

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

By

Faith Mmesomachukwu Kelechi*

ABSTRACT

The underutilization of gases, which has contributed to global warming, led to the modelling of an advanced refinery process of gas to liquids (GTL) conversion. GTL with a condensation point of 100°C and above is used in the conversion of natural gas and other associated hydrocarbons that are found in gaseous state into a longer chain hydrocarbon. This longer chain hydrocarbon includes high energy density such as residual oil, diesel fuel or gasoline. GTL is used in the production of liquid fuels, which are easily and readily conveyed when compared to methane. For methane to be liquidities under pressure, it must be cooled at a critical temperature of -82.3°C. Exceptionally, GTL diesel is sulfur-free with extreme cetane number that ranges from 75 – 80, and it is absolutely clean. As of 2010, Nigeria had a proven natural gas reserve of 185 trillion cubic feet (Tcf), which ranked Nigeria as the largest proven reserve country globally and topping the list in Africa. On the contrary, Nigeria has contributed to the global flaring of natural gas with about 11% in 2010 as reported by the Nigeria National Petroleum Corporation (NNPC), which resulted to the loss of billions of dollars in revenue. This paper identifies the prospective opportunities associated with GTL technology in Nigeria. GTL has an unlimited market, which renders innovative/attractive options to accessing the proven gas reserves. This will further commercialize the flared gases, thereby reducing and possibly eliminating gas flaring in Nigeria.

Keywords: Gas flaring, Proven natural gas reserve, Gas to liquid conversion, Longer chain hydrocarbon, Nigeria National Petroleum Corporation (NNPC)

Introduction

Nigeria stands tall among Africa's primary natural gas producers, boasting abundant and confirmed reserves of this vital resource. Official data from the Nigerian National Petroleum Corporation (NNPC) underscores the country's robust position, revealing that Nigeria's proven natural gas reserves clocked in at an impressive 206.53 trillion cubic feet (tcf) as of 2021. The heart of these reserves lies predominantly within the Niger Delta region, which simultaneously holds sway as a significant crude oil producer. Intriguingly, Nigeria's historical energy narrative bears a paradox – despite possessing substantial natural gas reserves, a noteworthy proportion of this resource has historically been wasted through flaring. This undesirable practice has been attributed to inadequate infrastructure and insufficient investments dedicated to the essential tasks of processing and transporting gas¹.

Nevertheless, recent times have ushered in a change in the wind. A collective effort by both the government and stakeholders in the industry has taken root. Their shared objective is two-fold: to stem the wasteful tide of gas flaring and to cultivate a more robust pathway for the nation's

*Department of Geology, University of Nigeria Nsukka, Nigeria. Email: kelechif4@gmail.com
Telephone: +2349057233185

¹ Ayoola-Daniels, N. (2014), Nigerian Power Sector Reform: Policy, Legal, Regulatory and Business Issues, Unpublished lecture notes, Emerald Energy Institute, University of Port Harcourt, Choba, Port Harcourt

substantial natural gas resources². This coordinated action underpins Nigeria's resilience in addressing the challenges that have hindered the full realization of its energy potential. In this unfolding narrative, Nigeria is poised for transformation. The nation's journey transcends past limitations to embrace solutions that capitalize on its abundant natural gas wealth for comprehensive, sustainable growth³. The concentrated push to curtail gas flaring and to nurture the development of natural gas assets heralds a promising chapter.

Gas Projects

Nigeria's expansive energy resources are primed to significantly contribute to both its internal growth and its role in the global pursuit of sustainable energy. Some of the major natural gas projects in Nigeria include:

Nigerian Liquefied Natural Gas (NLNG): The Nigerian Liquefied Natural Gas (NLNG) project, a collaborative initiative involving the Nigerian National Petroleum Corporation (NNPC), Shell, Total, and Eni, is a beacon of Nigeria's prowess in harnessing its natural gas resources. Nestled on the picturesque Bonny Island within the Niger Delta, NLNG's cutting-edge liquefied natural gas (LNG) facility boasts an impressive production capacity of 22 million tonnes per annum. This facility epitomizes Nigeria's strategic pivot towards value-added energy products and global market diversification⁴. NLNG plays a transformative role on both national and international fronts. Domestically, it contributes to reducing gas flaring and aids the development of Nigeria's natural gas sector. Internationally, NLNG has solidified Nigeria's reputation as a reliable supplier in the global LNG market⁵. Its contributions extend to revenue generation, job creation, and technology transfer, fostering economic growth and sustainable development. NLNG's success story underscores Nigeria's commitment to responsible resource management, technological advancement, and environmental stewardship. As a trailblazing example of public-private collaboration, NLNG signifies Nigeria's determination to leverage its abundant natural gas reserves for socio-economic progress and environmental betterment. NLNG plays a transformative role on both national and international fronts⁶.

Brass LNG: Brass LNG, a pivotal joint venture involving the Nigerian National Petroleum Corporation (NNPC), ConocoPhillips, ENI, and Chevron, is poised to reshape Nigeria's energy landscape. Set against the backdrop of Bayelsa State's Brass region, this ambitious liquefied natural gas (LNG) project signifies Nigeria's resolve to expand its role in the global energy arena. Anticipated to have a substantial capacity of 10 million tonnes per annum (mtpa), the Brass LNG facility aims to serve both domestic and international LNG markets, enhancing Nigeria's position as a significant LNG exporter⁵. This venture not only harnesses Nigeria's vast natural gas resources but also bolsters economic diversification and technological advancement. Brass LNG resonates

² Global Gas Flaring Reduction Partnership (GGFR) and the World Bank, Guidelines on flare and vent measurement, 700, 900-6 Avenue S.W. Calgary, Alberta, T2P 3K2 Canada (Sep. 2008).

³ Climate & Clean Air Coalition. (2020). Gas flaring has dangerous side effects but these mitigation opportunities could be a win for everyone. [online] Available at: <https://www.ccacoalition.org/en/news/gas-flaring-has-dangerous-side-effects-these-mitigation-opportunities-could-be-win-everyone>.

⁴ Ejiohu, A.R. (2013). Gas flaring in Nigeria: costs and policy. *Energy & Environment*, 24(6), pp.983–998. Available at: <https://www.jstor.org/stable/43735213>.

⁵ Ige, D.O. (no year), The Nigerian Gas Master-Plan: Investor Road-show, NNPC (Group General Manager / Senior Technical Advisor to Group MD), Abuja.

⁶ Kolb, R.W. (2014), *The Gas Revolution: At the Pivot of the World's Energy Future*, Pearson, New Jersey.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

with Nigeria's strategic shift from crude oil dependency, championing value-added endeavors. Beyond its economic implications, this project underscores Nigeria's commitment to responsible energy development, environmental stewardship, and sustainable growth. By fostering job creation, technology transfer, and global market access, Brass LNG stands as a testament to Nigeria's dedication to leveraging its resources for holistic development and sustainable progress on regional and international scales⁶⁻⁷.

Ogidigben Gas Revolution Industrial Park: The Ogidigben Gas Revolution Industrial Park holds the promise of catalyzing transformative change in Nigeria's economic landscape. Envisioned as a dynamic complex in Delta State, this visionary project is poised to accommodate a range of gas-based industries, including fertilizers, petrochemicals, and methanol production⁸. By strategically capitalizing on Nigeria's abundant natural gas reserves, the Ogidigben Industrial Park aims to not only meet domestic demand but also elevate Nigeria's position as a regional industrial hub. This initiative aligns with the nation's aspirations for economic diversification and technological advancement⁹. The project's multifaceted impact cannot be understated. Beyond fostering industrial growth, it is poised to stimulate job creation, skill development, and technology transfer. The park's establishment in Delta State holds the potential to uplift the region, drive local economies, and contribute significantly to Nigeria's economic prosperity. Furthermore, the Ogidigben Industrial Park exemplifies Nigeria's commitment to sustainable development, as it gravitates towards cleaner energy alternatives, reducing environmental impact. This project stands as a testament to Nigeria's vision for harnessing natural resources for comprehensive, inclusive, and environmentally responsible growth.

