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Research Article

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Enhancing Urban Agricultural Activities through Renewable Energy Development

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Abstract

Although Urban Agriculture (UA) is widely practiced in several Nigerian cities, it faces several challenges such as insufficient data on the practice, non-recognition of UA as a land use by Nigerian urban land laws, uncoordinated practice of UA, lack of support services for urban farmers such as providing access to improved seedlings, pesticides, technical training, machinery, medicine, etc, overt discrimination against female farmers in terms of denial of land ownership rights, limited access to markets, inputs, credit, etc.

The strategic use of Renewable energy in UA operations can address some of these challenges and contribute significantly to the attainment of the Sustainable Development Goals (SDGs) in Nigerian cities. In Ibadan, the energy mix favors large scale use of biomass, particularly the fermentation of animal waste in biogas digesters to produce fertilizer and methane gas. This promotes local energy independence from inefficient and centralized power stations and grids and energy security.

Since 2015, Lifeforte International High School, Awotan, Ibadan has been the recipient of the International School Award, an international benchmarking scheme of the British Council. This award is meant to encourage primary and secondary school students in partner schools to develop global citizenship skills such as empathy, critical and creative thinking, conflict resolution, communication, collaboration and taking action. Such skills are meant to empower these students to become solution providers to global problems such as poverty, hunger, inequality, climate change, etc. Lifeforte seeks to consolidate on its successful crop harvest on its school farm by building a biogas digester on it. This facility will produce fertilizer and methane gas. A Business model will mobilize the proceeds from the sale of gas to train local farmers, thereby strengthening their capacity to operate their own digesters for increased crop yield, higher income and local energy independence and security.

Keywords: Urban Agriculture, Renewable Energy, Sustainable Development Goals, Energy Mix, Biomass, Biogas Digester, Global Citizenship Skills, Energy Independence

Introduction and Background

Although Urban Agriculture (UA) is widely practiced in several Nigerian cities, it faces several challenges such as insufficient data on the practice, non-recognition of UA as a land use by Nigerian urban land laws, uncoordinated practice of UA, lack of support services for urban farmers such as providing access to improved seedlings, pesticides, technical training, machinery, medicine, etc, overt discrimination against female farmers in terms of denial of land ownership rights, limited access to markets, inputs, credit, non-availability of data on UA, etc [1].

The development of renewable energy can address some of these challenges, in terms of increasing the crop yield, hence the income of urban farmers. In Ibadan, the city's energy mix favours the large scale production of methane gas and organic fertilizer, based on the anaerobic fermentation of food and animal waste. Such a development can significantly increase the crop yield of urban farmers, hence their income. With an increase in income, urban farmers can invest in machinery, improved seeds, more land, training to improve their skills, etc, thereby expanding commercial, intensive agriculture. In addition, renewable energy development promotes energy independence and savings from the nation's inefficient and centralized power supply network which also provides sustainable local solutions to the nation's energy crisis.

This energy crisis has its origins in the 1970s, according to Iwayemi [2]. At the time, the nation was under military rule, as the military rulers changed Nigeria from a federal to a unitary nation, centralizing considerable power and resources at the federal level of government. The military involvement in the nation's governance occurred between January 1966 and 1979, December 1983 to June 1998. Consequently, the military government built highly centralized hydro-electric power stations with the highest generating capacities at Kainji in 1968 generating 800MW, Jebba in 1985 generating 540 MW and Shiroro in 1990 generating 600 MW. In addition, the military government built gas powered stations, namely Afam IV-V in 1982 generating 580 MW, Egbin generating 1,320 MW in 1985, Sapele generating 900 MW. It also established the state owned National Electric Power Authority (N.E.P.A) in 1972 and the Nigerian National Petroleum Corporation (N.N.P.C) in 1977 to manage the affairs of the downstream petroleum sector of the economy.

The implementation of price controls in the supply side of electricity, subsidies in the price of petroleum, kerosene and diesel products, input and output subsidies for N.N.P.C and P.H.C.N, institutional and governance failures all contributed to the near collapse of the energy sector. Furthermore the sharp fall in oil prices in 1984, excessive partisan politics, the prevalence of tribalism, nepotism and rent seeking behavior by contractors and politicians at the federal level during the nation's post-independence political history, also contributed to the energy crises. This, according to Iwayemi raised production costs of manufacturing industries by at least 20%, including industries that produce agricultural machinery that could power UA and potential Commercial farming ventures in Nigerian cities [2].

