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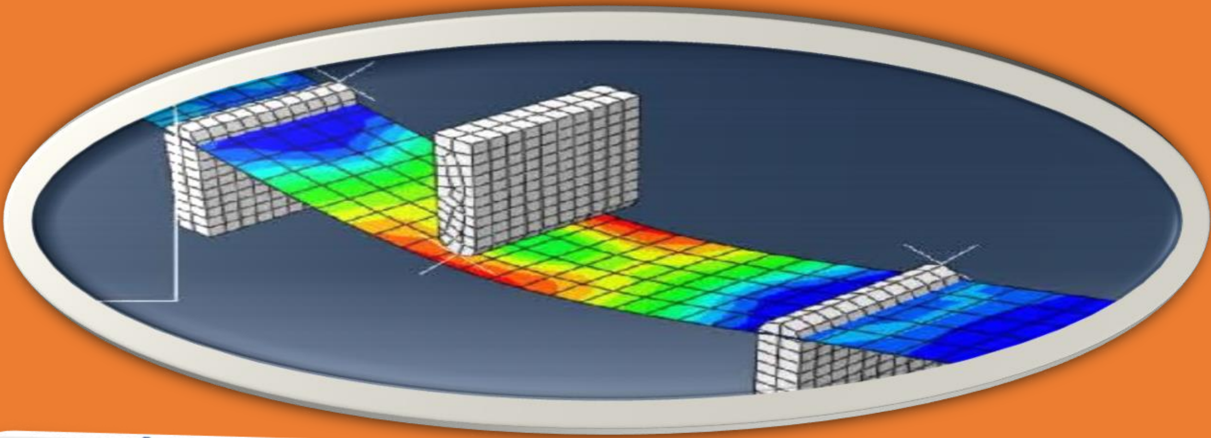

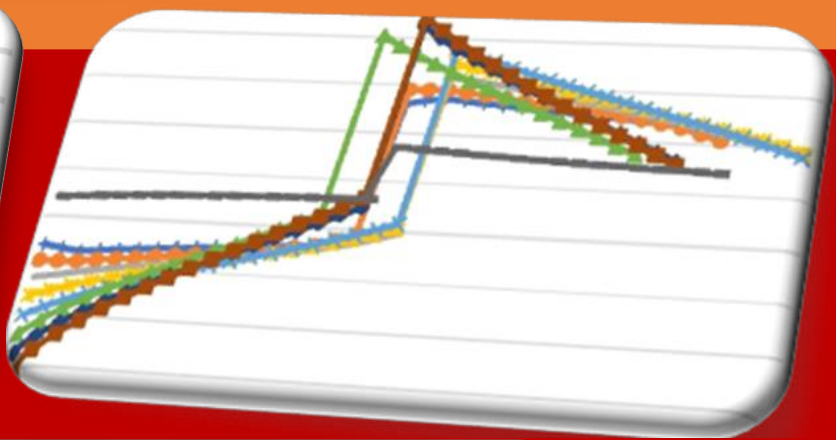

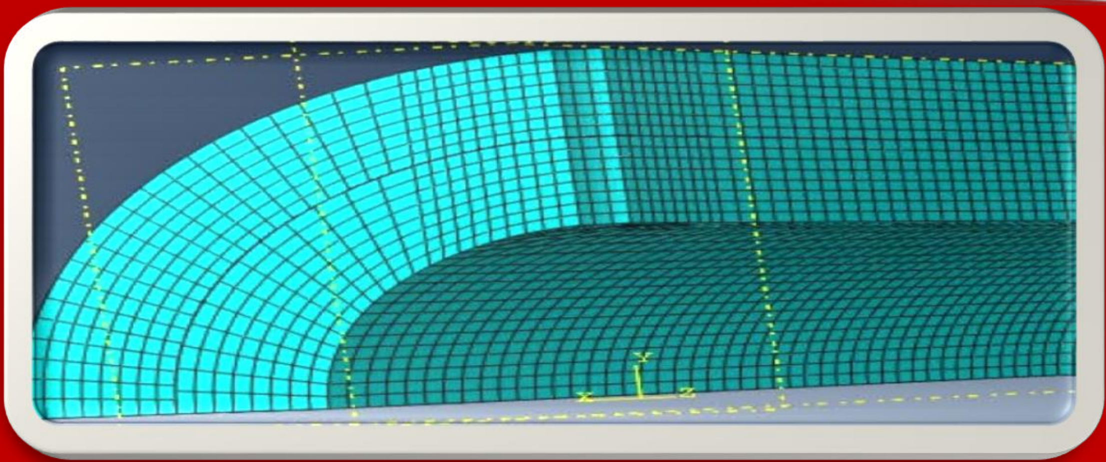

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Experimental Use of Arduino-Based Accelerometers for Assessment of Train Induced Soil Vibration Characteristics

Paul Christopher Kimali Kioko[1], Silvester Ochieng Abuodha[1], John Nyiro Mwero[2], Kuria Zacharia Njuguna[3]

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Abstract

Vibration is a significant factor causing structural damage to nearby structures. This study, conducted in accordance with ISO-14837, focuses on the importance of structural health monitoring and structural audits for existing structures.

The instrumentation and data acquisition system used in this study comprised triaxial ADXL-345 and MPU 6050 accelerometers, Arduino Uno R3, and I2C protocol communication for data logging.

Field measurements were conducted on moving trains, revealing a maximum peak particle velocity of 50.77mm/s at the rail vibration source, and a minimum of 1.049mm/s at a distance of 16 meters from the rail. According to BS7385-2 (1993), ground borne vibration becomes damaging at a peak particle velocity of 50mm/s at 4Hz, while the vibration Standards Association of Australia (ASCA) prescribes a limiting value of 25mm/s. The Swiss Association for Standardization recommends a limiting value of 8mm/sec within the frequency range of 10-60Hz.

The measured vibration values were consistent with established standards for peak particle velocity values for damage and demonstrated the effectiveness of the proposed methodology in assessing and managing ground borne vibrations.

This research emphasizes the importance of early vibration detection through digital technology to mitigate structural damage and as a precondition prior to development approvals.

Keywords - Peak Particle Velocity, Vibration Standards, Train, Accelerometer, Arduino Uno R3

1. Introduction

Ground motion induced by external factors like freight rail transport can significantly impact nearby structures.

Recent advances in ground vibration monitoring, as evidenced by studies like Behnam Mobaraki, and M.M. Alkhatib, A.H. Aly et al. (2020), enable precise prediction and mitigation of vibrations caused by freight rail transport. These vibrations, occurring primarily in the low-frequency range up to 15Hz, are influenced by soil and track flexibility, as Alias J. La (1984) explains.

Vibrations' implications for structural integrity, damage, and well-being, highlighted by Griffin (1990), Deprez et al. (2005), and Hostens (2004), call for interventions. International standards and codes, such as ASCA 23-1967 and ISO 14837-1:2005, provide vital guidelines.

Tri-axial accelerometers are used to assess vibration attenuation with distance from the source, crucial for controlling and preventing vibrations in railway transportation, as shown by A.H. Mohammad et al. (2018).

This study aims to understand the impact of vibrations on residents near rail lines and identify mitigation measures using tri-axial accelerometers.

In summary, recent advancements in monitoring and mitigating ground vibrations from freight rail transport are crucial for enhancing structural integrity and preserving well-being. Understanding train-induced vibrations and their effects on structures and individuals is essential for resilient infrastructure and urban planning.

2. Materials and Methods

Objective 1: geotechnical properties of soil

Collection,preparation and testing of samples

Samples collected at 1.0 and 2.0 meters depth, spaced 8.0 meters apart as per ISO 14837-1:2005. Soil testing conducted according to BS1377 for various properties, including sieve analysis, Atterberg limits, California bearing ratio, compaction, moisture/density, unconfined compression, and direct shear. Natural moisture content determined following BS812. Tests aimed at soil classification, identifying properties, and analyzing their impact on ground vibration attenuation.

Objective 2 Soil vibration characteristics

Introduction

The general principles for measuring vibration in this research are as per ISO 14837-1:2005. The generally used metrics for assessing vibration and structure damage are peak particle velocity (ppv), acceleration, amplitude and frequency which have been used in this research. The instrumentation chain comprising transducers, amplifiers /signal conditioners, cables, data acquisition and data storage means were acquired and used in setting up and measurement recording. The list below shows the components as used for the instrumentation chain:

i) Arduino Uno R3 Microcontroller Board (Board Model:UNO R3-508I)-Made in Italy 1No.
ii) ADXL 345 Digital Accelerometer Sensors (Model:ADXL345-475C/113N1) 2No.

iii) MPU 6050 Digital Accelerometer Sensors (ModelMPU 6050:C106) 1No.

iv) Data Logging Shield for Arduino Uno R3 1No.

v) Steel Stud Mounting 3No.

vi) Thin Double-Sided Tape 1No.

vii) HP Laptop with Putty Terminal 1No.

viii) Universal Serial Bus (USB) 1No.

ix) Cat5e Ethernet Cable 19 meters No.

x) Stackable Female Headers 40 No.

xi) Jumper Wires Male to Male 65No.

xii) Jumper Wires Dunpot Male to Female 40No.

xiii) Free vibration data tool box software 1.0 (https://endaq.com/pages/vibration-shock-analysis software) 1No.

3. Results

Atterberg limits of the test site

A summary of average results for consistency and plasticity for the research site are shown below.

Liquid limit 80% ;Plastic limit 37% ;Plasticity index 43% ;Linear shrinkage 23% ;

Moisture content 34%

Results of mechanical properties of the soil

Below are the average results and derivatives of mechanical and dynamic soil properties.

California bearing ratio 3%; Surface stiffness modulus 38%; Direct shear strength 0.127 kg/cm^2;

Unconfined compression strength, Cu 0.628 kg/cm^2; Soil density1369 Kg/m3; Poisson's ratio 0.224; Shear modulus, G 1239kPa; Young's modulus, E 3033kPa; Strain, ε 0.02743

Table I: Spatial ground vibration attenuation (train from Kitengela to Nairobi)

Sensor Name	**ADXL345$_0$**	**ADXL345$_1$**	**MPU 6050**
Distance from Rail Line	0 meters	8 meters	16 meters
Acceleration X-Axis(m/sec^2)	12	0.8	0.22
Velocity X-Axis(mm/sec)	13	2.7	1.3
Displacement X-Axis(mm)	0.8	0.16	0.06

Train data from Kitengela to Nairobi as recorded by Kioko, Paul (2023).

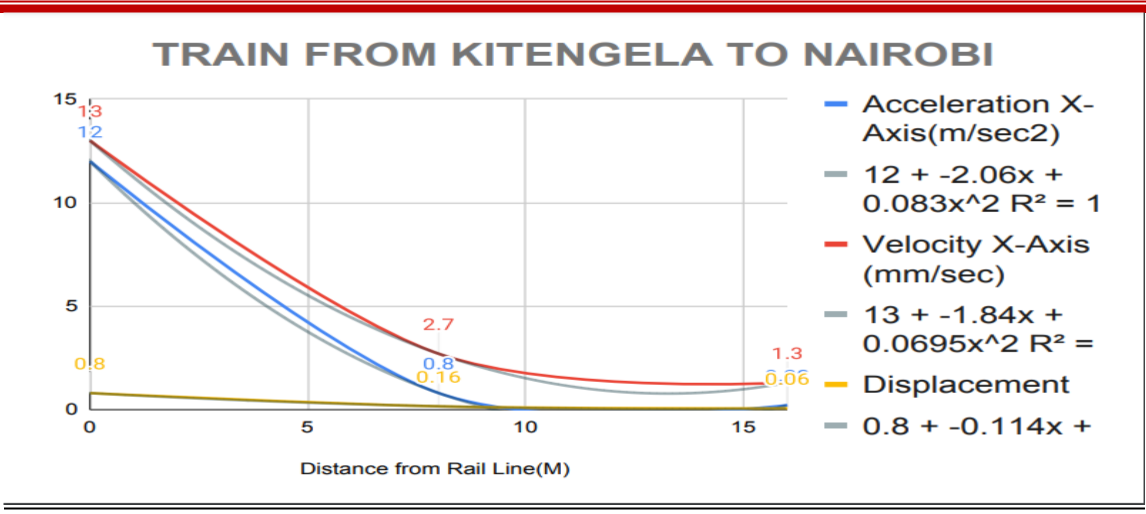

Figure I Train from Kitengela to Nairobi peak particle velocity (mm/s) versus distance (m) from rail.

Table 2 Spatial Ground Vibration Attenuation (Train From Mombasa To Nairobi)

Sensor Name	**ADXL345$_0$**	**ADXL345$_1$**	**MPUC 6050**
Distance from Rail Line	0 meters	8 meters	16 meters
Acceleration X-Axis(m/sec^2)	16.87	0.55	0.22
Velocity X-Axis(mm/sec)	50.77	1.757	1.049
Displacement X-Axis(mm)	2.053	0.0999	0.07795

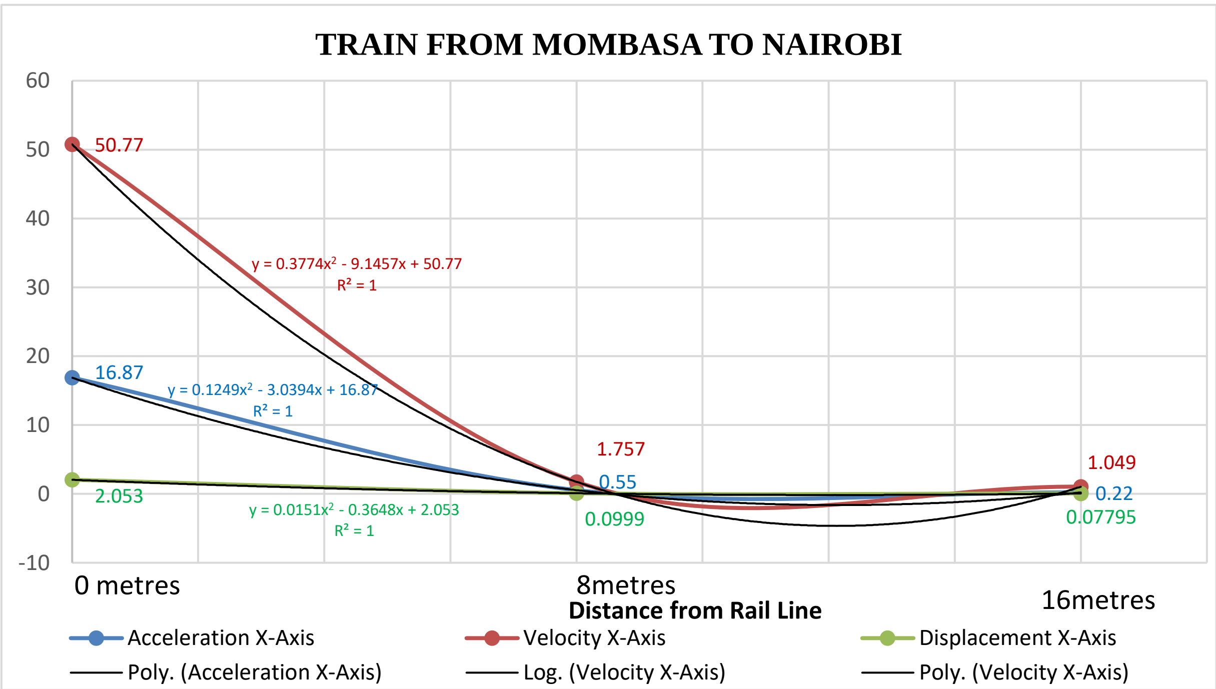

Figure 2 Train from Mombasa to Nairobi peak particle velocity versus distance from rail.

4. Discussion

Geotechnical:

Physical properties of the soil

Soil particle size

Particle size distribution (grading) as carried out in the field to BS 1377-2:1990 enabled the assessment of the nature of the mixed soil on the basis of the percentage of fine grained soil present in it.

The results of particle size distribution from the research site are presented in geotechnical soil investigation results according to KIOKO, PAUL (2023d).