Ajaokuta-Kaduna-Kano (AKK) Gas Pipeline: The Ajaokuta-Kaduna-Kano (AKK) Gas Pipeline stands as a monumental infrastructure project poised to revolutionize Nigeria's energy landscape¹⁰. This 614-kilometer pipeline, extending from the southern to the northern regions, embodies the nation's commitment to robust domestic gas utilization and economic revitalization. Designed to transport natural gas from the southern Niger Delta to the northern Kaduna-Kano corridor, the AKK Gas Pipeline is set to invigorate industries, power generation, and household consumption across Nigeria. This transformative endeavor is anticipated to significantly boost energy security, reduce gas flaring, and augment economic growth in the northern regions. Beyond its fundamental role in gas transportation, the AKK Pipeline carries the potential to stimulate industrial development, create jobs, and foster technological transfer along its route. By connecting regions with disparate energy needs, the pipeline acts as a conduit for harmonized national development, further enhancing Nigeria's energy resilience and sustainability. The AKK Gas Pipeline underscores Nigeria's strategic vision of harnessing its abundant natural gas resources for holistic progress¹¹. It exemplifies the nation's dedication to infrastructure development, economic

⁷ Ingwe, R., Ukwai, J.K. (2014), Socially-disruptive political processes in Africa's second largest economy (Nigeria): a theoretical review (Unpublished article on file at the CRADLE).

⁸ CAPP (2021). Crude Oil Extraction and Drilling Methods. CAPP. Available at: <https://www.capp.ca/oil/extraction/>

⁹ Aregbe, A.G. (2017). Natural Gas Flaring—Alternative Solutions. *World Journal of Engineering and Technology*, 5(1), pp.720–726. Available at: <https://m.scirp.org/papers/74459>

¹⁰ Al-Samhan, M., Al-Fadhli, J., Al-Otaibi, A.M., AlAttar, F., Bouresli, R. and Rana, M.S. (2021). Prospects of refinery switching from conventional to integrated: An opportunity for sustainable investment in the petrochemical industry. *Fuel*, 310, p.122161.

¹¹ Bahadori, A. (2014). Blow-down and flare systems. *Natural gas processing*, pp. 275–312. Available at: <https://doi.org/10.1016/B978-0-08-099971-5.00006-4>

diversification, and environmental stewardship. As a symbol of Nigeria's march towards energy sufficiency and inclusive growth, the AKK Gas Pipeline emerges as a cornerstone of the nation's energy transformation journey¹².

These and other natural gas projects in Nigeria have the potential to contribute significantly to the country's economic development and reduce its reliance on crude oil exports.

Gas Flaring

Gas flaring is the process of burning off natural gas that is produced during oil drilling operations. Natural gas is often found in association with crude oil in reservoirs and is brought to the surface along with the oil during drilling operations.¹³ However, sometimes there are no means of capturing or utilizing the gas, and as a result, it is burned off into the atmosphere. Gas flaring has several negative impacts on the environment and human health. It releases harmful pollutants such as carbon dioxide, nitrogen oxides, and sulfur dioxide into the atmosphere, contributing to climate change and air pollution. It also wastes a valuable resource, as the burned-off gas could have been used for fuel or other purposes¹⁴. Figure 1 shows the gas flaring statistics of Nigeria from 2012 to 2022 and the million standard cubic feet been flared.

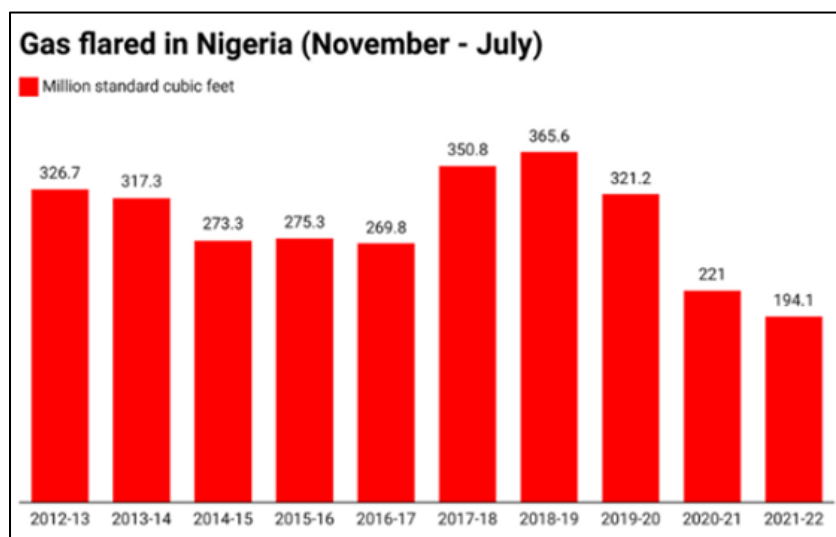


Figure 1: Nigeria gas flaring statistics.¹⁵

Approximately 140 billion cubic meters (bcm) of natural gas are burned off worldwide each year, constituting a significant contributor to CO₂ emissions, methane release, and the generation of

¹² . Barati, A. and Pirozfar, V. (2019). Flare Gas Review in Oil and Gas Industry. J Biochem Tech, 2, 71–89.

Available at:

<https://jbiochemtech.com/storage/models/article/pLXlfMuyZIG3ovwQXn0HcWrL9kDPXuj1NGJNEiEXDkv2I9GkUIgZ1MNzmBNH/flare-gas-review-in-oil-and-gas-industry.pdf>

¹³ Ayoola, T.J. (2011) Gas Flaring and its Implications for Environmental Accounting in Nigeria. Journal of Sustainable Development, 4(5), 244–250.

¹⁴ Beigiparast, S., Tahouni, N., Abbasi, M. and Panjeshahi, M.H. (2021). Flare gas reduction in an olefin plant under different start-up procedures. Energy, 214, 118927. Available at:

<https://www.sciencedirect.com/science/article/pii/S036054422032034X>

¹⁵ Abubakar Ibrahim (2022), Nigeria's gas flares lowest since 2012 as use increases, Business Day, August 12, 2022

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

harmful black soot, which poses health risks¹⁶. In the year 2022, the global volume of gas flared decreased by roughly 5 billion cubic meters (to 139 bcm), representing a reduction of about 3%. This reduction in flaring activities translated into the emission of 500 million metric tons (Mt) of CO₂ equivalent greenhouse gases (GHGs) in 2022¹⁷. A considerable portion, approximately 70%, of the flared gas, is directed towards flares that continuously operate.

In line with the Net Zero Emissions by 2050 (NZE) Scenario, all non-essential flaring activities will be eradicated on a global scale by the year 2030. Figure 2 shows, the direct CO₂ combustion emissions from flaring and flaring intensity in the Net Zero Scenario, 2010-2030. This ambitious objective is anticipated to lead to a remarkable 95% reduction in flared gas volumes and prevent the release of 365 million metric tons of CO₂-equivalent emissions¹⁸.

