International Journal of Innovative Mathematics, Statistics & Energy Policies 6(1):1-10, Jan-Mar, 2018

 www.seahipaj.org ISSN: 2467-852X

Renewable Energy Initiative: To Produce Bio-energy from Gurara Local Government Food Waste

[1]Umar Adam Abba & [2]Musah Aminu

Department of Integrated Science,
Federal College of Education (Tech) Potiskum, Yobe State, Nigeria.
[1]08038397475; [2]musahaminu16@gmail.com)

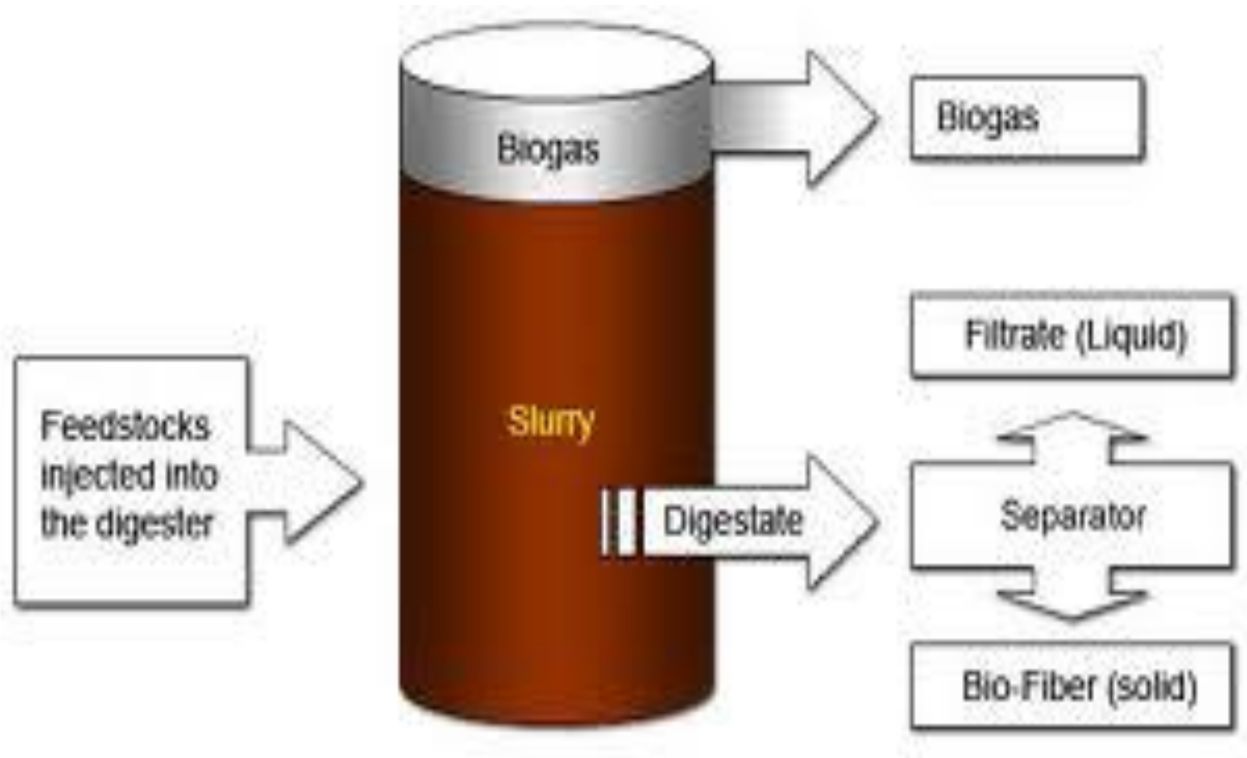
ABSTRACT
A study on renewable energy project is to convert , from Gurara Local Government (GLG) Waste dumps, cafeterias and streets into usable energy, including gases, liquid and solid fuels, as well as fertilizer solids. GLG is currently generating approximately 1800 kg of food waste per week of which the majority is land filled. Food waste is the single largest category of solid waste (SW) being land filled comprising > 15% of total SW in Niger State. The technical approach was to build an off-campus dry anaerobic digester coupled with an algae photo bioreactor that resulted in significant volumes of near pipeline quality methane along with the production of biodiesel and solid fuels from the growth of algae. The pilot unit was designed to handle ~ 90 kg per week of food wastes.
Keywords: renewable energy, food wastes, Anaerobic digestion