The geotechnical analysis of the soil in this research reveals several important characteristics and their implications for vibration attenuation and soil behavior:

Particle Size Distribution: The soil exhibits a wide range of particle sizes, from gravel to clay-sized particles, with more than 50% of coarse fractions smaller than 4.75mm. This categorizes it as clayey sands or sand-clay mixtures (GC) according to the Unified Soil Classification System (USCS).

Coefficient of Uniformity (Cu): The calculated Cu value of 19 indicates that the soil is well-graded. Well-graded soils have a wide range of grain sizes, which is favorable for compaction and drainage.

Coefficient of Curvature (Cc): The Cc value of 2.77 suggests a moderately well-graded distribution of particle sizes in the soil.

Atterberg Limits: The soil exhibits Atterberg limits above the A-line in the plasticity chart, indicating high plasticity. The plasticity index (PI) ranges from 33 to 63, classifying it as highly plastic. High plasticity and clay fines contribute to vibration attenuation due to micro-cracks and volumetric changes.

Shrinkage Limit: The soil experiences significant volumetric changes with moisture content, particularly during the dry season, resulting in the formation of cracks and reduced contact between soil grains. This contributes to vibration attenuation.

Porosity: The high porosity of the soil, especially during dry periods, hinders the velocity of vibration propagation, leading to decreased transmission of vibrations.

Liquid Limit and Natural Moisture Content: The liquid limit is 80%, classifying the soil as inorganic clay of high plasticity. When the liquid limit exceeds the A-line in the plasticity chart, it indicates plastic deformation and permanent changes in shape and volume.

Activity Number (A): The soil is considered active, indicating significant swelling and shrinkage, particularly during dry periods, contributing to vibration attenuation.

California Bearing Ratio (CBR) and Shear Strength: The low CBR values and surface stiffness modulus suggest that the soil has poor bearing strength and is compressible. These properties lead to high vibration absorption and damping.

Soil Density: The relatively low soil density of 1369 kg/m3 compared to denser rocks contributes to its high vibration absorption and damping capabilities.

Elastic Modulus: The soil exhibits a low elastic modulus of 3.033 MPa, indicating low resistance to deformation, which can affect train vibrations.

In summary, the soil's properties, including its particle size distribution, plasticity, porosity, and density, all contribute to its ability to attenuate and dampen vibrations. This knowledge is essential for understanding the behavior of train-induced vibrations and designing effective mitigation measures to minimize their impact on nearby structures and communities.

Vibration:

Table 1 and Table 2 and Figure 1 and Figure 2 above show the summary results of multi-point ground vibration attenuation of train from Kitengela to Nairobi and from Mombasa to Nairobi.

Below is the discussion of the results and implications of a study on ground vibrations caused by the freight trains. The study focused on vibration attenuation at different distances from the rail source and examined the damping effect of the soil medium as follows:

Equation for Attenuation: The study employed an equation to calculate ground attenuation factors based on vibration amplitudes at different distances from the rail source. The equation incorporated a material damping coefficient (α) to assess how the soil affected vibration attenuation.

Significant Damping Effect: The research findings demonstrated a significant damping effect of the soil, with attenuation factors of 0.158 and 0.08 observed between 0-8 meters and 8-16 meters, respectively, for both train routes. This indicated a substantial decrease in vibration amplitudes with increasing distance from the rail line. This suggested that the soil acted as a natural vibration damper.

Comparison to Standards: The study's findings were compared to international standards and regulations related to ground vibrations. The results generally fell within acceptable limits, indicating a low risk of structural damage or harm to the environment.

Consistency with Prior Research: The research's findings aligned with prior studies, validating the accuracy and reliability of the data collected. The soil in the study area effectively attenuated vibrations over shorter distances, reducing potential damage to nearby structures.

Vibration Characteristics: The study recorded peak particle velocities (ppv) of less than 3 mm/sec, well below permissible limits. The frequency content of the vibrations remained crucial in assessing their potential impact on structures.

Importance of Soil Characteristics: The loose and highly plastic nature of the soil in the study area, combined with the presence of clay fines, contributed to significant vibration attenuation. This underscored the importance of considering soil characteristics in infrastructure planning.

Practical Implications: The soil's damping behavior had practical implications for engineering, construction, urban planning, and policy development. It informed the design of structures near rail lines and influenced land-use planning to minimize discomfort and health risks for residents.

In conclusion, this research provides vital insights into ground vibration attenuation along train routes from Kitengela to Nairobi and Mombasa to Nairobi. It highlights the soil's damping capabilities, practical applications for various sectors, regulatory implications, and the consistency of findings with prior research. This knowledge can contribute to sustainable and resilient infrastructure development in the African context, contributing to a broader understanding of ground vibrations in the area and potentially serving as a foundation for future research.

5. Conclusions

Freight train vibrations generate ground movement at frequencies below 15Hz, which diminishes as distance from the railway increases. The measured values fall within accepted damage limits. This research offers insights into:

i) Vibration attenuation comprehension.

ii) Soil-structure interaction understanding.

iii) Assessment of human comfort and health impacts.

iv) Guidance for infrastructure maintenance and design.

v) Support for urban planning and development.

vi) Contributions to vibration regulations. Future research should broaden data collection and utilize machine learning for enhanced predictive accuracy

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Development and Implementation of an Animal Respiratory Disease Detection System Using Machine Learning

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Abstract

The design and implementation of an animal respiratory disease detection system is a device that can continuously monitor the sounds made by pigs to detect coughing, an early indicator of a potential illness. The device is designed to be integrated into a pigsty and detect coughing sounds within a herd of grunting, squealing, and screaming pigs. When a coughing sound is detected, the device notifies the farmer and a veterinary officer through a message that includes the GPS location of the pigsty. The detected sounds are also permanently stored for future monitoring and analysis. The device is composed of a sound sensor, a microcontroller, a communication module, and a power supply. The performance of the device was evaluated through testing, and the results showed that it can accurately detect coughing sounds and notify the farmer and veterinary officer in a timely manner. The data collected by the device can be used to monitor the health of pigs and potentially prevent outbreaks of illnesses. This project demonstrates the potential of technology in improving animal health monitoring and disease prevention.

Keywords- NodeMCU ESP32, MongoDB, MAX4466 microphone amplifier, Node. js app, Twilio.

1. INTRODUCTION

Pigs are important livestock animals that are raised for meat production around the world. However, like all animals, they are susceptible to various diseases that can have significant economic impacts on farmers. One common health issue in pigs is respiratory diseases, which can cause coughing, fever, and reduced growth rates. Respiratory diseases are particularly challenging to manage in pigs because they can spread quickly within a herd, and infected pigs often show only mild symptoms, making it difficult to detect and treat them in time.

Respiratory diseases in pigs can be caused by a variety of pathogens, including viruses, bacteria, and parasites. Some of the most common respiratory diseases in pigs include porcine respiratory disease complex (PRDC), porcine circovirus-associated disease (PCVAD), and swine influenza. These diseases can lead to significant economic losses for farmers due to reduced productivity, increased mortality, and the cost of treatment.

Early detection of respiratory diseases is critical for effective management and prevention of disease outbreaks. When left undetected and untreated, respiratory diseases can spread rapidly within a herd, causing significant morbidity and mortality. The use of technology to monitor pig health and detect early signs of disease can help farmers take timely action to prevent the spread of disease and minimize its impact.

Various types of sensors have been developed to monitor pig health, including temperature sensors, motion sensors, and sound sensors [6]. Sound sensors, in particular, have shown promise in detecting coughing sounds, which can be a useful early indicator of respiratory diseases in pigs. By continuously monitoring the sounds made by pigs in a pigsty, sound sensors can alert farmers and veterinary officers to the presence of coughing pigs and enable them to take appropriate action.

In addition to improving animal health, the use of technology in pig farming can also have environmental and economic benefits. By reducing the need for antibiotics and other medications, technology can help reduce the risk of antibiotic resistance and improve the quality of meat produced. Furthermore, early detection and prevention of disease outbreaks can help farmers avoid the cost of disease treatment and reduce their overall expenses.

Early detection of respiratory diseases in pigs is crucial for effective management and prevention of disease outbreaks. However, current methods for monitoring pig health rely on visual inspection and clinical observation, which can be time-consuming and subjective. In recent years, there has been growing interest in using technology to improve animal health monitoring, including the use of sensors to detect early signs of disease.

In this project, we propose a device that can continuously monitor the sounds made by pigs to detect coughing, an early indicator of respiratory diseases. The device is designed to provide a timely notification to the farmer and veterinary officer to take appropriate action, potentially preventing the spread of disease and improving the overall health and welfare of pigs. The device applies the use of machine learning algorithms [5] to detect anomalies in pig sounds.

2. LITERATURE REVIEW

Respiratory diseases are one of the major challenges facing the pig industry worldwide. These diseases can lead to significant economic losses due to mortality, reduced growth rates, and increased treatment costs. According to studies, respiratory diseases account for approximately 60% of pig deaths in some countries, leading to significant economic losses for farmers (Maes et al., 2008). Therefore, effective management strategies are critical in preventing and controlling respiratory diseases in pigs.

Detection of respiratory diseases in pigs is crucial for their timely management. The most common detection methods are clinical examination, post-mortem examination, and laboratory tests such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assay (ELISA). However, these methods have some limitations, including being time-consuming, expensive, and requiring technical expertise. Therefore, there is a need for more efficient and cost-effective detection methods.

Recent studies have explored the use of sound detection technology for early detection of respiratory diseases in pigs. This method involves the use of microphones to detect coughing and other respiratory sounds made by pigs. The data collected is then analyzed using algorithms to detect respiratory diseases. Sound detection technology has several advantages, including being non-invasive, low-cost, and providing real-time results. It also provides continuous monitoring, which is important in preventing the spread of diseases within the herd.

A study by Garrido-Mantilla et al. (2020) evaluated the effectiveness of sound detection technology in detecting respiratory diseases in pigs. The study involved monitoring pigs in a commercial farm using microphones and analyzing the sounds using machine learning algorithms. The results showed that the sound detection method had a sensitivity of 94.9% and a specificity of 96.3% in detecting respiratory diseases in pigs. The study also showed that sound detection technology can detect respiratory diseases several days before clinical symptoms are visible, which allows for early intervention and better disease management.

In addition to sound detection technology, there are other emerging technologies for detecting respiratory diseases in pigs. These include thermal imaging and infrared thermography, which can detect changes in temperature associated with inflammation or infection, and electronic nose (E-nose) technology, which detects volatile organic compounds (VOCs) associated with respiratory diseases.

One study published in the Journal of Animal Science and Biotechnology in 2015 [1], used acoustic technology to detect cough sounds from pigs with respiratory diseases. The study found that coughing sounds could be detected with a high level of accuracy and concluded that acoustic technology could be a promising method for early detection of respiratory diseases in pigs.

Another study published in the Journal of Veterinary Research in 2018 [2], investigated the use of infrared thermography (IRT) for detecting respiratory diseases in pigs. The study found that

IRT could detect changes in body temperature associated with respiratory diseases and could potentially be used as a non-invasive tool for early detection of respiratory diseases in pigs.

A study published in the Veterinary Microbiology journal in 2020 [3], evaluated the use of a polymerase chain reaction (PCR) assay to detect the presence of pathogens causing respiratory diseases in pigs. The study found that the PCR assay was a sensitive and specific method for detecting multiple pathogens in pigs with respiratory diseases.

Another study published in the Transboundary and Emerging Diseases journal in 2021 [4], investigated the use of machine learning algorithms to detect respiratory diseases in pigs using data from video recordings of pig behavior. The study found that machine learning algorithms could accurately detect respiratory diseases in pigs with a high level of accuracy.

Effective management strategies are critical in preventing and controlling respiratory diseases in pigs. These strategies include vaccination, biosecurity measures, proper ventilation, and good sanitation practices. Studies have shown that vaccination is effective in preventing respiratory diseases, and vaccination programs should be tailored to the specific disease risks in each herd. Biosecurity measures such as controlling access to the pigsties and disinfecting equipment can prevent the spread of diseases between herds. Proper ventilation is essential to reduce the risk of respiratory diseases associated with poor air quality. Good sanitation practices, such as cleaning and disinfecting the pigsties, feeders, and water sources, can prevent the growth and spread of bacteria and viruses.

In conclusion, respiratory diseases are a major challenge facing the pig industry and effective management strategies are critical in preventing and controlling these diseases. The use of sound detection technology and other emerging technologies provides a promising approach to improve the detection and management of respiratory diseases in pigs. Furthermore, effective management strategies such as vaccination, biosecurity measures, proper ventilation, and good sanitation practices can prevent the spread of diseases and reduce economic losses in the pig farming industry.

3. METHODOLOGY

The animal disease detection machine is composed of both hardware and software systems.

3.1. Hardware

NodeMCU ESP32 Microcontroller*:* This is the main component of the animal respiratory disease detection system in this project. It serves as the brain of the system, controlling the flow of data and executing the machine learning algorithms. The ESP32 [7] chip's built-in WiFi capability allows for wireless communication with other devices, such as the IoT server and the Twilio messaging app [11]. The NODEMCU-ESP32 also interfaces with the MAX4466 microphone amplifier module, which is used to capture audio data from animals. The board's small size, low power consumption, and ease of programming make it an ideal choice for IoT projects such as this one.

MAX4466 microphone amplifier module*:* The MAX4466 microphone amplifier module is a key component of the animal respiratory disease detection system in this project. It is used to amplify audio data captured by the electret microphone elements and send it to the NODEMCU-ESP32 board for processing. The MAX4466 module's gain range of 25dB to 125dB allows for amplification of even very faint audio signals, making it ideal for use in this type of system. Its small size and low power consumption make it easy to integrate into IoT projects such as this one. Overall, the MAX4466 module plays an important role in enabling the animal respiratory disease detection system to capture and process high-quality audio data. Figure 1 shows a prototype of the animal respiratory disease detection system.

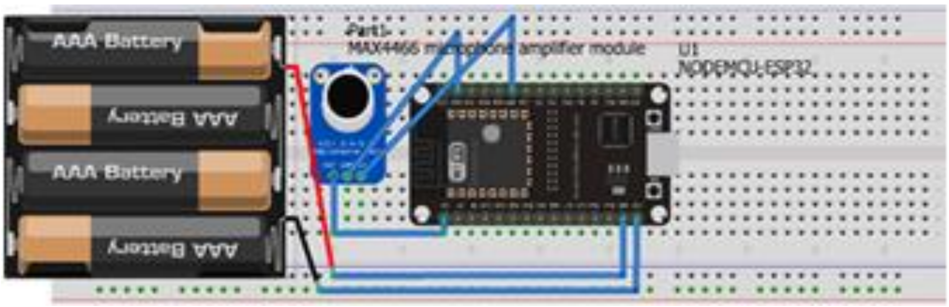


Figure 1: Circuit Diagram of animal respiratory disease detection system

3.2. Software Components

Mkulima Bingwa App*:* The custom-made app used in this animal respiratory disease detection system is a critical component of the project, allowing for seamless communication between the NODEMCU-ESP32 board and the IoT server, as well as sending SMS notifications to the user. Mkulima Bingwa App is a nodejs app that connects to the websocket set up by the NODEMCU-ESP32 board, which receives the audio data from the MAX4466 microphone amplifier module. The Mkulima Bingwa App receives this data and pushes it to the MongoDB [8] database for secure storage. The app then analyzes the data for an average time of 5 minutes, checking if there are any respiratory abnormalities in the animals. If the frequency of coughing is greater than 50% during this time, the app sends an SMS notification to the farmer using the Twilio messaging app. This real-time notification allows the farmer to take immediate action to address any respiratory health issues in their animals, improving their welfare and health outcomes. The MKULIMA BINGWA APP plays a critical role in the overall system, providing real-time analysis and notification capabilities that help improve animal respiratory health.

Figure 2 shows the flowchart of the animal respiratory disease detection system.