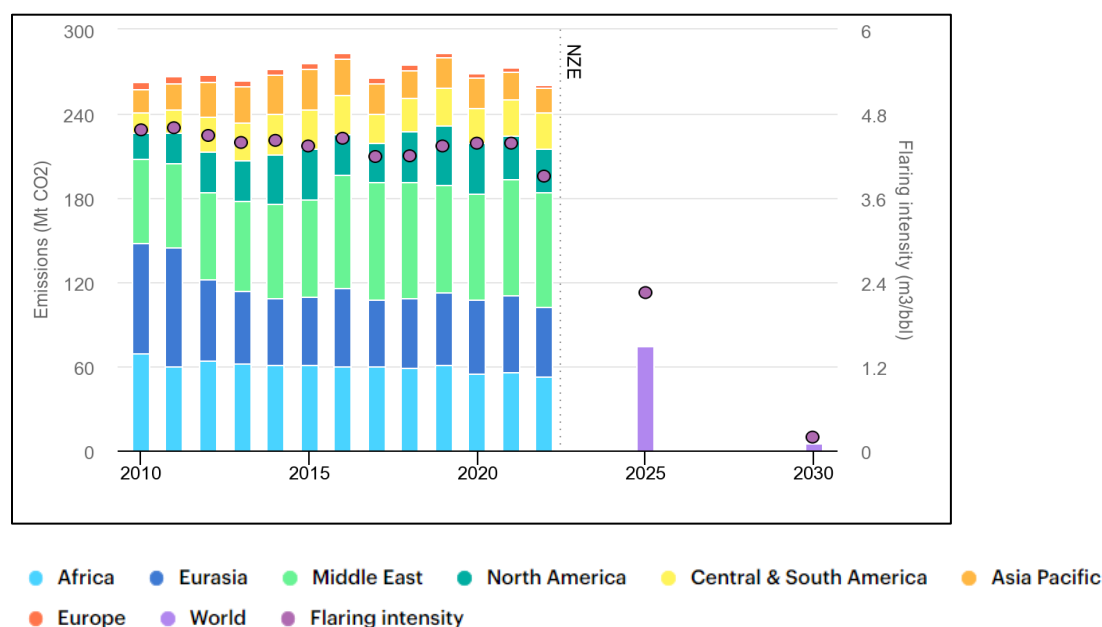


Figure 2: Direct CO₂ combustion emissions from flaring and flaring intensity in the Net Zero Scenario, 2010-2030.¹⁹

Additionally, gas flaring can be a safety hazard, as it can lead to explosions and fires at drilling sites¹⁹. In recent years, there has been a growing movement to reduce or eliminate gas flaring. Many countries and companies have implemented regulations or initiatives to capture and utilize the gas, such as by building pipelines to transport it to processing facilities or using it for power generation. This not only reduces the environmental impact of gas flaring, but also provides a source of energy that would otherwise be wasted.

¹⁶ Aregbe, A.G. (2017). Natural Gas Flaring—Alternative Solutions. *World Journal of Engineering and Technology*, 5(1), pp.720–726. Available at: <https://m.scirp.org/papers/74459>

¹⁷ . Enetimi, I.S., Sylvester C.I. (2017). A review of impacts of gas flaring on vegetation and water resources in the Niger Delta Region of Nigeria. *International Journal of Economy, Energy and Environment*, 2(4), 48-55. doi: 10.11648/j.ijeee.20170204.11

¹⁸ IEA report July 2023

¹⁹ American Association for the Advancement of Science. (2010). *Eyes on Nigeria: Gas Flaring*. [online] Available at: <https://www.aaas.org/resources/eyes-nigeria-technical-report/gas-flaring>

Why are gases flared?

Gases are flared for a variety of reasons. However, Figure 3 shows the sources of natural gas flaring. One of the main reasons is that natural gas that is produced during oil drilling operations may not have a market or infrastructure for transportation and utilization²⁰. In such cases, it may be easier and more cost-effective for the operator to simply burn off the gas rather than trying to capture, process and transport it. Another reason for gas flaring is to maintain safety at the drilling site. Natural gas is often produced under high pressure and can be a potential safety hazard if it is not controlled properly.

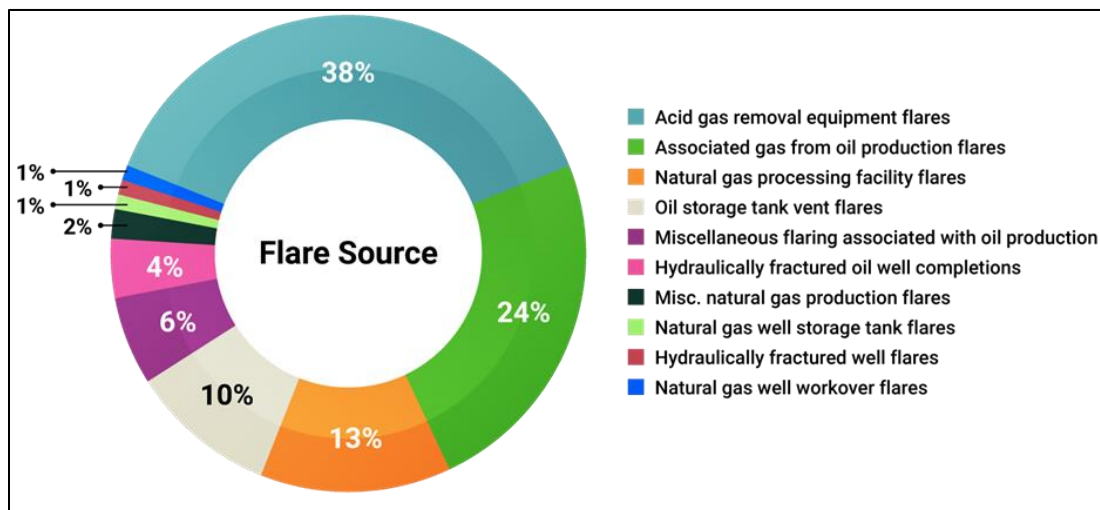


Figure 3: Natural gas flaring sources.²³

Flaring the gas is a way to safely release and burn off any excess gas that cannot be safely stored or utilized²¹. Finally, gas flaring may be done as a result of regulatory requirements. Figure 4 and 5 shows the flare volumes and intensity for the top 30 flaring countries from 2012 to 2021, respectively. In some countries, regulations require oil and gas operators to flare certain volumes of gas to reduce the risk of dangerous buildups of gas in pipelines or at production facilities²². Despite these reasons, gas flaring is considered a waste of resources and has negative environmental and health impacts. Therefore, many countries and companies are now implementing initiatives to reduce or eliminate gas flaring and promote the capture and utilization of natural gas²³.

²⁰ Akanimo, S. (2008) Gas flaring: Nigerian govt under pressure as FOEI joins campaign. Scoop Independent News, 16 December 2008, available at: <http://www.scoop.co.nz/stories/AVOQ812/S00359.htm>

²¹ AfricaNews (2021). Nigeria's Delta attempts cleanup after decades of oil spills, gas flaring.

²² Akoroda, M. (2000) Remediation Response in the Nigeria Delta", Paper presented at a Seminar to mark Anniversary of Jesse Fire Disaster, Nigeria Institute of International Affairs.

²³ Abdulkareem, A.S., Afolabi, A.S., Abdulfatai, J., Uthman, H. and Odigure, J.O. (2012). Oil Exploration and Climate Change: A Case Study of Heat Radiation from Gas Flaring in the Niger Delta Area of Nigeria. [online] www.intechopen.com. IntechOpen. Available at: <https://www.intechopen.com/chapters/38113>

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

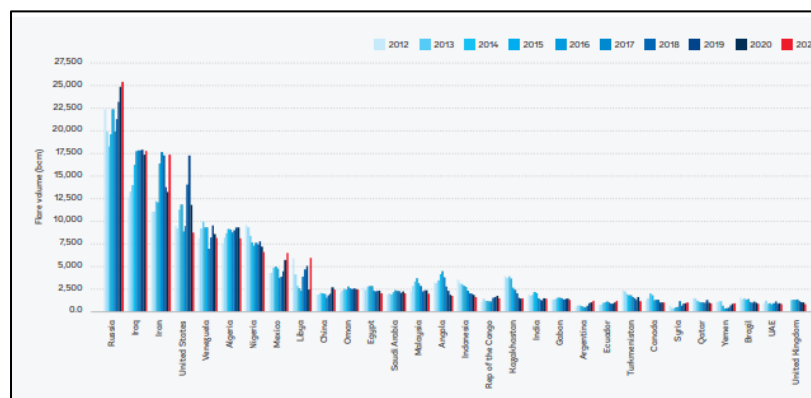


Figure 4: Flare volumes for the top 30 flaring countries from 2012 to 2021 (sorted by 2021 volume, shown in red)²⁴

