RIVERS STATE UNIVERSITY
PORT HARCOURT

DISTINGUISHING AND CELEBRATING THE POWER BEHIND 'STOMACH INFRASTRUCTURE'

AN INAUGURAL LECTURE

BY

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DEDICATION

This inaugural lecture is dedicated to the memory of my dear late mother, Mrs. Felicia Ibienebo Igoni.

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The University Librarian
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Heads of Departments and Units
Distinguished Professors and Members of Senate
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Your Royal Majesties and Highnesses
Se Alapu of Ancient Grand Bonny Kingdom and Other Chiefs
The Amaopuseniapu, Amaopuereapu and Amaseniapu of the Ancient Grand Bonny Kingdom
Members of the Fourth Estate of the Realm
All Invited Dignitaries
Distinguished Ladies and Gentlemen

1.0 PREAMBLE

Let me join our award-winning learned Vice Chancellor and Chairman of this programme, Professor Nlerum Sunday Okogbule, FCIAbr, DSSRS, to heartily welcome us to this inaugural lecture, which is the 86th in the series of the University's inaugural lectures. I am very glad, indeed excited to have to stand before you for this presentation, as I feel particularly privileged to be granted this opening at this time.By the original schedule, I should have been due sometime in 2029, but when the Committee Chairman, Professor N. H. Ukoima, announced some vacant dates on the floor of Senate, in its meeting of December, 2022, I indicated interest, even before I had started any preparations, and was granted. With this, I shall then be recorded as the 10th presenter in the Faculty of Engineering and 2nd in the Department of Agricultural and Environmental Engineering. Thank you.

1.1 A Brief Background of Agricultural Engineering

Mr. Vice Chancellor, Sir, I like to begin this lecture with a cursory review of the discipline of Agricultural Engineering. The public perception of the discipline of Agricultural Engineering usually reminds me of the story that was told about a pastor who, when he was newly posted to a church, kept preaching a particular sermon on repentance from sin and living rightly with God, for several months, until the members became bored and accosted him on the matter. They asked why he would not change his sermon for so long. He told them that since he had been preaching on the subject of repentance, that he had not seen any visible sign of repentance in them and that was why he was continuing on it.

The pastor's dilemma appears to be the situation of the discipline of Agricultural Engineering – that in spite of the over one hundred and twenty-two years of its global existence and about sixty years in Nigeria, the society still wonders at what the discipline is all about. It was in this same regard that the revered Agricultural Engineering guru, Engr. Professor E. U. Odigboh, in his inaugural lecture at the University of Nigeria, Nsukka in 1985 expounded the subject to his audience (Odigboh, 1985). The situation has not changed much, as even some colleagues in the wider engineering professional family also seem lost in the knowledge of the place of the discipline. Several reasons have been adduced for this poor knowledge of the discipline, including the backstage accorded agriculture in the scheme of national events (Igoni, 2013a, 2013b, 2018).

Therefore, Vice Chancellor, Sir, like the pastor in our opening story, I have a compelling sense of professional patriotism to yet present the subject matter of the meaning of Agricultural Engineeringto this revered audience. It will also help us here to contextualize the subject of this inaugural lecture on the issue of the power behind 'stomach infrastructure'.

To effectively understand the discipline of agricultural engineering is to severally and jointly understand the meanings of agriculture and engineering. Whereas agriculture is the art and science of cultivating the soil, growing crops and raising livestock, including the preparation of plant and animal products for people to use and their distribution to markets (NGS, 2022a), engineering, is “the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property" (ECPD, 1947). This is why agricultural engineering is then the application of engineering techniques to the production of food and fibre and the distribution of same to their desired destination.

Agricultureprovides food and fabrics for man as and when due, in a systematic manner. Cotton, wool, and leather are all agricultural products. It also provides wood for construction and paper products.As agriculture feeds a nation and guarantees its general wellbeing, it contributes tremendously to the nation's foreign exchange earnings and, hence,builds its foreign reserves and gross domestic products. Similarly, engineering creates things that hitherto did not exist in nature, one way or the other, to make life more meaningful and comfortable for man.In fact, the word engineering was derived from the Latin word – ingenerare – meaning to create. This is why it is easy to assert that after God ended creation, it was engineers He handed over to, when He charged them to Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion . . . (Genesis 1:28). So, the ultimate foci of agriculture and engineering are respectively the betterment of the general conditions of man. When agricultural engineering combines the two super disciplines, the result is a professional whose business is the satisfaction of man.

1.2 Developmental Trajectory of Agricultural Engineering

It is now known that agricultural engineering is a marriage between agriculture and engineering, fundamentally deriving from the basis that agricultural problems are amenable to engineering solutions. In human evolutionary trajectory, what was to be called agriculture began as unplanned farming, in the days of prehistory, when man hunted and foraged for food; during which process man discovered that the seeds of fruits he had eaten and thrown away in the forest, germinated and reproduced their kinds after several months/years.

The development of agriculture, at around 12,000 years ago, happened independently in different parts of the world, when man changed from the nomadichunter-forager pattern of living to a more organized system of living and farming (NGS, 2022b). Man began to systemically domesticate animals and grow crops. Agricultural development involves the intensification of the processes used in the extraction of resources from the environment for food and fibre. It was this intensification that elicited the transition from manual methods of farming to a more systematized and mechanized agriculture, which is also constantly undergoing improvements up until now. This was how engineering got involved in the business of agriculture, as, indeed, it is the businessof engineering to provide the tools, devices, equipment and machines required for the agricultural mechanization bid.

Agricultural engineering was actually first used before 2000 B.C.,to describe the introduction of irrigation in large scale agriculture in the Nile and Euphrates rivers(Davidson, 1913). Fire was regarded as one of the earliest tools of agriculture, as Native Americans used it to control the growth of berry-producing plants. Farm lands were cultivated manually, using axes to cut trees and digging-sticks for soil tillage. The development later got to the use of farming tools of bone, stone, bronze and iron; and then to newer and more improved devices (NGS, 2022b).Plates 1(a) to (d) are pictorial representations of the transition of agricultural development practices over the years.

Plate 1a. Primitive farming with bare and sticks

Plate 1b. Animal-drawn implement farming – Type 1

Plate 1c. Animal-drawn implement farming – Type 2

Plate 1d. Tractor-drawn implement farming

The resultant of these constantly changing mechanization devices is the accompanying increase in agricultural productivity.

According to Engr. Professor E. U. Odigboh, the discipline of agricultural engineering became formalised first in the United States of America, when a group of Engineers, trained in other fields of engineering, as Mechanical Engineers, Civil Engineers, Electrical Engineers, etc., but working in agriculture, realized that the application of their engineering knowledge to the solution of agricultural problems demanded a knowledge of agricultural practices, especially the intricacies of the biology of agricultural operations. When they acquired the required additional knowledge, they preferred to distinguish themselves from the other lot, by adopting a new and distinct nomenclature, as the former Mechanical Engineer became known as an Agricultural (Mechanical) Engineer, the Civil Engineer, an Agricultural (Civil) Engineer, the Electrical Engineer, an Agricultural (Electrical) Engineer, etc. It was only a matter of time that they felt their new nomenclature was somewhat clumsy and had to shorten it to simply: Agricultural Engineer.

1.3 The Various Specializations of Agricultural Engineering

The congregation of all other engineering specialists on the farm accounts for the various specializations of the discipline of agricultural engineering being based on the distinctive divides of the fields of Mechanical, Civil, Electrical, Chemical, etc. Engineering, enumerated by NIAE (2001), as follows:

i. **Farm Power and Machinery Engineering:** This is also referred to as Agricultural Power and Machinery, to reflect the broader scope of agriculture beyond the farm. It is made up of two major components, viz: Farm Power and Farm Machinery and involves advances in farm mechanization – tractors, field machinery and other mechanical equipment. Whereas Farm Power refers to all prime movers and power sources used for all phases of agricultural production, processing and distribution, like tractors, electric motors, stationary engines, engines of trucks, etc.,Farm Machinery refers to the machines used for production, which may or may not be powered by the power source of the 'Farm power', such as equipment for land clearing, tillage, planting, weeding, harvesting and transportation (NIAE, 2001; Onwualu *et al,* 2006). This is why power and machinery are regarded as complimentary, as power would be useless if there is no machine to operate, and machinery would not be able to function without power.

ii. Farm Structures and Environmental Control Engineering: This is concerned with the provision of shelter for animals and human beings, crop storage, farm roads and other specialized facilities, which require general planning of farm buildings' layout, structural design of farm buildings and structures, and mechanization and control of the environment within the buildings, including control of temperature, humidity and other environmental factors for optimum performance. This field also deals with general aspects of waste management and conversion technologies.

iii. Processing or Post-Harvest Systems Engineering: This is concerned with the development of processes and machines for the transformation of agricultural produce into finished consumer goods. It involves such processes as cleaning, sorting, grading, cooling, drying, size reduction, etc. Also included here is the transportation of the farm produce to the point of processing, and containerization and packaging.

iv. Rural or Farm Electrification: This involves the provision of electricity in the farm, for the farmstead and every other aspect of farm operation, including water supply, milking and milk processing, heating of brooder houses and to operate other agricultural machinery and equipment.

v. Soil and Water Engineering: This involves harnessing the basic agricultural natural resources of land and water, to ensure maximum agricultural output. It is related to the design, development and operation of soil drainage, erosion, reclamation, irrigation, conservation, water supply, hydrology and flood control systems, including gully control structures, dams, canals, terraces, boreholes, etc.

vi. Food Engineering: This field involves the development of machines and techniques for food processing, containerization, preservation and transportation. It covers such areas as operation of rice mills, feed mills, flour mills, vegetable oil processing, beverage manufacturing, production of biscuits and bread, etc.

vii. Aquacultural Engineering: This area addresses the fisheries aspect of agriculture. It involves the development of systems, structures and machines adaptable to fishes and fishing environment.

viii. Wood Products Processing and Forestry Engineering: This is concerned with the development of machines and systems for the processing of wood and forest resources. It includes such machines as for planting, pruning and felling of trees, etc.

For the avoidance of doubts, Vice Chancellor, Sir, in the very beginning, there was just one field of engineering, called Military Engineering. However, in the process of time, the demands of societal activities constrained the operating professionals to unbundle that single field of engineering into several other fields of Civil, Mechanical, Electrical, Chemical, etc. So, whereas every other field of engineering evolved by fission – breaking away from a parent body, the agricultural engineering discipline was developed by fusion – an aggregation of the different engineering fields into one whole, as no one single engineering field could independently meet the demands of agriculture. For this reason, the curriculum of the discipline copiously includes all critical aspects of the other engineering fields relevant to the solution of agricultural problems and, therefore, seems over bloated. The agricultural engineer has to be trained as all the other engineers in one being, to be in charge of engineering in the farm.

1.4 Emergent Fields in Agricultural Engineering

In the vein of agriculture yielding itself to engineering, as the field of engineering evolves, so does agricultural engineering. At present, the constant evolution of the society and engineering has elicited some relatively new specializations in the discipline of Agricultural Engineering. Agric Farming (2022) enumerates some of these emerging fields as:

i. Amenity (Ecological) Engineering
ii. Mechatronics and Robotics
iii. Information and Communication Technology
iv. Renewable Energy
v. Environmental Engineering

1.5 The Crux of the Agricultural Engineering Discipline

The imposing content and composition of the Agricultural Engineer and the discipline, respectively, impelled Odigboh (1985) to assert that Agricultural Engineering is as extensive as agriculture and as diversified as engineering. According to Encyclopedia Americana (1978), Agricultural Engineering is the most versatile of all the engineering disciplines.

The mentality of the 'agriculturally improved' Engineers led to the formation of the American Society of Agricultural Engineers (ASAE) in 1907, which, at present is renamed American Society of Agricultural and Biological Engineers (ASABE). The ASAE gave a seemingly all-encompassing and somewhat generally acceptable definition of agricultural engineering, to wit: the application of any or all branches of engineering to the extent that they may be used in farming, in rural living, rural processing of farm products and such allied activities as malaria control and wildlife conservation (Igbeka, 1991). With the current inclusion, to effectively reflect the biological content of the discipline, the remodelled association now states that: Agricultural and Biological Engineering is the discipline of engineering that applies engineering principles and the fundamental concepts of biology to agricultural and biological systems and tools, ranging in scale from molecular to ecosystem level, for the safe, efficient and environmentally sensitive production, processing, and management of agricultural, biological, food, and natural resources systems (ASABE, 2022).

In Nigeria, Agricultural Engineering is a relatively new discipline in the comity of other engineering disciplines. Aboaba (1988) stated that the discipline started in Nigeria in around 1959, producing the first graduate in 1967 from the University of Nigeria, Nsukka. Mr. Vice Chancellor, Sir, this relative newness of the discipline of Agricultural Engineering, especially when further compared to the ancientness of agriculture and the dangerously prevalent neglect of agriculture in Nigeria would sum up to account for the pervading ignorance that seems to attend the knowledge of the subject, even amongst those who are expected to know; hence, this exposition.

However, in spite of all the overbearing factors militating against its sprouting, the discipline has continued to blossom, contributing greatly to the overall mechanization of agriculture and consequently boosting agricultural productivity. In the academia, it has transcended from a discipline that over about 80% of the students were coerced into studying, with the instrumentality of admission processes, to one that about more than 50% of the students now deliberately and intentionally chose to study in the first instance.

2.0 INTRODUCTION

Man loves power, but actually power belongs to God, and derives from Him. The Christian Bible expresses "That power belongeth unto God" (Psalm 62:11b) and "there is no power but of God: the powers that be are ordained of God" (Romans 13:1b). Therefore, if any man has any form of power, it came from God. In Luke 10:19, the Bible says: "Behold, I give unto you power to tread on serpents and scorpions, and over all the power of the enemy: and nothing shall by any means hurt you", and Acts 1:8 says: But ye shall receive power, after that the Holy Ghost is come upon you: . . . So, the subject of power is, indeed, a serious business and we shall exercise this divine power all the days of our lives, even in this lecture, because through and through, the word of God is truly true.

2.1 What is this Power?

Power means different things to different people. Literally, power could be regarded as the ability of a person to undertake an action or produce an effect, or to have a controlling influence or authority over others. This literal description seems to fit the power of the creative ability of God, part of which He bestows upon earthly leaders, under the overriding superintendence of engineers, who took over from God in creation.

The other variation of power is from the scientific perspective. This power describes the amount of energy that is expended in carrying out an activity over time. It is closely related to the concept of work, which is a measure of the amount of energy transferred when a force moves an object through a distance. The more energy a system has, the more it is able to move an object a farther distance in a given time, that is, the greater is its capacity to do work, which describes a higher energy content. This is why this scientific power is described as work done over time or the rate of doing work. It is this scientific power that is adopted for engineering purposes, as work, energy and power are all intertwined in the business of changing the physical state/performance of a system. So, the power rating of a system is a description of how much energy the system can expend in a unit time.

