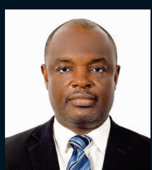
# Nigerian Chemical & Engineering Industry
## MAGAZINE

A Four-Monthly Publication of Nigerian Society of Chemical Engineers
(A Division Of Nigerian Society Of Engineers)

July - October 2024 | Vol. 7 No. 1 Edition

**Chemical Eng. & Green Chemistry**

Engr. Anthony Ogheneovo

**Chemical Recycling of PET Bottles**

Dr. Edith Alagbe

**Energy-Efficient Manufacturing**

Engr. Olanrewaju Adebayo

# POTENTIAL OF OIL & GAS AS ENERGY SUPPLY OPTIONS

ISSN 2714-2256

# NSChE VISION

"To be the Center of excellence for the Chemical Engineering Profession in Africa and the Prime Mover of Industrialization in Nigeria".

# NSChE MISSION


"To organize the Nigerian Society of Chemical Engineers into a virile professional body capable of promoting the relevance and versatility of the profession, achieving better training and updating of Chemical Engineers through its activities. Fostering of relationships with the academia, research institutes, industries, other professional bodies and government will be the basis for stimulating accelerated industrialization of the country and improving the quality of life of the Nigerian people".



*All correspondence to:*

The Editor-in-Chief
NSChE National Secretariat: Infinite Grace House. Plot 4, Oyetubo Street, (4th Floor)
Off Obafemi Awolowo Way, Ikeja, Lagos. Tel: 09035764128, 08023911323
Email: nsche_headquarters@yahoo.com, nationalhqtrs@nsche.org Website: www.nsche.org

The views and opinions expressed in this Magazine do not necessarily reflect those of NSChE.
"Nigerian Chemical and Engineering Industry" Magazine is produced three times a year by SENDINA LIMITED for Nigerian Society of Chemical Engineers.

Producer's Office: Sendina Limited: Plot 22b, Kola Olosan Street, Ofada (Via Mowe), Ogun State, Nigeria. Tel: +234(0)7060545011, 09065913181, 09055181454 Email: sendina7x@gmail.com

# Contents

# FROM THE *Editorial* SUITE

Nigerian Chemical & Engineering Industry Magazine is a valuable resource in print media for engineers, scientists, policy makers, tertiary institutions and the general reading public. Our presentations in the magazine over the years have been well received with encouraging testimonies of their rich educational and informative content. This edition Vol 7 No. 1, is another rich resource.

***Engr. Donatus Uweh**, FNSChE*
*(Editor-in-Chief)*

In this edition, Engr. Anthony Ogheneovo, Executive Secretary of NSChE, presents the second part of his paper on the topic: **AN OVERVIEW OF CHEMICAL ENGINEERING AND GREEN CHEMISTRY.**
He shares knowledge on the applications of Green Chemistry in Chemical Engineering. One may ask "Why Green?" The green concept in today's world is now the driving force in many processes to mitigate the adverse environmental impact in industrial processes. Environmental concerns constitute global phenomena not limited to any particular country or region of the world. Though Engr. Ogheneovo is providing examples of Green Chemistry in Chemical Engineering, it should be noted that there are wider applications which concern other disciplines even beyond engineering. Environmental concerns now face everyone and everything in planet earth.

Another major presentation is on the topic: **EXPLORING THE POTENTIAL OF OIL AND GAS AS ENERGY SUPPLY OPTIONS AND THEIR PROSPECTS FOR DEVELOPMENT** by Engr. Dr. Abdulrasheed Babalola, FNSE, FNSChE, FNISafetyE, Associate Professor of Chemical Engineering, Federal University of Technology, Ikot Abasi (FUTIA). The erudite scholar covers various aspects of Oil and Gas development. Oil and Gas serve as a vital energy source which is critical to developing various countries of the world to industrialized status. The author provides the advantages of Oil and Gas and the options for development. Read and get more. A treatise on the topic: **CHEMICAL RECYCLING OF WASTE PET BOTTLES** by Engr. Dr. Edith Alagbe, MNSE, FNSChE is a highly educative and valuable presentation. It should be of interest to all stakeholders including environmentalists who want to see the end to the menace of wasteful disposal of Polyethylene Terephthalate (PET) bottles. Her in-depth presentation on the subject is profoundly enlightening and serves as a good basis for further research to reduce the environmental menace posed by waste PET bottles. Readers will learn about some of the solutions proposed in chemical recycling methods.

A versatile consultant, Engr. Olanrewaju Adebayo Bamidele, MNSChE, MNSE, AMIChemE, AIChE, AMNIM, Founder & CEO, Olanab Consulting Ltd, makes a presentation on the topic: **FINANCIAL & ENVIRONMENTAL GAINS IN ENERGY-EFFICIENT MANUFACTURING.** Energy serves as the driver for many industrial processes including manufacturing. In his presentation, Engr. Olanrewaju focusses on Manufacturing and how efficient energy usage can provide numerous benefits. Among the benefits are energy cost reduction, extended equipment life, improved profitability, reduction in greenhouse gas emissions. Do you want to know more?, then read his article fully in this edition.
As a professional body, NSChE conducts numerous events of interest to its fellows, members, policy makers and the general public. One of such events is shown in the form of memorable pictures. It is the Fellows' Conference held in 2024. Check inside for the details.
Finally, we express our appreciation to all those who contributed to the successful publication of this edition.

***Relax and enjoy your reading.***
***Engr. Donatus Uweh, FNSChE***
***Editor-in-Chief***

# AN OVERVIEW OF CHEMICAL ENGINEERING AND GREEN CHEMISTRY (PART TWO)

*...continued from **Part One** in Vol. 6 No. 3 Edition*

***Engr. Anthony Ogheneovo**, FNSChE*
*(Executive Secretary, NSChE)*

## 3.0 APPLICATIONS OF GREEN CHEMISTRY IN CHEMICAL ENGINEERING

i. **Green Synthesis and Catalysis:** Developing eco-friendly synthesis methods using non-toxic reagents and catalysts. Example: Using solid acid catalysts in place of hazardous liquid acids.

ii. **Renewable Energy and Materials:** Producing biofuels and bioplastics from renewable resources. Example: Converting agricultural waste into bioethanol.

iii. **Process Intensification:** Designing processes that increase efficiency and reduce the environmental footprint. Example: Using microreactors to enhance reaction rates and selectivity.

iv. **Waste Minimization:** Reducing waste generation at the source through better process design. Example: Implementing zero-waste manufacturing processes.

v. **Cleaner Production Technologies:** Adopting technologies that reduce emissions and resource consumption. Example: Using green solvents in pharmaceutical manufacturing.

vi. **Life Cycle Assessment (LCA):** Assessing the environmental impacts of products and processes from cradle to grave. Example: Conducting LCA to compare the environmental impact of conventional and green manufacturing processes.

> *"Integrating Green Chemistry principles into Chemical Engineering practices is essential for developing sustainable and environmentally friendly industrial processes."*

## 4.0 EXAMPLES OF GREEN CHEMISTRY IN CHEMICAL ENGINEERING

i. **Biodegradable Plastics:** Production of polylactic acid (PLA) from corn starch, which is biodegradable and compostable. Example: Nature Works' Ingeo biopolymer is used in packaging and textiles.

ii. **Green Solvents:** Using ionic liquids and supercritical $CO_2$ as green solvents in chemical reactions. Example: BASF's use of supercritical $CO_2$ for polymer synthesis.

iii. **Catalytic Converters:** Development of catalytic converters that reduce automotive emissions. Example: Platinum, palladium, and rhodium catalysts in catalytic converters.

iv. **Pharmaceutical Green Chemistry:** Pfizer's development of a green synthesis route for producing the drug sertraline (Zoloft): Example: Reducing the use of hazardous reagents and solvents in drug synthesis.

v. **Bio-based Chemicals:** Production of chemicals like succinic acid from renewable resources. Example: BioAmber's bio-based succinic acid used in resins, coatings and plastics.

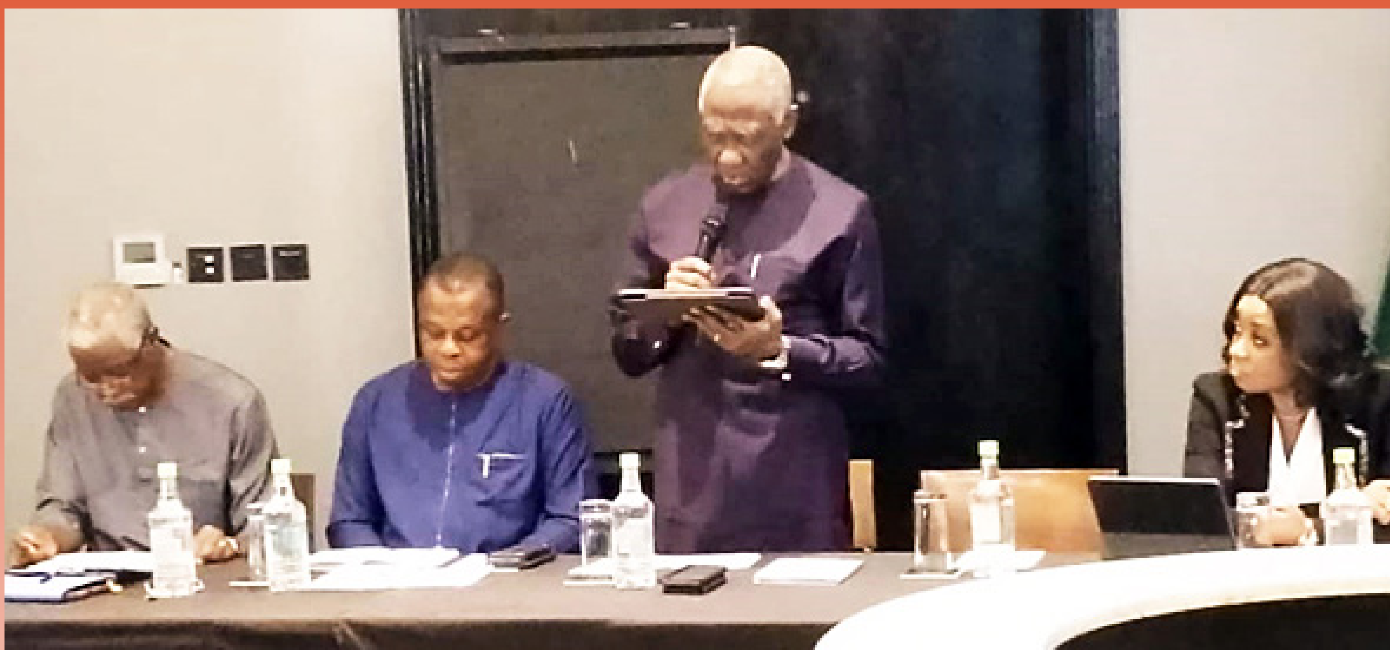
## 5.0 CONCLUSION

Integrating Green Chemistry principles into Chemical Engineering practices is essential for developing sustainable and environmentally friendly industrial processes. By focusing on waste prevention, energy efficiency and the use of renewable resources, Chemical Engineers can contribute to reducing the environmental impact of chemical production and promoting a more sustainable future. Through innovative research and application of Green Chemistry, the field of Chemical Engineering can drive significant advancements in creating safer and more sustainable products and processes.