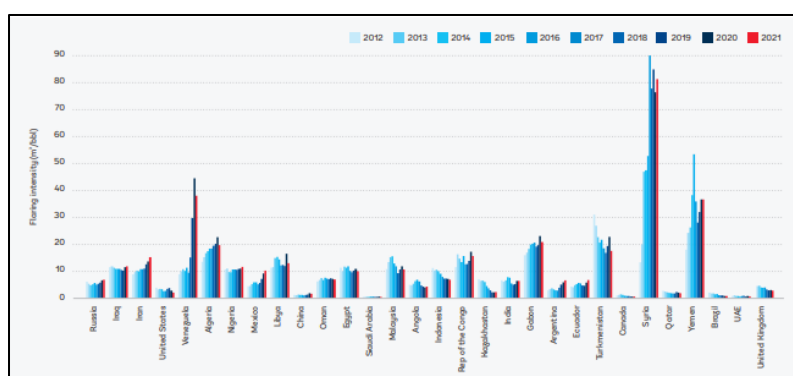


Figure 5: Flaring intensity for the top 30 flaring countries from 2012 to 2021 (sorted by 2021 volume, shown in red)²³

Nigeria gas flaring setback

Nigeria is one of the countries in the world with a high level of gas flaring. Despite having significant natural gas reserves, Nigeria flares a large portion of the gas produced during oil exploration and production²⁵. The image in figure 6 shows how 460.5 billion Naira (191,163.04USD) Lost to gas flaring could have been distributed to various sectors of the economy. According to estimates, Nigeria flares over 70% of the natural gas it produces, making it one of the top gas flaring countries in the world. Gas flaring in Nigeria is a major setback for the country, both economically and environmentally. Economically, Nigeria loses a lot of revenue that could have been generated from the gas that is flared. Gas flaring also contributes to environmental pollution, as it releases greenhouse gases into the atmosphere, which can lead to climate change and harm human health. The gas flaring also causes acid rain, which can damage crops and aquatic life²⁶. To address this setback, the Nigerian government has implemented policies and initiatives

²⁴ World bank (2022) Global Gas Flaring Reduction Partnership (GGFR)

²⁵ Yar' Adua, A.L. (2007), The Nigerian Gas Master-Plan, NNPC, Abuja.

²⁶ World Bank (2009), Project Appraisal Document ... for the Nigerian Electricity Generation Investment Project (NEGIP), World Bank.

aimed at reducing gas flaring²⁷. For example, the Nigerian Gas Flare Commercialization Programme (NGFCP) was launched in 2016 to promote the commercial use of flared gas. The program aims to attract investment into gas gathering and processing infrastructure, which will enable the utilization of flared gas for power generation and other industrial uses. The Nigerian government has also implemented regulations and penalties for gas flaring, to discourage the practice and encourage the development of alternative uses for natural gas.

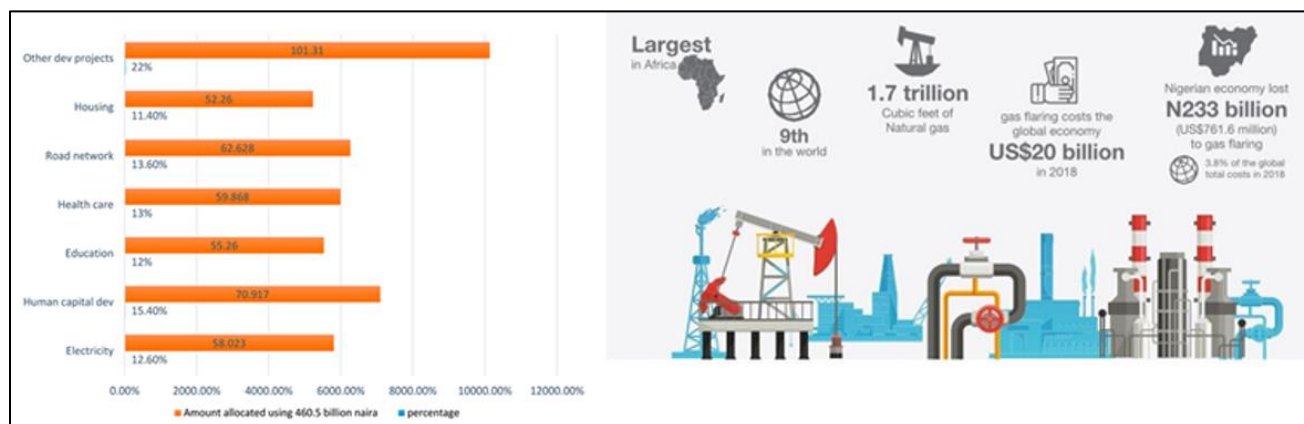


Figure 6: How 460.5 billion Naira (191,163.04USD) Lost to gas flaring could have been distributed to various sectors of the economy.²⁸

Challenges of gas flaring

Several challenges associated with gas flaring include but not limited to the following²⁹:

Environmental impact: Gas flaring releases large amounts of greenhouse gases such as carbon dioxide, methane, and nitrogen oxides into the atmosphere, contributing to climate change and air pollution. The burning of gas also produces harmful pollutants such as sulfur dioxide and particulate matter, which can harm human health and the environment.

Economic waste: Gas flaring is a waste of a valuable resource that could be used for power generation, fuel, or other applications. This results in significant economic losses for oil and gas companies and the countries in which they operate.

Safety hazards: Gas flaring can be a safety hazard, particularly if the flares are not properly designed, operated, and maintained. Flares can cause explosions, fires, and other accidents, which can lead to injury or loss of life, as well as damage to equipment and infrastructure.

Regulatory compliance: Gas flaring is subject to regulations in many countries, and failure to comply with these regulations can result in fines and other penalties.

Technical challenges: Capturing and utilizing natural gas requires specialized equipment and infrastructure, which can be expensive and difficult to install and maintain. This can be particularly challenging in remote or difficult-to-access locations.

Public perception: Gas flaring is often seen as a negative practice by the general public, and

²⁷ World Bank. (2019). Global gas flaring reduction: A time for action.

<https://www.worldbank.org/en/topic/climatechange/brief/global-gas-flaring-reduction-a-time-for-action>

²⁸ PwC (n.d) Assessing the impact of Gas flaring on the Nigeria Economy

²⁹ Olin, M.J.: A Sierra whitepaper. Flare gas mass flow metering innovations promise more economical choices. 2014. Available at: <http://www.controlglobal.com/assets/14WPpdf/140311-Sierra-FlareGas.pdf>.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

companies that engage in gas flaring may face reputational risks as a result.

Addressing these challenges requires a combination of regulatory frameworks, technical solutions, and economic incentives to promote the reduction or elimination of gas flaring. This may involve measures such as imposing stricter regulations and penalties on gas flaring, providing incentives for companies to capture and utilize natural gas, and investing in infrastructure to support the transportation and processing of natural gas.

