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MAGAZINE

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Perspectives On The Nigerian Industrial Solvents Market

Dr. John Erinne

Overall Equipment Effectiveness (OEE)

Engr. Olanrewaju Bamidele

APPLICATION OF ARTIFICIAL INTELLIGENCE IN PETROLEUM PRODUCTION

ISSN 2714-2256

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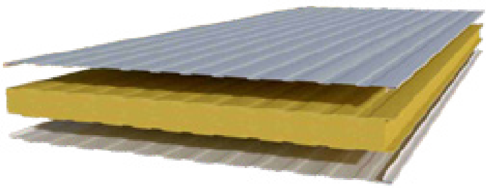

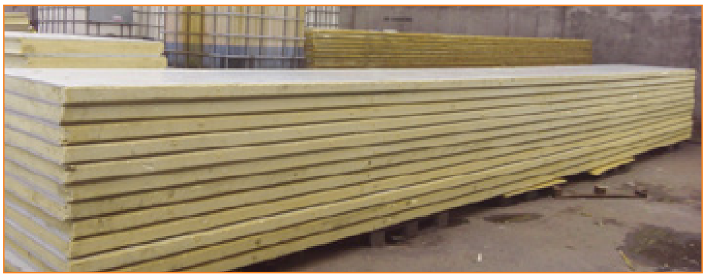

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NSChE VISION

"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".

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FROM THE Editorial SUITE

It is exciting for us to bring to our teeming readers this edition of NSCHE magazine which carries a compendium of lucid presentations.

Our magazine has continued to feature among those in the top-tier class in engineering media. We urge you to continue to be a committed reader of all editions when they are released to the public.

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

In the first presentation, Engr. Anthony Ogheneovo, FNSChE, Executive Secretary of Nigerian Society of Chemical Engineers (NSChE) elucidates on the benefits of joining NSChE.

That precisely means registering as a member of NSChE in any of the categories of membership depending on the qualification of the applicant. Standing alone as a practising Chemical Engineer is not the same as coming into a national umbrella professional body such as the NSChE. The benefits are enormous. Take time and read what the Executive Secretary is sharing.

This edition also carries memorable pictures of visits made to a destitute home as part of corporate social responsibility of NSChE as well as visits to cement companies and some past presidents of NSChE. View the pictures to note the details.

Another presentation is from Ms. Caroline Esiaba on "Application of Artificial Intelligence in Petroleum Production Engineering". Ms. Esiaba is a well-versed data scientist. She currently serves as the Business Development Operation Specialist in Caterpillar Inc., USA. Her presentation shows that advance in ICT research and application, particularly in the area of Artificial Intelligence (AI), is paying off in the upstream subsector of the Petroleum Industry.

Engr. (Dr.) John Erinne, FAEng, FNSE, FNSChE, Managing Consultant, Chex & Associates, brings to the fore a review and analysis of the market on industrial solvents. Entrepreneurs, key players in the Chemical Process Industry, Food/Beverage Industry including the Fuel subsector will find this presentation very educative.

This edition also carries an article on "Overall Equipment Effectiveness in Process Operation" by Engr. Olanrewaju Adebayo Bamidele, Principal Consultants, Olanab Consults.

"...magazine has continued to feature among those in the top-tier class in engineering media. We urge you to continue to be a committed reader..."

It is one thing for factories to run equipment and it is yet another thing to know if the operation of each equipment is effective. Engr. Bamidele shares knowledge in this critical area of factory operation.

Finally, we do appreciate all those who have made various contributions leading to the successful publication of this edition.

Enjoy your reading.

Engr. Donatus Uweh, MNSChE
(Editor-in-Chief)

BENEFITS OF JOINING THE NIGERIAN SOCIETY OF CHEMICAL ENGINEERS

Engr. Anthony Ogheneovo, _FNSChE_
(Executive Secretary, NSChE)

"Overall, joining a professional association can be a valuable investment in one's career..."

Joining a professional association can offer numerous benefits for individuals in their respective fields. These benefits can vary depending on the specific association and industry, but some common advantages include:

1. Networking opportunities: Professional associations provide a platform for members to network with peers, experts, and potential employers or clients. Building a strong professional network can lead to new job opportunities, partnerships, and collaborations.
2. Professional development: Associations often offer workshops, conferences, seminars, webinars, and training programs that help members enhance their skills and stay updated on the latest trends and advancements in their industry.
3. Access to resources: Many associations offer exclusive access to valuable resources such as research papers, industry publications, best practices, and tools that can aid in career growth and decision-making.
4. Advocacy and representation: Professional associations often advocate for the interests of their members on various issues related to their field. They may lobby for favorable policies, standards, or regulations that can benefit the profession as a whole.
5. Credibility and recognition: Membership in a reputable professional association can enhance an individual's credibility and reputation within their industry. It signals a commitment to the profession's ethical standards and continuous learning.
6. Mentorship opportunities: Some associations have mentorship programs where experienced members can guide and support younger or less experienced professionals, fostering career development.
7. Job opportunities: Many associations have job boards or career centres where members can find job postings specifically targeted at their industry or profession.
8. Awards and recognition: Some associations offer awards and honours to recognize outstanding achievements and contributions of their members, providing further recognition within the industry.
9. Discounts and benefits: Associations may offer members discounts on products, services, or events related to their profession. These savings can help offset the cost of membership.
10. Continuing education credits: Certain professions require ongoing education to maintain certifications or licenses. Some associations offer accredited courses that allow members to earn continuing education credits conveniently.
11. Industry updates and news: Associations often keep members informed about industry news, developments, and relevant changes in regulations or standards.
12. Community and support: Being part of an association creates a sense of belonging to a community of like-minded professionals, allowing for peer support and camaraderie.

Overall, joining a professional association can be a valuable investment in one's career, providing a range of opportunities for growth, networking, and staying current in a dynamic professional landscape.

Please log in to www.nsche.org and become a member.

PHOTOS OF NSCHE'S EVENT

NSChE Executive Secretary and his team members visit to Chemical Engineers working with Lagos State Government, Alausa, Ikeja Lagos State.

Celebration of the 92nd birthday of Past President Pa Anthony Shobo in the company of some NSChE board members, some exco of Lagos/Ogun states chapter and some NSChE national secretariat personnel.

Picture of Director, Mrs. Alice Okoliko and pupils at Centre of Destitute Empowerment International, Idimu, Lagos, with NSChE team during NSChE Water treatment commissioning.

Courtesy visit by the National Secretariat staff to past president, Chief JJ Apieye.

Courtesy visit of NSChE President, Engr. Anthony Ogbuigwe (5th from right) and his team to FIIRO Director General, Dr. (Mrs.) Adamu Tutuwa (4th from right) in Oshodi, Lagos.

Courtesy visit by NSChE Executive Secretary, Engineer Ogheneovo Anthony, FNSChE (2nd right) to the HOD of Chemical Engineering Department of the University of Lagos, Dr. (Mrs) Faith Babalola (2nd left).

Water Treatment Commissioning —Borehole water purification, treatment.

NSChE National Secretariat Courtesy visit to Dangote Cement, Ogun State. Led by Engr. Anthony Ogheneovo, Executive secretary with some Chemical Engineers working in Dangote cement .

NSChE National Secretariat Courtesy visit to Lafarge Cement, Ogun State.

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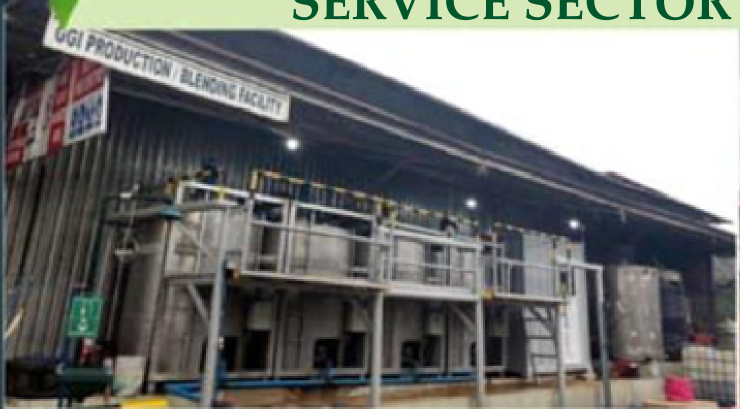