## NIGERIAN SOCIETY OF CHEMICAL ENGINEERS 32ND FELLOWS' CONFERENCE

# THEME: POWER SECTOR DEVELOPMENT – THE NEXUS BETWEEN INDUSTRIALISATION & ECONOMIC DEVELOPMENT

**VENUE: RADISSON BLU HOTEL, IKEJA | DATE: OCTOBER 10, 2024**



*Engr. Anthony Ogbuigwe, FAEng, FNSChE, FNSE. National President, NSChE, (3rd from L) presenting his Welcome Address, Others are: L – R: Engr. Bayo Olarewaju-Alo (NSChE Deputy National President), Mr. Aigbe Olotu and Mrs. Folake Soetan, Guest Speaker (4th from L).*


*Engr. Anthony Ogheneovo, FNSChE, NSChE Executive Secretary (L) Dr. Mrs. Mojirade Oloruntoba (R) serving as MC at the Confab*

*The Guest Speaker, Mrs. Folake Soetan, CEO, Ikeja Electric Plc, making her presentation*

*Cross section of participants*


*Cross section of participants*

*Mrs. Folake Soetan, CEO, Ikeja Electric Plc, Guest Speaker, displaying her Appreciation Award, presented by Prof. Ayo Ogunye, FAEng, on behalf of NSChE*

*Prof. Ayo Ogunye, FAEng (L) presenting NSChE Appreciation Award to Mr. Aigbe Olotu, Member of the Board of Ikeja Electric and Lapo who received on behave of the Confab Chairman, Mr. Kola Adesina, MFR, the GMD of Sahara Power Group and observed by Engr. Anthony Ogbuigwe (R)*

# Congratulatory Message to
# Engr. Uweh & NSChE

The Management and Staff of Chemsol Nigeria Limited, manufacturers of CRISCO vegetable oil, CRISCO Olein and CRISCO Pure Soya Oil, is using this medium to congratulate and felicitate with Engr. Donatus Uweh on your conferment of Fellowship award by the Nigerian Society of Chemical Engineers (NSChE). This is a testament to your professionalism and unflinching commitment to the field of Chemical Engineering in our nation, Nigeria. May you continue to make giant strides in your chosen profession.

We also felicitate with the Nigerian Society of Chemical Engineers (NSChE) on her 54th International Conference (on the theme: VALUE ENHANCEMENT IN SOLID MINERALS AND AGRO-ALLIED SECTORS FOR INDUSTRIAL DEVELOPMENT) and investiture of fellowship awards to deserving members.

**Engr. Biose Francis C.**
*MD/CEO*
*Chemsol Nigeria*
*(Manufacturers of CRISCO Oil)*

***Engr. Donatus Uweh**, FNSChE*
***(Editor-in-Chief)***

# EXPLORING THE POTENTIAL OF OIL AND GAS AS ENERGY SUPPLY OPTIONS AND THEIR PROSPECTS FOR DEVELOPMENT

***Engr. Dr. Abdulrasheed Babalola,*** *FNSE, FNSChE, FNISafetyE*
*Associate Professor of Chemical Engineering, Federal University of Technology, Ikot Abasi (FUTIA), (Sabbatical Appointment)*

## ABSTRACT

*This paper aims at exploring the potential of oil and gas as energy supply options and their prospects for development. It takes a closer and in-depth look at the current state of the oil and gas industry, its challenges and opportunities, and the potential for growth and development in the future. Through rigorous analysis and research, this paper provides a comprehensive overview of the global energy landscape and the role that oil and gas play in meeting the ever-increasing demand for energy. The tone of this paper is professional, as it seeks to present accurate and objective information on the subject matter. It is a valuable resource for policy makers, industry experts and anyone interested in understanding the complexities of the energy sector and the potential of oil and gas as a viable energy source.*

## 1.0 INTRODUCTION

The oil and gas industry is a major industry in the energy market that plays a crucial role in the global primary fuel sources [1].This oil and gas industry is often referred to as the energy sector and it is vital to global energy supply and the growth of the economy. Investment opportunities in the oil and gas sector can be directly through the purchase of the commodity or indirectly through the purchase of shares in the stock market.

The oil and gas sector includes a broad range of activities and companies responsible for:

- Exploration: Identifying potential oil and gas reserves
- Drilling: Extracting oil and gas from the earth
- Refining: Converting crude oil into usable products.
- Distribution: Transporting and delivering oil and gas to consumers

Nigeria is one of the largest oil producing countries in the world and has a significant impact on the global oil and gas industry. The oil and gas sector in Nigeria still holds promising prospects for the future.

Oil was discovered in Nigeria in 1956 at Oloibiri in the Niger Delta by Shell-BP. The oil and gas industry has undergone a significant transformation since its inception. According to Organization of the Petroleum Exporting Countries (OPEC), Nigeria ranked third (3rd) major oil producer in Africa in 2023. Over the years, oil and gas have been instrumental in fueling the industrial growth, technological advancement and economic development globally.

## 2.0 EXPLORATION AND PRODUCTION TECHNOLOGIES

Innovation and technology are critical components for the sustainability and growth in the oil and gas industry. Some of the technologies available that have revolutionized the oil and gas industry are:

i. **3D and 4D Seismic Imaging:** Utilization of the technology of 3D and 4D Seismic imaging has provided detailed images of subsurface rock formation with the use of sound waves.This technology has enabled companies to carry out target drilling and enhance reduction in exploration costs.

ii. **Unconventional oil and gas extraction:** Unconventional extraction of oil and gas with techniques involving horizontal drilling and hydraulic fracturing, have allowed companies to extract oil and gas reserves in regions that were considered too difficult or expensive to access.

iii. **Robotics and Automation:** The robotics and automation technology is used to automate processes such as drilling and well maintenance in order to improve the exploration and production efficiency in the oil and gas sector. Cost of production is reduced with the implementation of this technology as improvement in safety is sustained.

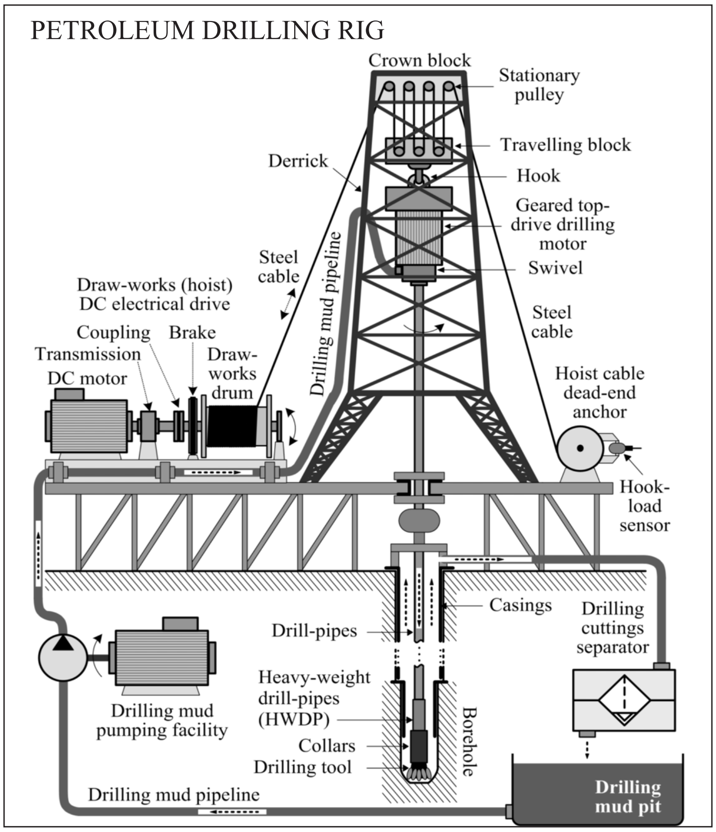



Fig. 1: Petroleum Drilling Rig

iv. **Data Analytics and Artificial Intelligence:** This technology can be used in the oil and gas industry to predict equipment failures and optimize drilling operations through the analyzation of voluminous operations data and provision of insights based on the analyzed data. Decision making and operational efficiency can be improved.

v. **Digital Twining:** This technology involves creating a virtual model of an oil and gas asset such as a well or refinery with the use of advanced softwares. This has enabled the simulation of production processes and the prediction of outcomes as models created as exact replica of the original process.

## 3.0 PETROLEUM DRILLING RIG

Fig. 1 shows a typical petroleum drilling rig.

## 4.0 CRUDE OIL AND PRODUCTS DISTRIBUTION

Fig. 2 shows Crude Oil and Products Distribution

## 5.0 NATURAL GAS PIPELINE DISTRIBUTION

Fig. 3 shows Natural Gas Pipeline Distribution

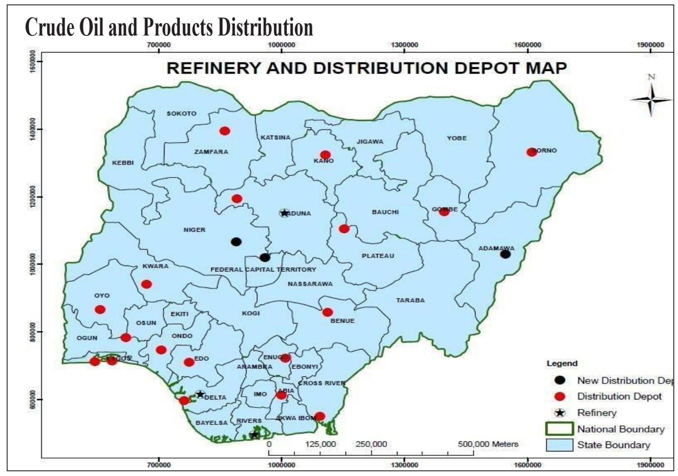



Fig. 2: Crude Oil and Products Distribution

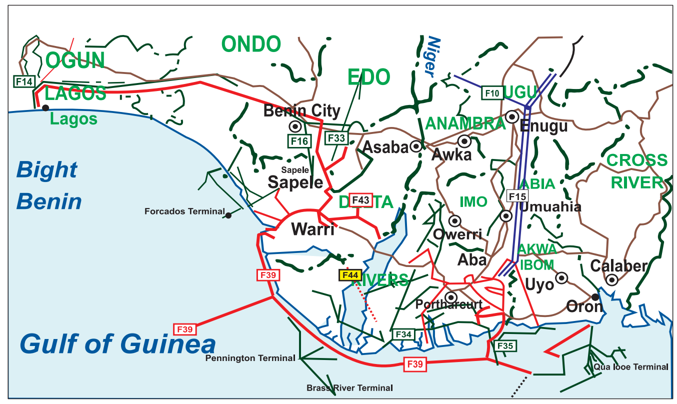



Fig. 3: Natural Gas Pipeline Distribution

## 6.0 CURRENT STATE OF OIL AND GAS RESOURCES IN NIGERIA

i. **Oil Reserves:** Nigeria continues substantial proven oil reserves, primarily in the Niger Delta region. The country is one of the top oil producers in Africa, with estimates of around 37 billion barrels of proven reserves.

ii. **Gas Reserves:** Nigeria holds significant natural gas reserves, making it one of the world's top gas reserves holders. Nigeria's gas reserves is reported to be 209Tcf: Ranks first in Africa and tenth in the world. See Fig. 4.