INTRODUCTION
Food waste represents one of the greatest opportunities for the generation of renewable fuels and also one of the least utilized of all organic waste materials. A report[2] from the United Nations' Food and Agriculture Organization shows that global food waste is the world's third-biggest emitter of greenhouse gases from landfills, behind only the United States and China, releasing the equivalent of more than 3.6 billion tons of carbon dioxide into the atmosphere from the release of methane. Only about 2.5% of food waste is currently recycled in Nigeria and the principal technology is composting, which does provide an alternative to land filling food waste, but requires large land area, produces smog precursor VOCs, emits carbon dioxide to the atmosphere, and consumes energy. Diverting food waste from landfills can contribute to producing significant quantities of renewable fuels while achieving the need for energy by Nigerians and also the reduction in atmospheric pollution due to incomplete combustion of fuel[1].

Figure 1. Potential uses food waste

Anaerobic digestion (AD) is the biological degradation of organic matter in the absence of oxygen yielding two products, biogas and digestate. Benefits of AD include being a renewable energy source, reduction in greenhouse gas emissions (compared to land filling), reduction in water pollution, and the generation of a valuable revenue stream. Biogas is comprised of 60-70% methane and 30-40% carbon dioxide, and digestate consists of water and bio-solids which are high in nutrient content and can be filtered and used as a fertilizer or soil conditioner. Anaerobic digestion is a better alternative to land filling food waste because it results in significant waste volume reductions and provides for the creation of these beneficial end products. Food waste is an excellent candidate for anaerobic digestion due to its high moisture and organic content. While anaerobic digestion is commonly used in wastewater treatment, there are few examples of food waste digesters. Biogas is capable of operating most devices intended for natural gas, although the carbon dioxide content reduces the heat available from the gas. Typically, when the biogas is used as a combustion fuel, the carbon dioxide is simply sent along with the methane and it passes back into the atmosphere unused.[7]

Figure 2. Food wastes



Basic Anaerobic Digestion Process

Microalgae species are aquatic organisms that produce complex organic compounds from simple inorganic molecules using carbon dioxide (CO_2) as their carbon source, and energy primarily from sunlight (photosynthesis). They produce lipids which are organic compounds containing fats, oils, and related substances that, along with proteins and carbohydrates, are the structural components of living cells. Some species of algae consist of as much as 80% of their mass as lipid content. They have rapid growth rates and can double in mass every 24hours. A byproduct of their metabolic and reproduction cycles is the production of oxygen (O_2) and hydroxyl ion (OH-) which increases the solution pH with time if not neutralized with the addition of absorbed CO_2. This coupled with their rapid growth rates makes them ideal candidates for the production of alternative fuels (biofuels), especially biodiesel and solid fuels, from the biomass media. In addition, algae contains ~23,500 kJ/kg, has no chlorine, little or no sulfur or heavy metals, is non-toxic, and its biofuel is highly biodegradable. In addition, researchers have recently reported that a life-cycle Analysis[4] of small-scale operations at an algae-to-fuel facility show that substantial reductions in greenhouse gases will be achieved over petroleum based fuels along with a sustainable energy return when algae-culture (the commercial production of algae) is fully developed. They also found that algae-based fuels from the pilot plant are on par with commercial-scale, first-generation biofuels. The study concluded that greenhouse gas reductions and energy returns are set to increase significantly once economies of scale in production take hold.[6]

METHOD

An off-campus site was chosen for the location of the combined system of an anaerobic digester (AD) coupled with an algae photo bioreactor. AD technologies consist of wet (3-10% solids) or dry (> 15% solids) systems. We utilize dry digestion as it significantly reduces the volume of the AD reactor and saves on the digestate post processing costs by minimizing the amount of volume that has to be handled. Water is added to food waste for wet digestion, but not for dry digestion. Another major advantage of dry systems is that they can be built to scale-up (batch/modular units) easily as more waste becomes available, and they require less space than wet systems[4].