Although, the federal and state governments have been implementing 'Renewable Energy Policies' since 2005 and consequent projects such as solar powered street lights across the country's cities, solar powered grid sponsored by the World Bank, the Renewable Energy and Energy Efficiency Project, the Nigerian Energy Support Programme, the hydro-electric power station at Mambilla plateau, etc , there is a need for more initiatives to strengthen the capacity of local communities to build, construct, maintain and expand on Renewable Energy related business, to enhance UA activities in Nigerian cities. These local initiatives create better opportunities for local ownership of these businesses, based on the use of local materials which are prerequisites for sustainable energy development. The strategic use of Renewable energy in UA operations can address some of these challenges and contribute significantly to the attainment of the Sustainable Development Goals (SDGs) in Nigerian cities. In Ibadan, the energy mix favors large scale use of biomass, particularly the fermentation of animal waste in biogas digesters to produce fertilizer and methane gas. This promotes local energy independence from inefficient and centralized power stations and grids and energy security.

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Materials and Methods

Aim and Objectives

The aim of this project is to construct, maintain and expand a socially inclusive Anaerobic digester at Lifeforte International High School for the expansion of UA activities in the Awotan neighbourhood of the school. The specific objectives are as follows:

1. Establish a Sustainable Development Goal 7 (SDG 7 referring to Affordable and Clean Energy) team of students and teachers who will anchor the project;
2. Complete a pilot study where the SDG team will assemble a simple, homemade digester that will ferment organic waste that is available locally;
3. Impart the lessons learned from this pilot study in a socially inclusive programme that includes the students of public schools in the Awotan community.

Methodology

The methodology uses an 'Active Learning Approach' to impart the requisite skills into the Lifeforte students to establish the simple, homemade digester on the premises of Lifeforte. This commenced with a pilot study, as the anchoring teachers, Dr. Aboyade and Mr. Salawu, a Chemistry teacher, engaged Grade 10 students about applying core concepts in Anaerobic digestion outside the classroom. Other senior students in Grade 11, 12 and Advanced Level students were involved in the Cambridge International, West African Examinations Council and Joint Admission and Matriculation Board examinations and were therefore unable to participate in this pilot phase of the project, which started on May 2019. The underlying concepts of Anaerobic digestion are taught In Chemistry and Biology curricula of Grade 10, making it easier for participating students to assimilate the concepts related to Anaerobic digestion.

Collection of materials

A cheaper way of making a homemade digester was used. The Anaerobic digester consisted of an empty and unused and black 25 litre jerry can and a gas cylinder that supplies cooking gas to a connected gas cooker within the flat of one of the anchoring teachers. Other materials such as a screwdriver, pliers, cow dung and antiseptic solution were purchased from convenience stores within the neighbourhood at reasonably low costs. The cost breakdown of these materials is shown in table 3.1 below.

Table 2.2.1 Cost breakdown of materials used to assemble the home made digester

Serial Number	Item purchased	Date of purchase	Cost (Naira, N)	Location of purchase
1	Screwdriver	02/05/2019, 2nd May, 2019	150.00	Corner shop in Awotan
2	Pliers	10/07/2019, 10th July 2019	700.00	Corner shop in Awotan
3	One bucket of Cow dung	11/07/2019, 11th July 2019	500.00	Bodija market (about 3 km from Awotan)
4	Antiseptic solution	13/07/2019, 13th July 2019	460.00	Convenience store at Bodija (about 3 km or 1.86 miles from Awotan)
5	Total		1,810.00	

Source: Fieldwork data (July, 2019)

The total amount spent in Naira is N1, 810.00. The equivalent total cost in dollars was calculated based on the parallel exchange rate monitor of the Guardian Newspaper of Nigeria of N360 to $1 at the time of editing this paper on 25th July 2019 [3]. The principle of 'Direct Proportion' as follows:

N360 = 1$
N1,810 = X

Cross multiplying the diagonal numbers and variables gave,
(X)(N360) = (N1,810) ($1)

Making X the subject of the formula meant dividing both sides of the equation by N360 to give
X = (N1,810)($1)
(N360)
= $5.03

Hence, the pilot phase of the biogas project cost Five dollars and three cents, reflecting a low initial cost of the project.