These reserves are significant for both domestic use and export purposes, contributing to Nigeria's economy and energy sector.

iii. **Oil Production:** Nigeria's oil production declined to 1.23 million barrels per day in March 2024. According to the Organization of the Petroleum

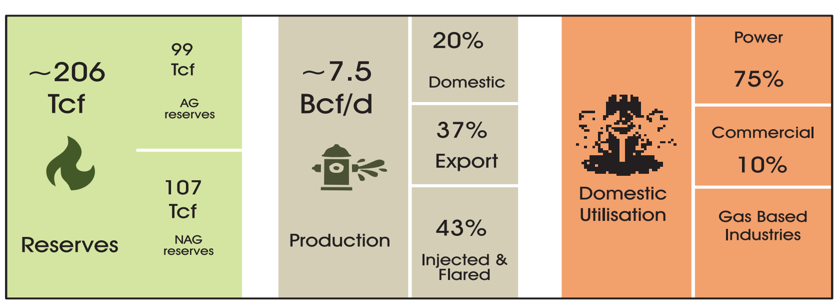



Fig. 4: Nigeria's Natural Gas Reserves.

*"Oil and gas extraction and processing can lead to air and water pollution, oil spills and habitat destruction. These issues can have detrimental effects on local ecosystems and human health."*

Exporting Countries (OPEC), the decline was attributed to oil companies pipeline problems and maintenance [6]. Challenges such as pipeline vandalism, theft and political instability also contributing factors. Nigeria's average oil production dropped to 1.4 million barrels from 1.5 million barrels per day during the second quarter of 2024.

iv. **Gas Production:** Nigeria's gas production is also substantial but underutilized domestically. Most gas production is geared towards exports, especially LNG. The major area where gas is utilized in Nigeria is in power generation which has some hiccups [8].

## 7.0 FUTURE POTENTIAL OF OIL & GAS IN NIGERIA

i. **Reserve Expansion:** There is potential for discovering new reserve through exploration activitiess, particularly in deep-water and offshore areas. Ongoing exploration and advancements in seismic and drilling technology could lead to new discoveries.

ii. **Production Capacity:** With improved infrastructure and investment in technology, Nigeria could increase its oil and gas production capacity. Enhancements in field development and recovery techniques will be critical.

iii. **Gas Utilization:** There is significant potential to boost gas production and utilization domestically. Expanding gas infrastructure and investing in domestic gas-to-power projects could enhance energy security and economic development.

## 8.0 TECHNOLOGICAL AND ENVIRONMENTAL ADVANCES

i. **Sustainability:** Adopting cleaner and more efficient technologies will be crucial as Nigeria navigates global energy transition trends. Investments in technologies such as carbon capture and storage (CCS) could help mitigate environmental impacts.

ii. **Energy Transition:** Nigeria's future oil and gas industry will need to balance traditional fossil fuel production with investments in renewable energy sources. This may involve hybrid energy strategies and diversification into renewable sectors.

## 9.0 ECONOMIC AND POLICY FACTORS

i. **Regulatory Environment:** Effective implementation of regulatory reforms, such as the Petroleum Industry Act (PIA), will be critical in creating a conducive environment for investment and development.

ii. **Global Market Trends:** The global shift towards decarbonization will impact oil and gas demand. Nigeria's ability to adapt to these changes while optimizing its resource base will determine its future role in the global energy market.

iv. **Integrated Approaches:** Governments need to adopt integrated policies that balance economic benefits with environmental protection. This includes designing frameworks that promote sustainable development while supporting economic growth.

v. **Incentives:** Providing incentives for cleaner technologies and sustainable practices can encourage companies to invest in environmentally friendly solutions.

vi. **Stakeholder Engagement:** Engaging with local communities and stakeholders ensures that the benefits of oil and gas projects are shared and environmental concerns are addressed. Community development programs and transparent communication are vital.

vii. **Diversification:** To ensure long-term economic and environmental sustainability, planning for a diversified energy portfolio and investing in future technologies is crucial. This will mitigate the risks associated with fluctuating oil and gas markets and environmental challenges.

viii. **Pollution:** Oil and gas extraction and processing can lead to air and water pollution, oil spills and habitat destruction. These issues can have detrimental effects on local ecosystems and human health.

ix. **Greenhouse Gas Emissions:** Burning fossil fuels contributes to greenhouse gas emissions, which drive climate change. This poses long-term environmental and economic risks.

## 10.0 ADDRESSING ENVIRONMENTAL CONCERNS

i. **Regulations and Standards:** Implementing stringent environmental regulations and standards is crucial for minimizing pollution and ensuring that companies adhere to best practices. This includes regular environmental impact assessments and compliance monitoring.

ii. **Technology and Innovation:** Investing in cleaner technologies, such as carbon capture and storage (CCS) and improving operational efficiencies can help reduce environmental footprints. Innovations in renewable energy integration also contribute to sustainability.

iii. **Corporate Responsibility:** Many oil and gas companies are increasingly focusing on sustainability initiatives, including reducing emissions, managing waste and restoring impacted environments.

v. **Transition to Renewables:** To address long-term environmental goals, integrating renewable energy sources into the energy mix and diversifying beyond fossil fuels is essential. This will help to balance economic benefits with environmental stewardship.

## 11.0 ECONOMIC IMPLICATIONS

i. **Direct Jobs:** The oil and gas industry creates direct employment opportunities in exploration, extraction, refining and distribution. This includes roles in engineering, geoscience, and technical operations. The sector also supports indirect employment in areas such as construction, transportation and services. For instance, supply chain roles, maintenance services and support staff are also integral.

ii. **Economic Multipliers:** The industry's activities can stimulate local economies through spending on goods and services, infrastructure development and community investments.

iii. **Domestic Supply:** For oil-producing countries, maintaining and enhancing production capacity can improve energy security by reducing reliance on imported fuels and stabilizing domestic energy prices.

iv. **Economic Stability:** A strong oil and gas sector can contribute to national revenue and economic stability. This revenue can be used to fund public services and infrastructure development.

v. **Government Revenue:** Oil and gas are major sources of government revenue through taxes, royalties and production sharing agreements. This revenue can support national development projects and social programs.

## 12.0 TECHNOLOGICAL ADVANCEMENTS IN OIL AND GAS PRODUCTION:

i. **Enhanced Oil Recovery (EOR):** Techniques like chemical flooding, thermal recovery and gas injection are being employed to boost extraction from aging oil fields.

ii. **Seismic Imaging and Data Analytics:** Advanced seismic imaging and data analytics technologies are improving the accuracy of subsurface mapping and reservoir management.

iii. **Automation and Digitalization:** The use of automation and digital tools, including real-time monitoring and predictive maintenance, has optimized operations and reduced downtime.

iv. **Floating Production Storage and Offloading (FPSO) Units:** These vessels are being used to exploit deepwater and offshore reserves more efficiently.

v. **Gas Flare Reduction Technologies:** Technologies to capture and utilize flared gas are being implemented to reduce environmental impact and enhance gas utilization.

## 13.0 POLICIES AND REGULATIONS IN OIL AND GAS RESOURCES

i. **Petroleum Industry Act (PIA) 2021:** This comprehensive legislation reforms the sector, aiming to enhance transparency, attract investment, and improve the management of oil and gas resources. It includes provisions for the establishment of regulatory bodies, such as the Nigerian Upstream Regulatory Commission and the Nigerian Midstream and Downstream Petroleum Regulatory Authority. The PIA provides the establishment of Host Communities fund and it comes with an array of innovations that will affect the private, public sectors and stakeholders in the oil and gas industry.

ii. **National Oil and Gas Policy:** This policy outlines the framework for the development of the oil and gas sector, focusing on increasing local content, promoting transparency, and ensuring sustainable practices.

iii. **Local Content Act (NOGICD Act):** The Nigerian Oil and Gas Industry Content Development Act promotes the participation of Nigerian companies and the use of local resources and personnel in the oil and gas sector.

iv. **Environmental Regulations:** The Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN), enforced by the Department of Petroleum Resources (DPR), (succeeded by a new regulator called Nigerian Upstream Petroleum Regulatory Commission, NUPRC), sets standards for environmental protection and waste management.

v. **Gas Flare Commercialization Program (GFCP):** This initiative aims to capture and utilize flared gas, reducing environmental impact and improving gas resource management.

vi. **National Environmental Standards and Regulations Enforcement Agency (NESREA):** NESREA regulates environmental compliance across various sectors, including oil and gas, to ensure sustainable practices.

## 14.0 FUTURE PROSPECT AND VIABILITY OF OIL & GAS IN NIGERIA

i. **Declining Demand:** The shift toward renewable energy sources and increased energy efficiency is likely to reduce global demand for oil and gas over time. This trend is driven by policies aimed at reducing carbon emissions and the growing adoption of electric vehicles.

ii. **Investment in Technology:** Oil and gas companies are investing in technologies like carbon capture and storage (CCS) and low-carbon innovations to mitigate their environmental impact. These technologies could help extend the viability of fossil fuels by addressing some of their sustainability concerns.

iii. **Diversification:** Many oil and gas companies are diversifying their portfolios to include renewable energy projects and green technologies. This transition can provide new revenue streams and align with global sustainability goals.

iv. **Geopolitical Factors:** Oil and gas will continue to play a significant role in global geopolitics, with ongoing investments in exploration and production, particularly in regions where fossil fuels remain a critical part of the economy.

v. **Regulatory Pressure:** Increasing regulatory pressure and carbon pricing mechanisms could impact the profitability and operational viability of oil and gas projects, pushing the industry toward cleaner alternatives.

vi. **Market Dynamics:** Market volatility, driven by geopolitical events, technological advances, and shifts in consumer preferences, will continue to influence the role of oil and gas in the global energy mix

vii. **Offshore Oil & Gas:** Offshore exploration and production, particularly in deepwater regions, have unlocked new opportunities for the oil and gas industry. While these reserves are considerable, their development demands substantial investment and cutting-edge technology.

viii. **Enhanced Oil Recovery (EOR):** can greatly prolong the lifespan of mature fields and increase production by employing techniques such as thermal recovery, gas injection, and chemical flooding. These methods are designed to maximize the extraction of oil from existing reservoirs.