A novel algae reactor system with an extremely small footprint will utilize the CO_2 portion of the biogas. CO_2 scrubbing is accomplished with a unique gas separation system developed by the PIs producing scrubbed effluent gas, which consists of methane and water vapor and has the characteristics of pipeline natural gas. The algae harvests continuously for further processing using techniques which have been developed by the PIs.[8]

A schematic flow diagram of the system is shown in Figure 1, which is not drawn to scale. The processed food waste enters the anaerobic digester via an air seal where it has a residence time of approximately ~15 days. After steady state condition is achieved, biogas consisting of 60-70% methane and 30-40% carbon dioxide is continuously generated.

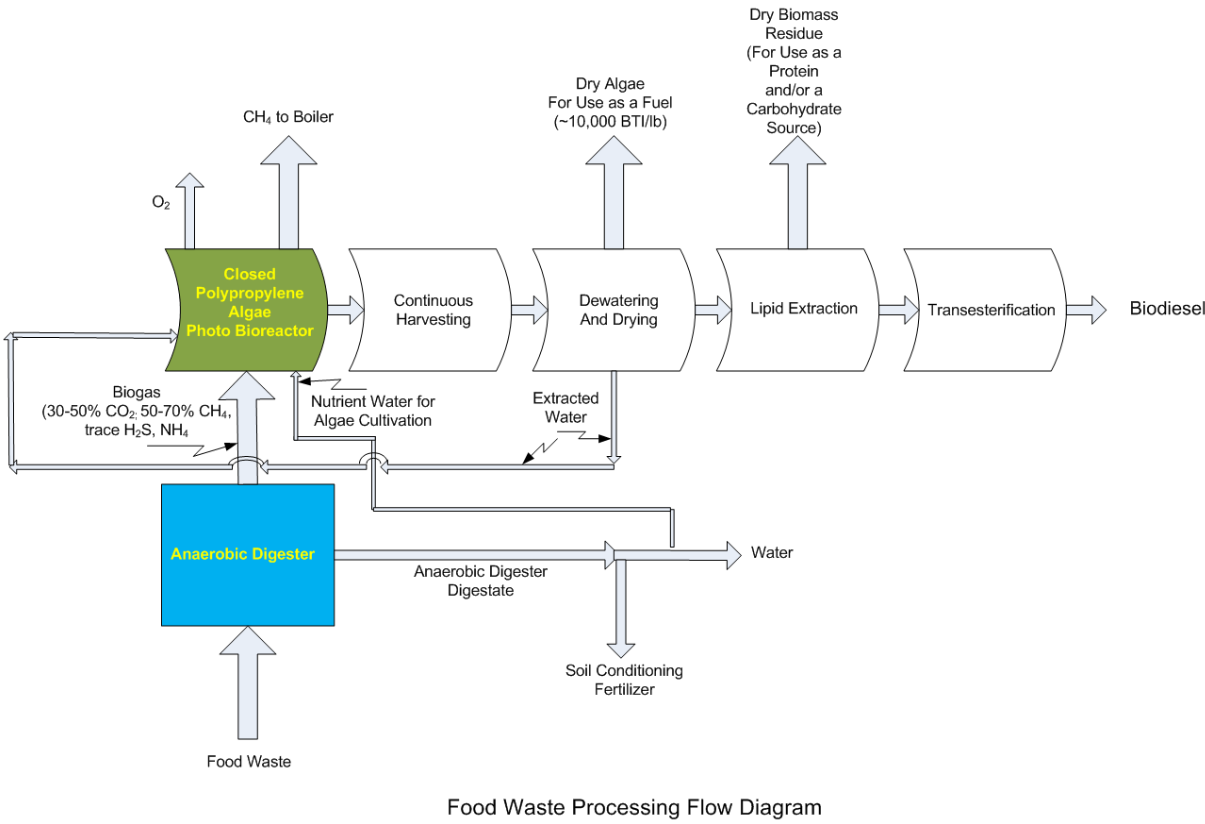


Figure 4. Flow Diagram of food waste processing

The volumetric flow rate of the gas depends on the amount of volatile material in the waste, and the waste mass flow rate into the reactor. The biogas is conveyed to a scrubber where an algae solution at a suitable pH will absorb the CO_2 into the aqueous solution forming dissolved carbonate species and this solution is conveyed to a closed, polypropylene photo bioreactor where the dissolved carbonate is utilized by the algae as their carbon source in the presence of sunlight. As methane is essentially insoluble, it passes through the scrubber unchanged in molar volumetric flow rate, and only has the addition of water vapor whose concentration is a function of the scrubber operating temperature. The pH of the influent scrubber solution is approximately 8.0 and the effluent solution is approximately 6.8. The methane is conveyed to a holding tank for further use[6].