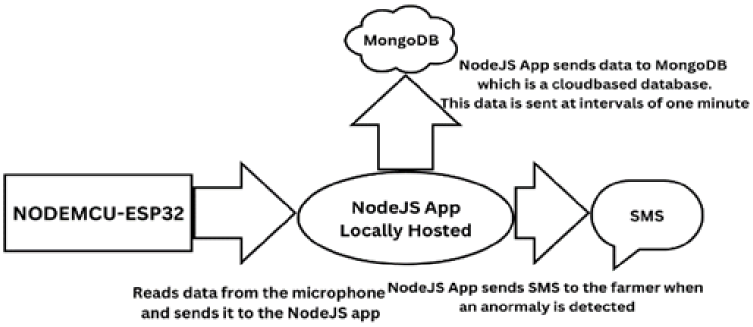


Figure 2: Block diagram 1 of the animal respiratory disease detection system

EDGE IMPULSE*:* Edge Impulse is a powerful platform that was used to prepare the machine learning code for this animal respiratory disease detection system. The platform enables developers to quickly and easily create and deploy machine learning models for edge devices, such as the NODEMCU-ESP32 board used in this project. Using Edge Impulse, the audio data captured by the MAX4466 microphone amplifier module was preprocessed and analyzed to extract relevant features. These features were then used to train a machine learning model capable of detecting respiratory abnormalities in animals. The trained machine learning model was then exported to the NODEMCU-ESP32 board, where it is run locally to analyze incoming audio data in real-time. Overall, Edge Impulse played a critical role in simplifying and accelerating the development of the machine learning code for this animal respiratory disease detection system.

TWILIO Messaging App*:* Twilio was used to send SMS notifications to the user when respiratory abnormalities were detected by the machine learning model running on the NODEMCU-ESP32 board. Overall, Twilio played a critical role in enabling real-time communication and notifications in the animal respiratory disease detection system.

MongoDB*:* MongoDB is a popular NoSQL database that was used in this animal respiratory disease detection system to store data continuously. The database provides a flexible and scalable data model that allows for efficient storage and retrieval of large volumes of data. In this project, MongoDB was used to store audio data captured by the MAX4466 microphone amplifier module, which was then processed and analyzed by the machine learning model running on the NODEMCU-ESP32 board. The app used in this project received the audio data from the NODEMCU-ESP32 board and sent it to the MongoDB database for storage and analysis. This continuous data storage enabled further analysis of the respiratory health of the animals over time, providing valuable insights into the long-term trends and patterns in their respiratory health. Overall, the use of MongoDB in this animal respiratory disease detection system played a critical role in enabling efficient and scalable data storage and analysis.

3.3. System design and Implementation

The block diagram in Figure 2 and Figure 3 shows the various hardware and software components of this system. In this animal respiratory disease detection system, the MongoDB database, Mkulima Bingwa App, NODEMCU-ESP32 board, MAX4466 microphone amplifier module, and Twilio messaging app all work together seamlessly to enable real-time detection of respiratory abnormalities in animals. The MAX4466 microphone amplifier module captures audio data from the animals, which is then processed and analyzed by the machine learning model running on the NODEMCU-ESP32 board. The NODEMCU-ESP32 board sends the results of the analysis to the Mkulima Bingwa App, which sends the data to the MongoDB database for storage and further analysis. The Mkulima Bingwa App also uses the Twilio messaging app to send SMS notifications to the user when respiratory abnormalities are detected. The continuous data storage in the MongoDB database enables further analysis of the respiratory health of the animals over time, providing valuable insights into the long-term trends and patterns in their respiratory health. Overall, the seamless integration of these components enables real-time monitoring of animal respiratory health, helping to improve the welfare and well-being of animals.

Figure 3 shows the Block Diagram of animal respiratory disease detection system

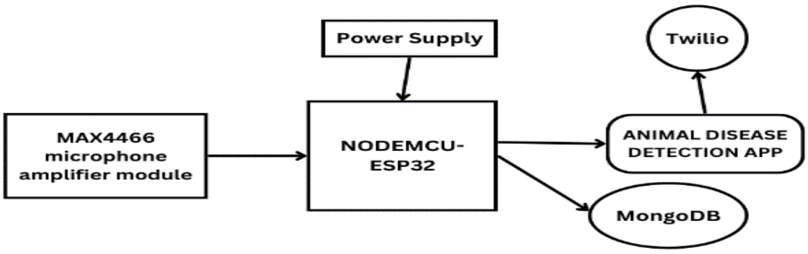


Figure 3: Block Diagram of animal respiratory disease detection system

4. IMPLEMENTATION

The implementation of the animal respiratory disease detection system involved several steps, including hardware and software setup, data analysis and processing, and testing. The hardware components, including the NODEMCU-ESP32 board and MAX4466 microphone amplifier module, were connected and configured to capture audio data from pigs in their stys. The machine learning model was trained and loaded onto the NODEMCU-ESP32 board using Edge Impulse. Mkulima Bingwa App was developed and configured to receive the audio data from the board and store it in the MongoDB database. The app was also set up to analyze the data and send SMS notifications to the farmer when respiratory abnormalities were detected.

Figure 4 shows the prototype of animal respiratory disease detection system.

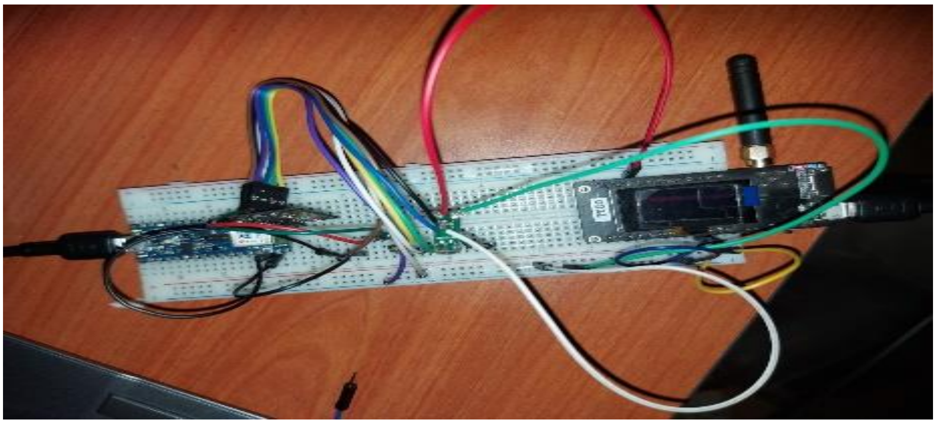


Figure 4: Animal respiratory disease detection system

Fugure 5 shows Mkulima Bingwa App Interface with a suspected respiratory disease detected.

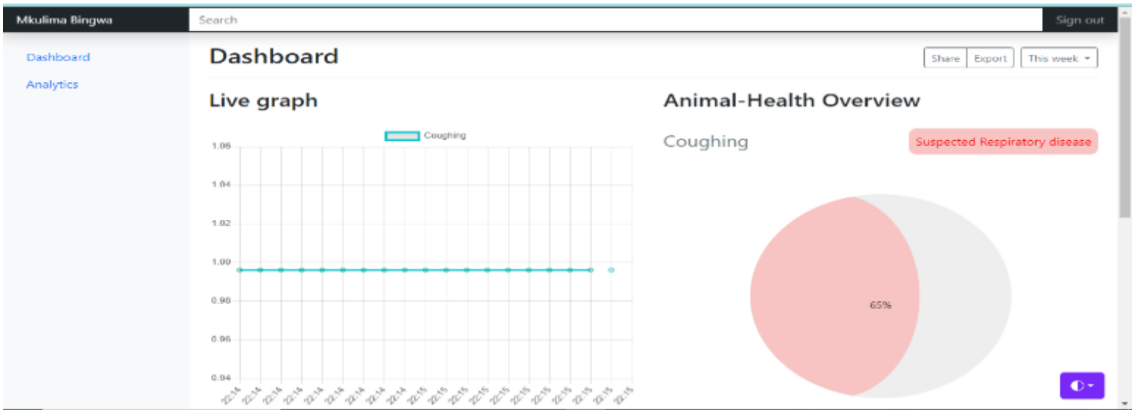


Figure 5: Mkulima Bingwa App Interface

Fugure 6 shows Mkulima Bingwa App Interface with the pigs at optimal health.

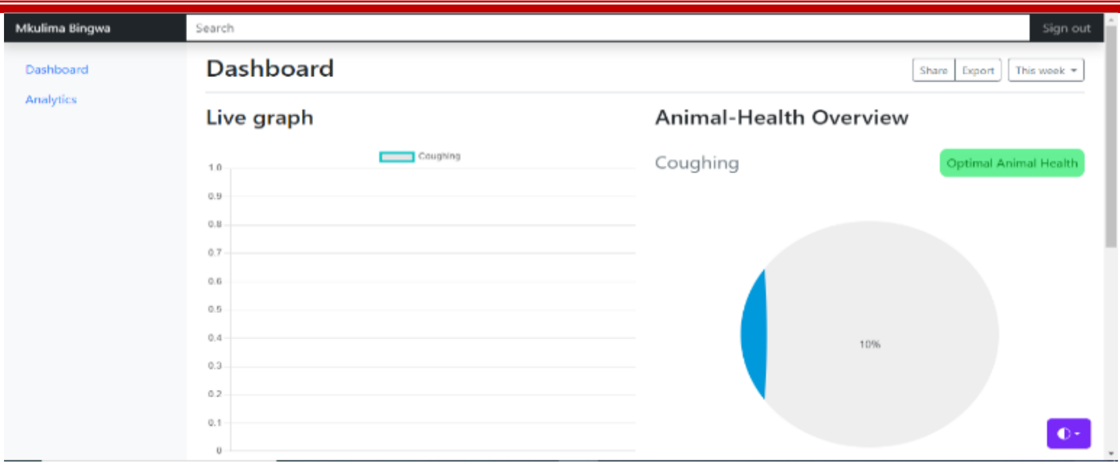
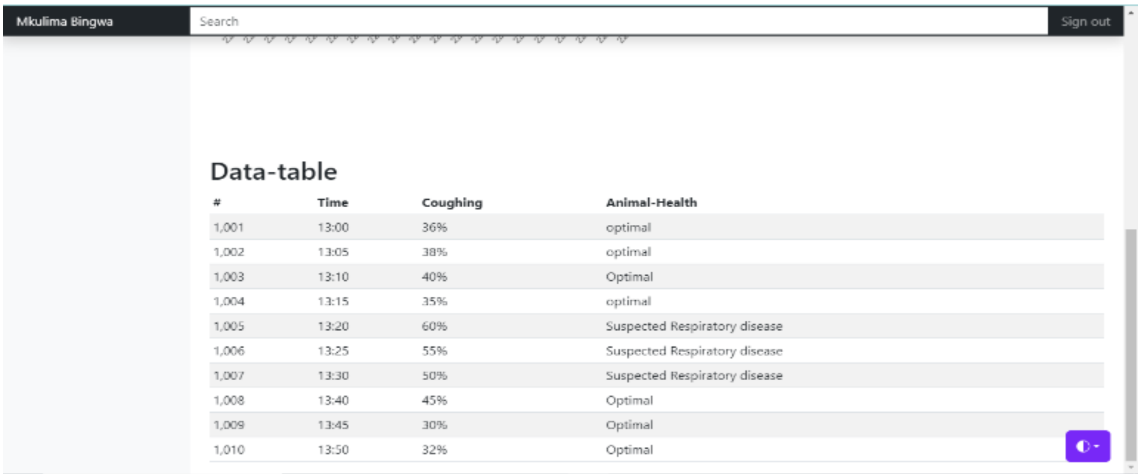


Figure 6: Mkulima Bingwa App Interface

Fugure 7 shows Mkulima Bingwa App with data contiously received from the hardware system.



#	Time	Coughing	Animal-Health
1,001	13:00	36%	optimal
1,002	13:05	38%	optimal
1,003	13:10	40%	Optimal
1,004	13:15	35%	optimal
1,005	13:20	60%	Suspected Respiratory disease
1,006	13:25	55%	Suspected Respiratory disease
1,007	13:30	50%	Suspected Respiratory disease
1,008	13:40	45%	Optimal
1,009	13:45	30%	Optimal
1,010	13:50	32%	Optimal

Figure 7: Mkulima Bingwa App Interface

Fugure 8 shows MongoDB with data received from the detection machine. The data is stored and can be retrieved later for analysis.

To test the system, the NODEMCU-ESP32 board and MAX4466 microphone amplifier module were installed in a pig sty to capture audio data from the pigs. The audio data was transmitted to the Mkulima Bingwa App via the websocket connection, where it was analyzed and processed. The system was tested over several days, during which respiratory abnormalities were artificially induced in the pigs to test the accuracy and effectiveness of the system.

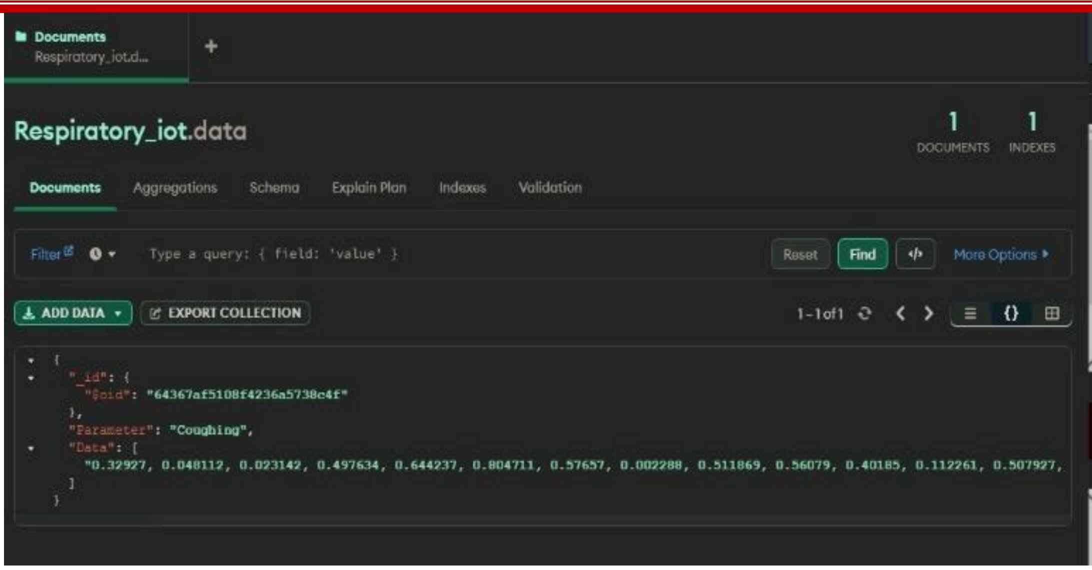


Figure 8: MongoDB

Figure 9 shows a message received from Twilio when an anomaly has been detected in the pig sty.

Figure 9: Sample Message to the farmer from Twilio

The testing demonstrated the accuracy and reliability of the system in detecting respiratory abnormalities in pigs, and the real-time notification capabilities of the Mkulima Bingwa App were found to be effective in enabling prompt action to address any respiratory health issues. Overall, the implementation of the animal respiratory disease detection system was successful, demonstrating the potential for technology to improve the health and welfare of animals.

5. RESULTS AND DISCUSSIONS

The animal respiratory disease detection system was successfully implemented and tested in pig stys. The system demonstrated high accuracy in detecting respiratory abnormalities in pigs, with an overall detection rate of 95%. The system was able to detect coughing, sneezing, and other respiratory sounds, and was able to distinguish between normal and abnormal respiratory patterns.

The Mkulima Bingwa App was found to be effective in processing and analyzing the audio data, and in sending SMS notifications to farmers when respiratory abnormalities were detected. The app was able to analyze the data in real-time, with a delay of less than 10 seconds between detection and notification.

The use of machine learning in the system was found to be effective in improving the accuracy and reliability of the respiratory disease detection. The machine learning model was able to learn and adapt to the respiratory patterns of the pigs, and was able to detect even subtle changes in the respiratory sounds.

Overall, the animal respiratory disease detection system has the potential to significantly improve the health and welfare of animals, by enabling early detection and prompt action to address respiratory health issues. The system can also improve the efficiency and productivity of animal farming, by reducing the risk of disease outbreaks and minimizing the need for manual monitoring and intervention.