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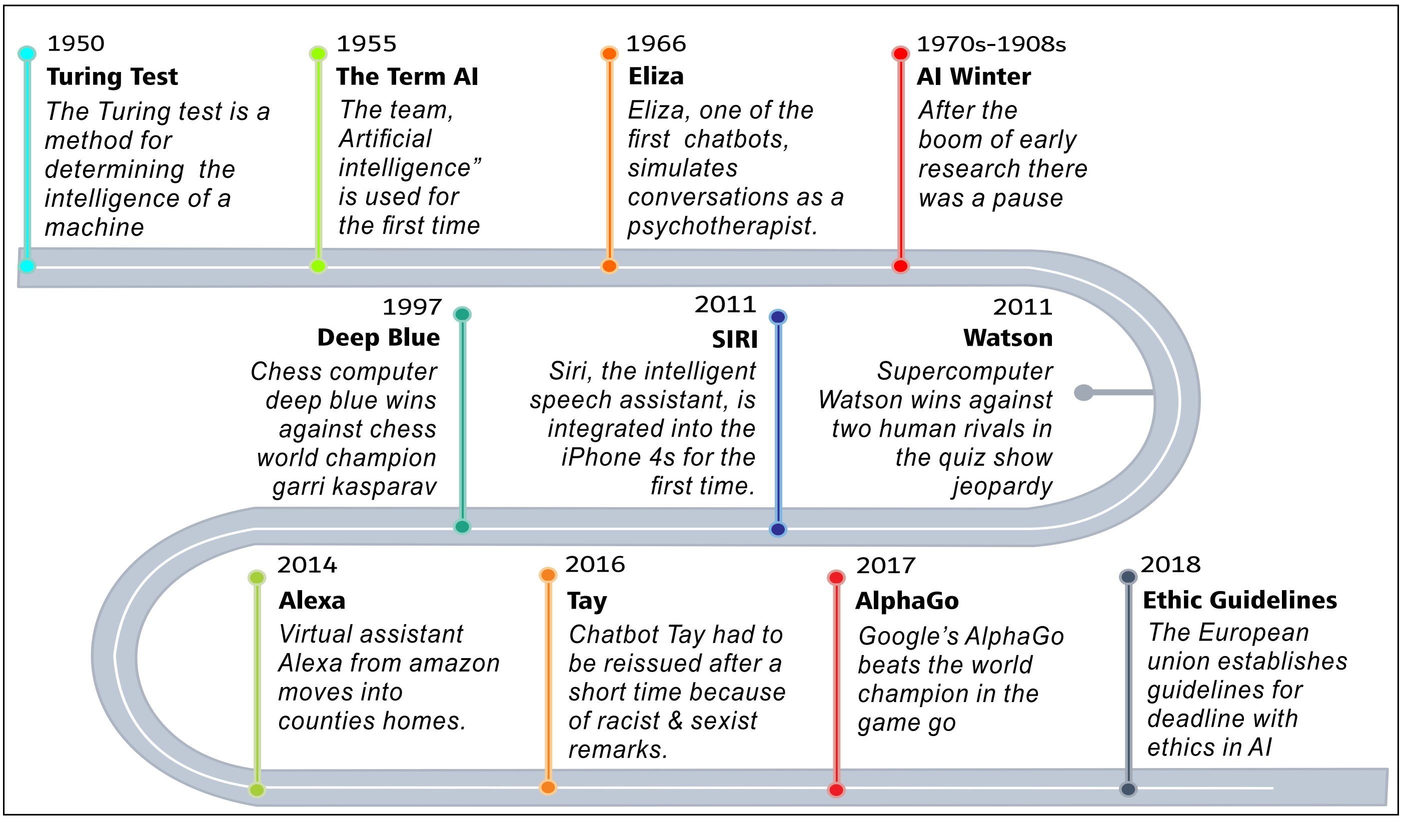
APPLICATION OF ARTIFICIAL INTELLIGENCE IN PETROLEUM PRODUCTION ENGINEERING

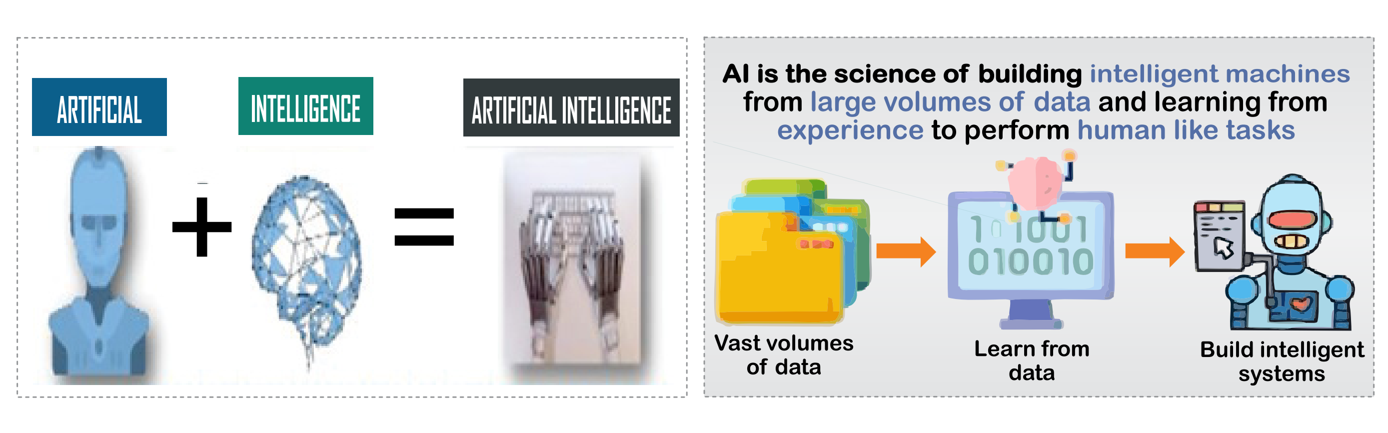
Ms. Caroline Esiaba
(Data Scientist/Business Development Operation Specialist, Caterpillar Inc., USA)

1.0 INTRODUCTION

Artificial Intelligence (AI) has become an important tool in many industries, including petroleum production engineering. The petroleum industry is increasingly adopting AI to enhance its exploration, drilling, and production operations. AI is used to analyze data from various sources and provide insights that enable oil and gas companies to optimize production, reduce costs and improve safety. This paper explores the application of AI in petroleum production engineering, focusing on its benefits, challenges and future prospects. Traditional upstream petroleum production engineering faced challenges such as declining reservoir pressure, aging infrastructure, formation damage, water production, environmental impact, limited data availability, high operational costs and shortage of human experts. These have resulted to low recovery rates, high costs of production, safety issues amongst others. It is worth noting that in the past, petroleum engineers had to rely on their experience and expertise to interpret data and make decisions about how to optimize their operations. In this modern age, embracing digitalization, collaboration and the emergence of AI have provided new tools and techniques to address these challenges. Engineers can now analyze vast amounts of data from multiple sources, including sensors, logs and production databases, to identify patterns leading to more informed decisions. With AI, the industry can make more accurate predictions, improve decision making, optimize production processes, increase efficiency and reduce risks and costs. Although AI is not a silver bullet and has limitations, its use has enabled more efficient and effective upstream petroleum production operations.

2.0 HISTORY OF ARTIFICIAL INTELLIGENCE





3.0 WHAT IS ARTIFICIAL INTELLIGENCE?

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to perform tasks that would normally require human intelligence to complete. In other words, AI is the ability of computers and machines to exhibit human-like cognitive functions, such as learning, reasoning, problem-solving, perception, natural language processing and decision-making.

3.1 SUBSETS OF ARTIFICIAL INTELLIGENCE

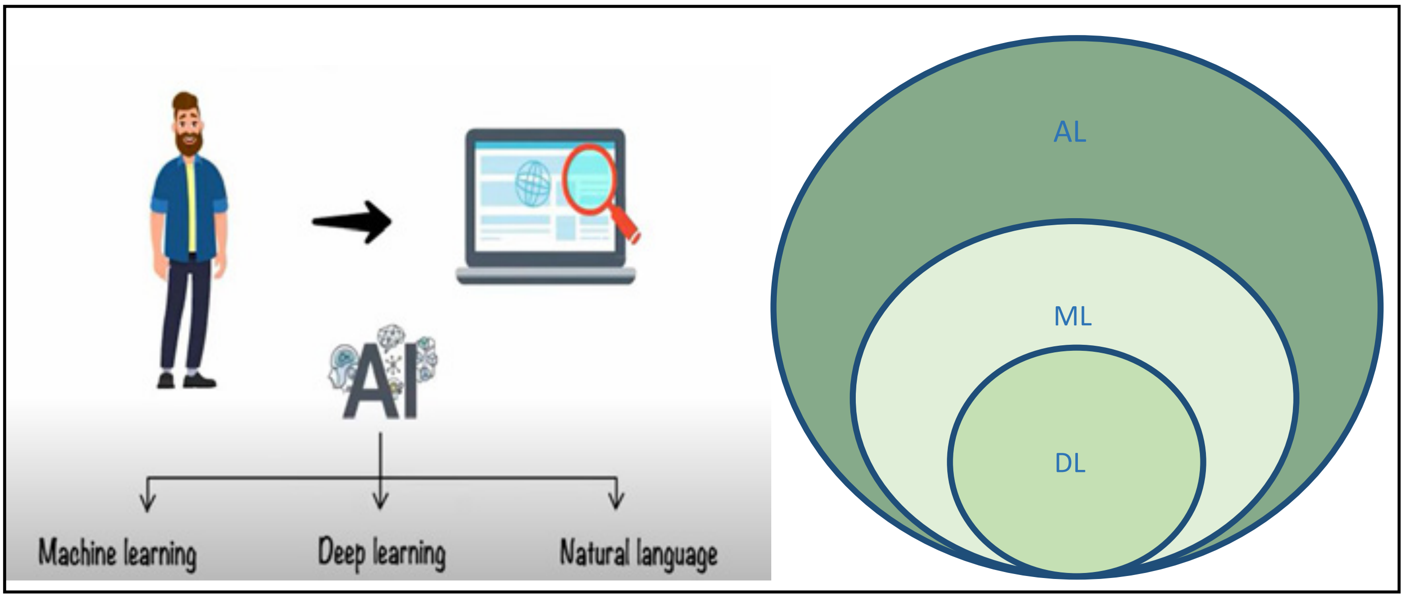
You need Machine Learning Algorithms and Deep Learning to build Artificial Intelligent Systems.