2.2.2: Preparation of Slurry and the Hydrolysis stage of Anaerobic Digestion

The preparation of slurry was carried out by three members of the SDG 7 team under the supervision of the anchoring teachers on Monday, 15th July 2019. First, the team collected food waste from the school's waste dump, consisting of leftover rice and spaghetti. Using a bathroom scale, the team weighed 1 kg of water and 1 kg of the food waste in a bucket (a ratio of 1:1) and mixed the two components to form a slurry.

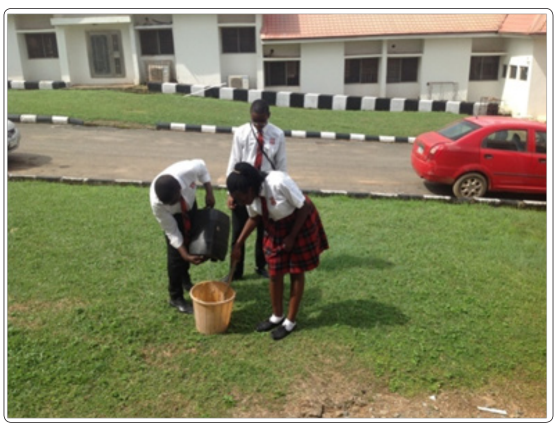

Figure 2.2.1: SDG 7 team members mix food waste with water under Dr. Aboyade's supervision

In addition, the team weighed 1 kg of cow dung and 3 kg of water using the same method as it did for the food waste and mixed them in a separate bucket. These ratios of food waste to water and cow dung to water are based on Princess Sirindhorn's Projects, showing how to produce biogas in Thailand [4]. Cow dung is useful for biogas production because it contains a large population of anaerobic bacteria that tend to break down the waste to produce the biogas. Food waste is used because aerobic bacteria that break down the waste in open waste dumps produce large amounts of carbon-dioxide, a greenhouse gas that contributes to global warming and its resultant environmental problems, such as more intense torrential rains, coastal flooding, sea level rise, destruction of habitats, etc.

Then, the team poured both slurries into the 25 litre (0.88 feet^3) jerry can and covered it at the top to make it airtight. The digester was left in a safe location next to the school building to allow the hydrolysis stage of anaerobic digestion to take place overnight. The mixing of the food waste and cow dung with water was meant to stimulate hydrolysis, the first stage of anaerobic digestion where the water molecules break down the biomass.

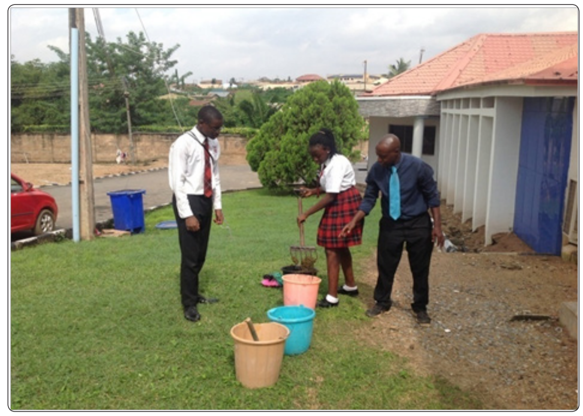

Figure 2.2.2: SDG 7 team members preparing to mix cow dung with water under Dr. Aboyade's supervision

2.2.3: Acidogenesis stage of Anaerobic Digestion and pH testing of the Slurry

During the acidogenesis stage of anaerobic digestion of the slurry, acidogenic bacteria convert sugars and amino acids, formed during the hydrolysis stage into carbon-dioxide, hydrogen, ammonia and organic acids. To hasten this process, the anchoring teachers supervised the SDG 7 team members regarding the measurement of 100 milli-litres of diluted sulphuric acid (H_2SO_4 (aq)) and pouring and mixing it in the 25 litre anaerobic digester to hasten this stage of the fermentation process. This is shown in Figure 3.3.1 below.