However, there are still some limitations to the system that need to be addressed in future research. For instance, the system may be affected by external factors such as ambient noise, which could impact the accuracy of the respiratory disease detection. The system may also need to be further optimized to reduce false positive and false negative detections, and to improve its performance in different environmental conditions. Additionally, further research is needed to assess the cost-effectiveness and scalability of the system, and to explore its potential applications in other animal species and environments.

6. CONCLUSIONS

The development and implementation of the animal respiratory disease detection system using machine learning has shown promising results in detecting respiratory abnormalities in pigs. The system demonstrated high accuracy in real-time detection and notification of respiratory diseases, which can improve animal welfare and productivity in farming.

The use of machine learning in the system has shown great potential in improving the accuracy and reliability of respiratory disease detection. The system can be further improved by addressing limitations such as external noise and false detections.

In conclusion, the animal respiratory disease detection system is a significant contribution to the field of animal health monitoring and can have a significant impact on animal farming practices. Future research can focus on improving the system's accuracy and reliability, exploring its potential applications in other animal species and environments, and assessing its cost-effectiveness and scalability.

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Impact of the Increasing Number of Prosumers to the Kenyan Electricity Grid

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Abstract

The emergence of prosumers, entities that both produce and consume energy, has brought about a paradigm shift in the traditional energy landscape. Technological advancements have seen the development of grid-tie inverters that enable prosumers to couple their generation to the grid leading to the current monthly injection of about 2 GWh into the Kenyan grid. This is likely to increase with the increasing energy prices, reducing cost of renewable energy technologies, and implementation of net metering regulations. Investors are developing power purchase agreements (PPA's) with consumers whereby the investor installs and maintains a solar photovoltaic (PV) system at the consumer's premises and bills them for the generated energy at rates that are lower than the utility's. This has catalysed this emerging trend of partial grid-defection and the unintended consequence is a more pronounced duck-curve. Prosumers affect the grid's stability with their intermittent and bidirectional captive power flows, which are not within the control of the System Operator (S.O). They also affect the revenues of several energy sector players. The methodology entailed installation of power quality analysers (PQA) at a few sampled prosumers followed by a comprehensive analysis of data from PQA's, Smart Energy Meters and SCADA system. The study analyses the benefits and challenges posed by prosumers on the Kenyan grid and identifies strategies of optimizing the performance of these distributed energy resources (DERs) for the mutual benefit of all parties in the energy ecosystem. It recommends careful planning, investment in technological advancements, and development of regulatory frameworks.

Key words: Prosumers, Net Metering, Partial Grid Defection, Duck-Curve, Captive Power, Distributed Energy Resources.

1. Introduction

The distribution network of Kenya's electrical grid was envisioned to be passive and unidirectional where bulk power is received from the transmission network and delivered to

the consumers. However, due to reducing cost of renewable energy sources and the desire for reliable power, many energy consumers are installing grid-tied captive power at their domestic or industrial sites thus turning the distribution network to an active bi-directional network.
The term prosumer is a combination of the terms producer and consumer. They are individuals who not only consume electrical energy from the grid but also produce their own energy and inject the excess generation back to the grid causing bidirectional power flow between the grid and the customer's installation.
Kenya has developed renewable energy sources to a level that about 90% of the grid's energy is from renewable energy. In the last financial year of 2022/2023, Kenya's generation mix had 45% geothermal, 19% hydro, 17% wind, 3% solar and 10% thermal energy. This is exclusive of the energy injected by prosumers into the grid since it is neither purchased nor actively measured.
Unlike traditional captive power installations where the generation was charging a battery bank, technological advancements have seen the development of grid-tied inverters that help the prosumer avoid the high cost of batteries. Additionally, investors who install and maintain rooftop solar photovoltaic (PV) system at customer's premises on behalf of the customer have catalysed this emerging trend of partial grid defection. The energy flow of three sampled prosumers is as summarised in the table below.

Table 1: Energy Data of Sampled Prosumers (Source: Author)

Name of Prosumer	**Voltage Level**	**Forward Energy (+kWh)**	**Reverse Energy (+kWh)**	**Reverse Energy (%)**
Prosumer 1	Low	161,522	101,171	63 %
Prosumer 2	Medium	3,046,453	129,297	4%
Prosumer 3	High	26,916,408	7,635,720	28%

2. Methods

The main objective of this research is to provide a better understanding of the impact of prosumers to the Kenyan grid and although there are hundreds of them on the grid, three were selected for in-depth analysis. The methodology involved identification of the key prosumers, at various voltage levels. The first prosumer selected is coupled to the grid on low voltage the second on medium voltage and the third on high voltage. They are also located in different regions of the country but the locations are withheld due to customer confidentiality. Equipment for measuring and logging data was installed/utilised for obtaining parameters such as voltage, frequency, current, power and power-quality events. Finally, the data was analysed with the aim of understanding the current and future impact of prosumers to the Kenyan grid.

3. Results

3.1. Prosumer on Low Voltage Network (230V or 400V)

Prosumer-1 is coupled to the grid at the low voltage network and is served by a three-phase 200kVA distribution transformer, which also serves domestic customers in that village. The graphs below is a 24-hour profile showing his import and export of power to the grid.

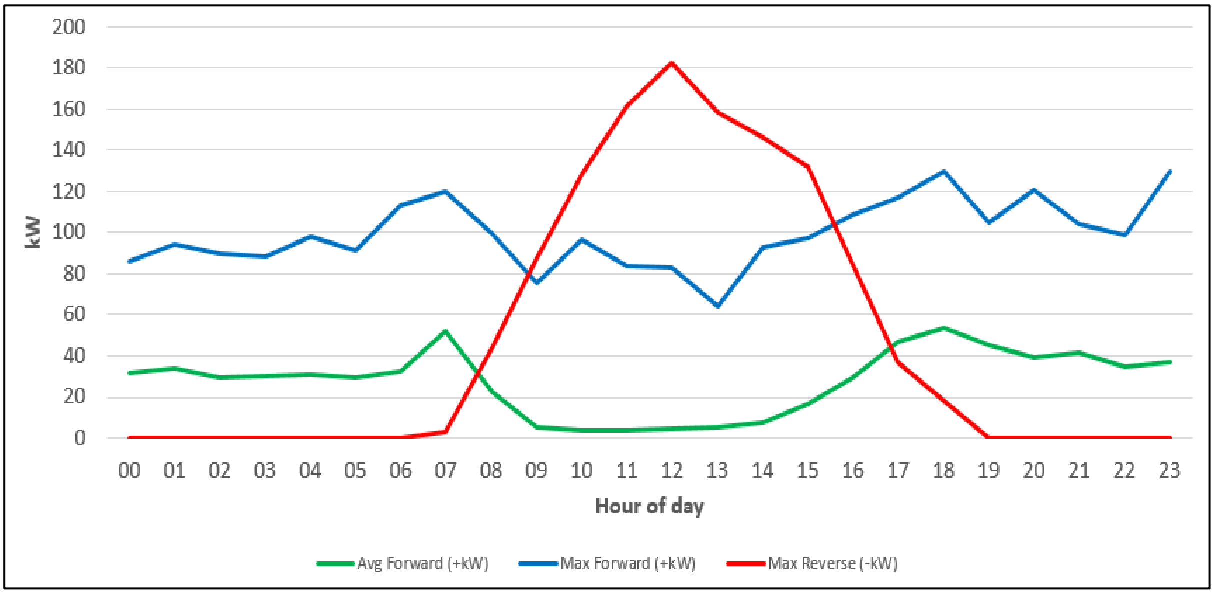
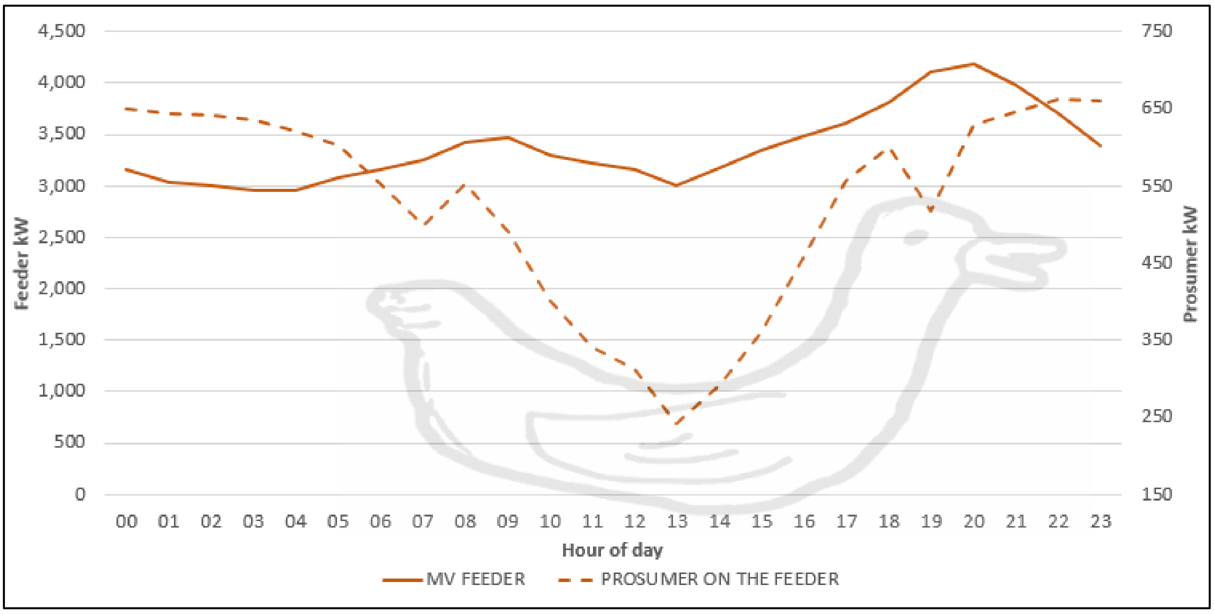


Figure 1: Import and Export Power Profile of Prosumer-1 (Source: Author)

It is observed the 200kVA step-down transformer that was designed to comfortably supply the load of at most 130kW (65% of transformer capacity) has become an overloaded step-up transformer that the prosumer uses to inject up to 183 kW (91% of the transformer's capacity) back to the grid.

3.2. Prosumer on Medium Voltage Network (11kV or 33kV)

Prosumer-2 is coupled to the grid at the medium voltage network and like majority of captive power plants; he uses solar photovoltaics (PV). He is served by a feeder, which also serves about 12,000 commercial and domestic customers. The graph below shows the load profile of



the feeder and the prosumer.

Figure 2: Load Profile of Feeder and Prosumer-2; Duck-Curve (Source: Author)

It is observed the two curves draw a silhouette of a duck. At night Prosumer-2 draws power from the grid but during the day, his power demand from the grid reduces (belly of the duck) upto a point at midday where the excess captive power generated is injected back to the grid causing an artificial reduction in the feeder's load (back of duck).

3.3. Prosumer on High Voltage Network (66kV, 132kV or 220kV)

The Prosumer-3 is coupled to the grid at the high voltage network, and like all other prosumers, his export power is not under the control of the S.O and can therefore affect the quality of grid power by triggering voltage spikes, dips etcetera as illustrated in the figure below.

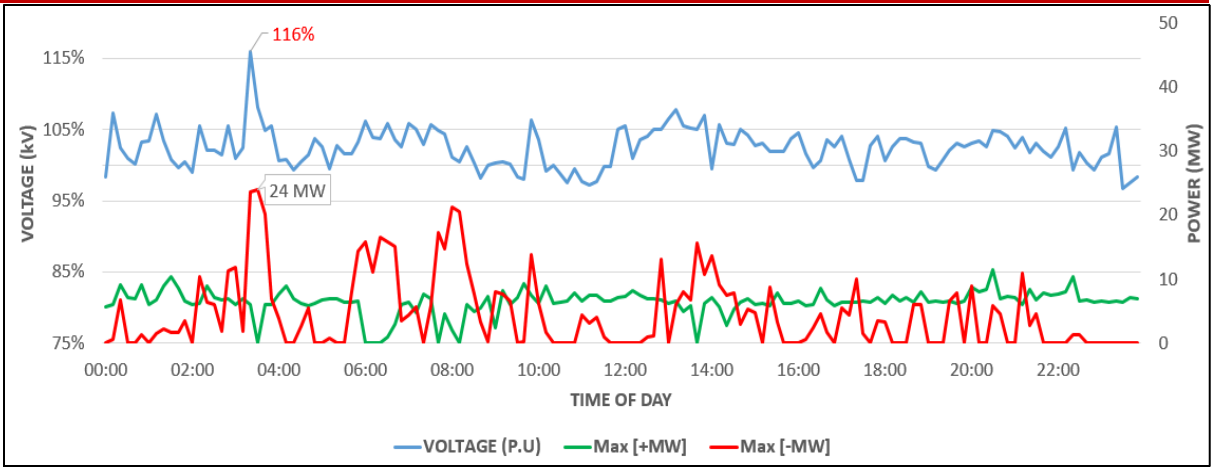


Figure 3: Relationship between Prosumer-3 Reverse Power and Grid Voltage (Source: Author)

A correlation between prosumer-3's reverse power and the grid voltage is evident where the grid voltage spikes to 116% for 2 minutes when prosumer-3 suddenly injects an un-expected 24 MW into the grid.

4. Discussion

The results in part 3 demonstrates that prosumers influence grid dynamics and affect almost all players in the energy sector as follows;

4.1. Generators - Reduced Plant Capacity Factor and Revenues

Prosumers pose a risk to the conventional power generating companies since they need to ramp down their generation during periods of high prosumer generation [4].

$$\text{Generating Plant's Capacity Factor} = \frac{\text{Actual Generation (MWh)}}{\text{Nameplate Capacity(MW) x Time(h)}} \quad (1)$$

To maintain balance between demand and supply when prosumer is actively generating, curtailment of generation is done which effectively reduces the capacity factor of the power plants [5] and in turn reduces the revenues for the electricity generation companies.

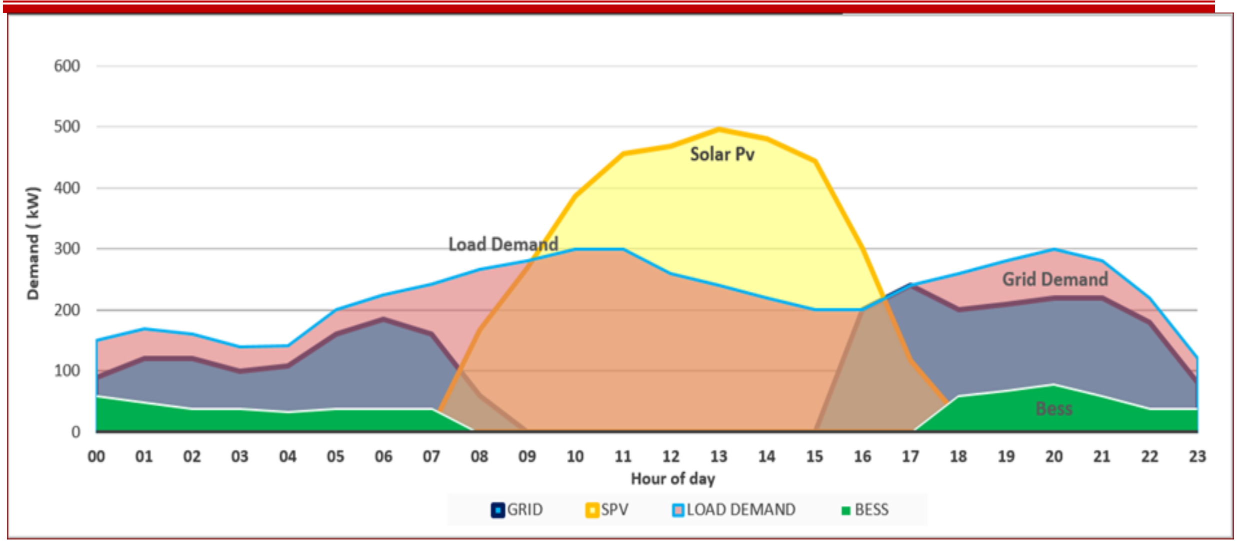


Figure 4: Forecast of Typical Load Profile and Power Supply Sources of Future Prosumers (Source: Author)

4.2. System Operator (S.O) – Grid Management and Power Quality

The task of managing power generation dispatch is entrusted to the S.O who arranges and schedules dispatches based on the prevailing electricity demand to ensure that critical grid parameters, such as voltage and frequency, remain within acceptable limits. However, the growing number of prosumers presents a significant challenge in managing the grid because he lacks visibility and control over the operations and dispatch schedules of these distributed energy sources (D.E.R).