Artificial Intelligence (AI) is a special kind of computer program that helps machines do things that normally only humans can do, like thinking, learning and making decisions. It is like a brain for a machine. Just like how you learn from your experiences, AI can learn from data and experiences too. It uses what it learns to help solve problems or make predictions. It is worth noting that Neflix, voice assistance, Tesla, ChatGPT use AI. The relevance of AI in the petroleum industry lies in its ability to provide insights and solutions that were previously unavailable. AI can help the industry to reduce the risks associated with exploration, increase the efficiency of production operations and improve the overall safety and sustainability of the industry.

In what follows, the subsets of AI are presented.

i. **Machine Learning (ML):** Machine learning (ML) is a subset of artificial intelligence (AI) that focuses on the development of algorithms and statistical models that enable machines to improve their performance on a specific task through experience. In other words, machine learning algorithms are designed to learn from data, identify patterns and make predictions or decisions.

In the context of AI, machine learning is an important tool for creating intelligent systems that can perceive their environment, reason about it and make decisions based on data. By leveraging machine learning techniques, AI systems can learn to perform complex tasks with a level of accuracy and speed that would



"Deep learning is a type of machine learning that uses artificial neural networks..."

be impossible to achieve through traditional programming methods alone.

ii. **Deep Learning:** Deep learning is a type of machine learning that uses artificial neural networks which are modeled after the way human brain works to learn from data. Just like the human brain has many interconnected neurons that work together to process information, deep learning models have many layers of interconnected artificial neurons that have the ability to learn and recognize patterns and relationships in data. The "deep" in deep learning refers to the fact that these neural networks have many layers, which allow them to learn complex patterns in the data.

iii. **Natural Language Processing (NLP):** Natural language processing (NLP) is a type of artificial intelligence that deals with the interactions between computers and human languages, such as English, Spanish, Chinese and many others. NLP allows computers to understand, interpret and generate human language. This is useful in many applications, such as chatbots, speech recognition, machine translation and text analysis

3.2 TYPES OF ARTIFICIAL INTELLIGENCE

i. **Artificial Narrow Intelligence (ANI):** Artificial Narrow Intelligence (ANI) refers to artificial intelligence that is designed to perform a specific task or set of tasks and is not capable of generalizing beyond those tasks. ANI can be found in many common applications such as virtual assistants, image recognition software and self-driving cars. We are in the era of Artificial Narrow Intelligence.

ii. **Artificial General Intelligence (AGI):** Artificial General Intelligence refers to an artificial intelligence system that has the ability to learn and reason in any intellectual domain, much like a human being. Unlike ANI, which is designed to perform specific tasks, AGI has the ability to adapt to new situations, learn from experience and reason about problems and concepts that it has not encountered before. The goal of AGI is to create an artificial intelligence system that is capable of performing any intellectual task that a human being can do, including recognizing and interpreting visual and auditory information and reasoning about abstract concepts. AGI is also capable of self-improvement, meaning it can learn to become better and more efficient at its tasks over time.

iii. **Artificial Super Intelligence (ASI):** An Artificial Super Intelligence system would be able to surpass all human intelligence. This would include decision making, taking rational decisions and includes things like making better art and building emotional relationships. ASI is often depicted in science fiction as a future where machines become self-aware and are capable of autonomous decision-making, posing both opportunities and risks for humanity. However, ASI is still a theoretical concept as at now.

4.0 KEY COMPONENTS OF AI

i. Algorithms: These are like recipes that tell the computer what to do. Algorithms are a set of steps that the computer follows to solve a problem or complete a task.

ii. Data: This is the information that the computer uses to learn and make decisions. Just like how you learn from your experiences, AI can learn from data and experiences too.

iii. Machine Learning: It involves the ability of an AI system to learn from data and improve its performance over time.

iv. Neural networks: These are like a computer's brain. Neural networks are made up of lots of small parts that work together to process information and make decisions. They are based on how the human brain works.

4.1 TYPES OF AI USED IN UPSTREAM PETROLEUM PRODUCTION ENGINEERING

i. **Machine Learning:** It involves the ability of an AI system to learn from data and improve its performance over time. Supervised machine learning is a type of machine learning in which an algorithm is trained on a labeled dataset to make predictions or decisions. The term "supervised" refers to the fact that the training data is accompanied by labels or target values that indicate the correct output for each input. Unsupervised machine learning is a type of machine learning in which an algorithm is trained on an unlabeled dataset to identify patterns or structure in the data without specific guidance or labeled examples. The goal of unsupervised learning is to discover hidden relationships and structures within the data, which can then be used to gain insights, perform data compression or reduce dimensionality or identify anomalies.

ii. **Reinforcement Learning (RL):** This is a type of machine learning in which an agent learns to make decisions by interacting with an environment and receiving feedback in the form of rewards or punishments. The goal of reinforcement learning is to develop a policy or set of rules that maximizes the cumulative reward over time. In reinforcement learning, the agent takes actions in an environment and the environment responds with a reward signal that indicates how well the agent is performing the task. Imagine you are playing a game and you get points for doing well. You'll try to do better and better to get more points.

iii. **Deep Learning:** It is a subset of machine learning that uses deep neural networks to learn from large amounts of data.

iv. **Natural Language Processing (NLP):** NLP is a science of reading, understanding, interpreting a language by a machine. Once a machine understands what the user intends to communicate, it responds accordingly. Computer vision algorithms try to understand an image by breaking down an image and studying different parts of the objects. This helps the machine classify and learn from a set of images, to make a better output decision based on previous observations. It involves the ability of an AI system to interpret and analyze visual information from images, videos, and other forms of visual data. Cognitive computing algorithms try to mimic a human brain by analyzing text/speech/images/objects in a manner that a human does and tries to give the desired output.

5.0 HOW ARTIFICIAL INTELLIGENCE WORKS

i. **Business needs:** AI is conceived to work to solve business problems to meet the business needs.

"The goal of unsupervised learning is to discover hidden relationships and structures..."

ii. **Data:** Data is a key component of an AI project, as AI systems rely on data to learn and make predictions or decisions. In the context of AI, data refers to any information or input that is used to train or test an AI system. Data can come from a variety of sources, including structured data, unstructured data, big data and real-time data

iii. **Modelling:** This is the process of creating a simplified version of a real-world system using mathematics or computer programming. In AI, we use different types of models like statistical, machine learning and neural network models to predict or control complex systems. To do this, we train these models on large amounts of data and use them to make decisions or predictions about new data. For example, we can use a predictive model to estimate future sales based on past sales data or a decision-making model to determine the best course of action in a specific situation. Modeling is essential to develop many AI applications, such as image recognition or natural language processing.

iii. **Model Evaluation:** This is the process of testing how well a trained AI model performs on new data that it has not seen before. It helps us to know if the model can work well on new problems and to compare different models to choose the best one. We use different metrics like accuracy, precision, recall, F1-score, and AUC-ROC to evaluate the model, depending on the type of problem we want to solve. We compare the model's predictions with the actual outputs in the new dataset to calculate these metrics. This helps us to understand how well the model matches the correct outputs and to identify any weaknesses or limitations of the model.

iv. **Model Deployment:** Model deployment in AI involves making a trained model available for use in the real world. It requires moving the model from the development environment to the production environment, where it can make predictions or decisions on new data. The purpose of model deployment is to integrate the model into real-world applications and ensure it meets performance requirements.

There are several steps involved in model deployment. These include:

a. Converting the model: The trained model must be converted into a format that can be used by the deployment environment for efficient use on the deployment platform.
b. Integrating the model: The model must be integrated into the deployment environment, which may involve integrating it into an application or web service or deploying it to a cloud computing platform.
c. Testing the model: The model must be thoroughly tested to ensure that it is performing accurately and efficiently in the deployment environment and to identify any potential issues or bugs.
d. Scaling the model: Depending on the application and the volume of data being processed, the model may need to be scaled up or down to ensure that it can handle the workload effectively.
e. Prediction and Optimization: Prediction and optimization are two fundamental concepts in artificial intelligence that are often used together to solve a wide range of problems.

Prediction refers to the process of using a trained model to make predictions or decisions on new data. This involves feeding input data into the model and using its algorithms to generate output data. For example, a machine learning model could be trained on historical sales data to predict future sales trends or on medical images to predict the likelihood of a particular disease.

Optimization, on the other hand, refers to the process of finding the best solution to a particular problem, given certain constraints or objectives.