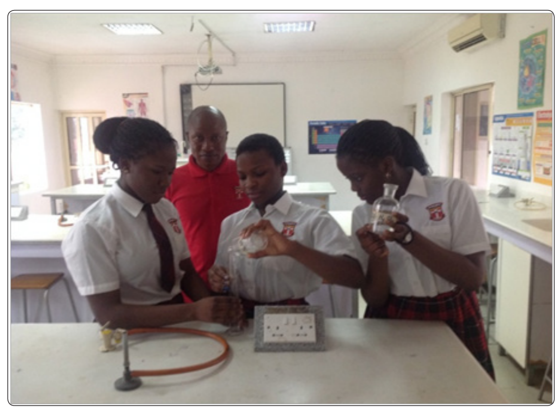

Figure 2.2.3: SDG 7 team members measure 100 ml of sulphuric acid under Mr. Salawu's supervision

The first pH testing of the slurry was carried out on Wednesday, 24 July 2019, using 'Universal Indicator Paper'. When the paper made contact with a sample of the fermenting slurry, the yellowish paper turned orange, indicating acidic slurry with a pH range between 3-4. This provided evidence that the fermentation process is ongoing.

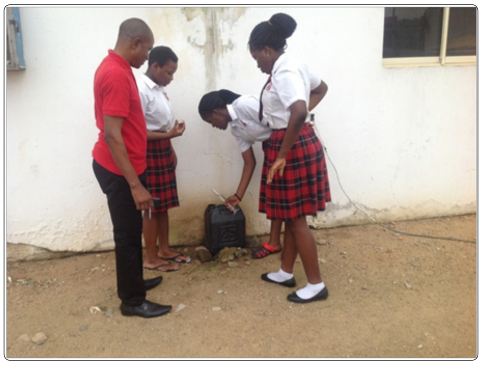

Figure 2.2.4: SDG team members pour 100 ml of diluted sulphuric acid into the digester under Mr. Salawu's supervision

The second pH measurement of the slurry was carried out on Friday, 26th July 2019 using the same Universal indicator paper. The results were similar to those of Wednesday, 24th July 2019 as the yellowish paper turned to orange, reflecting a pH between 3-4. In addition, an empty kitchen gas cylinder was weighed with a bathroom scale and the weight recorded was 16 kg (35.3 lbs). The cylinder was connected to the digester by a tube, as shown in Figure 3.3.6 below.

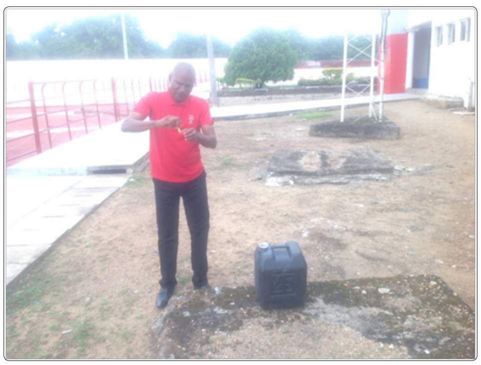

Figure 2.2.5: Mr. Salawu measures the pH of the slurry using Universal Indicator paper on Wednesday, 24th July 2019

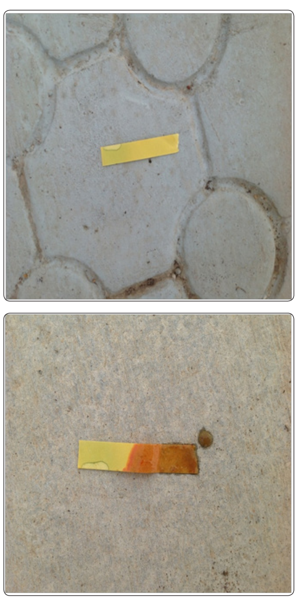

Figure 2.2.6: Yellowish Universal Indicator Paper turned orange on Friday, 26th July, 2019

Figure 2.2.7: Digester is connected to the Gas cylinder by a tube on Friday, 26th July 2019

Table 3.3 Daily temperatures in Ibadan between 15th July 2019 and 27th July 2019

Day Number	Date	Highest Temperature (°C)	Lowest Temperature (°C)
1	Monday, July 15th, 2019	29	24
2	Tuesday, July 16th, 2019	29	23
3	Wednesday, July 17th, 2019	31	21
4	Thursday, July 18th, 2019	28	24
5	Friday, July 19th, 2019	28	23
6	Saturday, July 20th, 2019	29	22
7	Sunday, July 21st, 2019	31	24
8	Monday, July 22nd, 2019	32	24
9	Tuesday, July 23rd, 2019	27	24
10	Wednesday, July 24th, 2019	30	23
11	Thursday, July 25th, 2019	31	24
12	Friday, July 26th, 2019	29	24
13	Saturday, July 27th, 2019	28	25
14	Sunday, July 30th, 2019	27	25