Power has various designations, as average or instantaneous power, mechanical power, electrical power, radiant power, etc. However, since power is the amount of energy consumed per unit of time, its' more general or holistic classification is contingent upon the form of energy driving the work of the power. Hence, power and energy are often wrongly used interchangeably, as they do not mean the same thing; whereas 'energy is power manifested over time, power is the rate at which energy is expended' (Gibilisco, 2007). This was why Hart (2018) was vehement in stating that the term "power generating plant" is meaningless, as according to him, "these plants in actual fact generate electrical energy or electricity, and the rate at which the electricity is generated is the power". So, Vice Chancellor, Sir, the subject matter of this presentation(stated as Power) in the title: Distinguishing and Celebrating the Power Behind 'Stomach Infrastructure', should actually be Energy-Source, as the focus is on extolling the beauties of the energy source behind man's daily sustenance, but, by reason of the general misconception and misuse of power for energy, it became imperative to start from what is the common knowledge to what should be the common knowledge. In the circumstance thereof, as the misconception had pervaded the literatures for a very long time, the interchangeability in the usage of power and energy will mildly be adopted in this presentation for the inevitability of clarification and the adoption of reference literatures.

2.2 The Concept of 'Stomach Infrastructure'

The stomach is a very important organ/component of the human body that grants the individual the ability to contain or hold the food the person eats. Primary economic theories postulate that food is one of the basic necessities of life; of course, so, as it is from food that the human body extracts the nutrients it requires for its sustenance, with the stomach contributing as part of the digestive system, to mix the food with digestive juices, preparatory to its effective utilization. So, the stomach requires food to even function, just as a society requires infrastructure – basic facilities/capital utilities for its proper functioning.

It is against the background of the relevance of food, the consequential very high premium placed on it, and the apparent insufficiency of its availability to the Nigerian citizenry, with the attendant food insecurity, that it became a potent tool in the hands of politicians to coerce electoral votes during elections. Stomach infrastructure is simply a political coinage to describe the foodstuffs and all such similar materials given to voters by politicians, to induce and/or manipulate them for their votes. This is why it is possible to say that, perhaps, 'stomach infrastructure',in the regard of its origination, is a euphemism for corruption, which, however, is not the sense of its usage in this context.

The term 'stomach infrastructure' was popularized and gained entry into the politico-economic lexicon of Nigeria when in 2014 Mr. Ayodele Fayose, who later became governor of Ekiti State, Nigeria, in that year, used it in describing his pre-election distribution of different types of foodstuffs, to woo the populace to his side for the election, and he succeeded. Although the practice of using foodstuffs to sway electorates was not strange to Nigeria, or even some other parts of the world, it was the incidence of the Ekiti State election that brought it to fore, when Mr. Fayose dropped the phrase in the public domain. Of course, he had deployed a similar tactic in 2003, and got voters on his side.

Anyhow, while the politicians are proceeding in their own direction, it is pertinent to state that the thrust of the 'stomach infrastructure' in this presentation is the necessity of the stomach requirement (food) as an inevitable ingredient for the sustenance of life, wherein the food is the source of energy for human beings.

2.3 Forms of Energy

Different forms of energy are categorized into two broad groups, namely potential and kinetic energies. These are further explained thus:

a. **Potential Energy:** This form of energy is used to describe the stored energy in any object or system, as a result of its position or arrangements. It includes the following forms of energy.

i. *Chemical Energy:* This is energy stored in the bonds of atoms and molecules. Typical examples of materials that contain chemical energy are batteries, biomass, petroleum, natural gas and coal. When any of these materials is burned, its chemical energy content is converted to thermal energy and used for work.

ii. *Mechanical Energy:* This is the kind of energy stored in objects as a result of tension existing in the object. Some examples of such forms of energy are compressed springs and stretched rubber bands.

iii. *Nuclear Energy:* This kind of potential energy is stored in the nucleus of an atom; it holds the nucleus together and is released in quantum as the nuclei undergo fission or fusion.

iv. Gravitational Energy: This is the kind of energy stored in an object as a result of its height. Its magnitude depends on the height and weight of the object - the higher and heavier the object, the more its stored gravitational energy. This is the kind of energy at play when falling water by gravity from a dam passes through a hydroelectric turbine to produce electricity.

b. Kinetic Energy: On the converse of potential energy is kinetic energy, which is the energy of a body or system that is in motion. It is usually considered relative to other stationary or moving objects in its immediate environment. It has the following variations:

i. Radiant Energy: This form of kinetic energy is the electromagnetic energy that travels in transverse waves, such as visible light, x-rays, gamma rays and radio waves. For instance, the energy from the sun is radiant energy.

ii. Thermal Energy: This is simply called heat. It is the energy that comes from the movement of atoms and molecules in a substance. When the particles move faster the heat increases. A typical example is the heat from the earth, called geothermal energy.

iii. Motion Energy: This is the kind of energy stored in the movement of objects. As objects are energized to move, when they slow down, the stored energy in the motion gets released. The faster an object moves, the more energy is stored. A typical example is the energy in wind.

iv. Sound Energy: Sound itself is the movement of energy through substances in longitudinal (compression/rarefaction) waves. It is the result of a force that brings about the vibration of an object and, in the process, energy is transferred through the object in wave form.

v. Electrical Energy: This is the form of energy delivered by tiny charged particles called electrons, as they move through a wire. It is the energy that brings about lightning.

Generally, in whatever form of energy that power is manifested, in other words, whichever form of energy is expended for work to be done in a given time, if it was so done in accomplishing a farm work, then that power is called farm power. Farm power is, thus, the ability provided or available on the farm to execute a defined amount of work in a given time. These various forms of energy are derivable from different sources of energy.

3.0 SOURCES OF FARM ENERGY

The energy used to perform different kinds of work on the farm is derived from various sources; the choice of any of the sources at any point in time being dependent on a variety of factors, including availability; sustainability; cultural attitudes; scientific and technological developments; and political, economic and environmental considerations.

Common energy sources include human beings, animals, fossil fuels, water, wind, sun and biomass. They are individually expounded as follows:

i. Human Muscles: At the beginning of agricultural times, human beings were the major source of energy for farm work; they still are in most developing countries, including Nigeria, especially for the operation of small tools and implements. Essentially, human muscles, which entail a lot of manual labour is only suited for primitive farming, as its energy output is very low and the operations grossly inefficient. Unfortunately, in Nigeria, human energy, as a 'source of power', accounts for about 86% of the total land cultivated and 90% of the current total energy-use (Stout & Cheze, 1999)

ii. Work Animal: Animals such as cows, horses, camels, oxen, donkeys and their likes are used to do work on farms, in pulling of some implements and in transportation. It has been stated that 'animal power' accounts for about 20 percent of agricultural mechanization in developing countries (Ojha & Michael, 1993). In Nigeria, draught animal accounts for 4% of total land cultivated and 8% of current total energy-use (Stout & Cheze, 1999). As with human energy, the energy offered by animals is low, leading to a very limited power capability. This is aside the fact that effective animal husbandry is required to groom animals for such energy exploitation (Onwualu *et al.,* 2006), yet without a commensurate value.

iii. Fossil Fuels (Coal, Oil and Natural Gas): Fossil fuels are usually converted into other end products like gasoline and premium motor spirit. Their major use on the farm is to generate engine power, to operate tractors and other stationary engines, generate electricity to operate irrigation systems and other farm processes. According to Stout & Cheze (1999), engine power accounts for 10% of source of power per percentage of total land cultivated and a mere 2% of current total energy-use, 18 Watts/ha or 0.008 hp/acre. The use of fossil fuels, especially Oil, in agriculture, as a source of energy, has gained general acceptability in Nigeria, despite their adverse effects on the environment.

iv. The Sun: The sun is the source of solar energy, which can be converted into electricity for farm work. At present, solar energy is used on farms in Nigeria mainly for electricity, and heating and drying of agricultural products.

v. Hydroelectric Energy: This is the major source of hydropower and constitutes the major energy source on Nigerian farms, as it makes up over 80% of the energy that gets into the national grid.

vi. Wind Energy: Wind is another energy source that can be used to generate mechanical and electrical power. Although it is not in common usage on Nigerian farms, it is gradually being introduced into most large-scale farms. It has the potency of being one of the cheapest sources of energy if properly harnessed.

vii. Biomass Energy: This is produced from organic materials, plant and animal remains. Basically, through the photosynthetic process in plants, the plant's chlorophyll captures the sun's energy by converting carbon dioxide from the air and water from the ground into carbohydrates. Simply, plants combine radiant energy from the sun with carbon dioxide and water to give glucose ($C_6H_{12}O_6$), oxygen and heat, thereby converting solar energy into chemical energy stored in the chemical bonds of the plants. Biomass is made up of crops, plants, trees, yard clippings, wood chips and animal wastes. They can be burned and used for heating and generation of electricity. They are also biodegraded to produce biogas for electricity. Although they give off carbon dioxide and water into the atmosphere, their net carbon emission is zero, as they only give off what they originally took from the environment. Some farms in Nigeria have started exploiting this energy source for some of their operations, like providing lighting and heat for animal buildings. Biogas plants in Nigeria as at 2017 have installed capacity of 586 m3 (Itodo *et al.,* 2022).

4.0 THE THERMODYNAMICS OF EVALUATING ENERGY SOURCES

Thermodynamics basically involves the analysis of how heat energy relates with other forms of energy. It studies the flow of heat in systems and the accompanying work. This study is critical for energy systems because almost all forms of energy would require to be converted into thermal energy for them to be useful in work processes; and their conversion is guided by thermodynamic laws. So, an effective appraisal of the various forms of energy and their sources would also be properly accomplished by the principles of thermodynamics.

4.1 Energy Processes of a System

Bassey (1994) used a typical industrial process system comprised of three subsystems – processing subsystem (reactor and separating units), heat and power generation and heat exchanger network subsystems, schematized in Fig. 1, to demonstrate energy conversion processes.

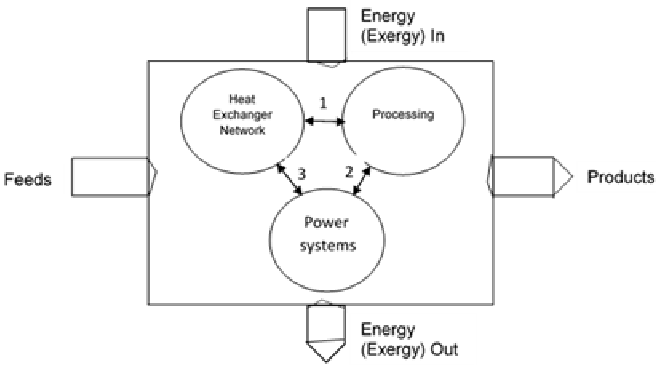

Figure 1: Energy Subsystems of a Process
Adapted from Bassey (1994)

In the various subsystems indicated, energy is either converted into heat or consumed to create work or even transferred from one medium to another. Therefore, until the energy input to the subsystems is capable of eliciting the desired transformation of energy to achieve work, it may not be of any practical relevance. The transformation reaction involving these energy sources is usually spontaneous and can be appropriately analysed using thermodynamic principles, especially the second law of thermodynamics.

4.2 Energy Analysis with Thermodynamic Principles

There are fundamental principles of thermodynamics upon which some thermodynamic laws have been developed. These laws, namely the first and second laws of thermodynamics, have found substantial applicability in the analysis of energy and energy systems, especially in the determination of the degree of usefulness of the energy source.

4.2.1 Considerations of the First Law of Thermodynamics

The first law of thermodynamics has been used to establish the relationships amongst the various forms of energy and energy interactions. From experimental deductions, the first law deals with the conservation of energy, stating that, no matter the convertibility of energy from one form to another, the overall composition of energy in the system would remain the same; i.e. that energy can neither be created nor destroyed, but only transformed. So, every bit of energy in a process has to be accounted for, without any loss.

The principle of the first law, which is deeply rooted on the experiments of Joule in the first half of the nineteenth century (Cengel & Boles, 2006), is that, for a closed system undergoing adiabatic processes between specified states 1 and 2, the net work done is the same regardless of the nature of the closed system and the details of the process. A thermodynamic closed system is one that has well-defined boundaries, with fixed amount of mass, such that no mass can cross its boundary, i.e. no mass can enter or leave the system, hence it is also referred to as a control mass. On the other hand, an open system, also called a control volume, is one that has a well-defined region in space and allows mass and energy to flow across the boundary.

The thrust of the first law is an amalgamation of all the energy occurring within the specified states of the process, called the total energy, which change must reflect the value of the net work that depends on the end states of the system, considering that the net work for all adiabatic processes of a closed system between two specified states is the same. Therefore, the energy balance of the first law system is mathematically expressed as:

$$\begin{pmatrix} \textit{Total Energy} \\ \textit{Entering The System} \end{pmatrix} - \begin{pmatrix} \textit{Total Energy} \\ \textit{Leaving The System} \end{pmatrix} = \begin{pmatrix} \textit{Change in the Total} \\ \textit{Energy of the system} \end{pmatrix} \quad 1a$$

Which is symbolically expressed as:

$$E_{in} - E_{out} = \Delta E_{system} \quad 1b$$

Designating the end states of the process, then:

$$Energy\ change = Energy\ at\ final\ state - Energy\ at\ initial\ state \quad 2a$$

i.e $$\Delta E_{system} = E_{final} - E_{initial} = E_2 - E_1 \quad 2b$$

As energy exists in various forms, like internal (sensible, latent, chemical and nuclear), kinetic, potential, electric, magnetic, etc., they will all contribute to form the total energy of the closed system. Therefore, the change in total energy can be expressed as:

$$\Delta E = \Delta U + \Delta KE + \Delta PE \quad 3a$$

Where

△U – change in internal energy, J $= m(u_2 - u_1)$ 3b

m – mass of the system, kg

u1 – specific internal energy of the initial state, J/kg

u2 – specific internal energy of the final state, J/kg

△KE – change in kinetic energy, J $= \frac{1}{2}m(V_2^2 - V_1^2)$ 3c

V1 – velocity of the initial state of the system relative to a fixed reference frame, m/s

V2 – velocity of the final state of the system relative to a fixed reference frame, m/s

△PE – change in potential energy, J $= mg(z_2 - z_1)$ 3d

g – gravitational acceleration, m/s2

z1 – elevation of the centre of gravity of the system at the initial state relative to a reference level, m

z2 – elevation of the centre of gravity of the system at the final state relative to a reference level, m

So that $\Delta E = m\left[(u_2 - u_1) + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1)\right]$ 3e

When the system is stationary, as obtains in most practical situations, there would not be changes in velocity and elevation, so that △KE = △PE = 0; then:

$$\Delta E = \Delta U = m(u_2 - u_1) \quad 4$$

As the internal energy of a system is more related to its molecular structure and the degree of molecular activity, even when the system is stationary, its molecules will have their own kinetic and potential energies, from where the internal energy can be assessed. This is why internal energy of a system can be manifested as sensible energy – those associated with the kinetic energies (translational, rotational, vibrational, etc.);latent energy – the internal energy associated with the phase of a system; chemical energy – associated with the atomic bonds in a molecule; nuclear energy– associated with the bonds within the nucleus of the atom; and electric and magnetic dipole-moment energies – when atoms are subjected to external electric and magnetic fields caused by the twisting of the magnetic dipoles from electric currents associated with the orbiting electrons.