## 15.0 IMPORTANCE OF ENERGY SUPPLY OPTION IN GLOBAL DEVELOPMENT

Various energy supply options are crucial for ensuring the stability and growth of global economies. Diverse energy sources include oil, gas, coal, nuclear provide the necessary flexibility to meet varying energy demands. The various energy sources are vital to transportation, power generation, heating and feedstock for various industrial processes.

*Prospects for development anchor on the following:*

i. **Technological Innovations:** Advancements in technology, such as digital oil fields, automation, and artificial intelligence, are crucial for unlocking new resources, enhancing recovery rates, reducing costs, and improving both efficiency and safety.

ii. **Environmental Considerations:** Addressing greenhouse gas emissions, managing water usage, and preventing spills are critical for sustainable development. Carbon capture and storage, along with cleaner production methods, are key strategies for tackling environmental challenges.

iii. **Investment and Financing:** Securing sufficient

*"The oil and gas sector will continue to play a pivotal role in the global energy landscape for the conceivable future. Although, the industry faces numerous challenges, including environmental concerns and market..."*

investment and financing is essential for the ongoing development of oil and gas projects. Nigeria's offshore deepwater oil fields offer significant investment opportunities, attracting interest from several international oil companies (IOCs).

iv. **Alternative Energy Resources:** Advancement into the search of alternative energy sources for long-term energy participation at the global level.

*Balancing development and sustainability anchor on the following:*

i. **Revenue and Employment:** The oil and gas sector is a major employer in Nigeria, directly and indirectly supporting millions of jobs. It also attracts significant Foreign Direct Investment (FDI), which is crucial for economic development.

ii. **Policies and Regulations:** Nigeria has implemented several policies to promote environmental sustainability, such as the Nigerian Gas Flare Commercialization Program (NGFCP), which aims to reduce gas flaring by converting flared gas into commercial products (Nigerian Ministry of Petroleum Resources).

iii. **International Agreements:** Nigeria is a signatory to the Paris Agreement, committing to reduce greenhouse gas emissions and enhance climate resilience.

## 16.0 CONCLUSION

The oil and gas sector will continue to play a pivotal role in the global energy landscape for the conceivable future. Although, the industry faces numerous challenges, including environmental concerns and market volatility, the potential for technological innovation and sustainable development remains significant. Embracing technological developments in the oil and gas sector will improve efficiency and address environmental impacts. The oil and gas industry can contribute to a balance and secure energy future.

## REFERENCES


[1] N. Burclaff, "Library of Congress," August 2022. [Online]. Available: https://guides.loc.gov/oil-and-gas-industry. [Accessed 27 August 2024].

[2] E. Alagoz, Y. Alghawi and M. S. Ergul, "Innovation in Exploration and Production: How Technology Is Changing the Oil and Gas Landscape," Journal of Energy and Natural Resources, vol. 12, no. 3, pp. 25-29, 2023.

[3] . P. ŠPRLJAN, D. PAVKOVIĆ, . M. CIPEK, . M. KLAIĆ, T. STAROVEŠKI and D. KOLAR, "Automation Systems Design and Laboratory Prototyping Aimed at Mature Petroleum Drilling Rig Retrofitting," Technical Gazette, vol. 27, no. 1, pp. 229-236, 2020.

[4] T. Herbert, O. O. G. and A. T. O, "Mapping and Spatial Distribution of Petroleum Products by Marketers in Nigeria," in 21st Century Human Habitat: Issues, Sustainability and Development, Akure, 2016.

[5] "Nigeria Pipelines map - Crude Oil (petroleum) pipelines - Natural Gas pipelines - Products pipelines," 18 March 2017. [Online]. Available: https://theodora.com/pipelines/nigeria_oil_gas_and_products_pipelines_map.html#map. [Accessed 18 August 2024].

[6] D. Onyango, "Nigeria's Oil Production Drops in March Due to Pipeline Issues and Maintenance," Pipeline Technology Journal, 18 April 2024. [Online]. Available: https://www.pipeline-journal.net/news/nigerias-oil-production-drops-march-due-pipeline-issues-and-maintenance. [Accessed 18 August 2024].

[7] C. Ademola, "Nigeria's average oil production drops to 1.4 million barrels per day in Q2, 2024 – NBS," Nairametrics, 27 August 2024. [Online]. Available: https://nairametrics.com/2024/08/26/nigerias-average-oil-production-drops-to-1-4-million-barrels-per-day-in-q2-2024-nbs/. [Accessed 03 September 2024].

[8] S. A. Olagoke and O. O. Awolola , "Natural Gas Utilization in Nigeria Industries: The Way Forward," in National Engineering Conference of the Nigerian Society of Engineers, Ilorin, 2012.

[9] T. Thompson, "Business Day," 22 June 2023. [Online]. Available: https://businessday.ng/opinion/article/unlocking-nigerias-wealth-and-job-creation-potential-through-gas-exports/. [Accessed 16 September 2024].

[1 0} G. O. Aigbe, L. C. Stringer and M. Cotton, "Gas Flaring in Nigeria: A Multi level Governance and Policy Coherence Analysis," Anthropocene Science, vol. 2, pp. 31-47, 2023.

[11] S. C. Nwokolo, E. . L. Meyer and C. C. Ahia, "Credible Pathways to Catching Up with Climate Goals in Nigeria," Climate, vol. 11, no. 9, pp. 1-32, 2023.

[12] "Oil and Gas Investment FAQs: Indirect vs. Direct Investments," 24 March 2021. [Online]. Available: https://www.dwenergygroup.com/oil-and-gas-investment-faqs-indirect-vs-direct-investments/. [Accessed 27 August 2024].

# A strong player in the Oil & Gas Service Sector

**What WE DO**

- **Oilfield** TREATMENT CHEMICALS
- **COMMODITY** CHEMICALS
- **Lab** SERVICES
- **DELIVERY TANKS** & OILFIELD FACILITY UPGRADES



**GGI Place:**
Plot 8 GGI Crescent
[Opposite Mikab Filling Station]
East/West Road, Rumuodara,
Port Harcourt 500001
Rivers State, Nigeria.

+234 (0) 814 774 0791,
+234 (0) 904 932 4030

ggi_group@yahoo.com,
enquiries@ggigroupltd.com,
www.ggigroupltd.com

**Port Harcourt Facility Annex 1**
Golf Estate Opp. Deeper Life Bible Church
East/West Road, Rumuodara,
Port Harcourt, Rivers State, Nigeria.

**Port Harcourt Facility Annex 2**
GGI Lane, Igwuruta,
Ikwerre LGA, Rivers State, Nigeria.

**Lagos Office:**
6 Ijora Causeway,
Ijora, Lagos State, Nigeria.

+234 (0)817 206 4304

**Eket Office:**
#7 Inyang Udofa Street, Eket,
Akwa Ibom State, Nigeria

+234 (0) 81720634305,
+234(0)8029933955


## GGI INT'L (NIG) LTD

*...Nigerian Coy, global spirit!*

ISO 9001:2015 REGISTERED FIRM — Quality Management Systems
ISO 14001:2015 REGISTERED FIRM — Environmental Management Systems
ISO 45001:2018 REGISTERED FIRM — Health & Safety Management Systems

PETAN
MEMBER OF Port Harcourt Chamber
PIN
NEPC

An ISO 9001:2015, ISO 14001:2015 & ISO 45001:2018 Registered Company and NEPC Export Registered Company with No. 0023869.

# CHEMICAL RECYCLING OF WASTE PET BOTTLES

## 1.0 INTRODUCTION

Polyethylene Terephthalate (PET) offers a variety of advantages that make it one of the most widely used plastics in the packaging industry. Its lightweight, unbreakable nature, resistance to UV rays, excellent gas and water barrier properties, and impact strength make it a preferred choice for packaging beverages like juices and water. PET is also known for its high recyclability and environmental safety compared to other plastics, making it safer and stronger. The high-volume recycling of PET, with a focus on sustainable development, further underlines its environmental advantage.

*Engr. Dr. Edith Alagbe, MNSE, FNSChE*

PET is most commonly used in packaging, particularly for food and beverage containers. PET bottles are extensively used for packaging water, carbonated beverages like Coca-Cola, Sprite, Mountain Dew, and fruit juices. See Fig. 1. PET's applications extend beyond packaging. It is used in making polyester fibers for textiles, which was originally the reason for its development in the 1940s. The durability and versatility of PET also make it suitable for various other uses like packaging consumer goods, healthcare products, and pharmaceuticals.

*Fig. 1: Uses of PET bottles*

**Advantages of PET**

i. Plastic polyethylene terephthalate is widely available and reasonably affordable.
ii. High strength-to-weight ratios can be found in polyethylene terephthalate.
iii. PET is a polymer that has a high level of moisture resistance.
iv. Polyethylene terephthalate has excellent chemical resistance to water and organic substances (it is not biodegradable, which is good and bad, depending on your perspective and its intended use).
v. Polyethylene terephthalate would not shatter like glass packaging, making it practically shatterproof when it falls from a height.
vi. Recycling polyethylene terephthalate is simple. It can be disassembled into its component raw materials and then reconverted back into the original resin through a series of washing procedures.
vii. High transparency can be found in polyethylene terephthalate.

**Disadvantages of PET**

i. Boiling water, alkalis, and powerful bases can all easily influence PET in its amorphous form.
ii. Ketones, chlorinated and aromatic hydrocarbons, diluted acids, base solutions, and high temperatures (>60°C) can all quickly damage it.
iii. Even PET polymers can oxidize. Beer and wine have are known to have a long shelf life and the potential for taste degradation, hence PET bottles are not used for preserving these types of beverages.
iv. Depending on how they are used, the fact that PET polymers cannot biodegrade may or may not be a desirable thing.