The algae solution is continuously pumped to a separation unit where a portion of the algae is separated for processing. This fraction is conveyed to a dewatering and drying step where the extracted water is re-circulated to the photo bioreactor. The dried algae has a heat content of ~23,500 kJ/kg and can be used in pelletized form as a direct substitute for coal or other solid fuels in fluidized bed combustors, or spreader stokers, or injected as a dry solid into pulverized coal combustors. If desired, the lipid content from the algae can be extracted, and process via trans-esterification reactions to produce biodiesel.[7]

From an analysis of typical food wastes available in the literature it is possible to generate ~6 m^3 of methane and 0.75 liters of biodiesel per day per 45 kg (100 lb) of as received food waste. This will represent a potential generation of 240 m^3 of methane and 30 liters of biodiesel per week for the 1800 kg of food waste currently being generated at GLG. However, I will build an integrated system to be able to handle ~90 kg per week which will be enough to generate 12 m^3 of methane and 1.5 liters of biodiesel per day. This is sufficient to provide us with adequate data necessary for scale-up in order to propose to build a larger system capable of handling all of the GLG’s food wastes in the future.

Renewable energy is capable of meeting our energy needs

Despite having public support and advantages over other energy sources, renewable technologies have been repeatedly characterized as unable to meet our energy needs. People have been presented only a choice between conventional fossil fuels and nuclear power. This, however, is a false choice. Renewable energy can reliably generate as much energy as conventional fuels, and can do so without producing carbon emissions or radioactive waste[8].

Renewable energy – which includes solar, wind, advanced hydro, certain types of biomass and geothermal energy[1] – has the potential to replace conventional fossil fuels and nuclear power. While non-hydro renewable presently provide just 2.3% of electricity in the world, it is technically and economically feasible for a diverse mix of existing renewable technologies to completely meet our energy needs. In fact, as much as 20% of the World electricity could immediately come from non-hydro renewable energy sources without any negative effects to the stability or reliability of the electrical grid. Over the longer term, improvements to the grid can be made, and renewable technologies could supply increasingly higher percentages[5].

Examining possible implementation and growth rates for different technologies, a 2004 report from the European Renewable Energy Council concluded that renewable energy could meet base load power needs[2] and in fact, could provide 50% of the world's primary energy by 2040[3]. Similar studies from Shell Oil have explored scenarios in which one third to one half of the world's energy can come from renewable by 2050.[4]

Importantly, renewable energy technologies produce virtually no greenhouse gas emissions and can effectively address climate change. If unchecked, the disruption of the earth's atmosphere poses the greatest threat to humankind in our lifetimes. Continuing to fill the atmosphere with greenhouse gases will melt the ice sheets, raise sea levels, bring extreme weather patterns, disrupt food production, and destroy whole ecosystems. Hundreds of millions of people may be left without food, shelter or clean water, causing political and social upheaval.[4] According to a study by Japan's Ministry for the Environment, renewable energy combined with efficiency measures could reduce greenhouse gas emissions to a level consistent with goals of global climate stabilization – a 70% reduction by 2050.[5] With minimal initial capital costs and short deployment times, renewable technologies could address global climate change more quickly than nuclear power, and without the production of radioactive waste or other significant types of pollution[2].

How much renewable energy is there?

In the near to medium term, the combination of wind, solar, advanced hydro, and some biomass and geothermal energy could completely meet the World electricity needs.[6] According to a recent National Renewable Energy Laboratory (NREL) analysis, the entire World electricity demand could technically be met by renewable energy resources by 2020[7]. In the longer term, the potential of domestic renewable resources is more than 85 times current world energy use.[8]

Wind Energy Researchers at Stanford University recently evaluated the potential of wind power globally. After analyzing more than 8,000 wind-speed measurements, the researchers concluded that wind at specific locations could generate more than enough energy to meet world demands.[9] Of the sites measured, over 13% had mean annual wind speeds strong enough for economic power generation (speeds greater than 6.9 meters per second at 80 meters). These candidate sites are found in every region of the world, both inland and offshore. The researchers concluded that global wind could have generated about 72 terawatts (TW) in 2000. This is equivalent to 208 trillion kilowatt hours (kWh)—about one and a half times current annual world energy use[11].