For this reason, the energy balance is better appraised from the perspective of energy transfer to or from the system, which occurs in three forms of heat, work and mass flow. Therefore, the energy balance equation can be expressed as:

$$E_{in} - E_{out} = (Q_{in} - Q_{out}) + (W_{in} - W_{out}) + (E_{mass\ in} - E_{mass\ out}) = \Delta E_{system} \qquad 5$$

Where

'$E_{in} - E_{out}$'	-	net energy transfer by heat, work and mass
Q	-	amount of heat transferred
W	-	amount of work transferred
Emass	-	energy transport with mass
ΔE_{system}	-	change in internal, kinetic, potential, etc. energies

The subscripts 'in' and 'out' represent the quantities that enter and leave the system, respectively. Note that for closed systems, the energy mass terms equal zero.

4.2.2 Application of the Second Law of Thermodynamics

As the first law of thermodynamics addresses the conservation of energy in a system, in spite of its conversion into whatever form(s), the second law of thermodynamics is principally concerned with the transformational process of the energy as it is converted into the various forms. The statement of the second law is simply that it is impossible to receive heat from a high temperature reservoir and provide an equal amount of work output. This means that in course of the energy conversion, only a part of the energy would be available to be transformed, while the other part would be lost to the conversion process. The ratio of the useful energy to that lost to the system is affected by a variety of factors, which, according to Bassey (1994) includes level of technology, materials choice and safety consideration.

So, whereas the first law deals with the quantity of energy and the associated transformations, the second law is essentially concerned with the quality and the extent of degeneration of the energy during a process. Generally, the quality of energy is described in terms of the work output. Therefore, according to the prescription of the second law, the efficiency of a system that produces mechanical work from an amount of input thermal energy cannot be 100%. Attempting to evaluate this efficiency based on the principle of energy conservation will yield the following mathematical expression:

$$\eta_{th} = 1 - \frac{Q_2}{Q_1} \qquad 6$$

Where:

η_{th} - thermal efficiency of the system expressed as a percentage

Q_1 - heat transfer from hot reservoir, J

Q_2 - heat transfer to the cold reservoir, J

So, the work output here is equivalent to the net heat supplied, which is the difference between Q_1 and Q_2. Yet, this thermal efficiency does not properly qualify the energy, as it "reflects the quantities among energies, but does not account for the quality or grade of energy during the processes of energy transfer and conversion" (Shao *et al.,* 2018). A thermodynamic term used in the description of the quality of energy derivable from an energy source is exergy.

4.2.3 Exergy Analysis of Energy Sources

Energy has quantity and quality. For an energy source, the factor of quantity is good, but not enough to estimate its viability without an accompanying assessment of its quality. So, the quantity and quality of the energy must be considered simultaneously for an effective assessment.

The second law of thermodynamics addresses the quality of energy, its degradation during a process, the entropy generation and lost opportunities to do work (Cengel & Boles, 2006). Again, the quality of energy is in the optimal amount of useful work it is able to perform. The maximum amount of useful work derivable from an energy source, or process, to bring the system into equilibrium with the surrounding, is what is referred to as exergy. It is called the work potential of the energy source, or energy that is available to be used.

Exergy analysis considers that the work done during a process is dependent on the initial and final states of the process and the path of the process between the two states. The initial state is usually specified, with the work output maximized under reversible conditions, i.e. when change in entropy is zero.

In the thermal efficiency defined by equation 6, the quantities Q_1 and Q_2 are functions of their respective operating temperatures. It shows that the thermal efficiency decreases as the source temperature decreases, or that the higher the temperature, the higher the quality of the energy. Simply, heat that is supplied to a system at a high temperature has a greater possibility of conversion into work than the one supplied at a lower temperature. The property of the system that affects or determines the quality of energy, or the temperature at which heat is supplied is entropy. According to Rajput (2013), "Entropy is a function of a quantity of heat which shows the possibility of conversion of that heat into work. The increase in entropy is small when heat is added at a high temperature and is greater when heat is added at a lower temperature. Thus, for maximum entropy, there is minimum availability for conversion into work and for minimum entropy, there is maximum availability for conversion into work" (emphasis mine).

The change of entropy in a reversible process, when it proceeds from state 1 to state 2 is expressed mathematically as:

$$\Delta S = S_2 - S_1 = \int_1^2 \left(\frac{\delta Q}{T}\right)_R \qquad 7a$$

This can simply be expressed as: $dS = \left(\frac{\delta Q}{T}\right)_R$ 7b

Where:

S_1 - entropy at initial state 1, kJ/K
S_2 - entropy at final state 2, kJ/K
δQ - heat transfer, kJ
T - absolute temperature, K
dS - change in entropy, kJ/K
R - subscript indicating the process is reversible

This entropy expression is actually the mathematical formulation of the second law of thermodynamics. Considering the transition between the two states 1 and 2 in a reversible process, the system is expected to get to the dead state in state 2, for the maximum work potential to be achieved. At the dead state, the system is in thermodynamic equilibrium with the environment, i.e. at the same temperature and pressure with the environment.

Borel and Favrat (2013), cited in Hart (2018), stated that exergy accounting is the only way to accurately calculate the thermodynamic losses of a given process and to unambiguously define a thermodynamic efficiency expressing its level of perfection. They said it also allows for the evaluation of the thermodynamic quality of an energy system, when considering energy policies and economics, independent of size, complexity and the nature of the phenomena being looked at. Furthermore, Hart (2018) stated that exergy analysis is an effective method and tool for, among other things, "improving the efficiency of energy and other resources used (by identifying efficiencies that always measure the approach to ideality as well as the locations, types and true magnitudes of wastes and losses)".

The exergy, E, of a non-reacting, flowing stream of matter is given as:

$$E = (H - H_o) - T_o(S - S_o) \qquad 8$$

Where:

E - exergy, J

H - enthalpy of the fluid stream at a specified state, J

Ho - enthalpy of the fluid stream at reference environmental state, J

To - temperature of the fluid stream at the reference environmental state, K

S - entropy of the fluid stream at a specified state, J/K

So - entropy of the fluid stream at reference environmental state, J/K

Here, the entropy term, which poses some practical challenges to evaluate, has been simplified by Linnhoff *et al.* (1982) in Bassey (1994), as:

$$\Delta S = \Delta H \left[\frac{ln\left(\frac{T_2}{T_1}\right)}{T_2 - T_1} \right] \quad 9$$

So that, considering thermodynamic losses, the exergy balance will be:

$$\sum E_{in} = \sum E_{out} + \sum E_2 \quad 10$$

Where: ΣE2- exergy losses referred to as irreversibilities, J

Based on this, the second law efficiency becomes:

$$\varepsilon = \frac{\sum E_{out}}{\sum E_{in}} = \frac{\sum E_{in} - \sum E_2}{\sum E_{in}} \quad 11$$

Equation 11 shows that the thermodynamic efficiency is affected by the exergy losses. It shows that a decrease in ΣE2 will cause the efficiency to tend to unity; this will help to determine the relative performance of a system.
As the temperature of the sink relative to the source determines the maximum amount of work obtainable from the system, which is expressed in a Carnot cycle as:

$$W_e = Q\left(1 - \frac{T_o}{T}\right) \quad 12$$

Where *We* - maximum amount of work obtainable from the system,

and $\left(\frac{T_o}{T}\right)Q$ is the fraction of the heat lost to the environment, then the thermodynamic efficiency can be expressed in terms of temperatures as:

$$\varepsilon = 1 - \frac{T_o}{T} \qquad (13)$$

This relationship between the thermodynamic efficiency and the reservoir temperature is depicted in the curve of Fig. 2.

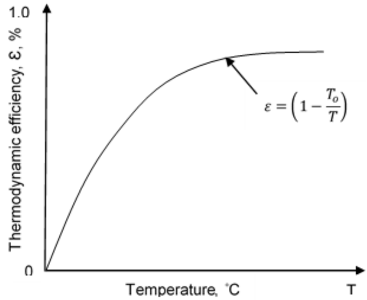

Figure 2: Dependence of thermodynamic efficiency of an energy source on temperature Source: Bassey (1994)

From the curve relating thermodynamic efficiency, Ɛ, with temperature, T, it is seen that the energy efficiency, which corresponds to the least losses of energy to the atmosphere, increases with increasing temperature. Also, from equation 13, the energy efficiency depends on the reference temperature, To, of the system. The higher the reference temperature, the lower is the efficiency value. Notably, energy may be lost to the atmosphere through heat dissipations, incomplete combustion of fuel or transfer of energy from the system. It is, therefore, instructive to curtail emissions or effluents from energy conversion and utilization systems in order to conserve energy and enhance energy efficiency (Bassey, 1994).

4.2.4 The Place of Microbial Thermodynamics

Contemporary energy generation has transcended the realm of inanimate sources to include the use of living organisms, mainly in biochemical activities. Life processes involve heat, which is the foundation of thermodynamic studies. Therefore, it is possible to evaluate the optimal work effectiveness of the energy content of living cells using thermodynamic principles.

The generation of biogas, for instance, from the anaerobic digestion of organic waste materials, which involves the use of microorganisms to decompose the waste, is a typical case of energy generation from living cells. It is the application of thermodynamic principles to the analysis of microbial activities in energy generation that is referred to as microbial thermodynamics.

The processes of living cells, according to Sincero & Sincero (1999), involve electron transport, which functions in a manner that is similar to a battery cell, as electrons move in the organism because of electrical pressure - the voltage difference. With this analogy, the maximum energy change in a living cell, described as that obtained from potentiometric measurements, where no energy is lost in the process, called Gibbs free energy is given as:

$$\Delta G = -nF \Delta E \qquad 14$$

Where:

$\triangle$G	-	Gibbs free energy, J
n	-	number of faradays involve in the reaction
F	-	number of coulombs per faraday
$\triangle$E	-	voltage difference

The negative sign in the equation indicates that the reaction is spontaneous–proceeds in a given direction under natural process conditions, yielding the desired products, without requiring an external influence.

Describing the Gibbs free energy in terms of total entropy, with the statement of the second law of thermodynamics, that 'for any spontaneous process there is an increase in the entropy of the universe, then:

$$\Delta S_{total} = \Delta S_{surroundings} + \Delta S_{system} \qquad 15$$

Now, when the temperature and pressure are constant, the entropy change in the surroundings would be given by the relation of equation 16.

$$\Delta S_{surroundings} = \frac{\Delta H_{system}}{T} \qquad 16$$

Combining equations 15 and 16 shows that:

$$T \Delta S_{total} = -(\Delta H_{system} - T \Delta S_{system}) \qquad 17$$

The equation 17 shows that as ΔS_{total} has to be positive for the process to be spontaneous, so would $T \Delta S_{system}$ and then the component $(\Delta H_{system} - T \Delta S_{system})$ must be negative. It is with this relationship that the Gibbs free energy is defined as:

$$\Delta G = \Delta H - T \Delta S \qquad 18$$

In this case, △G will be negative for the reaction to be spontaneous; and that will be exergonic -where energy is released. On the other hand, if △G is positive then the reaction will be spontaneous written in the reverse direction, or requires energy to proceed in the original direction. This reaction is called endergonic – requires energy to be driven. The system will be at equilibrium when △G is equal to zero. So, the driving force for a reaction is dependent on its △G, the more favourable will be the reaction (Canfield *et al,* 2005)

4.2.5 Relating Exergy with Gibbs Free Energy

There are striking similarities between exergy and Gibbs free energy. As exergy represents the maximum amount of energy available in a system to do work, even so is the Gibbs free energy the maximum amount of energy available in a living cell. Even their mathematical expressions appear the same, as: $\triangle H - T_{env} . \triangle S$. It shows that they are both dependent on the changes in enthalpy and entropy, with maximum work accomplishment at zero entropy. In isothermal-isobaric ensemble (N, P, T), i.e. in a closed system if the pressure, P and Temperature, T are constant, then exergy is equal to Gibbs free energy. However, whereas Gibbs free energy is dependent on whether the process is isothermal or isobaric, it is not so for exergy.

5.0 ENERGY-USE DEMAND ON THE FARM

A farm is a place designated for the growing of crops, rearing of animals and raising of fish, including hosting of a farmstead, where the farm family lives and various other farm and farm family-support activities take place. Consequently, there are so many energy-dependent operations that go on in a farm, like land preparation, crop cultivation, including weeding and fertilizer and pesticide applications, harvesting, processing and storage of agricultural products, containerization and transportation of same, and development of farm structures and infrastructure. In times past, a whole lot of farming operations were carried out manually, by the use of human muscles, which, as a power source, according to Liljedahl *et al.* (1989), are limited to less than 0.1 kW continuous output. They insist that if agricultural workers are to receive an adequate return for their labour, they must be efficient producers by controlling power rather than being the source of power. This very poor and unproductive energy output from manual labour has resulted in the development, introduction and use of machines for agriculture, which is the involvement of engineering in agriculture, leading to agricultural mechanization.

5.1 The Concept of Agricultural Mechanization and Energy-Use

Vice Chancellor, sir, energy-use demand on the farm is contingent upon the use of mechanical devices for agricultural operations, referred to as agricultural mechanization and this, indeed, is the focal point of engineering in agriculture. The concept of mechanization is generally about the interspersion of a tool between the hand and the workpiece and it is not limited to agriculture. It is when the mechanization is applied to agricultural operations that it is referred to as agricultural mechanization. Its primary purpose is to optimize energy application and utilization on the farm, thereby relieving man of the drudgery and hazards inherent in the farming business and boosting the production of food, fibre and fuel. The benefits of mechanization in agriculture have been variously espoused (Igoni, 2013b; 2018), namely:

I. Removal of drudgery from farm operations. Hand tools are energy sapping and so full of tedium and drudgery.
ii. Reduction, if not elimination, of hazards associated with manual operations.
iii. Increased productivity of the land, which will in turn increase agricultural production as the total area cultivated will increase.
iv. Increased economic returns to the farmer, with increase in the area cultivated assisted with improved systems.
v. Improved timeliness and precision of operation.

vi. Reduced losses and improved handling quality of food produced. This objective is realized by introducing improved handling systems to reduce damages.

vii. Improved working environment. By interposing a machine between the farmer and the soil, the farmer will be neater at the end of farm work.

viii. Increased dignity of the farmer. When the drudgery is removed and the farmer's income is improved, his dignity is raised in the society.

ix. Increased Gross National Domestic Product (GDP). Mechanization will increase the production of cash crops and so attract foreign exchange to the nation.

x. Ensures sustainable supply of raw materials to our industry.

xi. Ensures all round, timely and regular supply of farm produce.

xii. Improves the shelf life of farm produce.