6.0 DATA IN UPSTREAM OIL & GAS

Hard Data/constraints: Data that are derived from the lab or field:

- Well Logs (hard data)
- Geology & Characterization
- Porosity (porosity distribution is usually obtained through geo-statistic and is not hard constrain)
- Permeability
- Seismic
- Operational data
- Type of additives (solvents, chemical)
- Real time drilling, Distributed Acoustic Sensing (DAS), Bottomhole Pressure (BHP) in time
- Equipment failures
- Laboratory data
- Special Core Analysis (SCAL), Pressure Volume Temperature (PVT), Rock Mechanics (Triaxial data)

7.0 APPLICATIONS OF AI IN UPSTREAM PETROLEUM PRODUCTION ENGINEERING

i. **Production Optimization:** It analyzes data from various sources, such as well logs, reservoir models and production records which help engineers identify opportunities for improving well performance and increasing production rates. AI can be used to optimize production rates and maximize recovery from reservoirs. This can be achieved by training machine learning models to analyze real-time data from production systems, identify trends and patterns, and make recommendations for optimizing production. AI-based production optimization can improve efficiency, reduce costs and increase overall recovery rates.

ii. **Reservoir Modeling and Simulation:** AI can be used to build accurate reservoir models and simulations to predict future production rates and optimize production strategies. Machine learning algorithms can be used to analyze historical production data, geological data, and other relevant information to build accurate reservoir models that can be used to simulate various production scenarios.

"AI can be used to build accurate reservoir models and simulations to predict future production rates..."

iii. **Well Drilling and Completion Optimization:** AI can be used to optimize the drilling and completion of wells, which can help reduce costs and improve production rates. By analyzing geological data, well logs, and other relevant information, machine learning algorithms can be used to identify optimal drilling locations and completion strategies

iv. **Predictive Maintenance:** AI can be used to predict equipment failures before they occur, allowing for proactive maintenance and reducing downtime. By analyzing data from sensors and other monitoring systems, machine learning models can be trained to identify patterns and anomalies that indicate potential equipment failures.

v. **Safety and Risk Management:** AI can be used to monitor safety conditions in real-time and identify potential hazards before they become a safety issue. By analyzing data from sensors and other monitoring systems, machine learning models can be trained to identify patterns and anomalies that indicate potential safety hazards.

vi. **Real Time Monitoring and Control:** Used to monitor reservoir performance and identify potential issues, such as water breakthrough or gas coning, in real-time.

vii. **Well Placement Optimization:** Once the reservoir model has been created, AI algorithms can be used to optimize the placement of new wells. This involves analyzing the data to determine the optimal location, direction, and depth for new wells in order to maximize production and minimize costs

8.0 RECENT ADVANCES IN ARTIFICIAL INTELLIGENCES IN OIL AND GAS

i. **Optimize drilling operations - Chevron's**

Chevron developed a machine learning algorithm that used historical drilling data to predict the best way to drill a well. The algorithm analyzed data such as drilling speed, weight on the bit, and rotary speed, and used that information to make predictions about the optimal drilling parameters for the next well. Chevron was able to reduce the time required to drill a well by up to 20%, resulting in significant cost savings. ExxonMobil's use of AI for predictive maintenance.

ii. **Equipment Monitoring- ExxonMobil**

ExxonMobil developed an AI-based system that monitors the performance of critical equipment such as compressors and turbines and predicts when maintenance is needed. The system uses machine learning algorithms to analyze real-time data from sensors installed on the equipment, and then provides maintenance recommendations to operators. ExxonMobil has reported a 20% reduction in maintenance costs and a 15% improvement in equipment availability. BP's use of AI for reservoir characterization.

iii. **Predictive maintenance - SHELL**

Shell developed an AI-based system that predicts when equipment is likely to fail and provides recommendations for maintenance. The system uses machine learning algorithms to analyze real-time data from sensors installed on equipment, such as compressors and turbines. By predicting when maintenance is needed, Shell has been able to reduce unplanned downtime and improve equipment reliability.

iv. **Reservoir Model Accuracy - BP**

BP has used AI algorithms to improve the accuracy of its reservoir models. The company used machine learning to analyze large amounts of data from multiple sources, including well logs, seismic data, and production data, to build a more comprehensive and accurate model of the reservoir. This enabled BP to optimize drilling operations and improve production rates.

v. **Detecting Oil Seeps With AI-Powered Robots - ExxonMobil and MIT**
In December 2016, ExxonMobil announced that it is working with MIT to design AI robots for ocean exploration. Brian Williams, an MIT professor and a designer of the AI software that helped create NASA's Mars Curiosity Rover is a key member of the project team. While the business advantage of using AI in deep sea exploration may not be immediately apparent, the company aims to apply AI to boost its natural seep detection capabilities. Natural seeps occur when oil escapes from rock found in the ocean floor. An estimated 60 percent of oil underneath the earth's surface in North America is due to natural seeps. Robots with the ability to navigate these oceanic regions and detect oil seeps can contribute to protecting the ecosystem and serve as indicators for robust energy resources. It is unclear specifically when ExxonMobil's ocean exploring AI robots are expected to be deployed.

vi. **Analyze satellite images - Total**
Total has used AI algorithms to analyze satellite images and other data to identify potential drilling locations. The company used machine learning to analyze data such as soil types, vegetation patterns and terrain features to identify areas that are likely to contain hydrocarbons. This has enabled Total to reduce exploration costs and improve the accuracy of its drilling operations.

9.0 FUTURE OF AI

i. Emergence of AGI: The development of artificial general intelligence (AGI) is a long-term goal for AI researchers. AGI would be capable of performing any intellectual task that a human can, and it could lead to major changes in society.

ii. Autonomous operations: The oil and gas industry is investing in developing autonomous drilling and production platforms that use AI to make real-time decisions, such as adjusting drilling direction and optimizing well production.

iii. Digital Twins: The concept of digital twins, where a virtual replica of a physical asset or process is created is gaining popularity in the industry. The use of AI in digital twins will enable the industry to monitor and optimize production processes, predict equipment failures and optimize maintenance schedules, reducing downtime and improving operational efficiency.

v. More Personalized Experiences: AI will be able to provide more personalized experiences for individuals, such as personalized recommendations and tailored content. Eg, integrating voice to search for details.

vi. Robotics: The use of robots in upstream petroleum production engineering is expected to increase in the future. Robots can be used for various tasks, such as inspecting and maintaining pipelines, cleaning tanks, and drilling wells in hazardous environments.

vii. Ethical and Legal Challenges: The use of AI will bring ethical and legal challenges, such as data privacy and bias, that will need to be addressed by society and government.

"...the application of Artificial Intelligence in upstream petroleum production engineering has significant potential to improve the efficiency, safety, and sustainability of the industry. offering even more possibilities for improving..."

10.0 CHALLENGES OF AI IN UPSTREAM OIL & GAS

i. Data Management Availability: The oil and gas industry collects vast amounts of data, but most of it is in unstructured or semi-structured formats, which are difficult to analyze. Therefore, converting data into structured and high-quality data can be a challenging task.
ii. Security and Privacy: The oil and gas industry deals with a large amount of sensitive information, which is subject to privacy and security regulations. Therefore, it is essential to ensure that AI solutions used in the industry are secure and comply with these regulations.
iii. Human Expertise: The oil and gas industry heavily relies on human expertise, and the application of AI may be seen as a threat to jobs. Therefore, the industry needs to find ways to integrate AI with human expertise to get the best out of both worlds.
iv. Legacy Infrastructure: The oil and gas industry heavily relies on legacy infrastructure, which is often difficult to integrate with new technology, including AI. This integration can be time-consuming and expensive.
v. Complex Geology: The geology of oil and gas reservoirs is complex, which makes it challenging to develop accurate models to predict the behavior of the reservoir. AI can help in this area, but it is challenging to develop AI models that can accurately predict reservoir behavior
vi. Complexity of the Environment: The petroleum industry is complex, with several factors influencing production processes. AI models may struggle to capture all the nuances of the industry, leading to limited effectiveness

11.0 SKILLS TO LEVERAGING AI

The success of artificial intelligence critically depends on human intelligence. AI solutions are not generic – they cannot be just bought. Even when developed by third parties AI solutions have to be customized to the business context and database of a company.
Data analysis engineers should be proficient in data analysis techniques to understand, pre-process, and manipulate data effectively.

Problem-solving engineers should have strong problem-solving skills to develop effective AI solutions.

Statistical modeling engineers should have a good understanding of statistical modeling techniques to build effective machine learning models.

Programming engineers must have good programming skills to develop algorithms and models that can be trained on data to perform specific tasks.

Domain knowledge engineers must have a good understanding of the domain they are working in, be it healthcare, finance, manufacturing, or any other industry.

12.0 CONCLUSION AND RECOMMENDATIONS

In conclusion, the application of Artificial Intelligence in upstream petroleum production engineering has significant potential to improve the efficiency, safety, and sustainability of the industry. offering even more possibilities for improving the industry's performance.
As the industry continues to evolve, there are several recommendations to consider:

i. Collaborate and share data: The industry must work collaboratively and share data to improve the accuracy and effectiveness of AI models. Companies can work together to build and maintain large datasets that are accessible to all.
ii. Invest in research and development: Companies

should continue to invest in research and development to develop new AI algorithms and technologies that can be applied to upstream petroleum production engineering.

iii. Address ethical concerns: As the use of AI in the industry increases, there is a need to address ethical concerns related to privacy, data ownership, and bias.

iv. Train and hire AI experts: Companies must train and hire experts in AI and machine learning to develop and implement these technologies effectively.

v. Embrace sustainability: The industry should embrace sustainability and use AI to optimize energy consumption, reduce waste and emissions, and improve resource utilization.