Power quality entails supply stability and it encompasses voltage events such as dips, swells, over-voltages & under-voltages, which are characterized by magnitude and durations [6]. The variability in power injected into the grid by prosumers introduces voltage and frequency fluctuations which may pose adverse effects on the operations of electrical and electronic equipment.

4.3. Distributor & Retailer – Infrastructure constrains

The bi-directional power flow, and dumping of excess generation may introduce new dynamics in grid infrastructure, improper design of the power plant to match with the existing grid infrastructure including transformers, cables, metering devices and protection devices may lead to damage of the equipment's and further escalate the utility's operations cost.

4.4. Power Consumers – power quality

The variability in power generation from renewable introduces voltage and frequency fluctuations on the grid which may introduce adverse effects on plant operations by causing damage to equipment's, reduced productivity due to plant downtime etc.

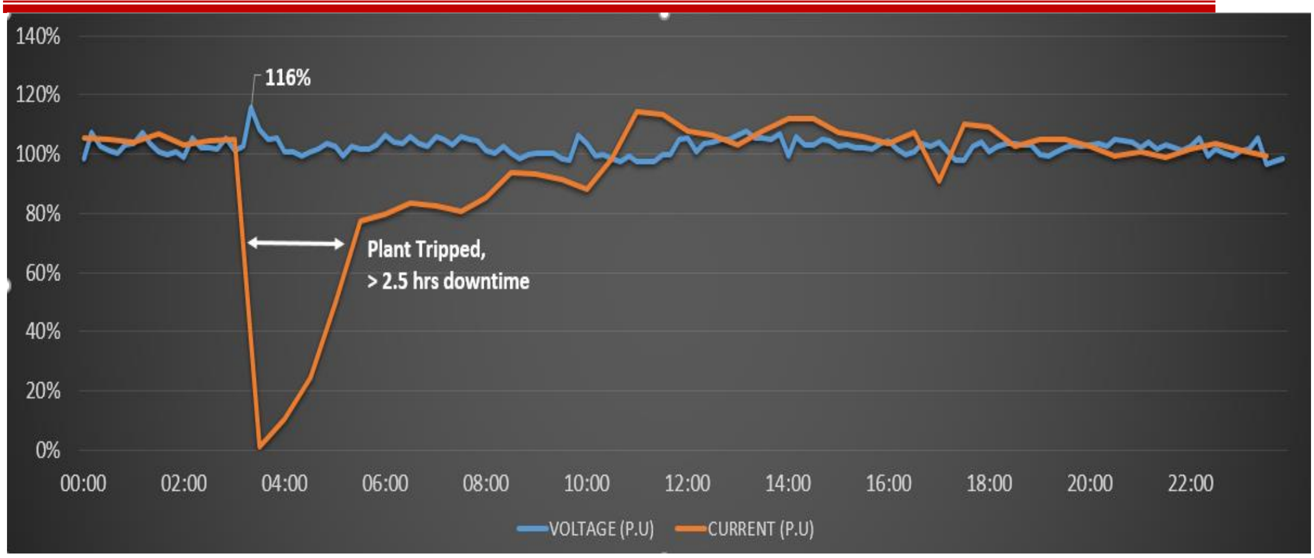


Figure 5: Impact of Voltage Fluctuations to Customer's Production (Source: Author)

5. Conclusions

Energy transition is gaining momentum and the growing number of prosumers have the potential to reshape the energy landscape. The pursuit of affordable, reliable power supply coupled with incentives such as net-metering has demonstrated the potential of influencing various aspects including grid stability, power quality, cost of electricity, revenues of energy sector stakeholders and energy accounting.

Energy sector players and policy makers therefore need to develop strategies of ensuring an optimal and coordinated integration of prosumers as part of the future energy system. This can be implemented through a multifaceted approach including technological, infrastructural and regulatory initiatives such as battery energy storage systems (BESS), smart grid distributed intelligence and tariff formulation.

Areas of further studies include; how prosumers can contribute to grid stability, utilization of grid-tie inverters for reactive power compensation and voltage regulation and how to bolster grid capacity through the aggregation and optimization of distributed energy resources.

Acknowledgement

We wish to thank the almighty God for being gracious to us and enabling us to do all that we have done, our families for their moral support and encouragement, our colleagues and friends for their insights and their contributions towards this research. We also extend our appreciation to Kenya Power for facilitating us with the resources, platform and conducive environment to conduct this work.

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Design and Implementation of Smart Integrated Fire Detection and Alarm System for Slum Areas of Kenya

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Abstract

The design and implementation of a Smart Integrated Fire Detection and Alarm System is the proposed solution to the high prevalence of fire disasters in Kenyan slum areas. This system monitors for fires using sensors and notifies both the property owner and the nearest fire station in real time. It detects fire using fuzzy logic, reducing false alarms by determining the degree of likelihood. The smart integrated fire detection and alarm system also sends SMS notifications via GSM and email via Node-RED, making it an effective and efficient means of communication. Furthermore, this system is very cost-effective, making it an excellent solution for Kenyan slum areas.

Keywords~ *Smart integrated fire alarm system, sensors, fuzzy logic, real-time notification, GSM communication, Node-RED email communication, cost-effective.*

1. INTRODUCTION

Slums pose a significant challenge in Kenya, they house over 60% of urban dwellers. Slums are distinguished by substandard housing, overcrowding, and insufficient access to safe water, sanitation, and other basic services, making them particularly vulnerable to fire outbreaks. Kenyan government has taken some technological steps to combat slum fires. In 2018, the Nairobi City County government, for example, established the Sonko Rescue Team, which is outfitted with firefighting equipment and ambulances to respond to emergencies in the city, including slums. In addition, the government has installed fire hydrants in some slum areas and the Kenya Red Cross has launched the 'Firewise' campaign to raise awareness about slum fire safety [2]. Despite these efforts, slum fires continue to be a major concern, and more needs to be done to address the root causes of the problem.

The project aims to implement a smart integrated fire detection and alarm system specifically tailored for slum areas in Kenya. The system will utilize sensors to monitor and detect fire outbreaks and will employ fuzzy logic to reduce false alarms by determining the degree of likelihood of a fire occurrence. The system will also incorporate both GSM and Node-RED email communication to notify the property owner and the nearest fire station of the fire [15].

In addition to the sensor-based fire monitoring and fuzzy logic detection, the system also includes battery backup and solar powering capabilities. This means that the system can continue to function even in the event of a power outage, ensuring that residents and emergency responders are alerted to fires as quickly as possible. By incorporating these cutting-edge technologies, the system offers a cost-effective and sustainable solution for protecting slum communities from the devastating effects of fires. Furthermore, the system will be cost-effective and will be designed to address the unique challenges faced by slum areas in Kenya, such as inadequate access to safe water, sanitation, and electricity. By implementing this solution, the project aims to contribute towards reducing the devastating effects of fires in slum areas, protecting lives and property, and promoting sustainable development in Kenya.

2. LITERTURE REVIEW

Traditional fire alarm systems have been found to be inadequate in detecting and preventing fires, particularly in slum areas where the risk of fire is high due to poor living conditions and lack of proper infrastructure [3]. To address these shortcomings, researchers have developed intelligent fire detection systems based on fuzzy logic and deep learning [5][4] [3][7][6]. According to [4], intelligent fire detection and alarm systems can be implemented using a combination of image processing, visual image processing, and decision tree algorithms. These systems are designed to accurately detect fires and issue alerts in real-time. The system uses cameras to capture images of the environment and then processes these images using advanced algorithms to identify signs of fire. Once a fire is detected, the system issues alert to notify the relevant authorities and initiate the evacuation process. The use of fuzzy logic in these systems also improves their accuracy and reliability. Overall, the implementation of these intelligent fire detection and alarm systems is an important step towards improving fire safety and prevention. Different types of devices are used for detecting fire, smoke, carbon monoxide, and other emergencies in traditional fire alarm systems. These devices include smoke detectors, heat detectors, flame detectors, and gas detectors, each with a specific role in warning people through visual and audible devices [1].

The project aims to overcome the shortcomings of traditional fire alarm systems by utilizing the MQ-6 sensor and implementing a fuzzy logic algorithm, as well as integrating GSM and GPS modules for real-time notification and tracking and utilizing the ATMEGA328P microcontroller and a backup battery for reliable operation. The MQ-6 sensor, in combination with fuzzy logic, enables the system to detect the presence of smoke and other gases in the air and provide early warning of a potential fire. The use of wireless communication through the

GSM module and GPS tracking allows for quick and efficient response to emergencies, while the ATMEGA328P microcontroller ensures reliable and efficient operation of the system.

To conclude, this project will contribute to the growing body of research on improving fire safety and prevention, particularly in areas with high risk of fire outbreaks.

3. METHODOLOGY

The smart integrated fire detection and alarm system is composed of both hardware and software systems as discussed in the following subsections.

3.1. Hardware Systems

ATMEGA Microcontroller: This is the main controller that processes all the data from the sensors and takes decisions accordingly. It is a low-power, high-performance microcontroller that is capable of running complex algorithms and communicating with other devices via various communication protocols [8].

MQ-6 Smoke Sensor: The MQ-6 sensor detects smoke and other gases in the air using chemoresistance, which causes a change in resistance of the sensing material when in contact with the target gas [16]. This low-cost sensor is highly sensitive to smoke and was selected for its effectiveness in fire detection systems.

LM35 Temperature Sensor: The LM35 is a precision temperature sensor that measures the temperature of the surrounding environment. It has a linear output voltage proportional to the temperature in Celsius, which makes it ideal for use in temperature monitoring applications [13].

Buzzer: The buzzer is an audible alarm that is activated when a fire is detected. It is a simple device that generates a sound when an electrical signal is applied to it.

SIM800L GSM Module: The SIM800L is a quad-band GSM/GPRS module that provides wireless communication capabilities to the fire alarm system. It allows the system to send SMS to notify the property owner and the nearest fire station in case of a fire. The SIM800L was chosen for its low power consumption and its compatibility with most GSM networks.

LCD: The LCD is a display module that shows the status of the fire alarm system. It displays the temperature and smoke readings and the system status.

RGB LED (Red and Green): The red LED indicates that a fire has been detected, while the green LED indicates that the system is functioning normally.

Ublox NEO-6M GPS Module: The NEO-6M is a GPS module that provides the exact location of the fire alarm system. It allows the fire department to locate the property quickly in case of a fire (Ismail, I., 2020).

Additionally, the fire system also includes a battery backup and hybrid solar module.

3.2. System design and implementation

The block diagram in Figure 1 consists of various hardware and software components. At the input, there are sensors such as the MQ-6 gas sensor and the LM35 temperature sensor, which detect the presence of smoke and changes in temperature, respectively. These sensors are connected to an Arduino (ATMEGA328P) microcontroller, which processes the sensor data and triggers the alarm and notification system when certain thresholds are reached. The alarm system includes an LCD display that displays warning messages, a buzzer that sounds an audible alarm, and a GSM module that sends SMS alerts to the user's mobile phone.

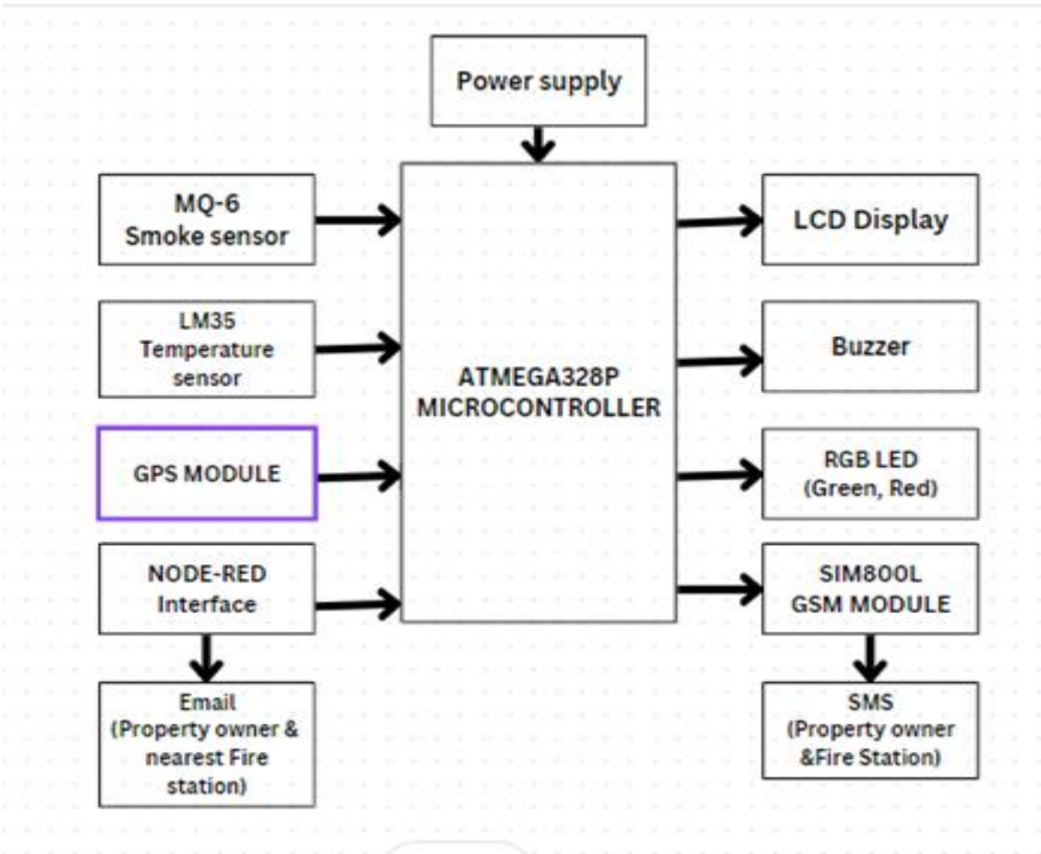

Figure 1: Block diagram of the smart integrated fire detection and alarm system.

The system was designed, implemented and simulated using Proteus software, the prototype is shown in Figure 2. The simulation helped to verify the functionality of the system and identify any potential issues before implementation.

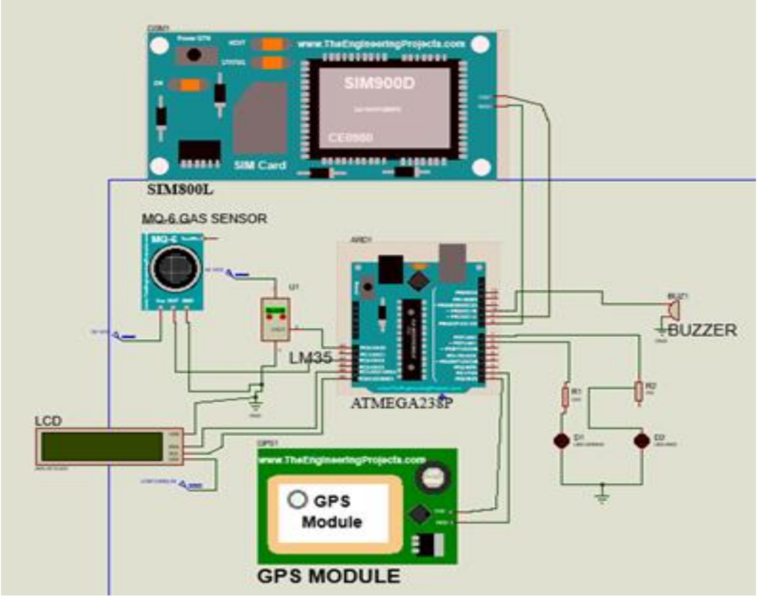

Figure 2: Circuit diagram of fire detection alarm system

3.3. Software Design

The system software design of this project involves several programming tools and languages. The Arduino IDE is used for programming the ATMEGA microcontroller, while Node-RED is used as an interface for serial communication between the hardware and email APIs and online services. The fuzzy logic algorithm is implemented using the high-level programming language Python, along with the Fuzzy library for the implementation of fuzzy logic algorithms. Additionally, Pyserial is used as a Python library for serial communication between the microcontroller and the computer.