Igoni (ibid) further stated that mechanization causes farm personnel to be trained, thereby building capacity and enhancing technical knowledge-base. This ultimately makes the farmer confident in his/her business and enhances his/her social status and societal acceptability. Mechanization also boosts the political image of the government, as one that can cater for the food needs of her citizenry; and substantially increase GDP.

The palpable relief provided by mechanization is demonstrated in Plates 2(a) and (b). Whereas Plate 2a shows the manual labour mode of weeding, with its' associated tedium, Plate 2b shows mechanized weeding with tractor-drawn implements under a conducive environment.

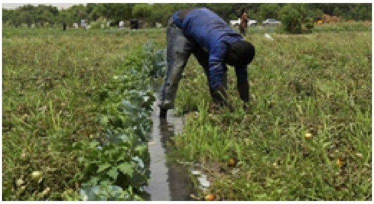

Plate 2a. Weeding with manual human muscles under the hot sun

Plate 2b. Weeding with tractor-mounted equipment in an A/C cabin tractor

However, despite the overwhelming benefits accruable from agricultural mechanization, it may seem inexplicable that Nigeria as a country has not shown substantial capacity in its' practical implementation, as over 80% of its agricultural energy inputs is still from human muscles. The following factors have been identified as partly responsible for this inadequacy, as follows:

i. Inadequate government attention to agriculture.
ii. Inadequate trained personnel for agricultural mechanization.
iii. Lack of encouragement for the few available trained personnel.
iv. Lack of, or insufficient funding of agricultural mechanization research and development.
v. The limit or scope of agriculture practiced in the country.
vi. Lack of appropriate synergy between training-tertiary-institutions and industry.
vii. Unavailability of attractive agricultural structures and infrastructure investments.
viii. The propagation of agriculture as a vocation for peasants and poor rural dwellers.
ix. The overwhelming problem of the Dutch disease syndrome.

x. The embarrassing and slavish dependence on imported technology.
xi. Patronage of foreign personnel called expatriates.
xii. Non-performance of government policy on agricultural mechanization.
xiii. Celebrated corporate corruption (unbridled institutionalized corruption).

5.1.1 Appropriate Technology in Agricultural Mechanization

The reliance on imported technologies that are alien to the peculiar organizational, socio-economic and development circumstances of our country has been identified as one of the major factors militating against our technological development and sustainable agricultural mechanization (Igoni, 2018; 2022a; 2022b). For mechanization to meaningfully impact on the agricultural development agenda of any nation, it has to be appropriate to the development needs of the people.

Appropriate technology is actually an economic concept that has found relevance and application in addressing issues of sustainable development. It was first proposed as intermediate technology by a German Development Economist, Dr. Ernst Friedrich "Fritz" Schumacher, and later changed to appropriate technology, as the word "intermediate" appeared to connote an inferior technology (Akubue, 2000), which was not the original intendment of the concept.

Dr. Schumacher, in his book: Small is Beautiful: Economics as if People Mattered, published in 1973, opined that (Igbeka, 1991):

"If you want to go places, start from where you are"
"If you are poor, start with something cheap"

"If you are uneducated, start with something relatively simple"

The fundamental premise of the erudite economist was that people and nations must strive to meet the demands of their peculiar situations. The implication of his proposition is that for technology to be sustainably impactful on a people, it must fit into their organizational and socio-economic disposition. For the avoidance of doubt, appropriate technology could be a highly sophisticated technology or a very simple one, but what is imperative is that it is within the ambit of what the people can cope with.

5.1.2 Indigenous Agricultural Mechanization Bids

Poised to overcome some of the challenges confronting mechanization in Nigeria, there has been a plethora of research and development efforts by indigenous agricultural engineers to evolve technologies to encourage agricultural mechanization and boost agricultural productivity. These efforts have yielded some fruitful dividends, ranging from land clearing machines (Faborode, 1989) to harvesting machines (Nkakini *et al.,* 2004) to processing machines (Odigboh, 1985) to storage systems/structures (Igbeka & Osiyemi, 2022) to energy systems (Zibokere & Akor, 2001; Fagunwa *et al.,* 2018)and the list is actually unending.

Mr Vice chancellor, sir, in the Rivers State University, we have developed a variety of implements, equipment and machines to support local agricultural producers improve on their mechanization bid and boost their agricultural yield. The fundamental considerations in the design of the machines were to make them appropriate/suitable for the environment and people that would use them, in terms of the climatic condition of the place, soil type/strength, local availability of materials of construction, socio-economic status, including level of education and technical knowhow, and ergonomic factors, for which we have generated anthropometric data for local Rivers State agricultural workers.

Vice Chancellor, Sir, my expedition into the design and development of appropriate agricultural machines and systems, to boost agricultural mechanization in Nigeria, began with "A Draft Design of a Motorized Mechanical Weeder" (Igoni, 1989). This design considered especially the peculiarity of our farming system and the anthropometry of the local producers. It has since been modified and developed into a functional machine (Igoni, 2006), which is still being reviewed for performance and cost considerations. A redesigned and developed motorized weeding machine is shown in Plate 3.

Plate 3. Full view of the motorized weeding machine

This weeding machine, which was designed on the engineering principle of rotary tillers, was developed as a replacement for the local hoe. The latter is not only inefficient in operation, but tedious, hazardous and ergonomically unwholesome, leading to musculoskeletal disorders in the physiological composition of the farmer.

The machine cost consideration was predicated upon the finding that indigent peasant farmers were unable to afford machines for their more or less subsistence level of farming and government intervention in most cases was half-hearted. Igoni (2004) appraised the activities of the Rivers State Tractor Hiring Unit (THU) and found that, despite the initial interest of government in procuring tractors to support farmers in the state, there was no concerted arrangement for the maintenance of the tractors. So, the tractors became scrapped without accomplishing their service lives. The consequence was that, despite that the state had been making mechanization efforts since 1971, its tractorization intensity (T.I.) of 0.345 hp/ha as at 2003 was very low compared to the T.I. of 0.5 hp/ha recommended for efficient agriculture at the time (Igoni *et al,* 2005).

Igoni and Okparanma (2004) had earlier shown that the relatively high cost of mechanization of N27,582.20 per hectare, at the time, (which would stand currently at about N220,656.00), was a major reason for the low level of farm mechanization in the state. Mechanization is capital intensive and requires a strong funding or support base to thrive. This is why government and financially highly-spirited individuals and organizations are enjoined to assist in promoting mechanized agriculture.

Continuing with the mechanization bid, Igoni (1991) developed a continuous-flow rotary-type sieving machine for gari processing. This has over the years been subjected to critical value engineering, resulting in the machine in Plate 4 (Ajanwachukwu *et al.,* 2021).

Plate 4. The gari sifting machine

In 2005, consulting for the United Nations Development Programme, we designed and constructed a manually-operated cassava lifter (Nkakini *et al.,* 2005)

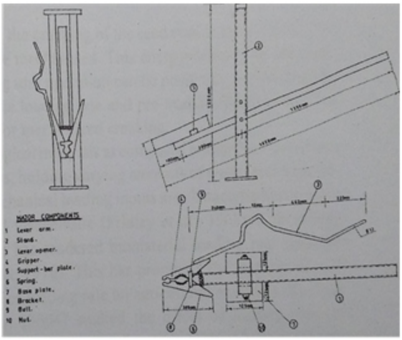

Figure 3. Design drawings of the manually-operated cassava harvester

Other machines we have so far designed and constructed include a Fish smoke-dryer, Fish feed dryer, Plantain, yam and fish roasting machine, Akara frying charcoal cooker, Lawn mower and Motorized pruning machine; all displayed in the Appendix of this presentation.

All these efforts were geared toward meeting the local agricultural producer at his/her very point of need, thereby supporting agricultural mechanization at the grassroots and boosting agricultural yield.

5.2 Determination of Energy Use by Farm Machinery

The introduction of machines into agricultural operations is the major avenue for increased energy demand in agriculture. Of course, farm machinery and farm power are complimentary and must go hand in gloves with each other. Therefore, farm mechanization must necessarily be accompanied by an increased energy demand. Different farm operations and their associated machinery use different amounts of energy to function. Farm energy demand and use have grown in leaps and bounds over the years.

Igoni and Fubara-Manuel (2016) investigated the energy required for cassava grating, in relation to the established laws of comminution, and found that the energy required is a function of the initial size dimension of the cassava tuber. They developed a model in the form of a polynomial function of order two, relating the principal variables of size and energy required, which approximated the values obtained using Kick's law. The model is as in equation 19.

$$E_e = 7[10^{-7}C_s^2 + 10^{-5}C_s] + 0.1871 \qquad 19$$

Where:
Ee - Effective energy required, J
Cs - Characteristic size dimension, m

In Igoni & Ayotamuno (2016), Igoni and Jumbo (2019), Igoni *et al.* (2020a; 2020b) we showed how various levels of soil compaction by tractor wheel, occasioned by the amount of energy expended in field operation, affected the growth and yield of maize in a tropical sandy-loam soil. Similar works have been done by Fubara-Manuel *et al.* (1999) Igoni & Amula (2004), Igoni & Fubara-Manuel (2005), Burubal et al. (2007a; 2007b; 2007c; 2008).

For some agricultural operations, Ojha & Michael (1993) and Stout & Cheze (1999) had reported the amount of energy required at different levels of mechanization – using human, animal and engine-powered devices. Tables 1-3 show the various amounts of energy expenditure.

Table 1: Human power consumption for various farming activities

S/No.	Activity	Gross Power Consumed (Watts)
1.	Clearing bush and scrub	400-600
2.	Felling trees	600
3.	Hoeing	300-500
4.	Ridging, deep digging	400-1000
5.	Planting	200-300
6.	Plowing with animal draft	350-550
7.	Driving 4-wheel tractors	150-350
8.	Driving single axle tractors	350-650
9.	Driving car on farm	150

Source: Ojha & Michael (1993)

Table 2: Efforts and energy expenditure of some draft animal species

Animals	Live weight	Force PC of LW	Speed (m/s)	Work time (h)	DE (MJ)
Donkey	100-150	10-16	0.7-0.9	3.0-6.0	5-8
Horse	200-300	10-16	0.9-1.0	4.5-6.5	16-24
Zebu	300-450	9-15	0.6-0.8	4.5-6.5	24-40

Source: Stout & Cheze (1999)

Table 3: Percentage of energy-use at different levels of mechanization in Nigeria

Source	Percent of Energy-use for overall agricultural production	Energy-use as % of total land cultivated	Amount of engine power (W/ha)
Human	90	86	-
Draught Animal	8	4	-
Engine	2	10	18

Source: Extracted from Stout & Cheze (1999)

FAO (2006) corroborated the findings of Stout & Cheze (1999), that the bulk of direct energy inputs in smallholder production is provided by human and draught animal power (DAP), stressing that agriculture in developing countries relies heavily on the physical capability of farmers. It identified such operations as planting, weeding, spraying and harvesting as requiring human skills and hand tools; and that the energy required for harvesting include mechanical energy for digging up root and tuber crops. Conversely, such activities as ploughing, soil preparation, water lifting, pulling inputs and threshing require fewer skills but greater energy input. Consequently, they are mostly powered by draught animals such as buffalos, horses, donkeys, camels or oxen. For some time now, there has been a gradual transition from draught animal mechanization to a better energy-source mechanization, using machines.

The major machine used to drive or power most farm implements and equipment, aside some other self-propelling equipment on the farm, is the farm tractor; and their energy usage is usually evident in that of the tractor. The energy utilized during land preparation operation, for instance, is readily seen in the amount of fuel consumed by the tractor in the process. Igoni *et al.* (2019) evaluated the fuel consumption of a tractor during ridging operation on a sandy loam soil in a humid tropical climate and developed a model that showed that the tractor fuel consumption during ridging is directly proportional to the draught, ridging speed, height of ridge and soil moisture content, and inversely proportional to the penetration resistance and width of cut. The distinct effects of the tractor speed and height of ridging on tractor fuel consumption were further expounded by Igoni *et al.* (2020c). Similar models have also been developed for the prediction of tractor fuel consumption during ploughing and harrowing (Nkakini *et al.,* 2019a; 2019b; Ekemube *et al.,* 2020; 2021a; 2021b).

Notably, besides the direct energy demand for agricultural operations, there are also indirect energy inputs in the form of sequestered energy in fertilisers, herbicides, pesticides and insecticides. The production, distribution and transport processes of these products all require one form of energy or another, which bear indirectly on the overall energy demand of the farming business (FAO, 2006).

6.0 ALTERNATIVE ENERGY FOR AGRICULTURAL MACHINERY

Like in most other sectors in Nigeria and I dare say globally, the predominant energy source in use for agricultural machines is fossil fuel, especially Automotive Gas Oil (AGO), commonly called diesel, and Premium Motor Spirit (PMS), commonly called petrol. For several reasons, ranging from its depletion status to its relatively very high pollution potential, this source of energy has been denounced as globally inappropriate to be used for any operation. This has elicited the current global energy transition towards a net zero carbon emission energy source.

Whereas the global energy transition initiatives and efforts are plausible and seem very rewarding to highly industrialized and developed nations, developing countries, like Nigeria must tread cautiously and not just follow the superpowers without consideration of the variegated implications of the transition. This is pertinent because the developed nations have considered what is best for them, in the circumstance of global energy exploitation, to seek a transition to suit their development and requirements. Nonetheless, there are a variation of alternative energy sources for agriculture in Nigeria.

6.1 Energy Resources in Nigeria

In Igoni (2022a), it was noted that Nigeria has abundance of renewable and non-renewable energy resources, including solar, hydropower, wind, biomass, etc., and coal, oil, gas and lignite, respectively. All of these resources have been found to occur naturally, in relatively very huge quantities in the country. Table 4 gives details of the energy resources in Nigeria.

Table 4.Energy resources in Nigeria

Resource	Reserves (natural units)	Production level (natural units)	Utilization (natural units)
Crude oil	36.22 billion barrels	2.06 million bpd	445,000 bpd
Natural gas	187 trillion SCF	7.1 billion SCF/day	3.4 billion SCF/day
Coal and lignite	2.734 billion tonnes	Insignificant	Insignificant
Tar sands	31 billion barrels of oil equivalent	0	0
Large hydropower	11,250 MW	1.938 MW(167.4 million MWh/day)	167.4 million MWh/day
Small hydropower	3,500 MW	30 MW (2.6 million MWh/day)	2.6 million MWh/day
Solar radiation	3.5 – 7.0 kWh/m^2/day	Excess of 240 kWp of solar PV or 0.01 million MWh/day	Excess of 0.01 million MWh/day solar PV

Wind		2 – 9 m/s at 10 m height	-	-
Biomass	Fuelwood	11 million hectares of forest and woodland	0.12 million tonnes/day	0.12 million tonnes/day
	Animal waste	245 million assorted animals in 2001	0.781 million tonnes of waste/day in 2001	Not available
	Energy crops and agric. residues	72 million hectares of agric. land and all waste lands	Excess of 0.256 million tonnes of assorted crops residues/day in 1996	Not available

Source: Akorede *et al.* (2017)

From Table 4, with the overflowing natural resources that Nigeria has, it is evident that the country can derive substantial amount of energy to sufficiently meet the energy needs of its citizenry, especially its agricultural business. Considering coal, for instance, Nigeria has a reserve of about 379 million tons, which makes her to be ranked as 44th position in global scale, with a total of one trillion tons (ECN, 2014). When assessed with lignite, the reserve strength of coal and lignite is put at 2.71 trillion tons. This coal was the major energy source of Nigeria up to 1960 (IEA, 2019), but had to be literally abandoned because the Nigerian Railway Corporation, which was the major consumer of coal in its coal-powered trains, had to transit to the use of trains with diesel engines.