Gas to Liquid conversion – An alternative to Gas Flaring

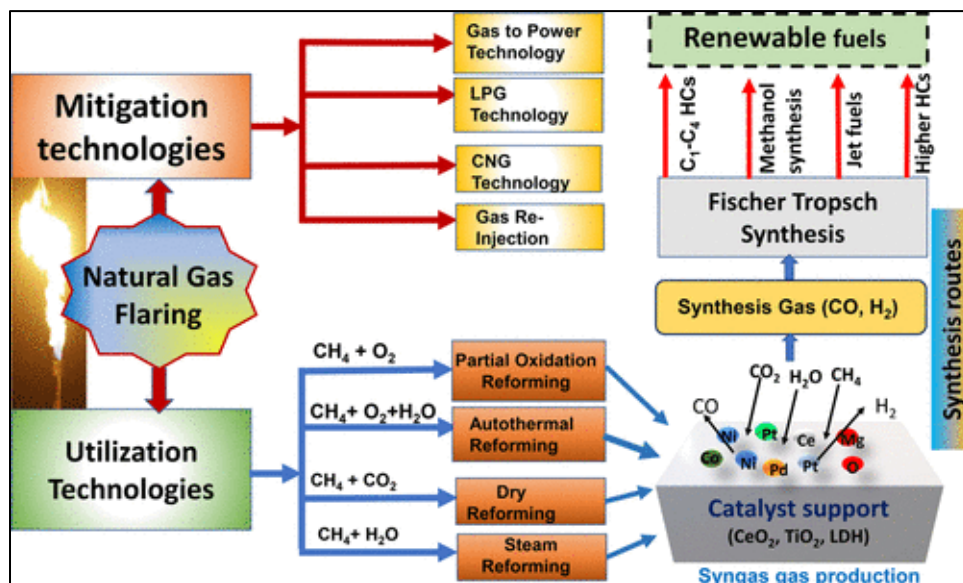


Figure 7: Diagram showing the processes of gas to liquid conversion.³⁰

Gas to Liquid (GTL) conversion as shown in Figure 7, is a technology that converts natural gas, which would otherwise be flared or vented, into liquid fuels such as diesel, kerosene, and naphtha³¹. GTL technology involves a two-step process: first, the gas is converted to synthesis gas (syngas), and then the syngas is converted into liquid hydrocarbons using Fischer-Tropsch synthesis. GTL conversion provides an alternative to gas flaring because it allows operators to monetize associated gas, reducing greenhouse gas emissions and promoting more sustainable energy practices. GTL conversion can be particularly useful in remote locations where pipeline infrastructure is lacking, and it is not economical to transport the gas to market. One of the main advantages of GTL conversion is that the resulting liquid fuels are very clean and can be used directly in existing engines without modification³². The fuels have low emissions of particulate matter, sulfur dioxide, and nitrogen oxides, making them environmentally friendly. Additionally,

³⁰ de Smit, B.M. Weckhuysen, The renaissance of iron-based Fischer-Tropsch synthesis: on the multifaceted catalyst deactivation behaviour, *Chemical Society Reviews*, 37 (2008) 2758-2781.

³¹ Dybkjær, I.; Aasberg-Petersen, K. Synthesis gas technology large-scale applications. *Can. J. Chem. Eng.* 2016, 94, 607–612. <https://doi.org/10.1002/cjce.22453>

³² Ryi, S.-K.; Lee, S.-W.; Park, J.-W.; Oh, D.-K.; Park, J.-S.; Kim, S.S. Combined steam and CO₂ reforming of methane using catalytic nickel membrane for gas to liquid (GTL) process. *Catal. Today* 2014, 236, 49–56. <https://doi.org/10.1016/j.cattod.2013.11.001>.

GTL conversion can produce high-quality lubricants and chemicals, providing additional revenue streams. In spite of its benefits, GTL conversion has some limitations, including high capital costs, high energy consumption, and technical challenges associated with scaling up the technology for commercial use. Additionally, the economics of GTL conversion depend on the price of crude oil, which can be volatile³³. However, GTL conversion offers a promising alternative to gas flaring, and its potential as a sustainable energy solution is worth exploring further.

Methodology

Advanced refinery process of gas to liquids

Gas-to-Liquids (GTL) technology is an advanced refinery process that converts natural gas into high-quality liquid fuels and other products³⁴⁻³⁵⁻³⁶⁻³⁷. The process involves several steps, including

- Gas Pre-Treatment,
- Syngas Production,
- Fischer-Tropsch Synthesis,
- Product Upgrading
- Product Separation

Gas Pre-Treatment:

Gas pre-treatment is a critical step in the gas-to-liquid (GTL) conversion process. The pre-treatment step involves removing impurities such as carbon dioxide, sulfur, water, other trace elements and contaminants from the natural gas feedstock to ensure that it meets the requirements for downstream processing in the GTL plant. The cleaned gas is then compressed and sent to the syngas production stage. The pre-treatment process typically involves several stages, including: - Acid gas removal: Natural gas often contains sulfur compounds such as hydrogen sulfide (H₂S) and carbon dioxide (CO₂). These gases must be removed from the feed gas to prevent corrosion and fouling in the downstream processing equipment. Acid gas removal is typically achieved using an amine absorption process, where the gas is contacted with a liquid amine solvent that selectively removes the acid gases³⁸.

Dehydration: - Natural gas also contains water vapor, which can cause problems in downstream processing equipment such as freezing and corrosion. Dehydration is typically achieved using a molecular sieve or glycol dehydration system, which removes the water vapor from the gas stream. Mercury removal: - Some natural gas deposits contain trace amounts of mercury, which can cause problems in downstream processing equipment and be hazardous to health and safety. Mercury removal is typically achieved using specialized adsorbent materials that selectively remove the mercury from the gas stream.

³³ Wood, D.A.; Nwaoha, C.; Towler, B.F. Gas-to-liquids (GTL): A review of an industry offering several routes for monetizing natural gas. *J. Nat. Gas Sci. Eng.* 2012, 9, 196–208. <https://doi.org/10.1016/j.jngse.2012.07.001>.

³⁴ Sousa-Aguiar, E.F.; Noronha, F.B.; Faro, J.A. The main catalytic challenges in GTL (gas-to-liquids) processes. *Catal. Sci. Technol.* 2011, 1, 698–713. <https://doi.org/10.1039/C1CY00116G>.

³⁵ Sorrell, S. Reducing energy demand: A review of issues, challenges and approaches. *Renew. Sustain. Energy Rev.* 2015, 47, 74–82. <https://doi.org/10.1016/j.rser.2015.03.002>.

³⁶ Bao, B.; El-Halwagi, M.M.; Elbashir, N.O. Simulation, integration, and economic analysis of gas-to-liquid processes. *Fuel Process. Technol.* 2010, 91, 703–713. <https://doi.org/10.1016/j.fuproc.2010.02.001>.

³⁷ Goellner, J.F.; Shah, V.; Turner, M.J.; Kuehn, N.J.; Littlefield, G.C.; Marriott, J. Analysis of Natural Gas-to-Liquid Transportation Fuels via Fischer-Tropsch, Report DOE/NETL-2013/1597; United States Department of Energy (DOE), National Energy Technology Laboratory (NETL): Pittsburgh, PA, USA, 2013.

³⁸ Tso, W.W.; Niziolek, A.M.; Onel, O.; Demirhan, C.D.; Floudas, C.A.; Pistikopoulos, E.N. Enhancing natural gas-to-liquids (GTL) processes through chemical looping for syngas production: Process synthesis and global optimization. *Comput. Chem. Eng.* 2018, 113, 222–239. <https://doi.org/10.1016/j.compchemeng.2018.03.003>.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

Particulate removal: - Natural gas can also contain solid particles such as sand and dust, which can cause damage to downstream processing equipment. Particulate removal is typically achieved using specialized filters or cyclones. The pre-treatment process can be complex and require specialized equipment and expertise. However, it is essential to ensure that the natural gas feedstock meets the requirements for downstream processing in the GTL plant, and to protect the integrity of the processing equipment.

Synthesis Gas production:

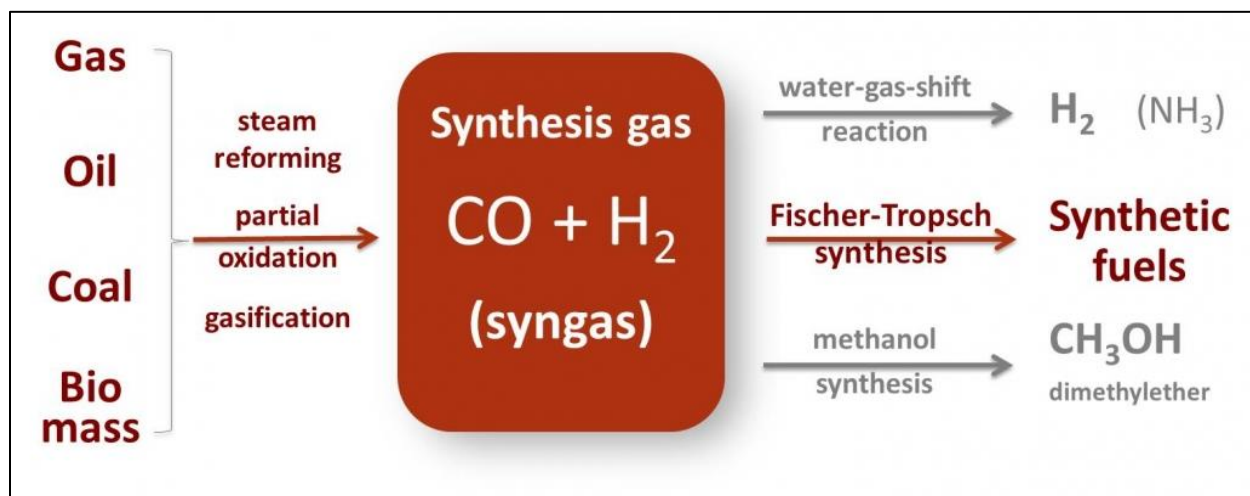


Figure 8: Diagram showing the processes of syngas production.³⁹

Synthesis gas, also known as syngas, is a mixture of hydrogen (H_2) and carbon monoxide (CO) that is used as a feedstock for the production of a variety of chemicals and fuels as shown in figure 8. The syngas is produced by reacting natural gas with steam and oxygen over a catalyst. The resulting syngas is then purified to remove impurities before proceeding to the next stage⁴⁰. The production of syngas can be achieved through several processes⁴¹, including:

Steam reforming: - In this process, natural gas or methane is reacted with steam and a catalyst to produce syngas. The reaction takes place at high temperatures (around 800-900°C) and high pressures (around 20-30 bar). Steam reforming is the most common method for producing syngas, as natural gas is a readily available and relatively low-cost feedstock.

Partial oxidation: - In this process, a hydrocarbon feedstock is partially oxidized with oxygen or air to produce syngas. The reaction takes place at high temperatures (around 1200-1500°C) and high pressures (around 20-30 bar). Partial oxidation is less commonly used than steam reforming, as it requires a higher-quality feedstock and produces more impurities in the syngas.

Auto thermal reforming: - This process combines elements of steam reforming and partial oxidation, using both steam and oxygen to produce syngas. The reaction takes place at high

³⁹ Centi, S. Perathoner, Opportunities and prospects in the chemical recycling of carbon dioxide to fuels, Catalysis Today, 148 (2009) 191-205.

⁴⁰ Klerk, A.d. Fischer-Tropsch fuels refinery design. Energy Environ. Sci. 2011, 4, 1177-1205.

<https://doi.org/10.1039/C0EE00692K>

⁴¹ De Klerk, A. Gas-to-liquids conversion. In Proceedings of the Natural Gas Conversion Technologies Workshop of ARPA-E, US Department of Energy, Houston, TX, USA, 13 January 2012.

temperatures (around 1000-1200°C) and high pressures (around 20-30 bar).

Biomass gasification: - In this process, biomass feedstock's such as wood, agricultural waste, or municipal solid waste are heated in the absence of oxygen to produce syngas. Biomass gasification is a renewable and potentially sustainable method for producing syngas, but it requires specialized equipment and can be more expensive than other methods.

The choice of syngas production process depends on factors such as feedstock availability and cost, desired product purity, and environmental considerations. Once produced, syngas can be further processed to produce a wide range of chemicals and fuels, including methanol, ammonia, and synthetic fuels such as gasoline and diesel.

Fischer-Tropsch Synthesis:

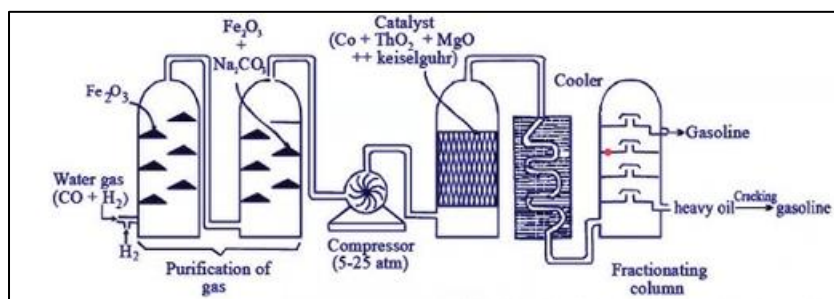


Figure 9: Fischer Tropsch process.⁴²

In the third step, the syngas is converted into liquid hydrocarbons using the Fischer-Tropsch synthesis process (A catalytic reduction of CO and H₂ to get straight chain alkane and olefins). The syngas is fed into a reactor containing a catalyst, where it reacts to form long-chain hydrocarbons. The hydrocarbons are then condensed and separated from the reaction products⁴³. The Fischer-Tropsch synthesis is a chemical process that converts synthesis gas (syngas), a mixture of carbon monoxide (CO) and hydrogen (H₂), into liquid hydrocarbons such as synthetic fuels, waxes, and lubricants with references to figure 9 above. The process was first developed by German chemists Franz Fischer and Hans Tropsch in the 1920s, and it played a significant role in Germany's fuel production during World War II. The Fischer-Tropsch synthesis is a multi-step process that involves the following main steps:

Production of synthesis gas: - Syngas is produced from a hydrocarbon feedstock (such as natural gas or coal) by steam reforming or gasification.

Preparation of catalyst: - The syngas is then passed over a catalyst, typically made of iron, cobalt, or nickel. The catalyst is prepared by reducing metal oxides at high temperatures.

Fischer-Tropsch reaction⁴⁴: - The syngas reacts with the catalyst to produce a mixture of

⁴² H. Hu, E. Ruckenstein, Catalytic conversion of methane to synthesis gas by partial oxidation and CO₂ reforming, *Advances in Catalysis*, Vol 48, 48 (2004) 297-345.

⁴³ Konarova, M.; Aslam, W.; Perkins, G. Chapter 3—Fischer-Tropsch synthesis to hydrocarbon biofuels: Present status and challenges involved. In *Hydrocarbon Biorefinery*; Maity, S.K., Gayen, K., Bhowmick, T.K., Eds.; Elsevier: Amsterdam, The Netherlands, 2022; pp. 77–96. <https://doi.org/10.1016/B978-0-12-823306-1.00006-6>.

⁴⁴ Nafees, A.; Al-Hashimi, S. Fischer-Tropsch Gas to Liquid Technology (GTL). In *Proceedings of the Second International Energy 2030 Conference*, Chemical Engineering Program, The Petroleum Institute, Abu Dhabi, United Arab Emirates, 4–5 November 2008; pp. 88–90.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

hydrocarbons. The reaction is exothermic and typically occurs at temperatures between 200 and 300°C and pressures between 20 and 30 bar.

Product separation and refining: - The hydrocarbon mixture is cooled and condensed to produce a liquid product. The liquid is then further processed to remove impurities and produce the desired final products.

The Fischer-Tropsch process has several advantages over traditional petroleum refining, including the ability to produce high-quality, sulfur-free fuels and the potential for using renewable feedstocks such as biomass or waste. However, the process is relatively expensive and requires significant capital investment in catalyst preparation and reactor technology. Despite these challenges, the Fischer-Tropsch process has been used commercially for several decades and is still used today in a number of applications, including the production of synthetic fuels for aviation and the military, as well as the production of high-quality lubricants and waxes.

Product Upgrading:

In the fourth step, the liquid hydrocarbons produced by the Fischer-Tropsch synthesis are upgraded to produce high-quality fuels such as diesel, kerosene, and naphtha. The upgrading process involves refining the hydrocarbons to remove impurities and adjust their properties to meet market specifications⁴⁵. Product upgrading is a process that converts lower-value hydrocarbons into higher-value products such as gasoline, diesel, jet fuel, and chemicals. The process is commonly used in the refining industry to improve the quality and value of petroleum products. There are several methods of product upgrading, including:

Hydro-treating: - This process involves the removal of impurities such as sulfur, nitrogen, and metals from crude oil or other hydrocarbon feedstocks using hydrogen gas and a catalyst. The resulting product is cleaner and more stable, with improved properties such as higher-octane ratings for gasoline and better cetane ratings for diesel⁴⁶.

Hydro-cracking: - This process involves breaking down heavier, longer-chain hydrocarbons into lighter, shorter-chain hydrocarbons by using high temperature, high pressure, and a catalyst. The resulting product is higher in value and can be used to produce gasoline, diesel, and jet fuel.