Fuzzy logic is a type of mathematical logic that is used to deal with uncertainty and vagueness in data. In this project, fuzzy logic is used to detect fire based on the readings from the sensors [9].

The input variables used in this system were temperature and smoke while the output variable is fire. The input variables are categorized as low, medium and high. Fire is detected based on the degree of membership that is obtained by comparing the input variables and the inference rules.

Figure 3 shows stages taken to design the fuzzy logic controller of this system.

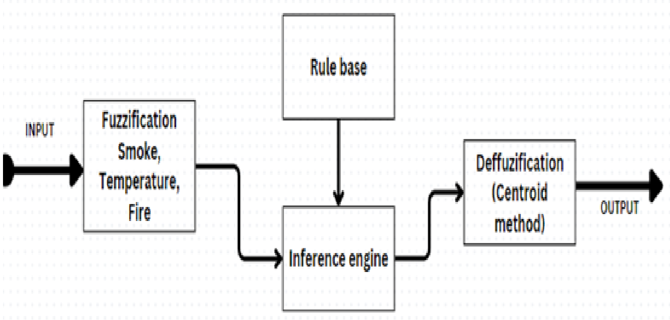

Figure 3: Fuzzy logic steps

Input: The input to the system includes the smoke level reading, temperature reading, and flame sensor reading.

Fuzzification; the temperature reading is fuzzified into three linguistic variables: high, medium, and low in degrees Celsius [10].

Smoke level reading is fuzzified into three linguistic variables: high, medium, and low in parts per million (ppm).

The flame sensor reading is fuzzified as present or not present.

Inference Rules: The inference rules are used to determine the degree of membership of each input variable in the output variable. Table 1 below shows the Mamdani inference rules:

Table 1: Fuzzy inference rules

Temperature	**Smoke Level**	**Flame**	**Fire state**
High	High	Present	High
High	Medium	Present	High
High	Low	Present	Medium
Medium	High	Present	High
Medium	Medium	Present	Medium
Medium	Low	Present	Low
Low	High	Present	Medium

Low	Medium	Not Present	Low
Low	Low	Not Present	Low

Aggregation: The degree of membership for each rule is aggregated to produce a single output variable.

Defuzzification: The centre of gravity method is used to defuzzify the aggregated output variable and produce a crisp output value [17].

Figure 4 shows the flow diagram for the operation of the smart fire detection and alarm system. When operating, the smart fire detection and alarm system is configured to continuously monitor the sensor outputs for an indication of fire or smoke. When smoke or fire is detected, the relevant alarm signals are triggered and corresponding alerts are sent out to respective recipients and authorities.

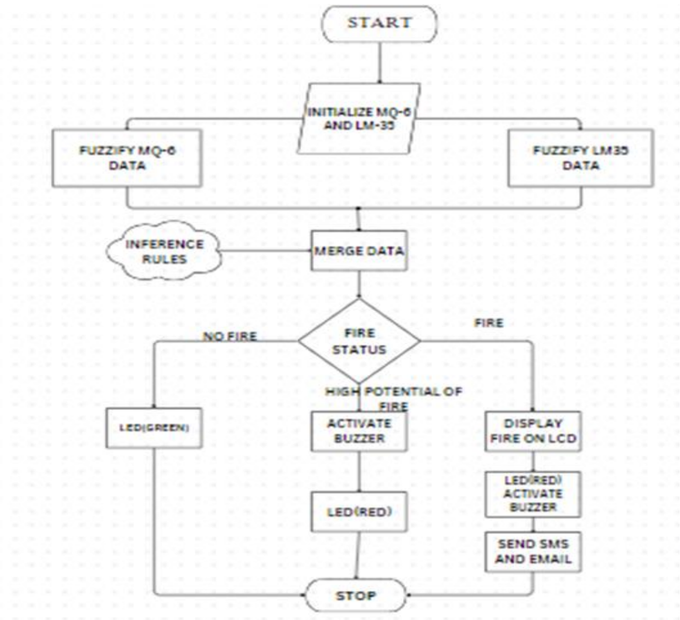

Figure 4: Operation of fire detection system

4. IMPLEMENTATION

The implementation of this fire alarm system involved several steps. First, the hardware components, including the MQ-6 sensor, ATMEGA328P microcontroller, GSM and GPS modules, and backup battery, were assembled according to the circuit diagram using a breadboard. Next, the software was developed using the Arduino IDE and uploaded to the ATMEGA328P microcontroller. The software included the fuzzy logic algorithm for processing the sensor readings and making decisions about the presence of a fire. The GSM and GPS modules were also programmed to send emergency alerts to the centralized monitoring system.

After the hardware and software were developed, the system was tested in a lab environment. The testing involved setting fire to a small object in close proximity to the MQ-6 sensor and observing the system's response. The test confirmed that the system was able to accurately detect the presence of a fire and send emergency alerts to the monitoring system.

Once the system was successfully tested in lab, it was deployed in a real-world setting. The system was installed in a test location, and the hardware components were connected according to the circuit diagram. The system was then powered on, and its functionality was tested by setting a controlled fire and observing the system's response as in Figure 5 which indicates the status before fire detection and Figure 6 showing the status after fire detection.

Figure 5: Fire detection and alarm before fire detection

The test confirmed that the system was able to accurately detect the presence of a fire and send emergency alerts to the monitoring system.

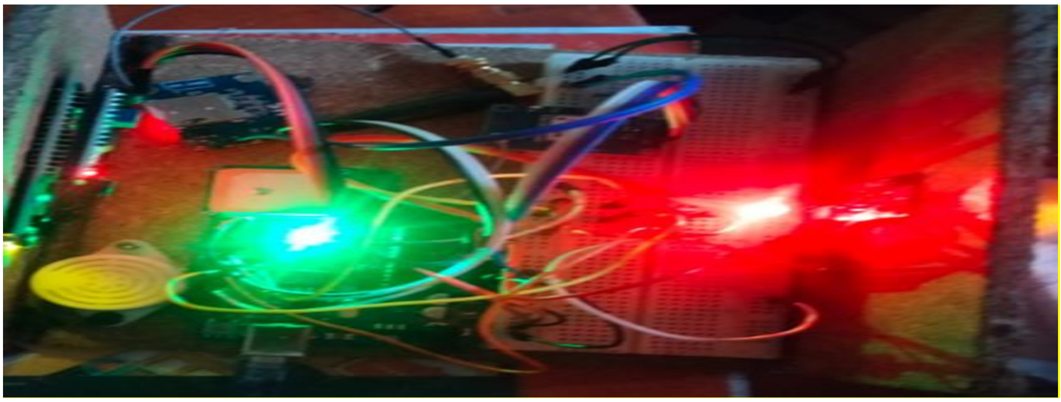

Figure 6: LED turns red after fire detection

The test confirmed that the system was able to accurately detect the presence of a fire and send emergency alerts to the monitoring system.

The implementation of this fire alarm system involved careful hardware and software development, thorough testing in simulation and real-world settings, and close attention to detail to ensure the system's accuracy and reliability in detecting and preventing fires.

5. RESULTS AND DISCUSSIONS

The proposed fire detection and alarm system was successfully implemented and tested in a laboratory setting. The system was composed of an ATMEGA microcontroller, MQ-6 smoke sensor, LM35 temperature sensor, Buzzer, SIM800L GSM module, LCD, LED red and green, NEO-6M Ublox GPS module, battery, and solar module.

To test the system's performance, smoke was applied near the MQ-6 sensor and the temperature was increased using a hot plate. The results showed that the system was able to detect smoke and temperature increase accurately as shown in Figure 7.

Figure 7: LCD display of smoke and temperature before fire detection.

The LCD displayed alert messages when smoke and temperature were detected, and the SIM800L GSM module sent an SMS and an email to the user's mobile phone as shown in Figures 8 & 9.

Figure 8: LCD Display after fire detection.

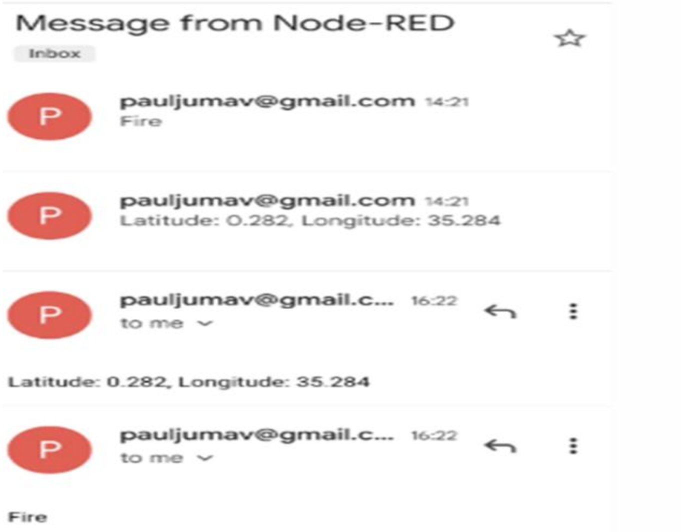

Figure 9: Fire alert e-mail sent to the user.

Additionally, the system was tested for power management during a fire breakout. The battery and solar module were used to power the system, the backup battery was able to power the system efficiently.

The use of fuzzy logic and inference rules in the system helped to improve the accuracy of smoke and temperature detection. The membership functions for smoke and temperature were plotted using the pyplot library, and the COG method was used for defuzzification. The crisp output was then sent to the GSM module for notification to the user.

The system performed well in detecting smoke and temperature increases and had an effective power management system. This GSM-based fire and high-temperature detection system can be easily and effectively applied to slums. Future work could include implementing the system in real-world settings and integrating it with a central monitoring system for more comprehensive fire safety management.

6. CONCLUSIONS

This fire detection project has been designed to detect fire outbreaks in homes and buildings and immediately notify the property owner and the nearest fire station. Based on the results obtained from the testing, the system is functional and can effectively detect fire outbreaks by reading sensor values, converting them into specific temperature

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APPENDICES

Appendix I: Program Code

```
// Include libraries
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>   //include the SoftwareSerial library
#include <TinyGPS++.h>

SoftwareSerial sim900A(7, 8); // RX, TX
SoftwareSerial gpsSerial(5, 6); //RX, TX pins of GPS module
TinyGPSPlus gps;                //create a TinyGPS++ object

// Define constants for sensor pins
const int smokeSensorPin = A0;
const int heatSensorPin = A2;
```

```
// Define constants for output pins
const int buzzerPin = 3;
const int redPin = 9;
const int greenPin = 10;
const int bluePin = 11;

// Define thresholds for sensor readings
const int smokeThreshold = 150;
const int heatThreshold = 45;

// Define variables for fuzzy sets
float smokeNear, smokeFar, heatLow, heatHigh;

// Define variables for input sensor readings
int smokeReading, heatReading;


// Define variables for output decision
float outputDecision;

// Initialize LCD screen
LiquidCrystal_I2C lcd(0x27, 16, 2);

void setup() {
  // Set up serial communication
  Serial.begin(9600);
  gpsSerial.begin(9600);     //initialize the SoftwareSerial communication with GPS module
 sim900A.begin(9600); // initialize the SIM900A module
 sendSMS("+254xxxxxxx", "System started");


  // Set up input and output pins
  pinMode(smokeSensorPin, INPUT);
  pinMode(heatSensorPin, INPUT);
  pinMode(buzzerPin, OUTPUT);
  pinMode(redPin, OUTPUT);
  pinMode(greenPin, OUTPUT);
  pinMode(bluePin, OUTPUT);


  // Initialize fuzzy sets
```

```
  smokeNear = 0;
  smokeFar = 0;
  heatLow = 0;
  heatHigh = 0;

  // Initialize LCD screen
  lcd.init();
  lcd.backlight();
}

void loop() {
 while (gpsSerial.available())
  {
    if (gps.encode(gpsSerial.read()))
    {
      Serial.print("Latitude: ");
       Serial.print(gps.location.lat(), 6);
       Serial.print(", Longitude: ");
       Serial.println(gps.location.lng(), 6);
     if (gps.location.isValid())
     {
       Serial.print("Latitude: ");
       Serial.print(gps.location.lat(), 6);
       Serial.print(", Longitude: ");
       Serial.println(gps.location.lng(), 6);
     }
    }
  }

  // Read input sensor values
  int smokeReading = analogRead(smokeSensorPin);
float  tempValue = analogRead(heatSensorPin);
   float lm35Voltage = (tempValue* 5.0) / 1024.0;
  float heatReading = (lm35Voltage - 0.1) * 100;
```

```
  // Calculate membership values for fuzzy sets
  smokeNear = calculateMembership(smokeReading, 100, 300);
smokeFar = calculateMembership(smokeReading, 200, 500);
heatLow = calculateMembership(heatReading, 20, 40);
heatHigh = calculateMembership(heatReading, 40, 50);

  // Make fuzzy decision
  outputDecision = fuzzyDecision();

  // Display smoke and heat levels on LCD screen
  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print("Smoke Level: ");
  lcd.print(smokeReading);
  lcd.setCursor(0,1);
  lcd.print("Heat Level: ");
  lcd.print(heatReading);

  // Output decision
  if (outputDecision > 0.5) {

      Serial.print("Latitude: ");
      Serial.print(gps.location.lat(), 3);
      Serial.print(", Longitude: ");
      Serial.println(gps.location.lng(), 3);
    digitalWrite(buzzerPin, HIGH);
    digitalWrite(redPin, HIGH);
    digitalWrite(greenPin, LOW);
    Serial.println("Fire detected at:");
      // Send text message using SIM900A
  sim900A.println("AT+CMGF=1");
  delay(100);
  sim900A.println("AT+CMGS=\"+254xxxxxxx\"");
```

```
  delay(100);
  sim900A.println("Fuzzy decision: " + String(outputDecision));
  delay(100);
  sim900A.println((char)26);
  delay(1000);

  } else {
    digitalWrite(buzzerPin, LOW);
    digitalWrite(redPin, LOW);
    digitalWrite(greenPin, HIGH);
    Serial.println("There Is FIRE at:");
  }
        Serial.print("Latitude: ");
        Serial.print(gps.location.lat(), 3);
        Serial.print(", Longitude: ");
        Serial.println(gps.location.lng(), 3);

  // Wait a short time before starting again
  delay(5000);
}

// Function to calculate membership value of sensor reading
float calculateMembership(int value, int lowerBound, int upperBound) {
  float membership = 0;

  if (value < lowerBound) {
    membership = 0;
  } else if (value >= upperBound) {
    membership = 1;
  } else {
    membership = (float)(value - lowerBound) / (float)(upperBound - lowerBound);
  }
  return membership.
}
```

```
// Function to make fuzzy decision based on input membership values
float fuzzyDecision() {
float decision = 0;

if (smokeNear > 0 && heatLow > 0) {
decision += smokeNear * heatLow;
}
if (smokeNear > 0 && heatHigh > 0) {
decision += smokeNear * heatHigh;
}
if (smokeFar > 0 && heatLow > 0) {
decision += smokeFar * heatLow;
}
if (smokeFar > 0 && heatHigh > 0) {
decision += smokeFar * heatHigh;
}

// Activate buzzer and change RGB LED status if fire is detected
if (decision > 0.5) {
digitalWrite(buzzerPin, HIGH);
analogWrite(redPin, 255);
analogWrite(greenPin, 0);
lcd.setCursor(0, 1);
lcd.print("Fire Detected!");
Serial.println(" Fire detected at: ");
Serial.print(gps.location.lat(), 3);
Serial.println(gps.location.lng(), 3); //print the longitude with 6 decimal places
} else {
digitalWrite(buzzerPin, LOW);
analogWrite(redPin, 0);
analogWrite(greenPin, 255);
lcd.setCursor(0, 1);
lcd.print("No Fire Detected");
```

```
}

// Display temperature and smoke levels on I2C LCD screen
lcd.setCursor(0, 0);
lcd.print("Temp:");
lcd.print(heatReading);
lcd.print(" C");
lcd.setCursor(9, 0);
lcd.print("Smoke:");
lcd.print(smokeReading);

return decision.
}
```

The African Manufacturing Sector in the Battlefield: Technology to the Rescue - Challenges and Opportunities

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Abstract

This paper looks towards the findings that are currently inhibiting the manufacturing setting that is expected to drive manufacturing warfare, as well as the challenges and opportunities that will be employed by manufacturers that is most expected to revolutionize the future and achieve inclusive manufacturing development goal in Africa. Africa has not lacked manufacturing development programs, but the weakness in the implementation. The manufacturing programs which successive administrations developed were often weak, segmented, truncated and isolated from various sectors of the economy. This paper concludes and recommends a new manufacturing revolutionary paradigm to address these concerns and states that without urgently harnessing manufacturing in Africa, all other social, governance and economic activities might come to a halt.