At present, Nigeria has the quantity of coal that can last it for 1,961 years, at current consumption rate (Worldometer, 2021), but is hardly involved in its mining because of its bandwagon followership of a world that discovered and started exploiting a juicier energy source at the time.

Furthermore, the crude oil reserve of the country as at 2013 was put at between 36.2 and 37.2 billion barrels. Earlier in 2006, it was estimated that Nigeria had the tenth largest reserve of crude oil, which contributed about 25% of its GDP, the second highest after crop production (Oyedepo, 2012) at the time. With the quantum of oil available in the country, it is expected that exploitation and use at current utilization rate will last over 42 years (Igoni, 2022a). Also, the natural gas reserve of Nigeria is estimated at 187 trillion SCF or 5.3 trillion cubic meters, placing the country as the 4th largest exporter of natural gas. These are in addition to other abundant fossil and renewable resources.

6.2 Nigeria's Energy Policy/Energy Mix

Nigeria's energy policy consists of a total of thirteen specific objectives, which bearing is mainly to ensure a robust energy mix for optimum exploitation of her vast energy resources. Some of the policy propositions of interest in this presentation are:

- To ensure the development of the nation's energy resources, with diversified energy resource option, for the achievement of national energy security and an efficient delivery system with an optimal resource energy mix.
- To guarantee adequate, reliable and sustainable supply of energy at appropriate cost and in an environmentally friendly manner, to the various sectors of the economy.
- To promote gender sensitivity and special attention to rural energy needs.
- To ensure effective coordination of national energy planning, programs and policy implementation.

By the policy statement, Nigeria inclines to a diversification in its exploitation and use of her huge and varied energy resources, which had been identified as coal, crude oil, natural gas, biomass, solar, hydro, wind, etc. However, this has been done disproportionately, as Emodi & Boo (2015) state that Nigeria's energy mix, especially its grid electricity is dominated by thermal plants (80%) and hydropower (20%). Generally, according to US EIA (2014), most of the energy used in Nigeria comes from traditional biomass and waste, making up about 83% of the total primary energy production, while the balance comes from fossil fuels (16%) and hydropower (1%). However, excluding electricity, the nation's primary energy supply is comprised of biomass and waste (80.9%), oil (5.7%), natural gas (9.4%) and hydro (0.4%) (GIZ, 2015; SE4ALL, 2016). IEA (2015) gives a tabulation of the energy balances for Nigeria as at 2012, as in Table 5.

Table 5. Energy balances for Nigeria in 2012 (kilotonne of oil equivalent, ktoe)

Classification	Coal and Peat	Crude Oil	Oil Products	Natural Gas	Hydro	Biofuels and Waste	Total
Production	30	129,409	0	33,645	487	108,142	271,712
Imports	0	0	8,440	0	0	0	8,440
Exports	0	-126,413	-755	-21,032	0	0	-148,201
International Marine Bunkers	0	0	-397	0	0	0	-397
International Aviation Bunkers	0	0	-186	0	0	0	-186
Stock Changes	0	1830	538	0	0	0	2,368
Total Primary Energy Supply (TPES)	30	4,825	7,640	12,613	487	108,142	133,736
TPES (%)	**0.02%**	**3.61%**	**5.71%**	**9.43%**	**0.36%**	**80.86%**	**100.00%**

Source: International Energy Agency, IEA (2015)

The necessary implication of Table 5 is that Nigeria is very backward in the development and utilization of its energy resources, and primitive in its utilization of biomass, which 80.86% supply is majorly the traditional burning of firewood and other inflammable waste materials. Second, in spite of the abundance of coal, crude oil and natural gas, their exploitations are at an abysmal level of 0.02%, 3.61% and 9.43% respectively. The exploitation of coal has been stopped and that of oil and natural gas are at the point of abandonment, following the clamour for resort to renewable energy sources, in the prevailing global campaign for energy transition, hinged on the climate change calamity.

Vice Chancellor, Sir, it is against the background of the abundance of these energy resources in Nigeria, especially of the fossil variation, that we believe that Nigeria should be circumspect about the global energy transition, and not heedlessly optimistic that the considerations of the western nations would cater for her interest. This is more so because one of the major reasons the developed nations are seeking alternative energy is to side-line the resources of developing nations. In extolling the potential of some renewable energy sources in America, Haynies (2008) stated that: Interest in improving air quality and reducing dependence on foreign energy sources (emphasis mine) are playing a key role in the development of solar power and biofuels. Again, Layton (2008) wrote that "Dwindling oil supplies (emphasis mine) and concern over climate change caused by combustion-engine emissions have sparked a new debate over alternative energy investment". These assertions are indicative of other serious considerations for the resort to alternative energy by global power brokers than the impact on the environment.

Furthermore, in the global environmental degradation caused by atmospheric carbon pollution, it has been shown (Joel, 2022) that Africa at 4%, of which Nigeria is a part, contributes the least with South and Central America, while Europe and North America are both at the top with 10% and 16% respectively. These allusions are reflected in Figure 4.

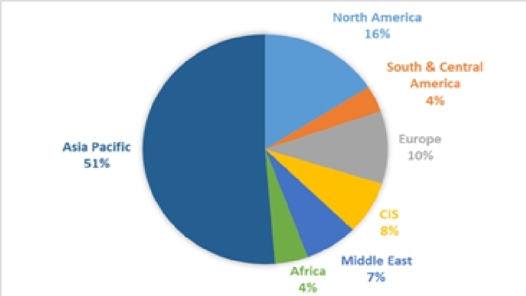

Figure 4: Carbon dioxide equivalent emissions (MMtCO$_2$e) from energy, process emissions, methane, and flaring. Source: Joel (2022)

Nonetheless, despite that Africa contributes a paltry 3.8% to total global emissions, according to Joel (*op cit*), it has borne the brunt of climate change. It loses \$7-\$15 billion annually, due to climate change, and this figure is expected to rise to \$50 billion by 2040. So, while Europe and America were enjoying and benefitting from the use of fossil fuels, Africa was bearing the brunt; and now that they have a breakthrough in effective exploitation of other renewable sources, Africa should abandon its huge available resources and sheepishly follow them in utter slavish dependence, instead of seeking reparations for devastation of its environment by their consumption of fossil fuels.

This situation is akin to the incidence of the COVID 19 regime, when some native Africans were not disposed to relying on the COVID theories of America and European countries. The complication here is that for a long time Europe has been seeking ways of reducing and/or controlling Africa's population.Vice Chancellor, Sir, let me crave the indulgences of this revered audience to follow me on this revealing excavation from Güntheret *et al.* (1995):

First, they stated that:

> *The global environmental situation of the Earth is becoming increasingly problematic and critical. The outlook for our future is increasingly gloomy.* ***The major reason for this pessimistic outlook is the exploding number of people.***

They recognized the interdependence of the global rise in population and technological development; how the developing countries are also desiring the good life usually elicited by technological advancement and further stated that:

> *We will not reach the goal of sustainable development if the present growth of both the world's population and the consumption rates continue or* ***if the developing countries succeed in their claim to living conditions similar to those in the developed part of the world without a drastic reduction in the global population numbers over some generations. Thus, sustainability calls for a decisive reduction in the growth rates of the global population***.

On this score, they wondered at the possibility of convincing people to kill themselves and concluded that:

> ***We will succeed only if we manage to set up a dramatic program to slow down the growth of population numbers.*** *To be politically feasible in the long run,* ***this goal requires reductions in the number of people in both the developed and the developing countries.***

Vice Chancellor, Sir, it is with the consciousness of the knowledge of the long outstanding desire and contemplation of the western nations to set up a dramatic program to reduce population in developing countries that some persons were sceptical about the genuiness of the COVID vaccines from the West, especially when all the attempts at developing anyone in Africa did not find relevance.

In the circumstances thereof, while not undermining the adverse environmental implications of the use of fossil fuel resources, it would appear that the global energy transition initiative is to make Africa abandon its abundant natural energy resources and be completely dependent on Europe and America at all times, as they will continually be dictating the nature, pace and direction of energy exploitation and use technologies. This was why Igoni (2022a) stated that:

> *If Nigeria is to strive towards energy security, then* ***it has to consolidate its energy resources development gains and expand its energy resource base, by enlarging its energy mix basket****. Although Nigeria is rich in energy resources, it is yet to exploit their potential, which is largely responsible for the very wide energy security gap. On the overall,* ***for Nigeria to close this energy security gap, it has to develop its capacity to exploit and utilize the various available energy resources, thereby enriching and stabilizing its energy mix balance.***(Igoni, 2022a)

So, for Nigeria, the energy transition escapade should not be a case of abandonment of abundant natural energy resources, but rather that of developing **appropriate technologies** to harness them for the ultimate benefit of man and society. This much was corroborated by Joel (2022), when he said that **a net-zero energy transition is not necessarily a renewable energy transition, but that which requires massive deployment of other technologies**, and carbon capture and sequestration technologies that capture carbon dioxide, either before it's released or from the air, and then store them. Mr. Vice Chancellor, Sir, the scary implication of this is that, if we do not develop appropriate technologies to handle our situation, the world will leave us behind and we shall just be glued to the apron string of Europeans and Americans, and now the emerging Asians.

Vice Chancellor, Sir, the approach we are canvassing is not strange to the world. It was adopted by China in her twenty-year development programme (1980-2000), when she had to pursue an energy production increment by coal combustion, in spite of the propagation of reductions in carbon dioxide output by western countries (Günther *et al.*, 1995). China charted her own course by exploiting its area of higher comparative advantage, not wanting to be railroaded into the trap of energy technology enslavement by western countries. Before this time, Nigeria had long abandoned the exploitation of her coal resource.

7.0 HARNESSING COMPLIMENTARY ENERGY RESOURCES

There is now no doubt whatsoever that the predominant energy resource exploited in Nigeria, and even globally, is fossil fuel. While we strive to develop technologies to limit the adverse consequences of harnessing it on man and his environment, it is also pertinent to develop the use of the other equally abundant energy resources, which are even adjudged as renewable and more environmentally friendly.

In the circumstances thereof, there has been a plethora of researches and developments in the exploitation of renewable energy resources in Nigeria, such as solar, wind, hydro, wave, biomass, etc (Nimame *et al.*, 2020a; 2020b; Itodo *et al.*, 2022). However, to the extent of the developments, only the hydropower seems to have been exploited to relevant national scale and incorporated into the national grid, to impact on national production capacities, as shown in Table 6.

Table 6. Energy production capacities of various energy sources in Nigeria

Energy source	Total Production (kWh)	% Production	Per capita (kWh)
Fossil fuels	73.72 bn	80.0	357.64
Nuclear power	0.00	0.0	0.00
Water power	17.51 bn	19.0	84.94
Renewable energy	0.00	0.0	0.00
Other energy sources	921.55 m	1.0	4.47
Total production capacity	92.16 bn	100.0	447.05
Actual total production	29.35 bn	31.8	142.38

Source: WorldData.info (2018)

Vice Chancellor, Sir, in about the year 2003, buoyed by the growing global interest in renewable energy development and the need to make it count in Nigeria, we began exploring all possibilities. We found that, in other parts of the world, like the UK and US, biogas was already being generated from waste and used for heating and electricity, even though it was still at the experimental stage (Xuereb, 1997). Furthermore, it was noted that the feedstock for the generation of biogas at the time was livestock farm waste (various manure, slurry and waste waters;

and that the next phase of the project was to generate the gas from the organic component of source-separated municipal solid waste (Vassiliou, 1997). In this realization and considering that the nature and quality of waste is location-specific (Hobson et al., 1981), we adopted the initiative and replicated the research in Port Harcourt, Nigeria. The allure to undertake the research was the imposing suffocation of Port Harcourt metropolis and indeed the entire Rivers State by the heavy burden of the municipal solid waste (MSW) generated therein, which literally turned the city from its original garden city status into a garbage city (Ayotamuno & Gobo, 2004; Igoni & Harry, 2017a).

We conducted a detailed investigation into the quantity and quality of the MSW in the metropolis and showed in Igoniet al. (2007) that the per capita per day generation of waste in Port Harcourt was an average of 1.11 kg. This now means that, with the current projected population of Port Harcourt metropolis of 3,325,000 persons (UN-WPP, 2022), the total annual MSW-load would be 1.35 million tonnes. Out of this mass, by the current field investigation of Amafabia (2022), reported in Igoni (2022c), the percentage of total organics in the MSW is 98.4, while that of easily biodegradable organics (putrescibles), i.e., exclusive of plastics, rubber, textiles and leather, is 58.44, as in Table 7.

Table 7. Current composition of MSW in Port Harcourt metropolis

Waste component	Mass composition (kg)	Percentage mass composition (%)
<u>**ORGANIC**</u>		
- Food waste	23.80	29.36
- Wood/Leaves	2.37	2.92

- Paper	5.29	6.53
- Plastics	24.81	30.60
- Textiles/Rubber/Leather	7.59	9.36
- Garden/Agric. Waste	4.24	5.23
- Miscellaneous organics	11.67	14.40
INORGANIC		
- Glass	1.07	1.32
- Metals	0.23	0.28
TOTAL	**81.07**	**100.00**

Source: Amafabia (2022)

In Igoni *et al.* (2005), we investigated the potential of generating biogas from MSW in Port Harcourt metropolis and found that the waste is rich in volatile organic matter, up to 66.6%, with a biodegradability factor of 83.1%. A carbon to nitrogen ratio of 27:1 of the waste indicated that it had large amounts of readily degradable carbon and a high capacity to sustain microbial growth. On the overall, the study showed that the MSW in Port Harcourt has a relatively high potential to yield biogas.

Having established that it was possible to use the MSW to generate biogas for energy, we sought to know the rate of progression of its biochemical processing. Igoni et al. (2006) investigated the bio-kinetics of anaerobic digestion of the MSW in biogas generation and determined the process kinetic parameters relevant to the design of anaerobic bioreactors for the waste. The investigation established that practical digesters for MSW processing would require an inoculation of the feed stream with microbes, or an operating system with cell recycle. Based on this finding, some of my doctorate degree students, including Ibiye D Amafabia, Deeka N. Tambari and Elochukwu Abbah, are currently conducting different levels of investigation on how to enhance the utility of MSW for energy generation, especially to elicit sustainable microbial content through co-digestion with other substrates, like sewage and some agricultural wastes. Their investigations are already yielding fruitful results.