In summary, the application of AI in upstream petroleum production engineering is a promising area that can drive significant improvements in the industry's performance. By collaborating, investing in research, addressing ethical concerns, hiring experts, and embracing sustainability, the industry can leverage these new technologies to optimize production processes and reduce costs, while also improving safety and sustainability.

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PERSPECTIVES ON THE NIGERIAN INDUSTRIAL SOLVENTS MARKET

PRESENTED TO

THE CHEMICAL PRODUCTS SECTORAL GROUP (CPSG)

NSChE

on

APRIL 14, 2023

By

ENGR. DR. N. JOHN ERINNE FAEng, FNSE, FNSChE
PAST PRESIDENT, NSChE

MANAGING CONSULTANT, CHEX & ASSOCIATES

Dr. John Erinne

INDUSTRIAL SOLVENTS

- CHEMICALS THAT ARE CAPABLE OF DISSOLVING, SUSPENDING OR EXTRACTING OTHER SUBSTANCES WITHOUT CAUSING CHANGES IN THE CHEMICAL NATURE OF EITHER MATERIAL

OR

- CHEMICALS THAT CAN THIN OR DILUTE CONCENTRATION OF A SUBSTANCE IN ORDER TO ACHIEVE DESIRED PHYSICAL CHARACTERISTICS

- USUALLY LIQUIDS

TYPES OF SOLVENTS

- TWO BROAD CATEGORIES
  - INORGANIC SOLVENTS
  - ORGANIC SOLVENTS

- INORGANIC SOLVENTS
  - WATER, AMMONIA

- ORGANIC SOLVENTS
  - HYDROCARBON/OXYGENATED/HALOGENATED SOLVENTS
  - WIDER RANGE & VARIETY

- OVER 80% OF APPLICATIONS ARE ORGANIC SOLVENTS

ORGANIC SOLVENTS

- HYDROCARBON SOLVENTS
  - ALIPHATIC & AROMATIC HYDROCARBONS
- OXYGENATED SOLVENTS
  - ALCOHOLS, KETONES, GLYCOL ETHERS, ESTERS, ETC
- HALOGENATED SOLVENTS
  - FLUORINATED/CHLORINATED/BROMINATED/ IODINATED/HYROCARBONS
  - RECEDING IMPORTANCE DUE TO ENVIRONMENTAL CONSIDERATIONS

TYPICAL ORGANIC SOLVENTS

	TYPE	TYPICAL SOLVENTS
1.	HYRDROCARBON SOLVENTS: ALIPHATIC	NAPHTHA, KEROSINE, DIESEL, WHITE SPIRIT, HEXANE, HEPTANE, ETC
2.	HYDROCARBON SOLVENTS: AROMATIC	BENZENE, TOLUENE, XYLENE, HEXANE, METHYL BENZENE, LAB, ETC
3.	OXYGENATED SOLVENTS	METHANOL, ETHANOL, IPA, ACETONE, MEK, MIBK, ETHYL ACETATE, PROPYL ACETATE, BUTYL ACETATE, BUTOXY ETHANOL, METHOXY PROPANOL, ETC
4.	HALOGENATED SOLVENTS	TRICHOROETHYLENE, METHYLENE DICHLORIDE, CARBON TETRACHLORIDE, TETRAFLUOROMETHANE, ETHYLENE DIBROMIDE, ETC

SOURCES & USES OF THE MAJOR INDUSTRIAL SOLVENTS

	SOLVENT	PRODUCTION	USES
1.	WHITE SPIRIT	FRACTIONAL DISTILLATION OF PETROLEUM REFINERY NAPTHA & KEROSINE CUTS	- SOLVENT FOR PAINTS, COATINGS, INKS, ADHESIVES, ETC - CLEANING AGENTS & THINNERS
2.	HEXANE	EXTRACTED FROM REFORMATE FROM CATALYTIC REFORMING OF PETROLEUM	- EXTRACTION SOLVENT FOR VEGETABLE OILS - CLEANING AGENT IN TEXTILES, LEATHER & PRINTING
3.	BENZENE	EXTRACTED FROM REFORMATE FROM CATALYTIC REFORMING OF PETROLEUM (BTX AROMATICS PROCESS)	- SOLVENT FOR PHARMACEUTICALS, COSMETICS, ETC - BLENDING INTO GASOLINE - FEEDSTOCK FOR PETROCHEMICALS PRODUCTION: DETERGENTS, PLASTICS, SYNTHETIC FIBERS, PESTICIDES, ETC
4.	TOLUENE	EXTRACTED FROM REFORMATE FROM CATALYTIC REFORMING OF PETROLEUM (BTX AROMATICS PROCESS)	- SOLVENT FOR PAINTS, ADHESIVES, INKS/ PRINTING, LEATHER TANNING, RUBBER, DISINFECTANTS, ETC - BLENDING INTO GASOLINE - FEEDSTOCK FOR PETROCEMICALS PRODUCTION: TDI, EXPLOSIVES, ACIDS, ALDEHYDES, ETC
5.	XYLENE	EXTRACTED FROM REFORMATE FROM CATALYTIC REFORMING OF PETROLEUM (BTX AROMATICS PROCESS)	- SOLVENT FOR PAINTS, ADHESIVES, PRINTING, RUBBER, LEATHER, PESTICIDES, DISINFECTANTS, ETC - PARAFFIN SOLVENT IN OIL & GAS PRODUCTION - FEEDSTOCK FOR PETROCHEMICALS PRODUCTION: PLASTICS, SYNTHETIC FIBERS, RESINS, PLASTICIZERS, ETC
6.	METHANOL	STEAM REFORMING OF NATURAL GAS TO SYNTHESIS GAS; CATALYTIC CONVERSION OF SYNTHESIS GAS TO MEOH	- FEEDSTOCK FOR CHEMICAL INTERMEDIATES & PETROCHEMICALS: ACETIC ACID, FORMALDEHYDE, ACRYLIC PLASTICS, SYNTHETIC FIBERS, RESINS, ETC - AUTOMOTIVE FUEL - SOLVENT FOR PHARMACEUTICALS, AGRICHEMICALS, ETC - ANTI-HYDRATE IN OIL & GAS PRODUCTION
7.	ETHANOL	FERMENTATION OF BIOMATERIALS	- SOLVENT FOR PAINTS, ADHESIVES, CLEANING PRODUCTS, PERSONAL CARE PRODUCTS, PHARMACEUTICALS, ETC - FEEDSTOCK FOR CHEMICAL INTERMEDIATES: ACIDS ALDEHYDES, ETC - FEEDSTOCK FOR ALCOHOLIC BEVERAGES - AUTOMOTIVE FUEL (BIOFUEL)

SOURCES & USES OF THE MAJOR INDUSTRIAL SOLVENTS (CONT'D)

	SOLVENT	PRODUCTION	USES
8.	IPA	HYDRATION OF PROPYLENE OR HYDROGENATION OF ACCTONE	- SOLVENT FOR PHARMACEUTICALS, COSMETICS, PAINTS, ETC - ANTISEPTIC IN DISINFECTANTS, CLEANING PRODUCTS, BODY CARE PRODUCTS, ETC - FEEDSTOCK FOR CHEMICAL INTERMEDIATES: ACETONE, ACETIC ACID, ETC.
9.	ACETONE	ALKYLATION OF BENZENE WITH PROPYLENE (CUMENE PROCESS) / OXIDATION OF CUMENE BY AIR	- SOLVENT FOR PLASTICS, SYNTHETIC FIBERS, RESINS, PHARMACEUTICALS - FORMULATION OF CLEANING CHEMICALS & DEGREASERS - FEEDSTOCK FOR CHEMICAL INTERMEDIATES AND PETROCHEMICALS: PLASTICS, SYNTHETIC FIBERS, RESINS
10.	MEK	CATALYTIC OXIDATION (DEHYDROGENATION) OF BUTANOL	- SOLVENT FOR RESINS, COATINGS, PAINTS, PLASTICS, SYNTHETIC FIBERS, ETC - FEEDSTOCK FOR CHEMICAL INTERMEDIATES & PETROCHEMICALS: PEROXIDES, RESINS, POLYMERS, ETC
11.	MIBK	CATALYTIC HYDROGENATION OF ACETONE	- SOLVENT FOR PAINTS, PESTICIDES, PHARMACEUTICALS, COSMETICS, RESINS - EXTRACTION SOLVENT IN MINERALS PRODUCTION - FEEDSTOCK FOR CHEMICAL INTERMEDIATES & PETROCHEMICALS: DIAMINES, POLYMERS, ETC
12.	ETHYL ACETATE	FISCHER ESTERIFICATION REACTION OF ETHANOL AND ACETIC ACID	- SOLVENT FOR PAINTS, INKS, ADHESIVES, PHARMACEUTICALS, COSMETICS - EXTRACTION SOLVENT FOR COFEE & TEA DECAFFEINATION