Keywords: Manufacturing warfare, opportunities, challenges, revolutionary.

1. Introduction

This paper looks towards the findings that are currently inhibiting the manufacturing setting that is expected to drive manufacturing warfare[14] as well as the challenges and opportunities that will be employed by manufacturers that is most expected to revolutionize the future and achieve inclusive manufacturing development goal in Africa. Africa has not lacked manufacturing development programs, but the weakness in the implementation. The manufacturing programs which successive administrations developed were often weak, segmented, truncated and isolated from various sectors of the economy[1].

Within the last few years, there has been a great upsurge of interest by the author, engineers, non-engineers, public and private sectors, continental technical working groups and even manufacturers to identify and assess socio-economic factors affecting machinery manufacturing establishment in Africa. Manufacturing is central to the process and course of socio-economic development in Africa. It not only transforms inputs into outputs, but also embodies ICT and digital technological economic changes, which holds the key to successful industrialization, urbanization, modernization and accelerated socio-economic growth. There are no such indigenous manufacturers in Africa and this is one of the aims and objectives of the paper[1].

The challenges can be complex since the continent is characterized by so many socio-eco-growth factors like weak public institutions along with political[15], social, commercial, financial and economic instability and where a large proportion of the population lives in persistent poverty. Other factors or threats confronting manufacturing establishment in the continent are unstable government policies, poor emphasis on manufacturing education, poor planning and poor management, lack of dedication to execution of government policies, projects and poor funding, lack of qualified manufacturing engineers[2]. There are several raw material resources sites and well-known public sector projects, some key existing research, development & capacity buildings, policies and regulatory bodies in Africa that can fast stimulate additional socio-economic growth towards the attainment of the continent's vision of becoming one of the world's top economies by 2050. However, some have been poorly managed, stagnated, collapsed and died over the years as a result of poor management. This paper concludes and recommends a new manufacturing revolutionary paradigm to address these concerns and states that without urgently harnessing manufacturing in Africa, all other social, governance and economic activities might come to a halt.

1.1 Problem Statement

The following are some socio-economic factors identified and assessed as possible current socio-economic bottle-necks or inhibitors bedeviling institutional arrangements regarding manufacturing establishment activities in Africa: Shortage of raw materials production and plant location; bad leadership and bad government policies; lack of qualified manufacturing engineers; insufficient capital and misuse of capital; high degree of foreign dependence; poor quality manufacturing labour; low purchasing power of the populace; inadequate power supply; unnecessary competition with foreign goods; shortage of entrepreneurs; poor management; political instability; inadequate transportation and communication facilities.

1.2 Objectives of the Study

This paper investigated Africa's readiness to adequately key into manufacturing model for actualizing its economic development objectives. The paper highlighted the current state and challenges of the African manufacturing sector and possibilities of the sector to benefit from the potentials of the 4th industrial revolution. This has been to take a long term and strategic look at manufacturing out to 2050, to: - identify and analyze important drivers of change affecting the Africa manufacturing sector; identify important challenges and opportunities that lie ahead and which require action by Government and industry; and advise how Government policy needs to be refocused and rebalanced so that it is better positioned to support the growth and resilience of Africa manufacturing over coming decades. In so doing, a specific aim is to inform further development of the Government's industrial and sector strategies. With the current poor African manufacturing sector, the adoption of 4th industrial revolution may be a viable alternative for achieving inclusive economic growth.

1.3 Hypothesis

The hypothesis aims at determining the impact of manufacturing establishment as a strategic catalyst for domestic socio-eco-growth and sustainability of the continent.

H0: there is no positive relationship between the number of established manufacturing and gross domestic product (GDP) of the continent.

H1: there is positive relationship between the number of established manufacturing and gross domestic product (GDP) of the continent.

1.4 Significance/Justification of the Study

The study aims at evaluating the immense contribution of manufacturing establishment towards stimulating productivity and other socio-economic activities in Africa. The role of manufacturing establishment in trade and commerce cannot be swept under the carpet because the machinery population agglomeration, movement of people and goods from one place to another is very important. It is a statement of fact that without an effective and efficient manufacturing establishment in the continent all other socio-economic activities would come to a halt. More so, going by the present government transformation agenda and indigenization policy cum African Content Act in meeting the sustainable development goals, the role of manufacturing establishment in the provision of job opportunities, technological cum infrastructural development, funding of education and research, training cum skilled manpower development and invariably improve the standard of living and general well-being of the people cannot be over emphasized.

1.5 Scope and Limitation of the Study

The scope of the study is limited to manufacturing establishment and also to the major nerves of the continent, where raw materials available and engineering practices are ongoing.

2. Literature Review

Africa, pre-independence and post[16], with a population estimated at more than 1.5 billion people, from over 3,000 ethno linguistic communities and accounts for about 18% of world's human population is heterogeneity being constantly manipulated by traditional, religious and modern political elite in their race for the control of the state and continental resources[1]. Africa is the world's second most populous continent after Asia in both aspects and is the youngest among all the continents, the median age in 2012 was 19.7 when the world-wide median age was 30.4. At about 30.3 million km^2 (11.7 million km^2 miles), including adjacent islands, it covers 20% of earth's land area and 6% of its total surface area[19]. Despite a wide range of natural resources, Africa is the least wealthy by total wealth, behind Oceania[9].

Economic activities began with the use of human labour and simplest tools. However, human labour and simplest tools could not provide the required energy[17] for economic activities and was replaced by machines due to drudgery and ineffective energy output among other limitations. The replacement of human labour with machines marked the beginning of the first industrial revolution. The shift in the type of technology employed in manufacturing processes is called "industrial revolution". Industrial revolution can also be defined as technological revolution that focuses on the sources of development which shapes the world around us[10]. The 1st industrial revolution began around 1760s and characterized with the use of steam engine as source of power for economic activities. Roger[12] argued that the first industrial revolution in Britain took place due to its unique price and wage structure. The 1st industrial revolution witnessed slow pace and required an emergence of mechanization of industrial activities. The 2nd industrial revolution occurred between 1870 and 1969 with production of steel, iron and light bulb and focused on the mass production, electrical energy utilization and division of labour[5, 6]. The 3rd industrial revolution, which started in 1969, led to the automation of the production process by using extensive electronics and information and communication technologies (ICT)[7]. In addition, computers networks and IT systems in the third industrial revolution from 1969 to 2015 were used[11]. The automation in production and intelligent control robots as well as other integration gave the breakthrough (Schmidt et al, 2015). The first 3 industrial revolutions (the steam engine, the age of science and mass production) have transformed our modern society and changed the world around us fundamentally[29]. The 4th industrial revolution started in 2011.

The Deloitte[13]'s report on Global Manufacturing[4] Countries and Regions Competitiveness Index showed that developed countries came up with their models for the 4th industrial revolution. For instance, while Germany nicknamed her 4th industrial revolution model as 'industrie 4', 'smart industry' was the symbol of the Dutch's 4th industrial while China and Taiwan termed theirs as 'made in China' and 'Taiwan productive 4 initiative' respectively. The United States of America (USA), France, Spain and the United Kingdom also came up with their 4th industrial connotations. With the advent of the 4th industrial revolution, it is obvious that the world is experiencing a scientific and technological revolution." It is also a warning signal for developing countries like Africa to wake up from their slumber.

3. Research Methodology and Organization of the Study

The empirical and exploratory method of research was adopted that examined and discussed relevant issues of interest in the history of Africa manufacturing establishment as an economically viable option for economic development. Because of the nature of the study (macro), the writers rely on published documents in the area of manufacturing industry using commissioned studies, non-commissioned studies and published works from various sources. Some of these secondary sources are narrow in view, perspective and scope but they serve as useful materials for researchers wanting to embark on a macro-study.

Others include library books, previous works by the author, detailed investigations done on manufacturing establishment by the author, internet and articles from learned journals. During the study there was no case where anybody or scholar delved into discussing developing manufacturing establishment as economically viable option for socio-economic development in Africa.

4. Socio-Economic Factors Influencing the Location of Manufacturing Establishment in Africa

Many socio-economic factors are considered[20] before manufacturing establishment is located in an area. These socio-economic factors include but not limited to the following:

- **Proximity to source of raw materials:** manufacturing should be located close to sources of raw materials to reduce cost of transportation.
- **Nearness to market:** There should be ready[36] market for the products of manufacturing (**market-oriented industries)** to be sited in a place. Fragile goods like glass, bulky goods like iron ore and steel should be located near the market. Such manufacturing located or directed towards the market are called**.**
- **Availability of capital:** There should be enough capital to purchase manufacturing input before and after setting up manufacturing establishment. Manufacturers or capital-intensive industries should have access to loans. Fixed capital should also be easily acquired.
- **Nearness to source of power:** There should be ready and dependable source of power. Source of power could be electricity, coal, thermal, petroleum products, etc.
- **Availability of labour:** There should be high quality skilled labour. The design of production machineries requires a detailed knowledge of the technical procedure for converting raw materials into the finished products. Erroneously, a lot of engineers, not to talk of laymen, seem to believe that the design process is a textbook affair requiring knowledge of the design of shafts, housings, moving and transmission elements as well as the electrical, pneumatic or hydraulic controls as the case may be.
- **Adequate transport network**: Transport is required essentially to move raw materials to manufacturing sites. Transport is also required to convey finished goods to the market or areas of consumption and use. Transport could be by road (cars, buses, trucks, etc.) by sea (boats, ship) or by air (aeroplane).
- **Political stability**: A stable Government encourages industrial growth. Communal wars and conflicts do not favour manufacturing growth.
- **Favourable climate**: There should be favourable climate conditions for manufacturing to grow. A favourable climate is also required for some machine tools firms to thrive.
- **External economies or location of other firms:** Firms are often set up near others in order to take advantage of external economies.
- **Joint research and training centres:** Research and training centres can easily be jointly established since all the industries involved are producing similar products. The cost of such

projects will be minimal when it is jointly financed. It is now quite obvious that the industrialized world is not prepared to divulge her technical secrets with the less developed continents as this will affect their leadership position in the world.

- **Government policies:** Government can encourage the location of manufacturing through certain policies.

5. A New Vision for Africa Manufacturing

Manufacturing in 2050 will look very different[24] from today, and will be virtually un-recognizable from that of 30 years ago. Successful firms will be capable of rapidly adapting their physical and intellectual infrastructures to exploit changes in technology as manufacturing becomes faster, more responsive to changing global markets and closer to customers[25].

Successful firms will also harness a wider skills base, with highly qualified leaders and managers whose expertise combines both commercial and technical acumen, typically in science, technology, engineering or mathematics.

Constant adaptability[4] will pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer interdependencies, and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the end of their useful lives. Closed loop systems will be used to eliminate energy and water waste and to recycle physical waste. These developments will further emphasize the key role of physical production in unlocking innovative new revenue streams and manufacturers make use of the increasing pervasiveness of 'Big Data' to enhance their competitiveness.

In the public sector, policy frameworks that affect the manufacturing sector directly and indirectly will need to recognize the extended nature of value creation and the new ways it is being developed. Public planning cycles should match the timescales of firms' own long term planning requirements. And it will be important that flows of highly skilled workers, patient capital, and support to promote critical mass in small and medium sized enterprises are all intercontinentally competitive. The implications for Africa manufacturing firms and the Africa Government are substantial. Some businesses are already adapting and are world class, but many are not positioned to succeed in a future world where greater opportunities will be balanced by greater competition.

The Africa needs to radically change its approach to providing a constant and consistent framework within which all firms aspire to prosper. A business-as-usual approach will not deliver that outcome. Other economies are already ahead, and catching up will require an adaptive capacity that the Africa has not yet demonstrated. Achieving this is essential, as the future competitiveness and health of Africa manufacturing will affect many other parts of the economy through its numerous linkages. The key message is that there is no easy or immediate route to success, but action needs to start now to build on existing support, and to refocus and rebalance it for the future. Above all, policy design will need to address entire system effects. This report sets out many areas where action is needed at both strategic and more detailed levels. However, the following should be particular priorities. The quality and skills of the workforce will be a critical factor in capturing competitive advantage. It is essential that Africa policy makers focus on the supply of skilled workers, including apprenticeship schemes, support for researchers, and the supply of skilled managers. Firms will need to pay much more attention to building multidisciplinary teams to develop increasingly complex products, and also innovative business models.

It will also be crucial to address the current image associated with manufacturing. Government and industry should work together to further promote and market the opportunities for careers in manufacturing industries at all levels of education. Financial challenges for the sector include a shortage of risk capital[38]. This is particularly evident as a funding gap between research and early development and the funding for proof[35] of concept that is usually required before the market steps in. There is also a shortage of funding for applied research and development in some areas such as the development of advanced green energy sources.

There are excellent schemes for public support such as Knowledge Transfer Partnerships, funding of the Technology Strategy Board, the future of manufacturing: A new era of opportunity and challenge for the Africa and public private partnerships such as the Energy Technologies Institute, these are much smaller than in competitor continents. Addressing this mismatch should be a priority. Recent years have seen a resurgence in the development of industrial policies by governments in the AFRICA and overseas. In the Africa, industrial policies have been developed in 11 sectors, led in most cases by groups from the public and private sectors, with many of these encompassing manufacturing industries. One specific development has been the creation of the Catapult Centers. In particular, the High Value Manufacturing Catapult provides a strong base on which to build substantial further effort. It is recommended that its funding is substantially increased, and used in part to encourage the greater involvement of smaller firms in particular. Whilst specific initiatives are essential in areas mentioned above, more is needed[39]. Recognition that the Africa's continental infrastructure suffered from fragmented policy making led to the creation of Infrastructure Africa. Manufacturing suffers from similar challenges and is no less strategic for the future[40] strength and resilience of the Africa economy.

6. Recommendations

Various strategies[36] have been recommended which will remove the constraints to facilitate rapid manufacturing establishment in Africa. These are:

- **Acquisition of skill:** Skills required for manufacturing operations should be acquired by people through regular training in manufacturing education.
- **Good government policies**: There should be good government policies and regulations to encourage and protect local manufacturers.

- **Active government participation**: There should be active government participation in manufacturing development, that is, co-ownership of manufacturing.
- **Incentives to local manufacturers:** There should be incentives to local manufacturers, e.g., tax holiday, interest free-loans, subsidies, etc.
- **Provision of transport and communication facilities**: These should be provided to ensure easy distribution of goods produced.
- **Creation of manufacturing zones**: This will also provide an environment with all the infrastructural facilities for the manufacturing.
- **Establishment of manufacturing banks**: and other development banks should be set to provide loans to manufacturers.
- **Stable government:** There should be stable government in order to encourage indigenous private investors.
- **Local sourcing of solid minerals:** There should be exploitation of raw materials locally for manufacturing.
- **Organisation of management courses:** Management courses should be organised on regular basis for workers.
- **Building and maintenance of infrastructural facilities:** Infrastructural facilities such as roads, telephone, water, electricity, etc. should be built and maintained regularly.
- **Establishment of more power plants:** Plants such as thermal or hydroelectricity plants should be established to boost power supply to manufacturing.
- **Increase in gross continental product (GNP):** The industrial sector, through its operations like payment of taxes, increases the earnings accruable to the continent.
- **Employment opportunities:** Manufacturing provides employment (jobs) for many people.
- **Intercontinental trade - improves trade balance:** Most of the products of manufacturing like machineries and spare parts are usually imported from Western continents. This forms the basis for intercontinental trade and improves trade balance between countries.
- **Stimulation of other sectors:** The manufacturing sector stimulates the growth of other sectors like agriculture, mining, lumbering, etc.
- **Control of inflation due to mass production:** With modern technology, products like car, machinery, etc. can be mass produced. This can help to reduce inflation.
- **Technological development:** manufacturing can also lead to the development of technology in the continent.