Fluid Catalytic Cracking (FCC): - This process involves the use of a catalyst to convert heavy, high-boiling-point fractions of crude oil into lighter, lower-boiling-point fractions such as gasoline, diesel, and jet fuel.

Alkylation: - This process involves the combination of smaller, low-value molecules such as butane or propane with an olefin such as propylene or butylene to produce high-octane gasoline components.

Product upgrading is important in the petroleum industry because it allows refiners to produce higher-value products from lower-value feedstock's, which can improve profitability and meet changing market demands. The specific methods of product upgrading used depend on the type and quality of the feedstock and the desired end products.

Product Separation

Product separation is a critical step in the gas-to-liquids (GTL) process, where the liquid hydrocarbons produced by the Fischer-Tropsch synthesis are separated into various fractions such

⁴⁵ Jager, B. Development of fischer tropsch reactors. In Proceedings of the AIChE Spring Meeting, New Orleans, LA, USA, 1 April 2003; pp. 1–9

⁴⁶ Gholami, Z.; Tišler, Z.; Rubáš, V. Recent advances in Fischer-Tropsch synthesis using cobalt-based catalysts: A review on supports, promoters, and reactors. *Catal. Rev.* 2021, 63, 512–595.
<https://doi.org/10.1080/01614940.2020.1762367>.

as diesel, gasoline, and high-value chemicals, depending on the desired end products. The product separation step typically involves several refining processes, including distillation, isomerization, and hydrocracking, among others.

Distillation is the most common method used for product separation in the GTL process. This process involves heating the liquid hydrocarbons to their boiling point and then separating them based on their different boiling points. The higher boiling point fractions such as diesel and heavy lubricating oils are typically separated from the lower boiling point fractions such as gasoline and naphtha⁴⁷.

Isomerization is another process used for product separation in GTL, which involves converting straight-chain hydrocarbons into branched isomers. This process is often used to improve the properties of gasoline, such as increasing its octane rating and reducing its tendency to knock. Hydrocracking is a process that is used to break down larger, heavier hydrocarbons into smaller, lighter hydrocarbons. This process is often used to produce high-quality diesel fuel from heavy distillates produced by the Fischer-Tropsch synthesis. In addition to these processes, other refining techniques such as solvent extraction and adsorption may also be used for product separation in the GTL process. However, the product separation step is critical to the success of the GTL process, as it allows for the production of a wide range of high-value liquid products from gaseous hydrocarbons⁴⁸.

Advanced GTL processes are being developed to improve the efficiency and economics of the process. These include the integration of the GTL process with other processes such as carbon capture and storage, as well as the development of more advanced catalysts and reactor designs to improve the efficiency and selectivity of the Fischer-Tropsch synthesis⁴⁹. Additionally, the use of renewable sources such as biogas and hydrogen in the GTL process is being explored as a way to reduce carbon emissions and promote sustainable energy practices⁵⁰.

GTL Diesel

GTL diesel is a type of synthetic diesel fuel produced through the Gas-to-Liquid (GTL) process, which involves converting natural gas into liquid hydrocarbons. GTL diesel is a high-quality, clean-burning fuel that can be used as a drop-in replacement for conventional diesel fuel in a variety of applications⁵¹. Compared to conventional diesel fuel, GTL diesel has several advantages, including:

Lower emissions: - GTL diesel contains virtually no sulfur and has lower levels of pollutants such as particulate matter and nitrogen oxides (NOx). As a result, it produces fewer harmful emissions and can help to improve air quality.

Improved performance: - GTL diesel has a higher cetane number, which means it ignites more

⁴⁷ Biloen, W.M.H. Sachtler, Mechanism of Hydrocarbon Synthesis over Fischer-Tropsch Catalysts, *Advances in Catalysis*, 30 (1981) 165-216.

⁴⁸ Alfano, M.; Cavazza, C. The biologically mediated water-gas shift reaction: Structure, function and biosynthesis of monofunctional [NiFe]-carbon monoxide dehydrogenases. *Sustain. Energy Fuels* 2018, 2, 1653–1670. <https://doi.org/10.1039/C8SE00085A>.

⁴⁹ Lapidus, A. Scientific principles of synthesis of liquid hydrocarbons from CO and H₂ in the presence of cobalt catalysts. *Bull. Acad. Sci. USSR Div. Chem. Sci.* 1991, 40, 2335–2349.

⁵⁰ Jager, B.; Kelfkens, R.; Steynberg, A. A slurry bed reactor for low temperature Fischer-Tropsch. In *Studies in Surface Science and Catalysis*; Elsevier: Amsterdam, The Netherlands, 1994; Volume 81, pp. 419–425.

⁵¹ Guettel, R.; Kunz, U.; Turek, T. Reactors for Fischer-Tropsch Synthesis. *Chem. Eng. Technol. Ind. Chem. -Plant Equip. -Process Eng. -Biotechnol.* 2008, 31, 746–754.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

quickly and burns more completely than conventional diesel fuel. This can result in improved engine performance, reduced engine wear, and increased fuel efficiency.

Versatility: - GTL diesel can be used in a variety of applications, including transportation, industrial, and marine sectors. It can also be blended with conventional diesel fuel to improve its properties.

However, GTL diesel has some drawbacks, including:

High cost: - The production of GTL diesel requires significant capital investment and energy inputs, which can make it more expensive than conventional diesel fuel.

Limited availability: - GTL diesel production is currently limited to a few locations around the world, which can make it difficult and expensive to transport and distribute.

Despite these challenges, GTL diesel has the potential to play an important role in reducing greenhouse gas emissions and improving air quality, particularly in applications where electrification is not yet feasible.

Uses of GTL

Products produced through Gas-to-Liquids (GTL) technology have a wide range of uses, including⁵²:

Transportation fuels: GTL technology produces high-quality diesel, jet fuel, and gasoline that meet the most stringent environmental regulations.

Chemicals and lubricants: GTL products are used in the production of specialty chemicals, plastics, and lubricants.

Power generation: GTL products can be used as a fuel for gas turbines, producing electricity with lower emissions compared to traditional fossil fuels.

Heating and cooking: GTL products can be used for domestic and commercial heating and cooking, particularly in areas where natural gas pipelines are not available.

Off-grid power supply: GTL technology can provide a reliable and independent source of energy for remote or off-grid locations, such as military bases or mining operations.

Renewable energy integration: GTL technology can be used to convert renewable sources of energy, such as biogas or hydrogen, into high-quality liquid fuels, allowing for greater integration of renewable energy into the energy mix.

However, GTL technology provides a versatile and efficient way to convert natural gas into a range of high-quality products with a variety of applications.

Prospective Opportunities Associated with GTL Technology

Prospective opportunities associated with Gas-to-Liquids (GTL) technology which includes⁵³:

- **Monetization of Natural Gas:** GTL technology offers a way to monetize natural gas resources that would otherwise be stranded or wasted through flaring. This technology allows the conversion of natural gas into high-value liquid fuels and chemicals, which can be sold at a premium price.
- **Diversification of Energy Sources:** GTL technology provides an opportunity to diversify energy sources and reduce dependence on crude oil. GTL fuels can be used as a substitute for diesel, jet fuel, and other petroleum-based products, reducing the demand for crude oil.

⁵² P. Steynberg, M.E. Dry, Fischer-Tropsch Technology, Studies in Surface Science and Catalysis, Vol. 152, Elsevier, Amsterdam, 2004

⁵³ Gregor, J. Fischer-Tropsch products as liquid fuels or chemicals. Catal. Lett. 1990, 7, 317–331.

- **Environmental Benefits:** GTL fuels have lower emissions of pollutants such as sulfur, nitrogen oxides, and particulate matter compared to conventional diesel and gasoline. This makes GTL fuels an attractive option for meeting environmental regulations and reducing air pollution.
- **Economic Development:** The development and implementation of GTL technology can create new industries, jobs, and economic opportunities in countries with significant natural gas resources.
- **Energy Security:** GTL technology can enhance energy security by providing a reliable and secure source of liquid fuels that can be produced locally, reducing dependence on imported oil.
- **Innovation and Technology Transfer:** The development and implementation of GTL technology require significant innovation and technology transfer, creating opportunities for collaboration and knowledge-sharing between countries and industries.