NIGERIAN INDUSTRIAL SOLVENTS DEMAND

- MAJOR CONSUMERS
  - PAINTS/COATINGS/ADHESIVE/INKS
  - PHARMA/FOOD
  - PERSONAL CARE PRODUCTS/COSMETICS
  - CLEANING PRODUCTS
- MAIN APPLICATIONS ARE FOR:
  - SOLVENTS
  - FORMULATIONS & BLENDS (ACTIVE INGREDIENTS)
- VERY LIMITED USE AS FEEDSTOCK FOR CHEMICAL INTERMEDIATES
  - NO CHEMICAL INTERMEDIATES INDUSTRY YET
- MARKET DEMAND ESTIMATES:
  - NIGERIAN DEMAND: OVER $700M PER ANNUM
  - GLOBAL DEMAND: NEARLY 50BN PER ANNUM
  - STILL MARGINAL
- DETAILED DATA ON NIGERIA NOT IMMEDIATELY AVAILABLE BUT ETHANOL CONSIDERED TO BE MOST IMPORTANT

LOCAL PRODUCTION OF SOLVENTS

- VERY LIMITED LOCAL PRODUCTION:
  - WHITE SPIRIT
  - BENZENE
  - ETHANOL
- WHITE SPIRIT & BENZENE FROM KRPC:
  - PLANT SHUT DOWN & PRODUCTION DISCONTINUED FOR OVER 2 DECADES
- ETHANOL:
  - PRIVATE SECTOR DRIVEN
  - SIGNIFICANT LOCAL PRODUCTION
- IMPORTS ACCOUNT FOR 85-90% WHILE LOCAL PRODUCTION ACCOUNTS FOR ONLY 10-15%
  - IMPORT BILL: OVER $700M PER ANNUM

FURTHER FOCUS

- PROPOSE TO FOCUS FURTHER ON ETHANOL
  - LARGEST DEMAND VOLUME
  - ONLY SIGNIFICANT LOCAL PRODUCTION
  - CONSIDERED THE MOST IMPORTANT INDUSTRIAL SOLVENT IN NIGERIA

PRODUCT ETHANOL

- A VOLATILE, COLORLESS & FLAMMABLE ORGANIC LIQUID
- CHEMICALLY KNOWN AS ETHYL ALCOHOL
- USES:
  - INDUSTRIAL SOLVENT
  - FEEDSTOCK (for CHEMICAL INTERMEDIATES PRODUCTION)
  - BEVERAGES & FOOD PRODUCTION
  - FUEL APPLICATIONS (BIOFUEL)

INDUSTRIAL SOLVENT ETHANOL

- USED EXTENSIVELY AS SOLVENT IN DIVERSE INDUSTRIES: ADHESIVES, PAINTS, INKS, COATINGS, PERSONAL CARE PRODUCTS, CLEANING PRODUCTS, PHARMACEUTICALS, ETC
- ESTIMATED TO ACCOUNT FOR ABOUT 5% OF GLOBAL ETHANOL MARKET

CHEMICAL FEEDSTOCK ETHANOL

- ABOUT 9% OF GLOBAL ETHANOL CONSUMPTION
- KEY FEESTOCK FOR MANUFACTURE OF IMPORTANT INDUSTRIAL CHEMICAL INTERMEDIATES SUCH AS: ACETIC ACID, ALDEHYDES, ETHANOLAMINES, ACRYLATES, ETC
- THE INTERMEDIATES ULTIMATELY FIND WIDE USE IN THE MANUFACTURE OF A WIDE RANGE OF CONSUMER CHEMICAL PRODUCTS: PAINTS, COATINGS, SYNTHETIC TEXTILES, PLASTICS, DYES, INSECTICIDES, PHARMACEUTICALS, PERSONAL CARE PRODUCTS, CLEANING PRODUCTS, ETC

BEVERAGES & FOODS ETHANOL

- ABOUT 6% OF GLOBAL ETHANOL DEMAND
- DIRECT APPLICATION AS FEEDSTOCK IN THE DISTILLERIES FOR PRODUCTION OF ALCOHOLIC BEVERAGES
- ALSO USED TO ENHANCE FLAVOR & AS A PRESERVATIVE IN THE FOOD & PHARMA INDUSTRIES
- REQUIRES A SPECIAL FOOD GRADE ETHANOL

FUEL ETHANOL

- ESSENTIALLY ETHANOL BLENDED INTO AUTOMOTIVE FUEL TO:
  - REDUCE DEPENDENCE ON HYDROCARBONS
  - REDUCE POLLUTION
- RAPID GROWTH IN RECENT DECADES
- NOW DOMINANT APPLICATION OF ETHANOL GLOBALLY
  - UP TO 80% OF GLOBAL ETHANOL DEMAND
- FUEL ETHANOL MANDATES NOW APPLICABLE IN MANY COUNTRIES INCLUDING NIGERIA
  - RANGE: ABOUT 5 – 30%

GLOBAL APPLICATIONS SUMMARY

	APPLICATION	GRADE OF ETHANOL	% CONTRIBUTION
1.	INDUSTRIAL SOLVENT	INDUSTRIAL GRADE	5.0
2.	INTERMEDIATE CHEMICALS FEEDSTOCK	INDUSTRIAL GRADE	9.0
3.	ALCOHOLIC BEVERAGES/FOODS	FOOD GRADE	6.0
4.	FUEL	DENATURED GRADE	80.0
			100.00

ETHANOL GRADE CHARACTERISTICS

	GRADE	ETHANOL PURITY (%)	REMARKS
1.	INDUSTRIAL	95.0 MIN	TOLERATES LIMITED CHEMICAL CONTAMINANTS
2.	FOOD	96.0 MIN	AVERSE TO CHEMICAL CONTAMINANTS BUT TOLERATES WATER
3.	FUEL	92.0 MIN	AVERSE TO WATER; DELIBERATELY DOSED WITH CHEMICAL ADDITIVES TO DENATURE

REGIONAL ETHANOL MARKETS

	REGION	MARKET SHARE	REMARKS
1.	NORTH AMERICA	48	ALL ROUND STRENGHT IN FUEL & NON-FUEL APPLICATIONS; GLOBAL LEADER
2.	SOUTH AMERICA & CARRIBEAN	30	DRIVEN BY FUEL APPLICATIONS, ESPECIALLY IN BRAZIL
3.	EUROPE	9	SIGNIFICANT NON-FUEL AND FUEL APPLICATIONS
4.	ASA PACIFIC/ MIDDLE EAST	12	STRENGHT IN NON-FUEL APPLICATIONS
5.	AFRICA	1	STILL VERY MARGINAL
		100	

NIGERIAN MARKET OVERVIEW

- 10% BIOFUEL MANDATE IN AUTO FUELS
  - VIRTUALLY NO APPLICATION IN PRACTICE
- MOST APPLICATIONS ARE FOR:
  - ALCOHOLIC BEVERAGES/FOODS: DISTILLERIES, FOOD & PHARMA INDUSTRIES
  - SOLVENT ALCOHOL: PAINT, PERSONAL CARE & CLEANING PRODUCTS INDUSTRIES
- VERY LIMITED CHEMICAL INTERMEDIATES FEEDSTOCK DEMAND

DEMAND PATTERN

- TOTAL NIGERIAN ETHANOL DEMAND:
  - ESTIMATED AT ABOUT 400 MILLION LITERS
- 75-80% OF DEMAND IS FOR ALCOHOLIC BEVERAGES/ FOODS
- UP TO 100 DISTILLERIES NATIONWIDE
- STEADY GROWTH
  - ABOUT 3-4% PER ANNUM

ETHANOL PRODUCTION PROCESS

- BROADLY TWO PROCESSES:
  - HYDROCARBON PROCESS
  - FERMENTATION PROCESS
- HYDROCARBON PROCESS BASED ON ACID-CATALYSED HYDRATION OF ETHYLENE
  - OLD TECHNOLOGY
  - DIMINISHED IMPORTANCE
- FERMENTATION OF BIOLOGICAL MATERIALS: DOMINANT SOURCE OF ETHANOL GLOBALLY
  - GRAINS
  - TUBERS
  - SUGAR
  - CELLUCLOSE MATERIALS
- USA DEPENDENT ON CORN WHILE BRAZIL RELIES ON CANE SUGAR

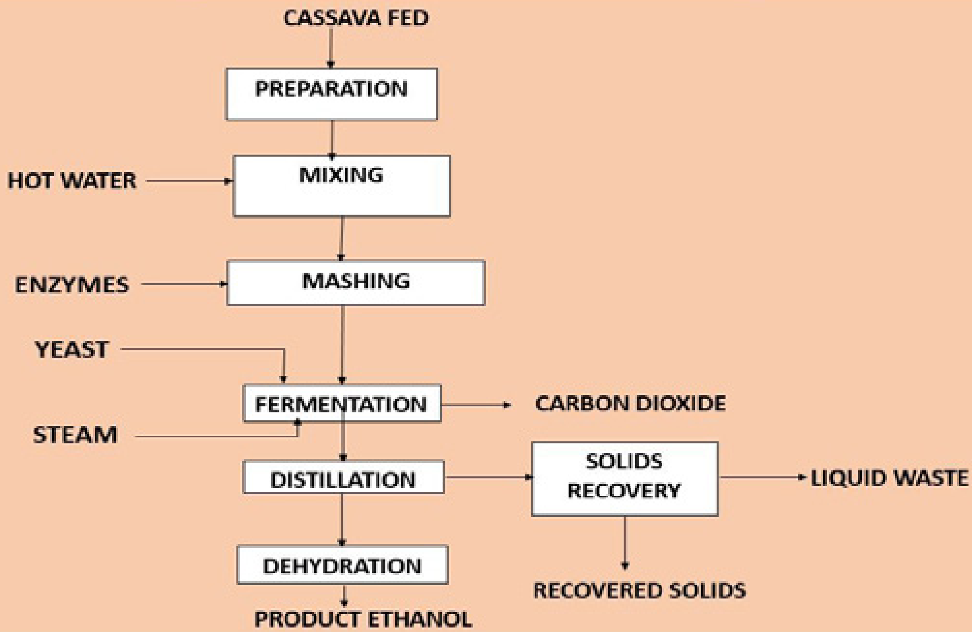
ETHANOL PRODUCTION FEEDSTOCK IN NIGERIA

- NIGERIAN CLIMATIC & GEOGRAPHIC CONDITIONS AMENDABLE FOR GRAINS, TUBERS & SUGAR PRODUCTION FOR ETHANOL MANUFACTURE
- IN PRACTICE MOST VIABLE & COMMON SUBSTRATES FOR ETHANOL ARE:
  - CANE SUGAR/MOLASSES (SUGAR)
  - CASSAVA (TUBER)
  - SORGHUM (GRAIN)