With the kinetic parameters of the anaerobic digestion of MSW, design and process models were developed for the simulation of biogas generation from MSW. This was done for both batch and continuous bio-reactors, which were appropriately sized and their dimensions established (Igoni *et al.,* 2007a; 2007b; 2007c; Igoni, 2016a; 2016b; Igoni & Harry, 2016a; 2016b; 2017b). In Igoni *et al.* (2008), the digester design considerations were elaborately described. The cost of the designed batch and continuous digesters were appropriately determined with relevant models (Igoni, 2006).

7.1 Energy Content of Municipal Solid Waste

The current composition of the Municipal Solid Waste(MSW) in Port Harcourt shows that 787,259.119.5 kg (or 787,259.12 tonnes) of the waste are available annually for biodegradable conversion into bioenergy. This quantity of waste can be converted into the various forms of energy, like chemical, electrical, mechanical, solar, thermal, etc. through different conversion methodologies, namely biochemical, thermo-chemical and physical processes, schematized in Figure 5.

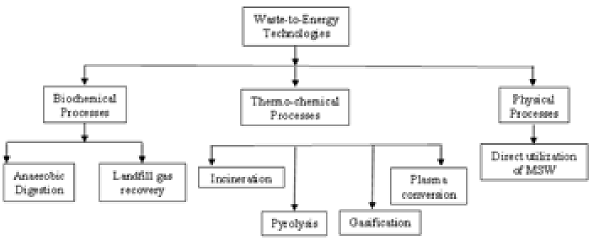

Figure 5: Process chart of extant waste-to-energy technologies
Source: Igoni & Harry (2016c)

Igoni (2022c) noted that these various waste-to-energy technology options are used depending on: i) the specific characteristics of the waste; and ii) the desired end product of the conversion process. Now, we can yet add other considerations, namely the availability of the technology and its appropriateness in any given environment. In Igoni & Harry (2016c) and Igoni (2019), the extent of applicability of, and derivable benefits from these different conversion processes were expounded:

7.2 MSW Conversion Processes

a. The biochemical conversion processes: These involve a combination of biological and chemical operations – they are a description of the chemical processes that take place in biological materials or living organisms, involving the breakdown and synthesis of their molecular constituents, to result in some more productive biomolecules. As in the Figure 5, the biochemical processes principally include anaerobic digestion (AD) and landfill gas recovery (LGR). Whereas the anaerobic digestion, which is also called biomethanation, involves the decomposition of the organic materials by microorganisms in the absence of air, the landfill gas recovery harnesses the anaerobic conditions in landfills to collect the methane produced by methanogenic bacteria. In the AD process, the organic waste material serves as a food source for the bacteria, which, in turn, convert it into various end products and by-products, including energy. The microorganisms degrade the organic matter, reduce its volume, pollution potential and generate energy in the process. Microorganisms thrive better in moist environments; so, wastes rich in organic content and with high moisture content, such as the MSW in consideration, will be better treated by biochemical processes.

Furthermore, the technology of biochemical conversion processes is not as sophisticated as that of some others. They do not require any initial energy input to commence or sustain the system. This was why Igoni & Harry (2016c, 2017) insisted that for this kind of waste type, with a 100% organic content and moisture content of over 60%, and with energy generation in focus, the biochemical processes will better serve the desired purpose.

b. **Thermochemical conversion processes:** These involve the use of heat to engender and facilitate the chemical activities in a waste material. It is the chemical transformation of biomass into energy and other chemical products, under different controlled heating (combustion) conditions. Some of the methods here are incineration, pyrolysis, gasification and plasma conversion. Incineration is the regulated combustion of waste at relatively high temperatures of between 750 and 1500 °C, in the presence of air, in a dedicated chamber called incinerator. It achieves waste volume reduction of about 95%; and the heat from the process can be used to generate electricity. On the other hand, pyrolysis is the decomposition of organic material at high temperatures of between 200 and 800 °C, in an oxygen-free environment. The process produces bio-char, bio-oil and such gases as methane, hydrogen, carbon monoxide and carbon dioxide. Gasification is the thermochemical biomass conversion that uses incomplete combustion or partial oxidation of a carbonaceous material, to produce gaseous combustible gas, usually referred to as producer gas; and plasma conversion is a gasification process that uses plasma torch to convert biomass into synthesis gas (syngas), comprised mainly of hydrogen and carbon monoxide. The plasma torch ionizes gas and catalyses the organic material into syngas, leaving slag as a by-product. These were originally designed to subject wastes to relatively very high temperatures, thereby drastically reducing their initial volume and deactivating the pathogens in the waste. They were not really for energy generation, as, of course, so much energy is required to achieve temperatures in the neighbourhood of 1,000 °C; they are also best suited for the treatment of wastes that are very rich in combustibles, like paper, plastics, etc. For instance, Incineration is widely used in developed countries, as the focus is on drastic reduction of waste volume. It is also preferred for wastes with heating value below 3,500 kcal/kg, combustible fraction of over 60% and moisture content of less than 30%, because of the high energy intensity of the process. So, for a feedstock like MSW in Port Harcourt metropolis, with very high moisture content of upwards of 60%, it will be counter-productive to process it by thermochemical means, if the target is to generate energy from the process, in an energy-deficient developing third world country, like Nigeria.

c. **The physical processes:** These processes of waste to energy conversion are an age-long and most common method in developing countries. They involve the direct utilization of the biomass by direct combustion (burning). Direct combustion is the burning of biomass in open air or in the presence of excess air or less-controlled environment. It can be, and is usually, carried out in a furnace, steam turbine, or boiler, at a temperature range of 800 – 1000 °C, to convert photosynthetically stored chemical energy of the biomass into gases (Lam et al., 2019). The heat generated in the process can be used directly for drying, or passed through a heat exchanger, to produce hot air, hot water or steam. These involve direct combustion of the feedstock. It is considered to be as archaic as it is obsolete, although it is still largely in use in most of rural Nigeria and can record energy-recovery efficiencies of up to 90%. It contributes adversely to greenhouse gases, even though it is arguable that its overall effect is a net-zero carbon emission. It is also injurious to the environment by its deforestation impact and contributes to global warming. However, what is required is not to discard it, but to develop appropriate technology to curtail its excesses.

Municipal Solid Waste has been proven globally to be a veritable source of energy (Igoni *et al.,* 2005; Igoni *et al.,* 2008; Michaels & Shiang, 2016), when subjected to the various forms of processing. The amount of energy derivable from it depends on the type of processing. Various scholars have found that the energy content of MSW ranges from 6.83 MJ/kg to 18.43 MJ/kg (Igoni *et al.,* 2007; Ujile & Lebele-Alawa, 2011; Amber *et al.,* 2012; Lawal & Garba, 2013; Tsunatu *et al.,* 2015). Table 8 shows the energy content of the various constituents of MSW in Nigeria.

Table 8. Energy content of MSW components

MSW component	Energy content (MJ/kg)
Organic/Putrescible	11.590
Paper	10.140
Cardboard	11.033
Plastics	14.890
Polyethene	46.500
Textile	9.270

Source: Amber et al. (2012)

With these data, for every kilogram of organic MSW, 11.59 MJ of energy would be obtained. Therefore, the organic MSW load of 787,259,119.5 kg per annum, is capable of yielding 9,124.33 million MJ of energy. If this were considered against the background of 100 tonnes of MSW generating 1 MW of electricity, then the organic MSW load would yield an estimated 7,872.6 MW of electricity annually.

However, if this MSW load were subjected to biochemical decomposition in an anaerobic reactor, then an estimated 100 m_3 of biogas would be produced per tonne of the waste. This would translate to obtaining 78.73 million m_3 of biogas from the waste. Then with an estimated 2 kWh of electricity obtained from 1 m_3 of biogas (Igoni *et al.,* 2022), it means that 157.46 million kWh of electricity would be available for consumption from the organic MSW in Port Harcourt annually. This amount of electricity is equivalent to 17.975 million J/s or 17.975 MW of electricity. The implication of this is that, with the current per capita per annum electricity consumption of around 117 kWh (WorldData.info, 2018), the electricity requirements of about 1,345,812 persons could be met by the energy generated from the organic MSW load in Port Harcourt. Therefore, as cost of electricity ranges from N23 - N36 per kilowatt-hour (Sasu, 2022), the energy from organic MSW would save the State a total of N4.72 billion annually, in addition to the whooping cost of managing the waste and its attendant health and environment effects.

Considering the entirety of Nigeria, with a waste load of approximately 27 million tonnes and biodegradable fraction of 60% (Igoni *et al.,* 2021), then about 3,240 million kWh or 369.87 MW of electricity would be available from the anaerobic digestion of the waste, to serve about 27,692,308 persons. This would save the nation upwards of N97.2 billion annually, exclusive of all other cost associated with managing the waste and the environment.

Furthermore, we had stated in previous works (Igoni, 2005a, 2005b, 2006, 2019, 2022a; Igoni *et al.,* 2007, 2021; Odoh *et al.,*

2011) that the conversion of MSW into energy will eliminate the seeming unending crises of MSW management in Port Harcourt and indeed Nigeria, by removing all the MSW from the streets. Notably, the energy from the processing of the organic MSW can be used to fuel the incineration of the inorganic/non-putrescible components of the MSW. A similar situation was recorded in Sweden, when in 2017 the country ran out of waste to burn for electricity generation and had to rely on imports from the United Kingdom and other countries to keep their plants running (Igoni, 2019). Also, the sludge residue left behind as a by-product of the MSW digestion process could be used as fertilizer, to grow crops, in addition to the elimination of environmental filth, nuisance and pollution.

8.0 COMPARATIVE EVALUATION OF FARM ENERGY SOURCES

Different energy sources have differing amounts of energy content and, hence varying potential to do work. According to BBC (2022), the nuclear energy within 1 kg of uranium, for instance, contains a very large amount of energy, but the gravitational potential energy stored by many thousands of tonnes of water held back by a dam contains less. It had been noted previously in this presentation that the fundamental basis for the assessment of an energy source is exergy, or when it concerns sources related to living organisms, Gibbs Free Energy. However, it was also noted that the reason for the global inclination towards shifting attention from one energy source to another is not related to any of the thermodynamic relations, but to the environmental implications of the energy-use. World 101 (2022) stated that the overall evaluation of an energy source is based not only on how clean it is, but also on its reliability, accessibility and affordability. In addition to all these is the issue of availability of the energy source. This means that beyond exergy and Gibbs Free Energy, which relate to the internal energy capacities of the energy source, there are other factors that could be used in the evaluation of energy sources, to ascertain their applicability in any given situation. Some other assessment criteria have been identified.

8.1 Assessment Based on Capacity Factor

Energy sources can be assessed on the basis of their capacity factor -a description of the sustainability of maximum power production by the energy source in a defined time frame. The United States Department of Energy (2021) evaluated different energy sources on the basis of their capacity factor and arrived at the conclusion depicted in Figure 6.

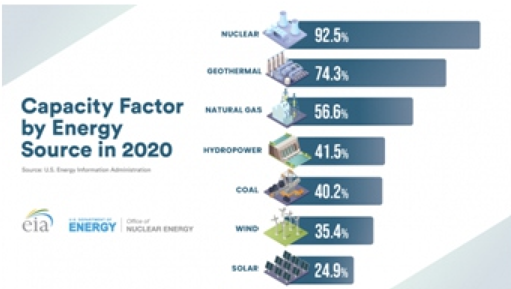

Figure 6: Evaluation of energy sources by capacity factor
Source: US Department of Energy (2021)

The Figure 6 features nuclear energy as having the highest capacity factor, being capable of producing maximum power more that 92% of the time in a year. It is rated better than other sources in the proportions stated, and adjudged more reliable. They are said to require minimal maintenance and configured to function for a very long stretch of time, up to between 1.5 and 2 years, before re-fuelling (US DoE, 2021)

8.2 Assessment Based on Energy Density

Energy density is essentially the amount of energy derivable from a defined unit of an energy source relative to a standard basis. The energy densities of different energy sources have hitherto been measured in varying units, thus making it difficult to do an across-the-board comparison of these sources using energy density. For example, whereas the energy densities of such resources as coal and oil are measured in dimensions of energy per unit volume or energy per unit mass, that of solar, wind and hydroelectric sources are dimensioned in power per unit area. Layton (2008) formulated a mathematical expression to denominate the energy densities of all energy sources in the same unit, as joules per cubic meter. This has now made it possible and easy to evaluate all energy sources commonly on the basis of their energy densities. Table 9 presents the comparisons of various energy sources based on their energy densities.

Table 9. Energy densities of various energy sources

S/No.	Energy Source	Joules per cubic meter
1.	Solar	0.0000015
2.	Geothermal	0.05
3.	Wind @ 10 mph (5 m/s)	7
4.	Tidal water	0.5-50
5.	Human	1,000
6.	Oil	45,000,000,000
7.	Gasoline	10,000,000,000
8.	Automobile occupied (5800 lbs)	40,000,000
9.	Automobile occupied (5000 lbs)	40,000,000
10.	Natural gas	40,000,000
11.	Fat (food)	30,000,000

Source: Layton (2008)

Oil has the highest energy density. The implication is that for a cubic meter of oil, relative to other sources, the derivable quantum of energy is the highest. It is forty-five quadrillion times more energy-dense than solar radiation and four billion five hundred million times more energy-dense than wind and water power. Ordinarily, the energy density of nuclear energy would have been over ten billion times more than that of oil, in the order of 1021 J/m_3, if all the mass of U235 that split in a typical reactor gets converted into radiant thermal energy. However, because the total global uranium available would be normalized by the volume of the earth, it renders the energy density of nuclear reaction equivalent to about 0.05 J/m_3.

8.3 Assessment Based on Greenhouse Gas Emission

The concept of greenhouse expresses the entrapment of heat from the sun by atmospheric gases, thus retaining the heat on the surface of the earth. Radiant thermal energy from the sun strikes the earth in the form of ultraviolet (shortwave) radiation and get absorbed by atmospheric gases, which retain and emit it as infrared (longwave) radiation that can no longer get out of the earth. This results in heating up of the earth, referred to as greenhouse effect. The atmospheric gases, like water vapour, carbon dioxide, methane, etc., that have the potency to trap the heat from the sun are called greenhouse gases. Different energy sources discharge different levels of these greenhouse gases into the atmosphere; the more of them an energy source releases into the environment, the more environmentally unfriendly that energy source is said to be. Figure 7 shows the different levels of emission of greenhouse gases by the various energy sources.