## 2.0 MENACE OF WASTE PET BOTTLES ON THE ENVIRONMENT

Due to its many advantages, the use of PET products has increased over the years and has led to a global crisis in waste management, as improper disposal of products has caused significant environmental damage [1]. This problem is further compounded by the primarily single-use nature of the polymer as packages. Like other plastics, PET is a petroleum-based polymer, which means it is non-biodegradable and can persist in the environment for hundreds of years. This characteristic of PET poses a serious challenge for waste management. With global production of plastics rising to 141 million tons in 2015, the volume of PET in landfills has become a significant environmental hazard [2]. While PET does not directly harm the environment due to its stable chemical nature, its accumulation contributes to visual pollution and the risk of physical harm to wildlife [3]. See Fig.2 & Fig. 3.

*Fig. 2: Waste PET bottles in the streets following a flood*

## 3.0 DISPOSAL ROUTES OF WASTE PET BOTTLES

PET is typically disposed of in landfills, incinerated, or recycled. Incineration of PET, while it reduces waste volume, produces harmful emissions such as CO2 and toxic gases, which contribute to air pollution. Landfilling, on the other hand, only delays the environmental impact as PET is non-biodegradable, and its long-term persistence can lead to leaching of harmful substances into the soil and groundwater. In many developing countries where, PET waste is indiscriminately disposed of, they end up in drainages (See Fig. 3) and water

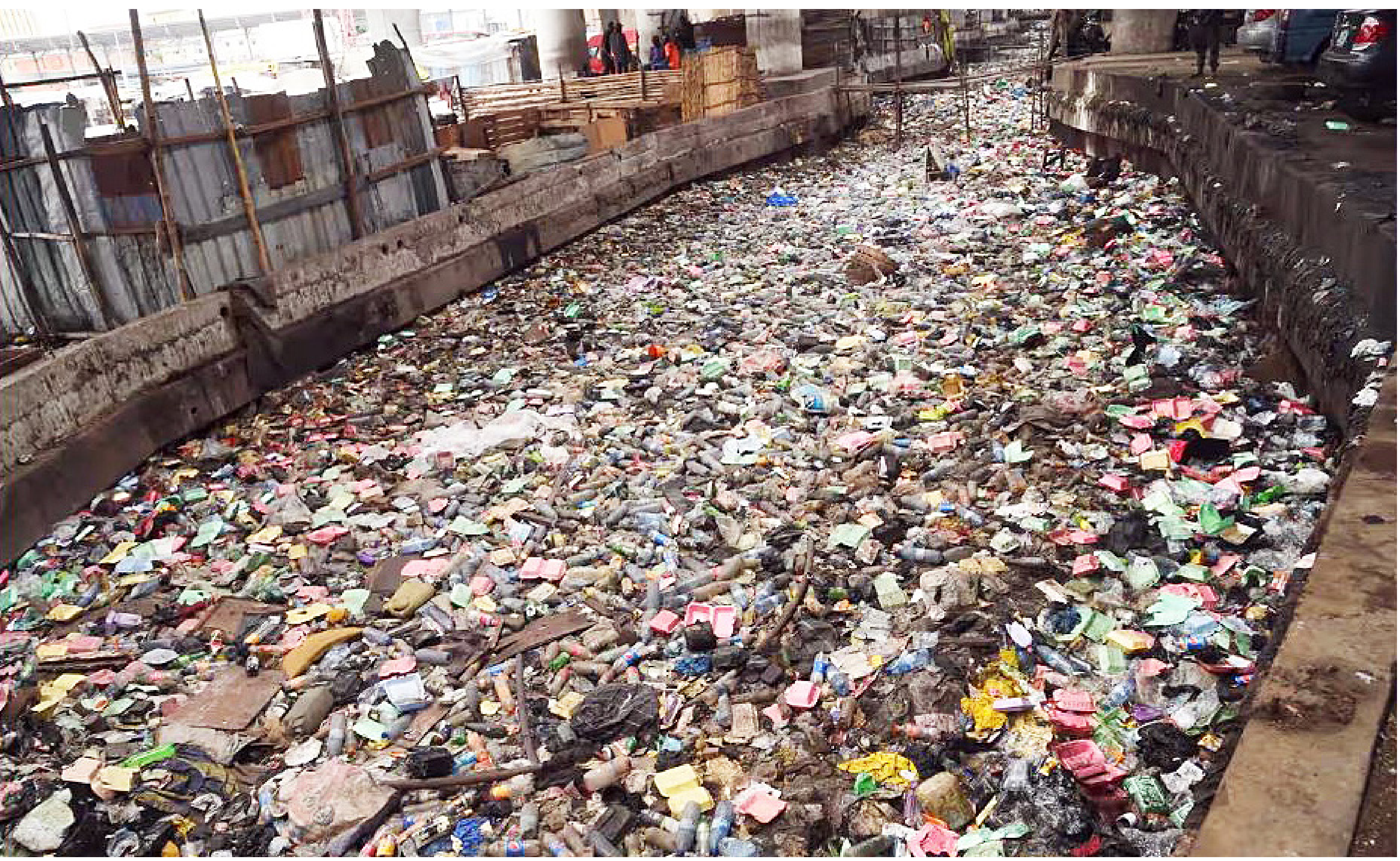


*Fig. 3: Waste PET bottles in a drainage*

*"Unlike many plastics, PET is highly recyclable, offering a path to transform waste into valuable resources."*

bodies like rivers and the seas. These sights are very appalling. Recycling is considered the most environmentally friendly disposal route, particularly chemical recycling, which breaks down PET into its constituent monomers for repolymerization.

## 4.0 RECYCLING OPTIONS FOR PET

Unlike many plastics, PET is highly recyclable, offering a path to transform waste into valuable resources. The growing focus on sustainability has spurred innovative methods to recycle PET, aiming to reduce pollution and close the loop on plastic usage.

There are four main methods of recycling PET: mechanical, chemical, and tertiary recycling. Mechanical recycling involves shredding PET bottles into flakes, which are then cleaned and melted to form new products. Products of this route include bottles, films, and fibres. This recycling route is cost-effective and energy-efficient [4]. Consequently, it contributes minimally to greenhouse gases (GHG). Chemical recycling involves breaking down PET into its monomers for repolymerization and is best aligned with sustainable development. Chemical recycling is a process that yields oligomers and other chemical substances after either complete or partial depolymerization. Post-consumer condensation polymers like polyamides, polyesters, and polyurethanes can be recycled via this route. The primary categories under which PET is chemically recycled include glycolysis, methanolysis, hydrolysis, aminolysis, and ammonolysis [5]. Tertiary recycling, often called energy recovery, involves converting waste PET into fuel or other chemicals through pyrolysis or gasification. Among these, chemical recycling stands out as the method that produces monomers of comparable quality to virgin materials.

## 5.0 CHEMICAL RECYCLING ROUTES

Chemical recycling of PET primarily includes processes like methanolysis, glycolysis, hydrolysis (acid, alkaline, and neutral), aminolysis, and ammonolysis. These processes are favored because they allow the recovered monomers to be re-used in making new PET, maintaining a closed-loop system.

**i. Hydrolysis**

Hydrolysis describes the reaction of an organic compound with water to form two or more new chemicals and refers to breaking chemical bonds by adding water. Hydrolysis for the chemical recycling of PET is becoming increasingly common because it is the only process that produces the reaction products terephthalic acid (TPA) and ethylene glycol (EG), which are the monomers from which PET is generated. The three environments in which hydrolysis can occur are alkaline, acidic, and neutral conditions. The disadvantage of the acidic environment; which uses concentrated sulfuric acid (H2SO4) or other mineral acids, is that using large quantities of concentrated sulfuric acid is expensive. The disadvantage of the neutral environment, which uses water or steam, is that the TPA produced is typically impure. By introducing water between the atoms of a chemical bond, the process of alkaline hydrolysis dissolves the link. Alkaline hydrolysis can be aided by enzymes, metal salts, acids, and bases. Bases are alkali metal hydroxides in water solutions, such as sodium hydroxide (NaOH) and potassium hydroxide. Terephthalic acid is an organic compound primarily used as a precursor to polyester. PET can be used in paint as a carrier and as a raw material to make certain drugs. It can be produced by oxidizing p-xylene with dilute nitric acid; it can also be synthesized in the laboratory by oxidizing a variety of para-disubstituted benzene derivatives, such as caraway oil or a mixture of cymene and cuminol with chromic acid. The most economical method of producing TPA is by depolymerizing PET bottles.

**ii. Methanolysis**

Methanolysis of waste PET bottles involves transesterification, where methanol reacts with PET to produce dimethyl terephthalate (DMT) and ethylene glycol (EG) by breaking ester bonds. Typically, this reaction requires high temperatures (180–280°C) and pressures (20–40 atm) for efficient conversion. Catalysts, such as alkaline compounds (NaOH, KOH), metal oxides (zinc acetate, magnesium oxide), and enzymes (e.g., lipases), improve reaction rates and selectivity. Alkaline catalysts are affordable but can produce by-products, while metal oxides offer higher purity [7]. Enzyme-based catalysts are environmentally friendly, operating under milder conditions, but may lack stability at large scales.

*"Despite its potential, chemical recycling faces several limitations. The processes often require high energy inputs due to the temperatures and pressures..."*

The major products, DMT and EG, are valuable in producing new PET and other industrial uses. The advantages of methanolysis include enabling closed-loop recycling of PET waste and yielding high-purity products comparable to virgin materials. However, the process's high energy demands and potential catalyst disposal issues are notable drawbacks. Methanol's corrosive nature also risks increased maintenance costs. For improvement, research into alternative, stable catalysts and energy-efficient systems, such as heat recovery, could reduce costs and environmental impact. Advanced purification methods, like membrane separation, could improve yields and reduce energy usage. With supportive recycling infrastructure and policies, methanolysis could become an effective strategy for PET waste management.

**iii. Glycolysis**

Glycolysis breaks down PET with ethylene glycol to produce bis(hydroxyethyl) terephthalate (BHET), which can be repolymerized into PET. It involves depolymerizing PET using ethylene glycol or other glycols at 180–240°C temperatures, breaking down the polymer into bis(2-hydroxyethyl) terephthalate (BHET) [8]. Metal acetates (like zinc acetate) and metal oxides (cobalt, manganese) are common catalysts that enhance reaction rates while emerging options like ionic liquids and enzyme-based catalysts offer eco-friendly advantages. The major product, BHET, can be repurposed for new PET production or other polymers [9]. Glycolysis enables high-purity BHET production under relatively mild conditions, supporting closed-loop PET recycling. However, catalyst costs and complex product separation are notable limitations. Improved catalyst research, energy-efficient systems, and advanced separation techniques could increase process efficiency. Supportive policies for recycling infrastructure would also encourage broader adoption. These enhancements could make glycolysis a more effective method for PET waste recycling and resource recovery.