NIGERIAN ETHANOL PRODUCTION

- TOTAL CAPACITY IS ABOUT 300 MILLION LITERS PER ANNUM BUT ACTUAL OUTPUT IS LESS THAN 150 MILLION LITERS PER ANNUM
  - <50% CAPACITY UTILIZATION
- CONSEQUENT IMPORT GAP OF OVER 250M MILLION LITERS PER ANNUM
  - ABOVE 60%
- MOST PLANTS BASED ON CASSAVA FEEDSTOCK
  - SUGAR & SORGHUM LIMITED
- IN ADDITION, SOME PLANTS CONFIGUTED TO REFINE IMPORTED CRUDE ETHANOL

SCHEMATIC BLOCK DIAGRAM OF CASSAVA ETHANOL PROCESS



SECTION OF AN ETHANOL PLANT

PRODUCTION CONSTRAINTS

- GENERAL MANUFACTURING SECTOR ISSUES
  - CREDITS & FUNDS
  - POWER SUPPLY
  - TRANSPORT INFRASTRUCTURE
  - ENERGY COSTS
  - FX SHORTFALLS /EXCHANGE RATE INSTABILITY
  - MULTIPLE TAXATION
  - HARASSMENT BY GOVERNEMNT OFFICIALS
  - POOR MANAGEMENT
- SPECIFIC CONSTRAINTS
  - CONSISTENCY & ADEQUACY OF FEED SUPPLIES
  - SECURITY THREATS
  - PRODUCT QUALITY

CONCLUSION

- THERE IS NO MEANINGFUL LOCAL CHEMICAL SOLVENTS INDUSTRY IN NIGEIRA YET AS MOST OF THE DEMAND IS MET FROM IMPORTS
- IMPORT BILL IS ESTIMATED AT ABOUT $700-800M PA
- ETHANOL IS THE MOST IMPORTANT CHEMICAL SOLVENT IN NIGERIA AND IS THE ONLY SOLVENT WITH SIGNIFICANT LOCAL PRODUCTION
- NIGERIA'S ETHANOL MARKET IS DYNAMIC AND GROWING
- LOCAL PRODUCTION OF ETHANOL IS MOSTLY FROM CASSAVA OR BY REFINING OF IMPORTED RAW ETHANOL
- LOCAL PRODUCTION IS HOWEVER INADEQUATE TO MEET DEMAND LEADING TO IMPORT GAP OF OVER 60%
- THERE ARE EVIDENTLY GOOD PROSPECTS & OPPORTUNITIES IN THE INDUSTRIAL SOLVENTS BUSINESS IN NIGERIA
- NIGERIAN CHEMICAL ENGINEERS ARE THEREFORE CHALLENGED TO RESPOND & LEAD THE CHARGE

OVERALL EQUIPMENT EFFECTIVENESS (OEE) IN PROCESS OPERATION

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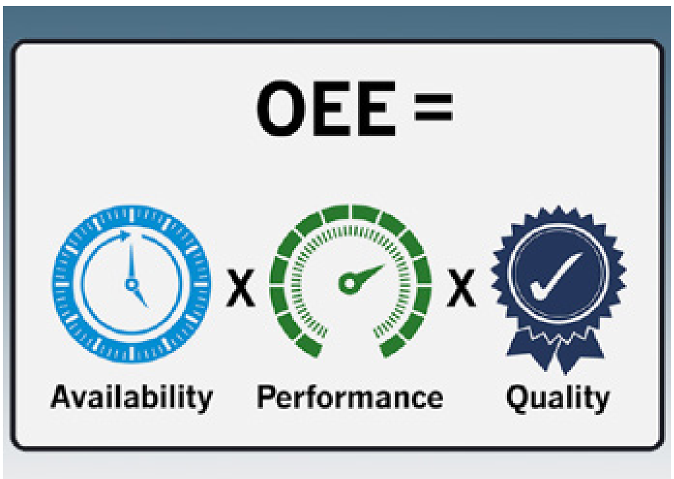
1.0 INTRODUCTION

OEE is an acronym which stands for Overall Equipment Effectiveness. It is a metric widely used in many process industries alongside other techniques such as Failure Mode & Effect Analysis (FMEA), Layer of Protection Analysis (LOPA), Hazard Analysis & Operability (HAZOP) study, Bow Tie Analysis (BTA) and many others. While LOPA, HAZOP & BTA are specifically used in process safety engineering and FMEA used in product management or say, product development, OEE is used in process improvement. It is an important metric which helps to determine how often equipment is available for work, how well the equipment does when it is running and how many quality products the equipment produce per cycle.

OEE is measured in percentage (%), calculated as the product of availability, performance and quality. It is a model having its root in total productive maintenance (TPM) and serving as a useful framework for improving process operations and achieving greater efficiency on the shop floor. An OEE score of 100% means you are producing or manufacturing only good parts/products (quality), as fast as possible (performance) with no stoppage time (availability). What that means is 100% quality standard (only good parts/products), 100% performance (as fast as possible) and 100% availability (no stoppage time).



2.0 BENEFITS OF OVERALL EQUIPMENT EFFECTIVENESS (OEE)

Overall Equipment Effectiveness (OEE) is an important technique for:

i. It is used in discovering losses in manufacturing processes such as in process start-up, minor stoppages or idling and others.

ii. It serves in benchmarking progress by comparing your company's operational successes/progress against that of your competitors to see if there is a gap in performance that can be closed through process improvement in order to gain a competitive advantage. As a benchmark, OEE score of 100% indicates perfect operation, 85% indicates world-class operation, 60% OEE is fairly typical for discrete manufacturers and indicates that there is much room for improvement in the process.

iii. It prompts Improvement in the productivity of process equipment through waste elimination such as in setup & adjustment, equipment breakdowns or failures etc.

3.0 ELEMENTS OF OVERALL EQUIPMENT EFFECTIVENESS

The OEE score shows the overall health of the process, but does not necessarily tell you where you should focus your improvement efforts. The three elements of OEE which are Availability, Performance and Quality are what indicate where your process improvement efforts should be focused on.

i. Availability: Availability is measured in percentage and it represents the scheduled time that the process is available to run. It takes into account 'Availability Loss', which includes events that stop planned production for a significant period of time such as breakdowns and setup & adjustments. Availability score of 100% means that your process is running without any stop during the time it has been scheduled to run.

ii. **Performance:** Performance refers to the speed at which the process is actually running compared to its designed speed. It is measured in percentage. Performance takes into account 'Performance Loss', which includes anything that causes the process to run at less than the speed it was designed and capable of running when it is in operation. Examples include idling and minor stops and reduced speed. Performance score of 100% means that when your process is running, it is running as fast as possible in line with the designated speed.

iii. **Quality:** This refers to the quantity of good units produced as a percentage of the total units for production. OEE Quality takes into account 'Quality Loss', which includes parts/products that do not meet quality standards such as production rejects, start-up rejects etc. 100% Quality means that your process is yielding only good units.

