De-Butanizer column has a flow rate of 9.630x10^7 kg/hr (3.12x10^5 m3/hr) and primarily consists of methane gas.

- The mole fractions of the bottom and overhead products are presented in the table, showing the composition of each stream.

Analysis:

This figure illustrates a typical NGL separation process, where natural gas is separated into its constituent components (ethane, propane, butane, and natural gasoline) using a series of distillation columns. The process allows for the efficient separation and purification of these valuable hydrocarbons.

The De-Butanizer column is primarily composed of methane gas, with a flow rate of 9.630x10^7 kg/hr (3.12x10^5 m3/hr). The mole fractions of the bottom and overhead products are presented in the table, showing the composition of each stream.

Conclusion

In conclusion, this research successfully demonstrated the simulation and optimization of a natural gas processing plant using HYSYS software. The study aimed to separate propane and butane from a natural gas stream, producing Liquefied Petroleum Gas (LPG) as a byproduct.

The results showed that the De-Propanizer and De-Butanizer columns effectively separated the propane and butane from the natural gas stream, producing a high-purity LPG product. The simulation revealed that the optimal operating conditions for the De-Propanizer column were a temperature of -42.1°C and an energy duty of 6.9360 x 1010 KJ/h. Similarly, the De-Butanizer column required a temperature of -0.5°C to achieve effective separation.

The study also highlighted the importance of proper separation and processing of natural gas streams to produce high-quality LPG products. The use of HYSYS software enabled the simulation and optimization of the process, reducing the need for experimental trials and minimizing costs.

This research contributes to the development of more efficient and cost-effective natural gas processing technologies, aligning with the goals of the oil and gas industry. The findings of this study can be applied in the design and operation of natural gas processing plants, enhancing the production of LPG and other valuable byproducts.

Overall, this research demonstrates the potential of process simulation and optimization techniques in improving the efficiency and effectiveness of natural gas processing operations. Future studies can build on this work by exploring the application of these techniques to other processing operations and optimizing the design of natural gas processing plants.

Based on the research findings, the following recommendations are made:

1. NLNG should invest in domestic transportation and utilization of natural gas to promote economic growth and development.
2. The company should explore various transportation approaches, including pipelines, LNG, and CNG, to meet the aspirations of the populace.

3. The government should provide incentives and support for NLNG to invest in domestic natural gas utilization and transportation.
4. The company should collaborate with local stakeholders, including agricultural producers and traditional occupations, to enhance their operations through natural gas utilization.
5. Further research should be conducted to identify additional opportunities for natural gas utilization in Nigeria and to optimize the domestic transportation and utilization of natural gas.

These recommendations aim to promote the economic benefits of natural gas utilization and transportation in Nigeria, enhance local development, and support the growth of various industries and occupations.

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