**iv. Aminolysis**

Aminolysis of PET is a chemical recycling process in which amines, such as ethylenediamine, react with PET to break its ester bonds and form valuable amide-based compounds. This nucleophilic substitution reaction typically occurs under moderate temperatures (120–200°C) and slightly elevated pressures, with reaction times between 2–6 hours depending on the amine and catalyst used [10]. Metal complexes, like cobalt and zinc acetates, and organic bases, such as triethylamine, are common catalysts that enhance reaction rates and improve product yields. Ionic liquids have also emerged as effective catalysts, enabling reactions at lower temperatures and reducing unwanted by-products [5]. The main aminolysis product is terephthalamide derivatives, which have various industrial applications in polymers, coatings, and adhesives.

The advantages of aminolysis include the production of versatile amide-based compounds, lower energy requirements compared to other methods, and the use of non-toxic amines and ionic liquids, which reduce environmental impact. However, the process has some limitations, such as the high cost of certain catalysts and the challenges involved in separating and purifying the products [11]. Additionally, the quality and reactivity of the amine can significantly influence the yield and quality of the final product. Improvements in aminolysis could focus on developing affordable and recyclable catalysts, integrating energy-saving systems, and refining separation techniques to enhance product purity. Supportive policies and recycling infrastructure could also promote the large-scale adoption of aminolysis as a sustainable method for PET recycling.

## 6.0 LIMITATIONS OF CHEMICAL RECYCLING

Despite its potential, chemical recycling faces several limitations. The processes often require high energy inputs due to the temperatures and pressures needed, making them costly. For instance, methanolysis operates at temperatures of 180-280°C and 20-40 atm pressures. The environmental impact of the chemicals used is also a concern, as some processes, such as pyrolysis, release toxic emissions. Separating the chemical by-products and purifying the recovered monomers can be challenging and expensive.

*"To mitigate the environmental impact of PET, it is recommended that recycling systems, particularly chemical recycling technologies, be improved to lower energy consumption and minimize emissions."*

## 7.0 ENVIRONMENTAL CONCERNS FOLLOWING THE CHEMICAL RECYCLING OF WASTE PET

The environmental concerns surrounding chemical recycling include releasing toxic substances, especially when high temperatures and pressures are used [13]. Pyrolysis, a common chemical recycling method, generates emissions that include CO2, methane, ethylene, and other gases that contribute to climate change. Furthermore, chemical recycling processes can have a significant carbon footprint due to the energy-intensive nature of the operations [14]. Despite producing valuable raw materials, the environmental benefits of chemical recycling are often overshadowed by its resource and energy demands.

## 8.0 CONCLUSION

PET is an invaluable material due to its advantageous properties like durability, recyclability, and lightweight nature, making it indispensable for packaging. However, its contribution to plastic waste and environmental harm is significant. Among the different recycling methods, chemical recycling offers the most promise for sustainable development as it returns PET to its original monomers, maintaining material quality. Nonetheless, challenges such as high energy consumption and environmental impact through emissions pose considerable barriers. More research and innovation are needed to make chemical recycling a more viable and environmentally friendly solution.

## 9.0 RECOMMENDATION

To mitigate the environmental impact of PET, it is recommended that recycling systems, particularly chemical recycling technologies, be improved to lower energy consumption and minimize emissions. Developing new catalysts that can operate under milder conditions could also help make chemical recycling more sustainable. Governments and industries should also incentivize the recycling of PET bottles and packaging to ensure a higher recycling rate and reduce landfill waste.

## REFERENCES


1. *Joseph, T. M., Azat, S., Ahmadi, Z., Jazani, O. M., Esmaeili, A., Kianfar, E., ... & Thomas, S., "Polyethylene terephthalate (PET) recycling: a review," Case Studies in Chemical and Environmental Engineering, p. 100673, 2024.*
2. *Olanrewaju, O. O., & Oyebade, D., "Environmental menace of plastic waste in Nigeria: Challenges, policies and technological efforts," In World Environmental Conservation Conference, pp. 322-333, 2019.*
3. *Elehinafe, F. B., Komolafe, T. C., Beture, O. C., & Babalola, O. A., "Waste Polyethylene Terephthalate Packaging Materials in Developing countries–Sources, Adverse Effects, and Management," Ecological Engineering & Environmental Technology, p. 22., 2021.*
4. *C. Jehanno, J.W. Alty, M. Roosen, S. De Meester, A.P. Dove, E.Y.-X. Chen, F.A. Leibfarth, H. Sardon, "Critical advances and future opportunities in upcycling commodity polymers," Nature, vol. 603, pp. 803-814, 2022.*
5. *Lee, H. L., Chiu, C. W., & Lee, T., "Engineering terephthalic acid product from recycling of PET bottles waste for downstream operations," Chemical Engineering Journal Advances, vol. 5, 2021a.*
6. *Kandasamy, S., Subramaniyan, A., Ramasamy, G., Ahamed, A. R., Manickam, N., & Dhandapani, B., "Study of alkaline hydrolysis of post consumed polyethylene terephthalate waste," AIP Conference Proceedings, vol. 2240, no. 1, 2020.*
7. *Tollini, F., Brivio, L., Innocenti, P., Sponchioni, M., & Moscatelli, D., "Influence of the catalytic system on the methanolysis of polyethylene terephthalate at mild conditions: A systematic investigation," Chemical Engineering Science, vol. 260, p. 117875., 2022.*
8. *Alagbe, E., Ayoola, A., Shokunbi, A., & Agboola, O., "GLYCOLYSIS OF WASTE PET BOTTLES USING ETHYLENE GLYCOL AS A SOLVENT AND A CALCINED SNAIL SHELL AS A CATALYST," Journal of Southwest Jiaotong University, vol. 58, no. 3, 2023.*
9. *Chen, X., Cheng, L., Gu, J., Yuan, H., & Chen, Y., "Chemical recycling of plastic wastes via homogeneous catalysis: A review," Chemical Engineering Journal, p. 147853, 2023.*
10. *Barnard, E., Arias, J. J. R., & Thielemans, W., "Chemolytic depolymerisation of PET: a review," Green Chemistry, vol. 23, no. 11, pp. 3765-3789., 2021.*
11. *Gupta, P., & Bhandari, S., "Chemical depolymerization of PET bottles via ammonolysis and aminolysis. In Recycling of polyethylene terephthalate bottles," pp. 109-134, 2019.*
12. *Laldinpuii, Z. T., Khiangte, V., Lalhmangaihzuala, S., Lalmuanpuia, C., Pachuau, Z., Lalhriatpuia, C., & Vanlaldinpuia, K., "Methanolysis of PET waste using heterogeneous catalyst of bio-waste origin," Journal of Polymers and the Environment, pp. 1-15., 2022.*
13. *Thiounn, T., & Smith, R. C., "Advances and approaches for chemical recycling of plastic waste," Journal of Polymer Science, vol. 58, no. 10, pp. 1347-1364., 2020.*
14. *Sinha, V., Patel, M. R., & Patel, J. V., "PET waste management by chemical recycling: a review," Journal of Polymers and the Environment, vol. 18, no. 1, pp. 8-25., 2010.*

# MORPOL Engineering Services Limited

NIS ISO 9001:2015 CERTIFIED COMPANY

NATIONAL CERTIFICATION SCHEME

MORPOL Engineering Services Limited is a maintenance and construction engineering Service Company doing business primarily in the oil & gas, power generation and waste & water treatment industries in Nigeria.

## EXECUTED AND ON-GOING PROJECTS

### OUR SERVICES:

- Engineering Procurement
- General Engineering Maintenance/Calibration Services
- Equipment Overhaul
- Tank Refurbishment, Rehabilitation & Construction
- EPC Pipeline Construction
- Plant Refurbishment, Rehabilitation
- Installation of New Equipment and Facilities
- Commissioning and Training
- Project Supervision and Management

### CONTACT US:

**Lagos Office:**
4 Warehouse Road
P.O.Box 187, Apapa, Lagos
Tel: +234-803-3023017
+234-807-0446060

**Port Harcourt:**
Plot 40 Wopara Street
Rumuobiokani, Port Harcourt,
Rivers State.
Tel: +234-84-750237, 0803-3023051
Email: morpolph@morpol.net

**Bayelsa Base:**
MORPOL Camp
SHELL LNG Road
Obunagha/Yenogoa

**Abuja Area Office:**
No.5 Leribe Close, Off Kolda Link
(Behind Oceanic Bakery), Wuse II, Abuja
Tel: +234-8023271735, 0803-4503387

# FINANCIAL AND ENVIRONMENTAL GAINS IN ENERGY-EFFICIENT MANUFACTURING

*Engr. Olanrewaju B. Adebayo,* *MNSChE, MNSE, AMIChemE, AIChE, AMNIM (Founder & CEO, Olanab Consulting Limited)*

## 1.0 INTRODUCTION

The manufacturing sector plays a crucial role in the global economy, producing goods and materials essential for daily life. However, this sector is also a significant contributor to energy consumption and environmental pollution. With increasing regulatory pressures, rising energy costs and growing consumer demand for sustainable products, energy-efficient manufacturing has emerged as a vital strategy for businesses. By optimizing energy use, manufacturers can achieve substantial financial savings while also reducing their environmental impact.

This article explores in details important financial and environmental gains of energy-efficient manufacturing, highlights key strategies for achieving these gains and illustrates 5 case studies of energy-efficient manufacturing systems.

## 2.0 FINANCIAL GAINS FROM ENERGY-EFFICIENT MANUFACTURING

By optimizing energy use, companies can significantly reduce operating costs, enhance productivity, and improve their environmental footprint. Beyond the immediate cost savings, energy-efficient manufacturing also offers long-term financial benefits, such as reduced maintenance expenses, increased asset value, and access to government incentives.

This approach not only strengthens a company's financial performance but also positions it as a leader in sustainability, driving competitive advantage in the market. Energy-efficient manufacturing yields substantial financial benefits for companies in the following ways:

i. **Reduced Energy Costs**
- Lower Utility Bills: By using less energy, companies can significantly cut their electricity, gas and water bills. This is one of the most immediate financial benefits of energy efficiency.
- Improved Energy Pricing: Energy-efficient processes may allow companies to negotiate better energy rates or take advantage of incentive programs for energy conservation.

ii. **Increased Operational Efficiency**
- Enhanced Process Performance: Energy-efficient systems often lead to improved overall process performance and productivity, which can translate into higher output and reduced operational costs.
- Reduced Downtime: Energy-efficient equipment tends to be more reliable and requires less maintenance, leading to fewer disruptions and decreased costs associated with equipment downtime.

iii. **Extended Equipment Life**
- Lower Maintenance Costs: Energy-efficient equipment typically experiences less wear and tear, resulting in reduced maintenance and repair costs.
- Prolonged Asset Life: By operating more efficiently, equipment and machinery can last longer, delaying the need for expensive replacements and capital expenditures.

iv. **Enhanced Profit Margins**
- Lower Production Costs: Reduced energy consumption lowers the overall cost of production, which can improve profit margins and make the company more competitive in the market.