Source: Accu Weather Forecast of Ibadan [5]

The temperature data from Ibadan, shown in table 3.3 above provides empirical evidence that the weather conditions in Ibadan are ideal for the large scale production of biogas. For the highest daily temperatures, the average temperature was 29.2°C and the corresponding temperature range was 4°C, while for the lowest daily temperatures, the average temperature was 23.6°C and the corresponding temperature range was also 4°C. These values fall within the recommended temperature range of the digester tank between 20°C-45°C, as recommended in Princess Sirindhorn's Projects [4].

Outcomes of the Biogas Project

The project produced a number of interesting outcomes which can provide a basis for more efficient and socially inclusive biogas production for the local Awotan community. First, the low initial cost of $5.03 will facilitate its practicality and value among low income working groups in the community, including urban farmers and raise prospects for its rapid spread and popularity in the community.

Secondly, the managers of the cow market where the cow dung was purchased were very responsive and cooperative upon approaching them to assist the SDG 7 team with an adequate supply of cow dung. This raises the prospects of rapid mopping up of cow dung in this market, thereby improving sanitation and public health and rapid, continuous production of biogas in the community for expanded UA activities and climate change mitigation.

Thirdly, six Grade 10 Lifeforte students, constituting the SDG 7 team received training on how to carry out the initial stages of biogas production, namely preparation of slurry, filling the digester with slurry, measurement and pouring of acid into digester to hasten acidogenesis, together with the core concepts of anaerobic digestion. As the project progresses, more students will be involved, providing them with valuable learning opportunities outside the conventional classroom and equipping them with the requisite global citizenship skills, such as cooperation, innovative and critical thinking skills, team work, leadership training, etc that will make them effective leaders in renewable energy development.

Implications for Future Research in Biogas Production

The results so far provide evidence that fermentation of the slurry is taking place and a sizeable volume of biogas will be produced, beginning from Monday, 28th July 2019 for testing. Future research will focus on accelerating the biogas production process to reduce the retention time in order to give the project commercial value and up scaling it to use larger digesters that will not only supply cooking gas for 352 students but also power diesel generators of the school and official vehicles of the school, making biogas the preferred energy resource of the school [6]. This will result in significant energy savings for the school, ensuring saved revenue is diverted into other aspects of school management to improve the learning environment for the students, thereby enhancing their global citizenship capabilities.

The lessons learned from these pilot studies will be incorporated into the 'Socially Inclusive Programme' of the school. Lifeforte High School is currently incorporating four other schools in the Awotan community namely Orisun, Apete Ayegun Awotan Araromi and Akufo in this programme. Such programmes include rehabilitation of classroom blocks and libraries, peer tutoring where students of the school tutor benefitting students from the above mentioned schools in core subjects in Mathematics, English and the Physical sciences, namely Physics, Chemistry and Biology, etc. In addition, these four schools participated in the inaugural 'Olubi Johnson Soccer Championship' to commemorate the 60th birthday anniversary of the Chairman of the Board of Trustees of Lifeforte, Pastor Olubi Johnson. Lifeforte supplied jerseys, boots and kits to players from these schools and gave them free access to the school's ultra modern sports complex to receive training from the school's coaches. Regarding the biogas project, Lifeforte will invite students from these schools to impart into them the skills they need to manage a biogas project to produce biogas for their energy needs and organic fertilizer to increase their crop yield. Lifeforte's existing partnership with the International Institute for Tropical Agriculture will ensure a steady supply of improved seeds to benefitting students to enhance their UA activities.

Conclusions

The project work done so far on the biogas project is a work in progress. However, the outcomes mentioned above are encouraging and with diligent and systematic research and training of the students, a foundation for self-sufficiency in the production and use of cleaner and cheaper biogas at Lifeforte and the Awotan community is being laid, which will contribute to the localization of the Sustainable Development Goal number 7 on the Use of Affordable and Clean Energy in Ibadan [7-10].

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