4.0 OEE ANALYSIS

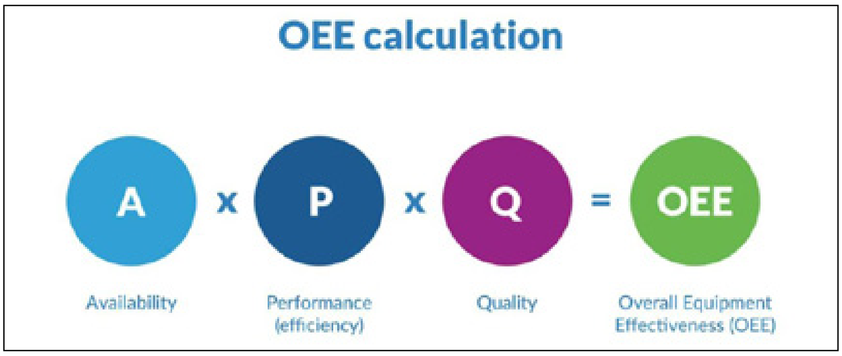
i. **All Time:** This is the 24/7 time which includes every minute of the day.

ii. **Scheduled Loss:** This is time that we have no intention of running production such as plant shut-downs, breaks/lunches or periods where there are no orders. This time should be excluded from OEE analysis.

iii. **Planned Production Time:** The remaining time after the scheduled loss has been subtracted is the Planned Production Time. OEE analysis starts with Planned Production Time putting into consideration all losses in productivity that occurs during this period.

iv. **Run Time:** This is the remaining time when events that stop planned production for an appreciable length of time (usually several minutes; long enough for an operator to log a reason) is subtracted.

v. **Net Run Time:** This is the remaining time when events that causes the process to run at less than the maximum possible speed when it is running (including both 'Slow Cycles' and 'Small Stops' is subtracted. It is the fastest possible time to manufacture a part/product.



vi. **Ideal Cycle Time:** This is the fastest cycle time that your process can achieve in optimal condition.

vii. **Fully Productive Time:** This is the remaining time when parts/products that do not meet acceptable quality standards is subtracted.

viii. **Availability:** Availability is calculated as the ratio of Run Time to Planned Production Time, that is, Availability = Run Time / Planned Production Time, where Run Time = Planned Production Time – Stoppage Time.

ix. **Performance:** Performance is the ratio of Net Run Time to Run Time. It is expressed as: Performance = (Ideal Cycle Time × Total Count) / Run Time.

x. **Quality:** Quality is calculated as the ratio of Good Count to Total Count that is, Good Count / Total Count. This is the same as the ratio of Fully Productive Time to Net Run Time that is, Fully Productive Time / Net Run Time.

Combining points 8 – 10, results in
OEE = Availability × Performance × Quality (i)

If the equations for Availability, Performance and Quality are substituted in the above and reduced to their simplest terms, the result is:

OEE = (Good Count × Ideal Cycle Time) / Planned Production Time (ii)

Equation (i) requires values for Availability, Performance and Quality for calculation which can be gotten from point 8 – 10 accordingly while equation (ii) can be calculated directly given values for each of the parameters (i.e. good count, ideal cycle time and planned production time). Equation (i) is the preferred method of calculating OEE because it captures how well your process is running (OEE) and provides insight into the three values that capture the fundamental nature of the losses associated with your process - Availability, Performance and Quality.

5.0 TACKLING THE SIX BIG LOSSES OF OEE

When trying to improve your OEE score, the focus should be on eliminating waste. These wastes result in losses of overall equipment effectiveness (OEE) which compromises availability, performance and quality and, they are together referred to as the Six Big Losses of OEE. The following highlights these Six Big Losses and essential ways to avoid and/or correct them.

i. **Breakdowns:** Breakdowns are mechanical failures that usually occur suddenly, making machines unavailable. This loss is the first big loss of OEE that has to be eliminated. The loss gives rise to all the other losses, in that, if the machine is not running, there would not be such thing as performance or quality.

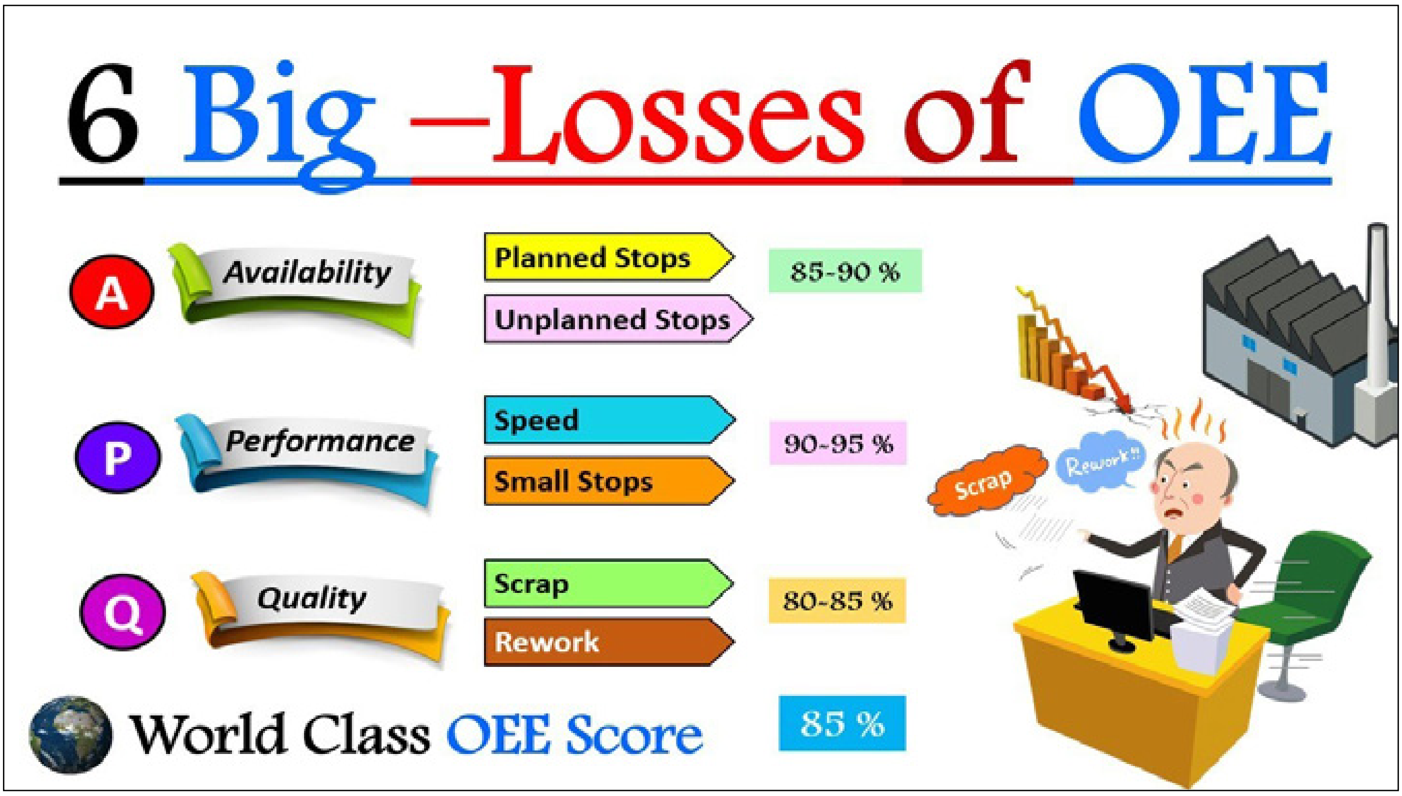
To prevent sudden breakdown of machine, endeavour to conduct regular preventive and predictive maintenance. Also, pay attention to trends in your past breakdowns through data analysis and then, figure out the root causes of those breakdowns. Once the root causes are determined you would be able to implement lasting corrective actions.

ii. **Set-up and Adjustment:** Whenever there is a change in part or machine tooling, there is a readjustment. The time it taken to set up an equipment for a new manufacturing operation leads to some form of losses. Set-up and adjustments can be classified as planned stops. The impact of these losses can be reduced through several ways including the following:
- Create process standards
- Strictly adhere to maintenance routines
- Seek high-quality parts
- Create work instructions in line with the manufacturer's guidelines and strictly follow them
- Ensure compatibility of your equipment
- For changeovers, implement a SMED (Single-Minute Exchange of Die) programme

iii. **Idling/ Minor Stoppages:** In this, production process is disrupted briefly. Examples of situations that can lead to idling or minor stoppages include: obstructed product flows, lack of raw material or tools, material jams, incorrect settings, blocked sensors, idle operators or a temporary malfunction etc.

While these stops last only for some few minutes and can be corrected easily by the operators, they still negatively affect cycle time which is why they are considered a performance loss rather than an availability loss.

These chronic stoppages often happen on a frequent basis, however, with the help of new sensory technology and IIoT, they can now be easily tracked,



thereby improving workflows and elimination of the stoppages.

iv. Speed: Losing speed also negatively affects cycle time and impacts performance. For instance, if the machine operates at a higher speed than the design speed, the machine may experience mechanical problems such as jamming or the operators might be operating it incorrectly or even leading to production of defective products. This loss can be avoided by applying the following:

- Checking the machine speed
- Regular machine cleaning
- Replacing worn-out equipment
- Changing filters and maintaining lubrication as specified by the equipment manufacturers
- Continuous operator training
- Implementing autonomous maintenance etc

v. Process defects and rework: Process defects refer to processes that result in the production of defective parts or products while rework takes into account parts/products that can still be reworked to make the products useful. Defective products represent quality loss. The following are some of the possible causes of defects and rework:

- Poor operator skill level which leads to improper handling of equipment and operating them with incorrect settings
- Ineffective maintenance of tools or machines
- Lack of raw materials or expired products etc

Depending on what the actual root cause is, there may be need to implement further operator training or better stock management.

vi. Start-up losses ("yield losses"): These losses occur when machines are warming up and start to produce start-up waste. It may also occur with newly installed equipment with the operators not yet familiar with how they are operated. These often lead to decrease in production output. While this is more common after changeovers, they can still happen after equipment start-up. To avoid start-up losses in OEE, the following can be implemented:

- Equipment Settings: Ensure you define and implement precise equipment settings, even if it is on a part-by-part basis.
- Material Tests: It is recommended to run some few materials to test each piece of equipment to see if it is possible to minimize start-up problems.

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