Moreover, GTL technology offers significant prospective opportunities for the energy industry, the environment, and economic development.

GTL Plants in Nigeria

There are currently two major GTL (Gas-to-Liquids) plants in Nigeria, which are⁷⁻⁸⁻⁹:

- **Escravos GTL Plant:** The Escravos GTL plant is located in the Niger Delta region of Nigeria and is owned and operated by Chevron Nigeria Limited. The plant has a capacity to produce 33,000 barrels per day of liquid fuels, including diesel, naphtha, and kerosene, using natural gas as feedstock. The plant was commissioned in 2014 and is one of the largest GTL plants in Africa.
- **Olokola GTL Project:** The Olokola GTL project is a proposed GTL plant located in Ondo State, Nigeria. The project is a joint venture between the Nigerian National Petroleum Corporation (NNPC) and Chevron Nigeria Limited, with a proposed capacity to produce 120,000 barrels per day of liquid fuels. The project has faced several delays and setbacks, including funding and regulatory issues, and its current status is uncertain.

It is worth noting that Nigeria has vast natural gas reserves, and there have been plans to develop additional GTL plants in the country in the past, but many of these plans have not come to fruition.

Benefits of GTL

Several benefits associated with GTL (Gas-to-Liquids) technology, including⁵⁴:

Cleaner burning fuels: GTL technology produces cleaner burning fuels, such as diesel and jet fuel, with lower emissions of pollutants such as sulfur dioxide, nitrogen oxides, and particulate matter. This makes GTL fuels attractive for use in transportation, particularly in areas with strict emissions regulations⁵⁵.

Versatility: GTL technology can produce a wide range of liquid fuels, including diesel, jet fuel, and naphtha. These fuels can be used for a variety of applications, including transportation, power generation, and industrial processes.

Energy security: GTL technology can provide a source of liquid fuels from domestic natural gas reserves, reducing a country's dependence on imported oil. This can enhance a country's energy security and reduce its vulnerability to supply disruptions.

⁵⁴ Singleton, A.H. Advances make gas-to-liquids process competitive for remote locations. Oil Gas J. 1997, 95, <http://worldcat.org/issn/00301388>.

⁵⁵ Teimouri, Z.; Abatzoglou, N.; Dalai, A.K. Kinetics and Selectivity Study of Fischer–Tropsch Synthesis to C5+ Hydrocarbons: A Review. Catalysts 2021, 11, 330.

Adoption of Gas to Liquid (GTL) Conversion Technology as a Solution to Gas Flaring in Nigeria.

Economic benefits: GTL technology can create jobs and generate economic growth through investment in new infrastructure and technology. In addition, the production of liquid fuels from natural gas can create new markets for natural gas, which can boost the economy of countries with significant natural gas reserves.

Carbon capture and utilization: GTL technology can be integrated with carbon capture and utilization (CCU) technologies, allowing for the capture and utilization of carbon dioxide emissions. This can help to reduce greenhouse gas emissions and mitigate climate change.

GTL technology has the potential to provide a range of environmental, economic, and energy security benefits, making it an attractive option for countries seeking to diversify their energy mix and reduce their dependence on imported oil. While GTL (Gas-to-Liquids) technology offers several benefits, there are also several challenges/limitations associated with its implementation, including:

High capital costs: GTL plants require significant capital investment due to the complexity of the technology and the need for specialized equipment. This can make GTL plants expensive to build and operate, making it difficult to achieve cost competitiveness with traditional oil refining processes.

Energy efficiency: GTL conversion requires large amounts of energy to convert natural gas to liquid fuels, and the process is not as energy-efficient as other technologies. This means that GTL plants can have a high carbon footprint, which can offset some of the environmental benefits of the technology.

Feedstock availability: GTL plants require a reliable and consistent supply of natural gas feedstock, which may not be available in all locations. In addition, the cost and availability of natural gas can vary, making it difficult to achieve price stability for GTL fuels.

Scale of production: GTL plants are typically large-scale facilities, which can limit their suitability for smaller markets or remote locations. In addition, it can take several years to develop and construct a GTL plant, which can create challenges in meeting changing market demand.

Regulatory challenges: GTL technology is subject to a range of regulatory and environmental requirements, including emissions standards and waste disposal regulations. Meeting these requirements can add additional complexity and costs to the operation of GTL plants.

The challenges associated with GTL technology can make it difficult to achieve widespread adoption and cost competitiveness with traditional oil refining processes. However, continued investment in research and development could help to overcome some of these challenges and make GTL technology a more viable option for producing liquid fuels from natural gas.

Recommendations for GTL conversion

Here are some recommendations for GTL (Gas-to-Liquids) conversion⁵⁶:

Focus on Research and Development: Research and development in the field of GTL conversion can help to improve the efficiency and reduce the costs associated with the technology. This can help to make GTL fuels more competitive with traditional liquid fuels, and increase their adoption in the marketplace.

Foster Partnerships: Partnerships between governments, private sector companies, and other stakeholders can help to facilitate the development and deployment of GTL technology. Collaboration can help to overcome some of the challenges associated with GTL conversion, such

⁵⁶ Davis, B.H. Fischer–Tropsch synthesis: Overview of reactor development and future potentialities. Top. Catal. 2005, 32, 143–168.

as cost and scale.

Expand Feedstock Availability: Expanding the availability of natural gas feedstock can help to increase the production of GTL fuels. This can be achieved through increased natural gas production, as well as through the development of new technologies that can access previously inaccessible natural gas resources.

Support Policy Framework: Supportive policy frameworks, such as tax incentives and subsidies, can help to encourage investment in GTL technology. This can help to accelerate the development and deployment of GTL plants, and increase the adoption of GTL fuels in the marketplace.

Address Environmental Concerns: While GTL fuels are generally cleaner burning than traditional liquid fuels, the production process can still generate emissions of greenhouse gases and other pollutants. Addressing these environmental concerns will be important for the long-term sustainability of GTL technology.

GTL conversion can be an important tool for reducing dependence on imported oil, diversifying energy portfolios, and reducing emissions of greenhouse gases and other pollutants. Implementing the above recommendations can help to accelerate the development and deployment of GTL technology and increase its adoption in the marketplace.

Conclusion

Gas-to-Liquids (GTL) conversion is a technology that converts natural gas into high-quality liquid fuels such as diesel, gasoline, and jet fuel. This technology offers an alternative to gas flaring, which is a common practice in the oil and gas industry that involves burning off excess natural gas. Approximately 140 billion cubic meters (bcm) of natural gas are burned off worldwide each year, constituting a significant contributor to CO₂ emissions, methane release, and the generation of harmful black soot, which poses health risks. In the year 2022, the global volume of gas flared decreased by roughly 5 billion cubic meters (to 139 bcm), representing a reduction of about 3%. This reduction in flaring activities translated into the emission of 500 million metric tons (Mt) of CO₂ equivalent greenhouse gases (GHGs) in 2022. GTL conversion has several benefits, including reducing greenhouse gas emissions and other pollutants, increasing the efficiency of natural gas utilization, and providing an alternative to traditional liquid fuels. The processes involved in GTL conversion includes gas pre-treatment, syngas production, fischer-tropsch synthesis, product upgrading and product separation. However, the technology also has some challenges and limitations, such as high capital costs, scalability issues, and environmental concerns. Several countries, including Qatar, South Africa, Malaysia, Nigeria, and Uzbekistan, have implemented GTL technology and have operational GTL plants. To further advance GTL conversion, recommendations include focusing on research and development, fostering partnerships, expanding feedstock availability, supporting policy frameworks, and addressing environmental concerns. GTL conversion has the potential to reduce the negative environmental impact of gas flaring and diversify energy portfolios, but will require continued innovation, investment, and collaboration to fully realize its potential.