*"With increasing regulatory pressures, rising energy costs...manufacturing has emerged as a vital strategy for businesses."*

*"Energy-efficient manufacturing is not only a powerful tool for boosting profitability but also a key driver of environmental sustainability."*

- Cost Savings from Waste Reduction: Efficient processes generate less waste, reducing disposal costs and the financial burden associated with handling and managing waste materials.

**v. Increased Competitiveness**

- Market Advantage: Companies that adopt energy-efficient practices can position themselves as environmentally responsible and innovative, which can enhance their brand image and attract customers who prioritize sustainability.
- Improved Compliance: Energy efficiency can help companies stay ahead of regulatory requirements and avoid potential fines or penalties associated with non-compliance.

**vi. Access to Financial Incentives**

- Government Grants and Subsidies: Many governments offer financial incentives, grants or subsidies for implementing energy-efficient technologies and practices, which can offset initial investment costs.
- Tax Benefits: Companies may be eligible for tax credits or deductions related to energy-efficient investments, further reducing the financial burden.

**vii. Lower Capital Costs**

- Reduced Energy Infrastructure Needs: Energy-efficient processes may reduce the need for large-scale energy infrastructure investments, such as additional power generation or cooling systems.
- Decreased Financing Costs: Improved financial performance and reduced operational costs can enhance a company's creditworthiness, potentially lowering the cost of financing for future projects.

**viii. Enhanced Return on Investment (ROI)**

- Faster Payback Periods: The cost savings from reduced energy consumption can result in shorter payback periods for energy-efficient investments, making them financially attractive.
- Higher Long-Term Returns: Energy-efficient projects often provide long-term financial benefits through sustained cost savings and improved operational efficiency.

**ix. Reduced Operational Risks**

- Mitigation of Energy Price Volatility: By reducing overall energy consumption, companies can lessen their exposure to fluctuations in energy prices and reduce financial risk.
- Resilience against Supply Disruptions: Energy-efficient processes can make operations more resilient to energy supply disruptions or changes in energy regulations.

**x. Improved Financial Performance and Valuation**

- Positive Impact on Financial Metrics: Energy efficiency improvements can enhance key financial metrics such as profit margins, return on assets and earnings before interest, taxes, depreciation and amortization (EBITDA).
- Increased Company Valuation: Strong financial performance resulting from energy efficiency can lead to a higher company valuation, benefiting shareholders and investors.

## 3.0 ENVIRONMENTAL GAINS FROM ENERGY-EFFICIENT MANUFACTURING

Energy-efficient manufacturing is not only a powerful tool for boosting profitability but also a key driver of environmental sustainability. By reducing energy consumption, manufacturers can significantly lower greenhouse gas emissions, minimize waste and decrease the environmental impact of their operations. This shift towards energy efficiency supports global efforts to combat climate change and promotes the responsible use of natural resources.

Furthermore, adopting energy-efficient practices can lead to cleaner production processes, less pollution and a smaller carbon footprint, ultimately contributing to the preservation of ecosystems and improving public health. Embracing energy-efficient manufacturing is a critical step for companies aiming to balance economic growth with environmental stewardship, ensuring a sustainable future for both industry and the planet.

Energy-efficient manufacturing offers significant

*Fig. 1: Effect of greenhouse gas emissions on process facilities & the environment*

environmental benefits by optimizing the use of energy within industrial processes. Here are some key environmental gains:

**i. Reduction in Greenhouse Gas Emissions**

- Lower $CO_2$ Emissions: Energy-efficient process engineering reduces the consumption of fossil fuels, directly leading to lower carbon dioxide ($CO_2$) emissions. This is crucial for mitigating global climate change. See Fig. 1.
- Decreased Emissions of Other Greenhouse Gases: Besides $CO_2$, energy efficiency can also reduce emissions of methane ($CH_4$) and nitrous oxide ($N_2O$), both potent greenhouse gases with a higher global warming potential.

**ii. Minimized Air Pollution**

- Reduced Pollutant Emissions: Efficient energy use leads to lower emissions of air pollutants such as sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM). These pollutants are major contributors to air quality issues like smog and acid rain.
- Cleaner Production Processes: Energy-efficient processes often involve cleaner technologies that emit fewer volatile organic compounds (VOCs) and other hazardous air pollutants, improving overall air quality.

**iii. Conservation of Natural Resources**

- Lower Resource Consumption: By optimizing energy use, processes consumer lower natural resources such as coal, oil, natural gas and water. This conservation helps preserve these resources for future generations and reduces environmental degradation.
- Efficient Use of Raw Materials: Energy-efficient process engineering often leads to more efficient use of raw materials, reducing waste and the environmental impact associated with resource extraction and processing.

**iv. Reduced Water Usage and Pollution**

- Decreased Cooling Water Demand: Energy-efficient processes typically generate less waste heat, which reduces cooling water needs. This lowers water consumption and the potential for thermal pollution in nearby water bodies.
- Improved Water Quality: By reducing energy use and optimizing processes, there is often less wastewater generated, and the water that is used is less likely to be contaminated with harmful chemicals, reducing the risk of water pollution.

**v. Waste Minimization**

- Lower Generation of Industrial Waste: Energy-efficient processes tend to produce less waste, including hazardous waste and by-products, which decrease the environmental burden of waste disposal.
- Increased Recycling and Reuse: Efficient processes are often designed to recover and reuse energy, materials and by-products, reducing the amount of waste sent to landfills and promoting a circular economy.

**vi. Reduction in Environmental Degradation**

- Minimized Land Degradation: Reduced energy demand leads to less extraction of raw materials, decreasing the environmental impact of mining, drilling and deforestation activities.
- Preservation of Ecosystems: By consuming fewer resources and generating less waste,

*"Energy-efficient process engineering reduces the consumption of fossil fuels, directly leading to lower carbon dioxide ($CO_2$) emissions."*

*Fig. 2: Environmental damage caused by emission of effluent gases*

energy-efficient process engineering helps protect ecosystems and maintain biodiversity. See Fig. 2.

**vii. Lowered Impact on Climate Change**

- Reduced Global Warming Potential: By minimizing the emissions of greenhouse gases and other pollutants, energy-efficient process engineering reduces the global warming potential of industrial activities, contributing to climate stability.
- Positive Environmental Feedback: Energy efficiency often leads to further innovations and optimizations, creating a desirable cycle of environmental improvements and reduced climate impact.

**viii. Enhanced Energy Efficiency of Products**

- Sustainable Product Life Cycles: Energy-efficient processes contribute to the sustainability of products throughout their life cycle, reducing the environmental impact from production to disposal.
- Lower Embodied Energy in Products: Products manufactured using energy-efficient processes have a lower embodied energy, meaning they require less energy to produce, which reduces their overall environmental footprint.

**ix. Promotion of Renewable Energy Integration**

- Facilitates the Use of Renewables: Energy-efficient processes often require less energy, making it easier to meet energy needs with renewable sources like solar, wind and bioenergy. This further reduces reliance on fossil fuels and decreases environmental impact.
- Support for De-carbonization: By reducing energy consumption, energy-efficient process engineering aligns with broader efforts to decarbonize industrial sectors, supporting a transition to a low-carbon economy.

**x. Improved Sustainability and Corporate Responsibility**

- Enhanced Corporate Sustainability: Companies that implement energy-efficient process engineering demonstrate a commitment to sustainability, which can improve their reputation and align with environmental, social and governance (ESG) goals.
- Contribution to Global Environmental Goals: Energy-efficient processes contribute to achieving international environmental goals, such as those outlined in the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), particularly in areas related to climate action, responsible consumption and production.

## 4.0 STRATEGIES FOR ACHIEVING ENERGY EFFICIENCY IN MANUFACTURING

In the face of rising energy costs and increasing environmental regulations, manufacturers are under growing pressure to optimize their energy use. The strategies for achieving this objective are outlined below:

**i. Process Optimization**

- Heat Integration: Use pinch analysis to identify opportunities for heat recovery and

*"Replace old, inefficient pumps, compressors and heat exchangers with modern, energy-efficient models."*

reuse within the process. This can significantly reduce the need for external heating and cooling.

- Advanced Process Control (APC): Implement APC systems to fine-tune process parameters in real time, thereby reducing energy consumption while maintaining product quality.
- Process Intensification: Redesign processes to achieve the same output with less energy by using novel equipment or methods (e.g., reactive distillation, membrane reactors).

**ii. Equipment Efficiency**

- Upgrade to High-Efficiency Equipment: Replace old, inefficient pumps, compressors and heat exchangers with modern, energy-efficient models.
- Variable Speed Drives (VSDs): Install VSDs on motors to adjust speed based on demand, reducing energy use during low-load periods.
- Regular Maintenance: Ensure all sets of equipment are well-maintained to operate at optimal efficiency, thereby avoiding energy waste due to wear and tear.

**iii. Energy Recovery and Recycling**

- Waste Heat Recovery: Capture and reuse waste heat from processes for preheating feedstocks or generating steam.
- Cogeneration: Implement combined heat and power (CHP) systems to generate electricity and useful heat simultaneously, thereby improving overall energy utilization.
- Energy Recycling: Identify streams that can be recycled back into the process or used in other operations to reduce the need for fresh energy inputs.

**iv. Process Design and Retrofit**

- Minimize Energy-Intensive Steps: Design processes to minimize or eliminate the most energy-intensive steps, possibly by integrating alternative technologies.
- Modular Design: Use modular process units that can be operated at optimum conditions and easily scaled up or down based on demand.
- Retrofitting Existing Plants: Analyze existing plants for retrofit opportunities where newer, more energy-efficient technologies can be implemented without complete overhauls.

**v. Insulation and Heat Loss Prevention**

- Improve Insulation: Upgrade insulation on pipes, vessels and other equipment to reduce heat losses.
- Prevent Heat Loss in Fluid Transport: Use insulated or heat-traced piping for transporting fluids at high or low temperatures to minimize heat loss or gain.

**vi. Energy Monitoring and Management**

- Energy Audits: Conduct regular energy audits to identify areas where energy is being wasted and implement corrective actions.
- Energy Management Systems (EMS): Implement EMS to monitor and control energy use across the plant, thereby optimizing consumption patterns.
- Real-Time Monitoring: Utilize sensors and IoT devices for real-time monitoring of energy use, thereby enabling quick adjustments to maintain efficiency.

**vii. Sustainable Energy Sources**

- Renewable Energy Integration: Where feasible, integrate renewable energy sources like solar, wind or biomass into the process to reduce dependency on fossil fuels.
- Energy Storage Solutions: Implement energy storage systems to capture excess energy for later use, thereby smoothing out demand and reducing peak energy consumption.