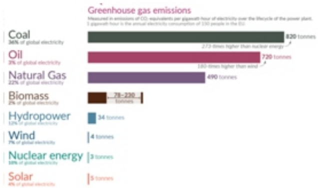

Figure 7: Emission of greenhouse gases by different energy sources Adapted from: Ritchie (2022)

From the Figure 7, the fossil fuels (coal, oil and natural gas) are the worst culprits in the introduction of greenhouse gases into the environment. A report showed that in 2020, 91% of global CO2 emission was from fossil fuels and industry (Friedlingstein *et al.,* 2021). The Figure 7 also shows that traditional burning of biomass is presumably the next culpable energy source in the emission of greenhouse gases, before hydro.

8.4 Assessment Based on Death Rate from Accidents and Air Pollution

Energy sources pose tremendous risks to human health/life, by the extent to which their by-products pollute the environment and by the technology/infrastructure of their exploitation and utilization. A veritable standard for comparing them, based on accidents and air pollution, is the number of deaths they cause per unit of electricity, measured in terawatt-hours, produced by the source. This also includes deaths from accidents and air pollution in the supply chain (Ritchie, 2022). Figure 8 shows the death rate from air pollution and accidents for different energy sources.

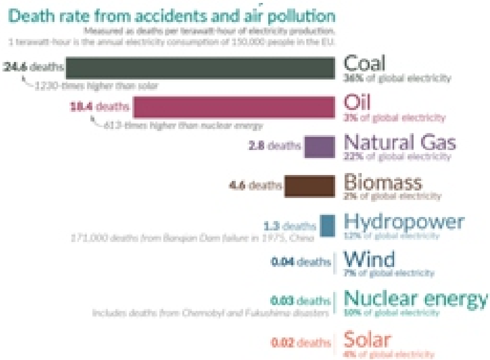

Figure 8. Death rate for different energy sources
Adapted from: Ritchie (2022)

Again, fossil fuels cause the death of more persons than all other sources, excepting biomass that, this time, surpassed natural gas.

8.5 Assessment Based on Appropriateness of the Energy Source

The concept of appropriate technology has been elaborately expounded in this presentation. The appropriateness of an energy source to a people, in terms of availability of the source and the operational technology and technical knowhow, level of understanding of the users; its reliability, affordability, accessibility, commonality, acquaintanceship, etc., is a fundamental consideration in the choice of an energy source as it will surely influence functionality and usability. Hitherto this consideration appears unknown in the literatures but, in our estimation, cannot be undermined. However, fragmented data on the subject matter can be used to assess the appropriateness of the various energy sources in Nigeria, as in Table 10.

Table 10. Appropriateness of the different energy sources in Nigeria

Sources of Energy	Capacity Factor	Energy Density	Greenhouse Gas Emission*	Death Rate	Availability	Technology	Technical Knowhow	Reliability	Accessibility	Acquaint-anceship	APPROPRIATENESS
Biomass	NA	Very Good	Good	Very Good	Excellent	Excellent	Excellent	Very Good	Excellent	Excellent	79.2% (Very Good)
Coal	Fair	NA	Poor	Poor	Excellent	Very Good	Very Good	Very Good	Good	Very Good	56.2% (Good)
Hydro	Fair	Fair	Excellent	Excellent	Excellent	Excellent	Very Good	Very Good	Excellent	Very Good	69.6% (Very Good)
Natural gas	Good	Very Good	Poor	Excellent	Excellent	Excellent	Very good	Excellent	Excellent	Very Good	73.1% (Very Good)
Nuclear	Excellent	Poor	Excellent	Excellent	Fair	Fair	Fair	Fair	Fair	Fair	55.6% (Good)
Petroleum	NA	Excellent	Poor	Good	Excellent	Excellent	Very Good	Excellent	Excellent	Excellent	75.8% (Very Good)
Solar	Poor	Poor	Excellent	Excellent	Very Good	Very Good	Good	Very Good	Excellent	Very Good	64.0% (Very Good)
Wind	Poor	Poor	Excellent	Excellent	Very Good	Very Good	Good	Very Good	Good	Very Good	60.4% (Very Good)
Geothermal	Very Good	Poor	NA	NA	Good	Good	Fair	Fair	Fair	Fair	46.9% (Fair)

Legend

Excellent	-	80 – 100%	(90%)
Very Good	-	60 – 79%	(69.5%)
Good	-	50 – 59%	(54.5%)
Fair	-	40 – 49%	(44.5%)

Poor	-	0 – 39%	(19.5%)
NA	-	Not Available	

A ranking of the performance of these various energy sources, in terms of percentage appropriateness will show the following classification.

.	First	(79.2%)	- Biomass
.	Second	(75.8%)	- Petroleum
.	Third	(73.1%)	- Natural Gas
.	Fourth	(69.6%)	- Hydro
.	Fifth	(64.0%)	- Solar
.	Sixth	(60.4%)	- Wind
.	Seventh	(56.2%)	- Coal
.	Eight	(55.6%)	- Nuclear
.	Ninth	(46.9%)	- Geothermal

9.0 THE STATUS OF THE POWER

Vice Chancellor, Sir, the most common denominator of every energy source is the generation of heat and/or electricity, to perform a certain amount of work (usually mechanical). This means that every energy source, whatever the variation, will ultimately yield thermal and/or electrical energy. Electricity is regarded as the highest quality of energy; it can be converted completely into an equal amount of thermal energy, which is the lowest quality of energy. However, the converse is not true, as only a small fraction of thermal energy can be converted back to electricity (Cengel & Boles, 2006).So, there is a high-quality energy and there is a low-quality energy, with other energy quality classes falling in between. So, energy can be graded and distinguished one from another based on their respective rankings.

To the extent of the exploitability of the various energy sources, Vice Chancellor, Sir, they all have contributions to make in boosting energy application to agricultural operations and hence increasing agricultural productivity and the livelihood of living things. It is in this consideration that the first law of thermodynamics can be replicated here, as every energy input to agriculture would not be lost, but reflected in the lives of man and other living organisms, which will in turn plough it back into the system to continue the cyclic conservationism. So, whether it is a high- or low-quality energy, every energy that is exploited would be useful to agriculture, to the extent that it can be applied to any agricultural process. It is the availability of the energy on the farm, and its eventual use for the accomplishment of a farm task that makes it Farm Power. It is the farm useful energy.

Energy is not applied to agriculture for its abundance or lack of any other point of application, but for the desire to mitigate food crisis at the local, regional and global levels. So, the focus of energy application in agriculture is to provide food on the tables of the global teeming population and especially Nigeria, and address the issue of 'stomach infrastructure'. From every perspective, the world is about man and the food that he would eat. This was why God completed the creation of every food source, from where man would obtain food, before creating man; and handed over everything to man, to ensure that he would not lack food (cf. Genesis 1:1-30).

Food is so essential to the sustenance of man that no living man can survive a very long time without food; even after forty days and forty nights of fasting by our Lord, Jesus Christ, He was afterward an hungred (Matthew 4:2), and this constituted the basis for His temptation by the devil. This is why politicians easily recourse to the provision of foodstuffs ('stomach infrastructure') for voters as inducement for their votes. It must be stated that the foundation of almost all corruption cases in Nigeria is the quest for sustainability of food provision. Therefore, whatsoever that will guarantee food security for a people, will not only be sustaining life, but addressing the root cause of the numerous societal challenges that abound everywhere, especially corruption in Nigeria.

In respect of the foregoing, energy occupies a central space in agricultural development, as it is the drive behind the engineering of agriculture for the enhancement of agricultural productivity. Vice Chancellor, Sir, my undergraduate lecturer and project supervisor, Late Engr. E. W. U. Essiet, may his soul continue to rest in the bosom of his creator, always told us in class that, because of the enviable status of agriculture in boosting and sustaining a nation and her people, agriculture is the backbone of any nation. Continuing, he would say also that, because agricultural engineering is the engine that drives agriculture to do its exploits, agricultural engineering is the backbone of the backbone.

Now, Vice Chancellor, Sir, we have seen that the foundation of the foundational backbone is the various energy sources collapsed into farm power. So, what my teacher did not tell us clearly at that time, which I dare to assert at this time is that the foundation of the backbone of the backbone is FARM POWER, as that is the strength of agricultural engineering. It is this power that is responsible for the production of what is now coined in Nigerian political parlance as 'stomach infrastructure'. It is the greatest of all the power given man by God; for if this farm power be destroyed, what can agricultural engineering do? Nothing. I so submit.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

It has been evidently established that a whole gamut of agricultural problems responds to engineering solutions, and that is the basis of the discipline of agricultural engineering, which is the application of engineering principles and techniques to the development of agricultural machines, systems and processes, and enhancement of the production of food and fibre for mankind. The strength of agricultural mechanization is the energy that operates the machines, in terms of the source of the energy and the ability of the machine to convert the energy into the desirable form.

Various sources of energy for agriculture, viz biomass, oil, coal, natural gas, nuclear, wind, hydro, solar, geothermal, etc., present with different exploitation and utilization characteristics, positioning them as either fit and proper to be used in a particular development situation or not. A review of their statuses revealed that the various sources would, to the extent of their exploitation, be useful in engineering farm operations. Every energy source will be good if the operational technology is right. So, the goodness and/or badness of an energy source for farm work are (is) dependent on the appropriateness of the technology applied in its exploitation and utilization.

The focal point of the application of energy in agriculture is the production of more food for the populace. It is this food that constitutes what Nigerian politicians now refer to as 'stomach infrastructure', which is usually used for inducement of voters, for vote buying and request for all such electoral favours. It is the engineering of agriculture that achieves that feat; agriculture itself being the development backbone of any developmentconscious country. This is why agricultural engineering is regarded as the backbone of the backbone. The strength of agricultural engineering is the energy utilization that fires the production of the 'stomach infrastructure', which is clearly life-sustaining in all its ramifications; hence we celebrate FARM POWER as the greatest of all the power given to man by God.

It has been reported by the National Academies of Science, Engineering and Medicine that by 2050, 70% more food would be required to feed the ever-increasing world population (ASABE, 2020). If this has to be adequately achieved, then appropriate technologies have to be developed at all levels, to elicit optimal exploitation of all available energy resources and their effective application in agriculture. Farm power predisposes to guarantee food security and eliminate the negatives associated with political 'stomach infrastructure'.

10.2 Recommendations

i. Nigeria should disentangle itself from the web of colonial mentality and slavish entanglement, to clearly chart its own energy course, instead of relying on the course charted by other developed nations for their own good.

ii. Nigeria should endeavour to rely on the research results and admonitions of her own indigenous experts rather than putting their trust and destiny in the hands of strangers whose sole interest is what they stand to gain.

iii. Nigeria should be mindful of the international treaties and agreements she subscribes to, in order that she does not wittingly surrender herself to energy slavery by the technologies of more developed nations, thereby mortgaging the future of unborn generations.

iv. Nigeria should make concerted efforts to identify its energy sources, where it has very high comparative advantages, and strive to consolidate the exploitation of these sources, thereby enhancing its energy mix, for the greater benefit of its citizenry.

v. The Nigeria government should establish an Agency for Appropriate Technology Development in each of the state capitals in the country. This Agency would consider the peculiarities of Nigeria and Nigerians and strive to develop technologies that would fit into their organizational and socio-economic frame.

vi. Nigerian government should re-invigorate and sustainably fund the already established but undermined appropriate machinery research and development institutions in the country, like the Federal Institute of Industrial Research, Oshodi (FIIRO) in Lagos, the Projects Development Agency (PRODA) in Enugu, National Centre for Agricultural Mechanization (NCAM), in Ilorin, etc.

vii. Efforts should be made at ensuring food security in Nigeria, as this will drastically reduce, if not eliminate the incidences of corruption in the country, now perpetuated by politicians under the guise of 'stomach infrastructure'.

viii. The previously operated tractor and equipment hiring units in the various states of the federation should be revived and sustained, to meet the needs of rural peasant agricultural producers.

ix. Nigerian government should promote the establishment of sustainable model agricultural structures and infrastructure, to give agriculture a future and encourage the upcoming generation to have something to look up to; be interested in agriculture; and build capacity.

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Vice Chancellor, Sir, on Thursday, 3rd September, 2015, I was shot by assassins in Port Harcourt, at a very close range, for which I'm still carrying the bullet in my body; yes, that's what the Lord called them - assassins. Before this, in 2009, I was kidnapped and spent five days in the kidnappers' mangrove forest. This was after I had escaped death from a deadly electric shock that glued me to the source of the electricity at the NPA fence in Orosikiri community, Bonny in 1981, by the intervention of one Mr. Simeon Benstowe, of blessed memory, who used a short dry piece of wood to push me off the fence. It is now evident that in all of these incidents and many more others that space has constrained their reproduction here, the **Most-High God - the God of gods, the Lord of lords and the King of kings** preserved me to become what He had designed for me - a Professor that will be celebrated today. Truly, God has been good to me. For all the favours that the good LORD has been doing for me, it is actually difficult, indeed impossible for me to find appropriate words to express my gratitude enough unto Him – All I have to say is: THANK YOU LORD, THANK YOU LORD, THANK YOU LORD, ALL I HAVE TO SAY IS THANK YOU LORD.

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APPENDIX

Plate A1: The fish smoke dryer

Plate A2: The fish feed dryer

Plate A3: The plantain, yam and fish roasting machine

Plate A4: The akara frying charcoal cooker

Plate A5: The Lawn mower

Plate A6a: The motorized pruning machine

Plate A6b: The pruning machine in operation

CITATION
on
Engr. Professor Asinyetogha Hilkiah Igoni

Asinyetogha Hilkiah IGONI was born on the 27th of June, 1967 into the family of Warisenibo Dr. Hilkiah T. Igoni and Late Mrs. Felicia I. Igoni of Isile-Ogono Banigo village in Bonny Local Government Area of Rivers State. He had his primary and secondary education respectively at Boyle Memorial School and Bonny National Grammar School, all in Bonny town and respectively obtained the First School Leaving Certificate and West African School Certificate/General Certificate of Education in 1978 and 1983. He proceeded to the Rivers State University of Science and Technology, Nigeria, as it then was, in 1984, and graduated in 1989 with a Second Class (Upper Division) Degree of *Bachelor of Technology* (BTech) in Agricultural Engineering. After his National Youth Service Corp (NYSC) programme in 1990, he enrolled for a *Master of Science* (M.Sc) Degree in Farm Power and Machinery Engineering at the University of Ibadan, Ibadan, Nigeria and graduated in 1991. In the year 2000, he obtained an international scholarship from India Technical and Economic Cooperation/Special Commonwealth Assistance for Africa Programme (ITEC/SCAAP) for a computer programme in New Delhi, India, where he obtained a Certificate in Computer Network Technology from Tata Info Tech Education Centre. In 2006, he obtained a *Doctor of Philosophy* (PhD) Degree in Environmental Management from the Rivers State University of Science and Technology, now Rivers State University, specializing in Renewable/Alternative Energy Development. In 2009, he obtained a Certificate in Best Practices in Election Management and Observation, from the Centre for Democracy and Election Management, School of Public Affairs, American University, Washington DC, USA. Yet, he has had other trainings in banking operations and safety at workplace.