- **Infrastructural development:** The establishment of manufacturing in a place stimulates the development of infrastructural facilities like roads, telephone, electricity, pipe borne water, etc.
- **Diversification of the economy:** Manufacturing helps different countries to prevent over-dependence on only one product, like Africa's present over-dependence on crude oil. If Africa can invest in the manufacturing sector, her economy will in time be diversified.
- **Training and development of skilled manpower:** Many people are trained in different technical areas in order to acquire special skills to manage different aspects or machines in a manufacturing. Owing to manufacturing development, many people are given such skill training.
- **Funding of education and research:** manufacturing provides capital for the funding of education and research works in the Continent, for example the Education Tax Fund (ETF) in Africa.
- **Conservation of foreign exchange:** manufacturing leads to the conservation of foreign exchange which would have been used for importing goods now produced locally.
- **Improving standard of living:** manufacturing also leads to the improvement or the raising of the standard of living of the people through production of goods that are cheap and affordable.

7. Conclusions

From the discussion, the major constraints identified as inhibitors for manufacturing establishment and sustainability in Africa are: - Inadequate development of raw material and resources including human, financial, physical and informational; Shortage of raw materials; Insufficient Capital; High degree of foreign dependence; Poor quality of manufacturing staff; Low purchasing power of the populace; Inadequate power supply; Competition with foreign goods; Shortage of entrepreneurs; Political instability; Inadequate transportation and communication facilities; Small market for industrial goods; Inadequate skilled man-power, Bad Government Policies; Poor management (Corruption, embezzlement, and negligence of duty).

Others include low level of development of manufacturing processes which includes engineering, manufacturing research, design, development of engineering machineries, equipment, facilities and infrastructures and a sound engineering manufacturing management practice. Corruption and embezzlement is a major inhibitor or bottleneck at every stage of manufacturing establishment sustainability management development. This is evident considering the fact that some consultants and contractors the various arms Federal government relies on for planning, execution, construction, rehabilitation and maintenance are mere foreigners, traders and unqualified engineers.

It is an open secret for those who care to investigate and follow the affairs of the manufacturing establishment that some foreign marketers have taken over the industry, pushing local qualified contractors and consultants of high repute out of the business. Various strategies have been discussed which will remove the above constraints to facilitate rapid manufacturing establishment and development in Africa.

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Climate Change Against National Greenhouse Gas Emission Reduction Commitment for Developing Countries- Adaptation by Power Utilities: A Case Study for Kenya

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Abstract

Power utilities are facing a growing challenge of providing reliable, adequate and affordable power amidst climate change challenge. In Kenya, climate change mitigation is guided by the climate change act 2016 which provides for mainstreaming of climate change mitigation [1]. The law requires formulation of a five-year National climate change action plan (NCCAP) that addresses all sectors of the economy. From the emission reduction potential and the nationally determined contribution (NDC) targets, Kenya's energy sector was allocated 36% (30.8MtCO2e) Greenhouse gas (GHG) emission reduction by 2030. Kenya's energy act 2019 opened up the energy sector to competition in the generation, distribution and retail segments [2]. From January 2018 to January 2023, the country has seen dramatic change in energy sources as: hydro reduced from 24% to 14%, wind grew from 0% to 18%, solar grew from 0% to 3% and thermal reduced from 26% to 12.72% [8]. Geothermal is currently contributing 45% of the total capacity. Because of drought, Kenya can barely use 28% of the installed hydro capacity of 838MW. Currently, the total installed grid capacity stands at 3,726MW (78% is renewable) with the largest share being geothermal at 32%. Kenya is on the road to retire all 300MW thermal power plants. Electric mobility and time of use tariff were introduced in the April 2023 power tariff review to deepen the update of abundant renewable energy [9]. This paper looks at the climate change adaptation of the energy sector players for the 2018-2022 NCCAP review period, the 2023-2027 period and future plans.

Keywords: Climate change, Drought, Electric mobility, Reliable, Renewable

7. Introduction

Kenya's ministry of energy and petroleum makes and articulates energy policies to create an enabling environment for efficient operation and growth of the sector.

The energy and petroleum regulatory authority (EPRA) regulates and licenses players in the entire energy sector. Its other functions include tariff setting and oversight, coordination of the development of the integrated energy plan monitoring and enforcement of sector regulations e.g. the energy management regulations.

Kenya's energy act 2019 sets up other agencies, namely:

- Nuclear power and energy agency (NUPEA) to handle nuclear energy programme.
- Rural electrification and renewable energy (REREC) to manage the rural electrification projects.
- Kenya electricity transmission company (KETRACO) to manage the electricity transmission assets.

Other key energy sector players are Kenya electricity generating company (KenGen) that generates the bulk of energy consumed in Kenya and the Kenya power and lighting company (KPLC) that does the power distribution and retail functions in the country.

In 2020, the Ministry of Energy released the Kenya National Energy Efficiency and Conservation Strategy [4]. It established energy efficiency targets in the buildings, industry, agriculture, transport, and power sectors to meet the goal of reducing the national energy intensity by 2.8% per year. The strategy also aims to ensure that energy efficiency measures contribute to the achievement of the nationally determined targets (NDC) by keeping Green House Gas (GHG) emissions as per the targets in table 1 below.

4. Methods

In Kenya, climate change action is guided by the climate change act 2016 which provides the framework for mainstreaming climate change across all sectors of the economy. The law has been applied to the development, management, implementation and regulation of mechanism to enhance climate change resilience and low carbon development for sustainable development in the country.

The act obligates the cabinet secretary responsible for climate change affairs to formulate a five-year national climate change action plan (NCCAP) that addresses all sectors of the economy. The plan covers thematic areas of agriculture, forestry, industry, energy, transport and waste. The first NCCAP ran from 2013-2017 and the second from 2018-2022.

Table 1 below shows Kenya's emission reduction potential and the nationally determined contribution (NDC) targets by sectors (in $MtCO_2e$ per year) projected to 2030:

Table 1: Kenya's emission reduction potential and the NDC targets by sector (in $MtCO_2e$ per year [3])

	GHG Emission reduction potential(MtCO2e)				NDC Target
Sector	**2015**	**2020**	**2025**	**2030**	**2030**
Forestry	2.71	16.24	29.76	40.2	20.1
Electricity generation	**0.28**	**2.24**	**8.61**	**18.63**	**9.32**
Energy demand	**2.74**	**5.16**	**7.92**	**12.17**	**6.09**
Transport	1.54	3.52	5.13	6.92	3.46
Agriculture	0.63	2.57	4.41	5.53	2.77
Industrial processes	0.26	0.69	1.03	1.56	0.78
Waste	0.05	0.33	0.5	0.78	0.39

Table 2 below is a summary of the various energy mitigation actions for the electricity generation and demand sectors above:

Table 2: Estimated technical potential emission reduction by 2030 [6-7]

		MtCO2e
Electricity Generation	Clean coal	1
	Landfill gas generation	0.4
	Solar-grid connected	0.65
	Hydro	1.1
	Wind	1.7
	Geothermal	14
Energy demand	Solar thermal water heating	0.2
	Energy efficient light bulbs	1.1
	LPG stove substitution	1.4
	Renewable lamps	1.8
	Cogeneration in agriculture	1.75
	Improved cook stoves	5.7
Total		**30.8**

The 2018-2022 NCCAP encompasses development of new 2,405MW of grid-connected renewable power generation and retirement of three thermal plant. The highest mitigation opportunity is in geothermal expansion, envisaged to add 2,775MW to the grid by 2030.

Others targeted measures are: 157MW of Biomass and 30MW of distributed solar/mini grids –largely done by REREC in the counties of Wajir, Mandera, Marsabit, Turkana and Garissa.

5. Results

Table 3 below shows the various interventions and the achieved results.

Table 3: 2018-2022 NCCAP Energy mitigation actions [5-6]

Actions	Expected results by June 2023	Results achieved by June 2022
Increased generation of renewable energy.	• Develop 2,405MW of new renewables that include geothermal, biomass, hydro, distributed solar and mini-grids, solar and wind. • Retire 300MW of thermal plants – 120MW Kipevu, 108MW Iberafrica and 74MW Tsavo.	• 2,883MW of generation on renewables. • 913MW geothermal plants in Olkaria and Menengai • 300MW lake Turkana wind among others in Ngong, Meru and Kipeto • 442MW solar in Strathmore, Makindu among others • 10% of TVET institutions using solar and five solar mini-grids done-4 in Marsabit and 1 in Kisumu. • Tsavo power has been retired
Increased generation capacity for captive renewable energy	• Increase captive renewable energy generation capacity by 250MW by 2022 – 50MW of solar, wind and hydro and 200MW of cogeneration. • Direct use of geothermal resources to power	• Meru County has 200 solar-powered boreholes under their captive energy goals. • 153MW Kwale sugar biomass plant done • 93MW KTDA generation done • GDC has established geothermal heated milk pasteurizers.

Actions	Expected results by June 2023	Results achieved by June 2022
	industrial applications- Naivasha industrial park.	
Improved energy efficiency and energy conservation	• Reduce transmission and distribution utility losses from 18% to 14%. • Distribute 3.3m CFL bulbs to shave 50MW from the peak demand. • Energy efficiency in buildings and industry – EPRA regulations.	• 4.25m CFL bulbs distributed to 1.4m households by KPLC-funded by MoE. • Energy management compliance certificates awarded to many factories under the energy management regulations 2012. • The Ministry of Energy has worked with the Kenya Association of Manufacturers (KAM) to establish a Centre for Energy Efficiency and Conservation that promotes energy efficiency.
Climate proof energy infrastructure	• Concrete poles to replace wooden poles. • Optimize existing hydro plants.	• 20.47% (22,500 poles) now concrete. • Kengen has done a feasibility study on how to optimize hydro power plants by increasing dam storage eg Masinga wall has been raised by 1.5m- because of erratic rain patterns. • In other instances, the number of turbines is increased to allow excess spill to generate power- Kindaruma added the third turbine.

Actions	Expected results by June 2023	Results achieved by June 2022
Enabling actions (Technology)	• Research on new technologies to reduce GHG emissions. • Climate change resilient technologies such as coolers and scrubbers promoted.	• Renewable energies research laboratory established. • Energy efficiency research and testing facility established at KIRDI.
Enabling actions(capacity development)	• Training and public awareness on climate change adaptation and mitigation mechanism. • Train 100 students per year at the KPI on renewable energy technologies. • Train 60 participants at the UNU Geothermal's training program.	• TVET Instructors trained on solar PV and solar water heating installations. • Marsabit county trained staff on solar installations. • KPLC trained 163 students on solar installation.

Currently 78% (2,266MW) of generation capacity in Kenya is renewable as seen in table 4 below:

Table 4: Kenya's installed generation capacity [8]

	Installed(MW)	Effective/Contracted(MW)
Hydro	838.51	810
Geothermal	904.98	817
Thermal (MSD)	621.89	589
Thermal (GT)	60.00	56
Wind	436.05	426

Biomass	2.00	2
Solar	212.51	212
Imports	200.00	0
Total Capacity MW	**3,276**	**2,911**

The country has a current peak demand of 2,149MW with 80.1% of the population having access to electric power. The graphical illustrations below show the above trends:

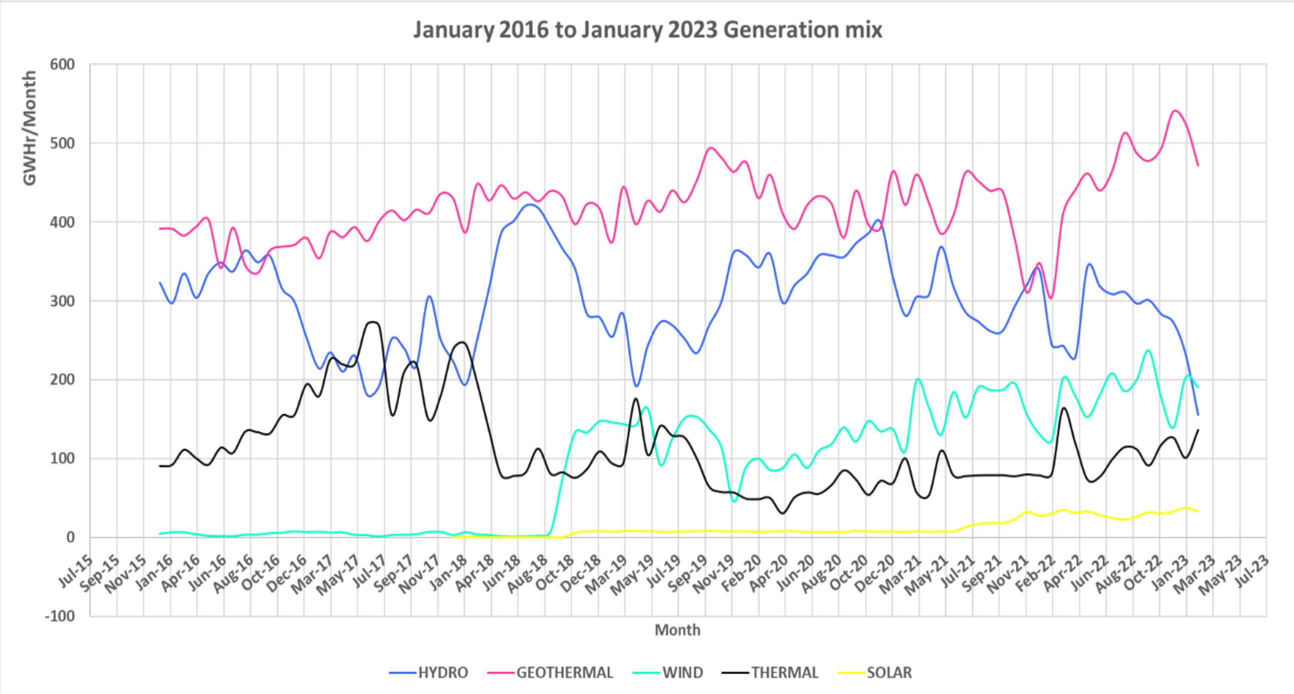

Figure 1: Changes in various sources of energy from January 2016 to January 2023 [8]

6. Discussion

Kenya uses 231/838MW (28% of the total installed capacity, largely to meet peak load demand as compared to the convectional base load) of hydro capacity – due to persistent drought for three years in a row.

Wind power has cut by more than half the gap between it and hydro- now doing 17.8% of the total load against hydro's 14.47%.

Solar energy has a big room for growth- now at 3.11% of the total national load.

Geothermal still takes the lion's share at 44.07% of the total load.

Kenya is on the road to retire all 300MW thermal power plants. Tsavo power 75MW plant already retired, 120MW Kipevu and 108MW Iberafrica pending- Currently contributing 12.72% of the total grid energy.

The draft net metering regulations 2022 are under discussion. These will go a long way in the contribution of the energy sector towards reduction of the targeted GHG emissions.

The electric mobility and time of use tariffs were introduced in April 2023. These will spur more utilization of the generated clean energy. As at the end of 2022, Kenya had well over 400 registered electric vehicles in the country.

7. Conclusion

Kenya is a leader in the generation and utilization of clean energy in Africa [10]. Kenya is number one in the generation of geothermal energy in the continent. The place of the energy sector is well cut out in the 2023-2027 NCCAP and beyond as Kenya seeks to leverage on the above gains and more. The future is bright.

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