**viii. Process and Material Substitution**

- Use of Alternative Feedstocks: Opt for feedstocks that require less energy to process, such as those with higher yields or lower impurity levels.
- Process Substitution: Replace energy-intensive processes with less energy-demanding alternatives, such as using membrane separation instead of distillation where appropriate.

**ix. Training and Culture**

- Employee Training: Regularly train operators and engineers on energy-efficient practices and the importance of energy conservation.
- Energy Efficiency Culture: Foster a culture of energy efficiency across the organization and

Fig. 3: Process data documentation for benchmarking against industry best practice.

encourage all employees to identify and report energy-saving opportunities.

x. **Benchmarking and Continuous Improvement**
   - Benchmarking Against Best Practices: Compare your plant's energy performance against industry benchmarks to identify gaps and areas for improvement. See Fig. 3.
   - Continuous Improvement Programs: Implement programs like Six Sigma or Lean Manufacturing to continually seek out and eliminate sources of energy inefficiency.

## 5.0 CASE STUDIES IN ENERGY-EFFICIENT MANUFACTURING

### 5.1 BASF: ENERGY EFFICIENCY IN STEAM CRACKER OPERATIONS

Background: BASF is one of the largest chemical companies globally, operates steam crackers that are integral to producing basic chemicals. These processes are highly energy-intensive, consuming significant amounts of energy to break down hydrocarbons into smaller molecules.

i. **Energy Efficiency Measures**
   - Process Optimization: BASF implemented advanced process control and optimization techniques to monitor and adjust the operating conditions in real time, thereby maximizing efficiency.
   - Heat Recovery Systems: BASF installed sophisticated heat recovery systems to capture and reuse heat from various stages of the steam cracking process.
   - Energy Monitoring: BASF employed state-of-the-art energy monitoring and management systems to track energy consumption and identify inefficiencies.

ii. **Results**
   - BASF achieved a reduction of over 20% in energy consumption per ton of product in its steam cracker operations.
   - The energy savings resulted in a significant reduction in operating costs and lowered $CO_2$ emissions by approximately 300,000 tons annually.

### 5.2 DOW CHEMICAL: IMPROVING ENERGY EFFICIENCY IN ETHYLENE OXIDE PRODUCTION

Background: Dow Chemical is a global leader in the chemical industry. The company focused on improving the energy efficiency of its ethylene oxide production process, which is energy-intensive and critical for producing various chemical intermediates.

i. **Energy Efficiency Measures**
   - Catalyst Optimization: Dow improved the efficiency of the catalysts used in the ethylene oxide reactors, thereby reducing the energy required for the reaction.
   - Process Intensification: The company implemented process intensification techniques, such as the use of high-performance heat exchangers and more efficient distillation columns, to minimize energy consumption.
   - Steam System Optimization: Dow optimized its steam systems to reduce energy losses and recover waste heat for reuse in other parts of the plant.

ii. **Results**
   - Dow reduced its energy consumption by 15% in ethylene oxide production, leading to cost savings of millions of dollars annually.
   - The improvements also reduced greenhouse gas emissions by over 150,000 tons per year.

### 5.3 SABIC: ENERGY EFFICIENCY IN POLYETHYLENE PRODUCTION

Background: SABIC is a global chemical manufacturing company. It sought to enhance the energy efficiency of its polyethylene production plants. Polyethylene production involves complex chemical reactions and large-scale polymerization processes that consume significant energy.

*Fig. 4: An energy recovery system*

**i. Energy Efficiency Measures**

- Advanced Process Control: SABIC implemented advanced process control systems to optimize the polymerization process, thereby reducing energy use while maintaining product quality.
- Energy Recovery: SABIC installed energy recovery systems to capture and reuse energy from exothermic reactions and other heat sources in the plant. See Fig. 4.
- Energy Audits and Retrofits: SABIC conducted comprehensive energy audits across its polyethylene plants, thereby identifying opportunities for retrofitting equipment with more energy-efficient alternatives.

**ii. Results**

- SABIC achieved a 10% reduction in energy consumption per ton of polyethylene produced.
- The energy efficiency improvements contributed to a substantial reduction in operating costs and a decrease in $CO_2$ emissions by approximately 200,000 tons annually.

## 5.4 SHELL: ENERGY EFFICIENCY IN HYDROGEN PRODUCTION

Background: Shell, a major player in the oil and gas industry, focused on improving energy efficiency in its hydrogen production processes. Hydrogen production is energy-intensive, particularly when using steam methane reforming (SMR), the most common method.

**i. Energy Efficiency Measures**

- Heat Integration: Shell optimized the heat integration within the SMR process, capturing and reusing waste heat to reduce the overall energy demand.
- Catalyst Improvements: The company developed and implemented more efficient catalysts that required lower operating temperatures and reduced energy consumption.
- Carbon Capture and Utilization (CCU): Shell integrated CCU technologies into its hydrogen production process to capture $CO_2$ emissions and utilize them in other industrial applications, reducing the overall carbon footprint.

*"Shell, a major player in the oil and gas industry, focused on improving energy efficiency in its hydrogen production processes. Hydrogen production is energy-intensive, particularly when using steam methane reforming (SMR), the most common method."*

*Energy-efficient manufacturing*

**ii. Results**

- Shell reduced energy consumption by 12% in its hydrogen production units, leading to significant cost savings.
- The implementation of CCU technology also reduced Shell's carbon emissions by over 1 million tons annually.

## 5.5 LYONDELLBASELL: ENERGY EFFICIENCY IN PROPYLENE OXIDE-STYRENE MONOMER PRODUCTION

Background: LyondellBasell, a leading multinational chemical company, targeted energy efficiency improvements in its propylene oxide-styrene monomer (POSM) production process. The POSM process is energy-intensive, requiring high temperatures and pressures.

**i. Energy Efficiency Measures**

- Process Integration: LyondellBasell implemented process integration techniques to optimize heat transfer between different units in the POSM plant, thereby reducing the need for external energy inputs.
- Advanced Insulation: The company upgraded insulation across critical process equipment, thereby minimizing heat losses and enhancing overall energy efficiency.
- Energy Management Systems: LyondellBasell deployed energy management systems to monitor and optimize energy use continuously, ensuring that the plant operated at peak efficiency.

**ii. Results**

- The energy efficiency measures led to a 15% reduction in energy consumption per ton of POSM produced.
- The improvements also resulted in a decrease in $CO_2$ emissions by approximately 250,000 tons annually, thereby contributing to the company's sustainability goals.

## 6.0 CONCLUSION

Energy-efficient manufacturing is a win-win proposition, offering significant financial and environmental gains. By reducing energy consumption, manufacturers can lower operational costs, improve equipment longevity, and gain a competitive advantage. Simultaneously, these practices contribute to the reduction of greenhouse gas emissions, conservation of natural resources and improved air and water quality. As the industrial landscape continues to evolve, the adoption of energy-efficient practices will be essential for companies seeking to thrive in an increasingly sustainability-focused world.

## REFERENCES


1. *Becis Incorporated, 2023. 9 Efficient Energy Tips for Manufacturing Facilities, https://be-cis.com/manufacturing-facilities-energy-tip/*
2. *CTI Controltech Industrial Combustion and Process Control Blog, 2024. https://blog.cti-ct.com/2016/05/boiler-efficiency-small-gains-can-bring.html*
3. *Energy Audit Electrical And Thermal, Location: Local Area, https://www.indiamart.com/proddetail/energy-audit-electrical-and-thermal-6974096062.html*
4. *Energy Audit, 2023. https://powerconsult.lk/energy-audit/*
5. *Mandatory Energy Audit, For Industrial, https://www.indiamart.com/proddetail/mandatory-energy-audit-2849597117788.html*
6. *Ortea Next, 2023. Energy efficiency in production plants, https://www.orteanext.com/energy-efficiency/energy-efficiency-in-production-plants/*
7. *Plastic 101, 2024. Recycling 101: Energy Recovery Technologies, https://thisisplastics.com/environment/recycling-101-energy-recovery-technologies/*
8. *Roland Berger, 2019. Energy efficiency services: a key market in the European industrial landscape. https://www.rolandberger.com/en/Insights/Publications/Energy-efficiency-services-a-key-market-in-the-European-industrial-landscape.html*
9. *Trent Hawkins, 2018. What to do after an Energy Audit. https://www.linkedin.com/pulse/what-do-after-energy-audit-trent-hawkins*

# ACTOLOG Solutions Limited

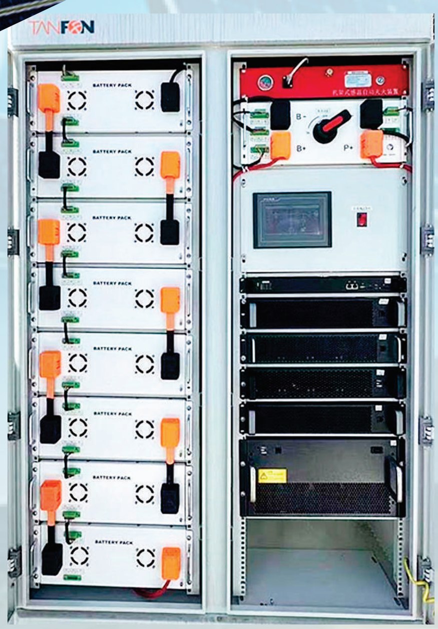
**Tel:** 01-342 7334, 0906 283 0781, 0906 283 0786-8, 0906 283 0785
**E-mail:** info@actolog.com, actologng@gmail.com
**Website:** www.actolog.com

**LAGOS**
1B, Owolegbe Street
Aturase Estate, Gbagada

**PORT-HARCOURT:**
22, Dan-Petals Plaza, Ada
George Road, Mgbuoba

**ABUJA**
De Avalon Plaza, Suit 003,
Plot 483, Ajose Adeogun
Crescent, Utako District

# INTEGRATED RENEWABLE ENERGY SOLUTION (IRES)



*•Our commercial Lithium-ion Energy Storage Module can be placed in parallel or cascade to achieve up to mini-grids of 10MWH*

## Our solution provides IRES Energy from four sources, viz:

- High quality Solar power through photovoltaics (PV) panels
- Renewable energy storage (lithium-ion, VRLA, Gel) battery system
- Public utility (grid) power supply
- Power generators

## Our UPS series: 10 - 1,000KVA Performance features

- True 3-level rectifier & inverter technology
- Ultra-High Energy Efficiency
- Full rated power factor KW = KVA

## Our Clients

*For more information about*

## ACTOLOG'S POWER SOLUTIONS

*visit our Website at*
**www.actolog.com or contact our business team at business@actolog.com.**

Explore our case studies and discover how we can help your business achieve operational efficiency & reliability