During his National Youth Service Corps programme, between 1989 and 1990, he worked as the *Workshop Supervisor/Field Engineer* in Sahara Engineers Limited, Ibadan (a machinery design and fabrication company), where he was in-charge of fabrication and installation of the company's agricultural and industrial machines, especially those for the First Lady's Better Life for Rural Women's programme. Upon completion of his M.Sc., he secured appointment with the Rivers State University of Science and Technology in May, 1992 as an *Assistant Lecturer* in the Department of Agricultural Engineering. He was afterwards upgraded a *Lecturer II* by 1993, but later resigned the appointment that same year, for a supposed greener pasture in Afribank Nigeria Plc. He worked with the bank as an *Executive Assistant* on 'B' signatory category, from 1993 to 1997, during which period he was very active in the Association of Senior Staff of Banks, Insurance and Financial Institutions (ASSBIFI), as the General Secretary of Nchia Branch, Eleme, Rivers State. In the pendency of this employment, his divine call for teaching constrained him to seek part time lecturing with the University, and taught as a *Part-time Lecturer* in the same Department from 1995 to 1997, before he finally left Port Harcourt, having secured appointment to work on the base project of the Nigerian Liquefied Natural Gas Company.

Between 1997 and 1999, he worked with TSKJ Nigeria Limited, Bonny Island – the major contractors for the NLNG plant, first as an *Assistant Camp (Maintenance) Supervisor* and later *Local Labour Camp Maintenance Manager*. Again, in this period, he was the General Secretary of the Construction and Civil Engineering Senior Staff Association of the company.

At the conclusion of his contract with TSKJ he sought reappointment into the Rivers State University and was appointed a Lecturer II in February, 2000. He was later promoted Lecturer I in 2003 and Senior Lecturer in 2006. A rank he held until November 2007 when he was appointed an *Electoral Commissioner* in the Rivers State Independent Electoral Commission. As an Electoral Commissioner, he was primarily in charge of conducting Local Government elections in Eleme, Emohua and Opobo/Nkoro Local Government Areas (LGAs), in addition to his Headquarters administrative assignment as the Commissioner in charge of Estate and Works of the Commission. He also superintended over rerun and by-elections in Ahoada-East, Degema, Obio/Akpor, Oyinbo and Port Harcourt LGAs, and bowed out of the Commission at the expiration of his tenure in November, 2011. On his return to the University, Igoni was subsequently promoted to the position of a *Reader* in 2017 and then *Professor* in September, 2020.

Between 2008 and 2013, Engr. Prof. A. H. Igoni served as member of the Rivers State Greater Port Harcourt Development Committee, in charge of the foundation planning and designing of the new Rivers State Government city, called Greater Port Harcourt, where he functioned effectively as the Secretary of the Waste Management sub-committee and member of the New Town and Water Resources sub-committees. He was respectively the Chairman of the Rivers State Ministry of Works' Projects Monitoring Unit (Team A) and Committee on the Formulation of Framework for Performance-Based Evaluation of Roads and Highways Maintenance from 2009 to 2011, which ensured that the over one hundred and fifty State government roads awarded and constructed, at the time, met their design specifications.

In 2012 he was appointed and served as the Administrative Secretary of the Inter-Ministerial Committee on the Sanitization of Port Harcourt, under the superintendence of the Rivers State Ministry of Urban Development, up to 2013; and was part of the membership of the Rivers State Committee on Accreditation of Private Secondary Schools in Rivers East Senatorial Zone of the State, in 2019. From 2019 to 2021 he served as a member of the Board of Directors, Rivers Cassava Processing Company, a Rivers State-owned Company located at Afam, Rivers State, Nigeria, and responsible for the production of High-Quality Cassava Flour, mainly for international consumption.

As a lecturer in the Rivers State University, Engr. Prof. Igoni has served and still serving the University in various capacities. He was the Departmental Examinations Officer from 1992 to 1993 and 2000 to 2004 and also Chairman, Departmental Curriculum Review

Committee (2002-2004). He was a member of the Faculty of Engineering Library Committee (2000/2001 session); Faculty Time-Table Officer (2000/2001 to 2004/2005 sessions) and then Chairman, Faculty Time-Table Committee and Member, Senate Calendar and Time-Table Committee during the same period. Engr. Prof. Igoni served as the Representative of the Faculty of Engineering on the Board of the Institute of Education in the University from 2004 to 2007; Member, Senate Second Ad-hoc Committee on Students Discipline (2002-2003) and also a Member of the University Committee on ASUU/FGN Agreement Implementation (2001).

Engr. Prof. Igoni was a member of the 9th Governing Council of the Rivers State University, representing the University Congregation, from 2006 to 2007, during which he served in various Standing and Ad-hoc Committees of the Council. Very recently, in November, 2022, he was nominated by the University Senate as a Senate Representative in the Joint Committee of Senate and Council on the Award of Honorary Degrees; and also the Chairman of the Faculty of Engineering Committee on Implementation of 30% Institutional Addition to NUC Core Curriculum and Minimum Academic Standards (CCMAS), since January, 2023.

Yet, some other responsibilities undertaken by Engr. Prof. Igoni in the University include:

- § 2012 - Member, Faculty of Engineering Committee on Investigation of Sexual Harassment against a Lecturer by Miss Queeneth Deedam of the Department of Civil Engineering.
- § 2012 - Chairman, Office Space Harmonization Committee, Faculty of Engineering, Rivers State University of Science and Technology.
- § 2015 - Convener, Rights and Privileges Committee, Academic Staff Union of Universities (ASUU), Rivers State University of Science and Technology.
- § 2015-2018 Convener, Committee of Advisors to the

Chairman of the Academic Staff Union of Universities (ASUU), Rivers State University of Science and Technology.

- § 2016 - Chairman, Committee on Infrastructure Development, Department of Agricultural & Environmental Engineering, Faculty of Engineering, Rivers State University of Science and Technology.
- § 2016 - Chairman, Committee for the Coordination/Preparation of Engineering Students for the 1st National Engineering Students' Competition by the Committee of Deans of Engineering and Technology of Nigerian Universities (2016).
- § 2017-Date - Member, Student Disciplinary Committee, Department of Agricultural & Environmental Engineering, Faculty of Engineering, Rivers State University of Science and Technology (2017 to Date).
- § 2017-Date - Member, Faculty Examination Misconduct Committee, Faculty of Engineering, Rivers State University.
- § 2017 - Secretary, Faculty of Engineering Ad-hoc Committee on COREN Re-Accreditation Visit to Engineering Programmes, Rivers State University.
- § 2017 - Chairman, Ad hoc Committee for the Revision of Departmental Curriculum, Department of Agricultural & Environmental Engineering, Faculty of Engineering, Rivers State University.
- § 2018-2021 - Acting Head, Department of Agricultural & Environmental Engineering, Faculty of Engineering, Rivers State University.

§ 2021-Date - Chairman, Departmental Committee on Collaboration with Corporate Organizations, Department of Agricultural & Environmental Engineering, Faculty of Engineering, Rivers State University.

§ 2022-Date - Member, ASUU Membership Sensitization and Mobilization Committee, Rivers State University.

§ 2022-Date - Convener, ASUU Rivers State University Law Review Committee, Rivers State University.

§ 2022 - Chairman, Faculty of Engineering Curriculum Development Committee for the proposed Department of Technology Entrepreneurship in the Faculty of Entrepreneurial Studies, Rivers State University.

§ August, 2022 - Acting Dean, Faculty of Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt.

§ 2022-Date - Chairman, Renewable Energy Generation Committee, Faculty of Engineering, Rivers State University, Port Harcourt.

Engr. Prof. Igoni is an active member of the Academic Staff Union of Universities (ASUU), where he functions effectively in various Committees of the Union. He was also the pioneer Chairman of the Committee of Academic Friends, an association of academic like-minds in the Rivers State University, from 2001 to 2004.

As an astute academic that he is, Engr. Prof. Igoni is usually very zealous about research and prolific in writing. He has over eighty academic papers published in national and international journals, conference proceedings and technical seminars and symposia, for which he has outstanding international ratings on Google Scholar and Scopus. Additionally, he has three well-researched and highly-rated text books to his credit, namely: ***Engineering of Solid Waste***

Management for Energy Generation, ***Practical Farm Power Engineering***and ***Agricultural Land Surveying and Development (With Practical Guides)***. As a result of his research and publications exploits, he won the **2021 Distinguished Senior Scholar of the Year Award**, of the Faculty of Engineering of the Rivers State University, as **the Best Researcher of the Year 2021**. In this 2023, he has been listed as one of the top 10,000 researchers in Nigeria, by AD Scientific Index. Engr. Prof. Igoni is also active in attending and participating in conferences and workshops, both locally and internationally.

Engr. Prof. Igoni has practiced and taught engineering for well over two decades, at both the undergraduate and graduate levels. During this period, he has successfully supervised and graduated several Bachelor's, about four Master's and nine Doctorate degrees' students, some of whom are already professors in various Universities within and outside Nigeria.

A practical and practicing engineer, Engr. Prof. Igoni, has designed and developed a variety of agricultural machines appropriate to our local processes, including a *Motorized Mechanical Weeder, Gari Sieving Machine, Fish Feed Dryer, Fish-Smoking Device,* and lots more. He has developed systems and models for the development of bio-reactors for the transformation of the organic fraction of municipal solid waste into renewable energy in the form of biogas; and currently working on an integrated systems approach to using co-digesting composite MSW for energy generation. He is a consultant to several organizations, as the Chairman of the Board of COMBEETS Limited and the Principal Partner of HILKIGO Konzults Limited, The Hillspring School and Hill Tech Press.

At the professional level, Engr. Prof. Igoni is a certified engineer by the Council for the Regulation of Engineering in Nigeria (COREN) of over twenty years' experience; for which he has been a member of the Engineering Regulations Monitoring Committee of COREN, as a COREN Inspector since 2006. He is a member of several professional organizations, including the Nigerian Society of Engineers (NSE), Nigerian Institution of Agricultural Engineers (NIAE), American

Society of Agricultural and Biological Engineers, Nigerian Institution of Safety Engineers and a Fellow of the Nigerian Institution of Environmental Engineers (NIEE).

In the NSE, Engr. Prof. Igoni has served as the General Secretary of the Port Harcourt Branch from 2006 to 2007; Vice Chairman from 2008 to 2009; and Branch Chairman from 2010 to 2011, during which period he won the NSE Headquarters Presidential Merit Award, as a distinguished Branch Chairman. Before these periods, he had at various times worked in different Committees of the Branch, including being a member respectively of the Technical and Investigation and Failure Analysis Committees; Secretary of Welfare and Publicity Committees respectively, functioning as the Editor-in-Chief of 'The Garden City Engineer' (which used to be a quarterly publication of the Branch); and Chairman of Infrastructure Score Card, Group Dynamics and Annual Lectures and Awards Committees, respectively. He is currently a member of the Strategic Development Committee of the Branch. In 2013, he won the Branch Award as the Most Active Past Branch Chairman.

Furthermore, between 2002 and 2004, he was a member of the Board of Directors of NSEPH Limited (a company owned by the Nigerian Society of Engineers, Port Harcourt Branch) and was the Secretary of the Board from 2004 to 2006. In 2021, Engr. Prof. Igoni was inducted into the Hall of Fame of the Nigerian Society of Engineers, Port Harcourt Branch, for his numerous contributions to the growth and development of the Branch.

At the national level of the Nigerian Society of Engineers, he has been a member of the Professional Examination and Interview Committee for prospective members for about twenty years now, and also served in various other committees. He has served as a member of the Career Development and Education Committee; member, Facilities Development and Management Committee; and Facilitator respectively for the Continuing Professional Education for Executive Engineers and the Mandatory Continuing Professional Education, to train prospective members of the NSE in Leadership and Strategic

Management, Legal Issues in Engineering Practice and Engineering Entrepreneurship/Economics.

In the NIAE, he has been serving at the national level as a member of the Committee on NIAE EXCO, Institutional Heads/Directors and CEOs, since 2021; and in the NIEE, Rivers State Chapter, he has been the Chairman of the Elections Committee since 2017.

Engr. Prof. Igoni is also very active in his community affairs. Between 1998 and 2000 he was respectively the Chairman of Bonny Graduates Forum and Chancellor, Banigo Youth Movement; and a Delegate to the Bonny Youth Federation. His leadership was instrumental to the special interview and training organized to ensure that Bonny youth were given their rightful recognition and recruited as staff into the NLNG; needless to say that he was eventually one of the facilitators at the training programme. In 2013, he was appointed and functioned as a member of the Pan-Bonny Conference Organizing Committee, saddled with the responsibility to develop a blueprint for the globalization of Bonny kingdom. He is a member of 'Bonagrams Friends', an association of 'old boys' of Bonny National Grammar School, Bonny in Rivers State, Nigeria. In 2016 he was graciously recognized and conferred with the honour of the traditional title of *Amasenibo* (Kingdom Elder) of the Ancient Kingdom of Grand Bonny, by the Amanyanabo and Natural Ruler of the Kingdom, His Majesty, King Dr. Edward Asimini William Dappa Pepple III, *CON, JP*, *DSSRS*, Perekule XI, and subsequently admitted into the membership of the Titled Citizens Assembly of the kingdom.

Engr. Prof. Igoni is a devout Christian of the Anglican Communion and a Knight of the Sacred Order of St. Christopher. He has been a Sunday School Teacher in St. Cyprian's (Anglican) Church, Port Harcourt, since 2005 and a member of the Church's Committee on Missions and Evangelism, where he once served as the Secretary. He had served as the Chairman of the Sunday School Revival Week Planning Committee and has been on the Executive Committee of the Niger Delta Diocesan Sunday School Council as the Literature Secretary since 2006 and a member of the Niger Delta Diocesan

Annual Adult Sunday School Planning Committee, since 2007. He is currently the Vice Chairman of the Diocesan Sunday School Council and, consequently, the Chairman of the Niger Delta Annual Adult Sunday School Conference Planning Committee, since 2020. Engr. Prof. Igoni has also been a Marriage Counsellor in the church, since 2006. At various times, he served as the Deputy Chairman and Chairman of the Harvest Committee of the church, and a member of the Christian Men Fellowship (CMF) of the church, particularly CMF welfare Group 5. He is, at present, a member of the St. Cyprian's Parish Church Council, member of the Church's Prayer Squad, and the Leader of the Deliverance and Healing Unit of the church. Outside the church, he had been a member of the Full Gospel Business Men's Fellowship International, where he served as the President of the 'Garden City Chapter' of the Fellowship.

By the special grace of God, **Engr. Prof. Asinyetogha Hilkiah Igoni** maintains a lovely and happy home with his God-given beautiful wife, Lady Rhoda Asinye-Igoni, for which they have twice won the *Outstanding Couple's Award* of the Mothers' Union of their church, in 2014 and 2022, for “keeping the Unity and Love of your marriage”. His marriage is also graciously blessed with five lovely and blessed children, Soibi, Tamunoipirinye, Tamunotaribo, Tamuno-Opubo and Tamunobie.