Wind Turbine

Evaluating the wind potential of the World, the Pacific Northwest Laboratory – a Department of Energy (DOE) national laboratory based in Washington state – has estimated that land-based wind across the contiguous United States is capable of producing almost one and a half times current World annual electricity use.[10] According to a recent analysis by DOE, there is also an additional 900 GW of power from offshore wind within 50 miles of the U.S. coastline. This is equivalent to at least 2.6 trillion kWh/yr – almost 70% of current U.S. electricity use.[11]

To produce this much energy, no significant developments in wind technology would be needed. Modern turbines are rugged horizontal-axis three-bladed designs that are turned into the wind by computer-controlled motors. The power capacity of these turbines has increased dramatically in the last twenty years, from 24 kW in 1981 to 1.5MW in 2006.[12] The turbines have been developed to function at high speeds, high efficiency, and with low stress, which all contribute to good reliability. Research on new lightweight composite materials, advanced control systems, and methods for addressing the additional variables involved in offshore sites will only improve the effectiveness of these designs.[1] Counter-rotating horizontal axis turbine designs, which capture a wider range of wind speeds, and vertical axis turbines, which have the potential to generate 4-10 megawatts (MW) per turbine, are also expected to become common in the next five to ten years. The most significant issue facing wind turbines will be the need for appropriate sitting and community approval[9].

Solar Energy

The amount of solar energy by any measure is also enormous. Every hour more energy strikes the surface of the Earth than is consumed globally in a year.[4] According to the DOE's Solar Energy Technologies Program, there is on average between 2.8 and 6.2 kilowatt-hours (kWh) of sunlight available per square meter (m^2) each day.[5] the exact amount of sunlight depends on the region and the season. In the United States, the annual average is 4.8 kWh/m^2 per day which is by far less than what is obtained in African continent.[6]

One way of using this solar energy is to transform it directly into electricity[17] two types of photovoltaic technology that have been developed for this purpose are photovoltaic panels (PV) and photovoltaic concentrators. For PV panels, the efficiency – or ability of the photovoltaic cells to capture solar energy and convert it into electricity – ranges from 12 to 25%. The panels themselves have efficiencies slightly lower than the actual cells because of structure and wiring. Traditionally, the highest efficiencies have come from expensive, thick silicon panels. Recent work by several scientists, however, has led to the development of cheap, flexible thin film panels capable of at least 15% efficiency.[8] These panels have begun to be produced on a significant scale.[9] As a result, with existing technology, PV could make a significant contribution to world energy production. According to a recent Energy Foundation study, assuming 15% panel efficiency and a conservative estimate of at least 7854 million m^2 available residential and commercial rooftop space, the world could accommodate about 1 million MW of PV by 2025, which would generate approximately 1.9 trillion kWh per year – almost half of current world. electricity use. [10] This does not include other distributed forms of PV electric generation, such as ground mounted PV, PV shingles, covered parking lots, windows, awnings, and sides of buildings. It also does not take into account additional improvements in panel efficiency. According to a recent NREL analysis, the total long-term technical potential of PV in the world is around 219 TW –which could provide over three times current world energy use[1].

Photovoltaic concentrators – systems that reflect or focus light from a wide area onto a small photovoltaic panel – could also make a significant contribution to meeting world energy needs. Solar concentrators move to track the sun, produce a more constant level of "peak energy" throughout the day, and operate at higher efficiencies than PV panels. Concentrators can also reduce costs by using less PV material per unit of energy generated (although they do require an inexpensive optical element and a support structure and tracker).[2] Concentrators could be well-suited for stabilizing the generation of wind farms and for installation along highways and transmission corridors. 40 KW Solar photovoltaic system on a commercial building in Pittsburgh, PA, Installation by Mountain Solar, Grass Valley, CA[12].

Advanced Hydropower

Hydropower currently provides 10% of the electricity generation in the world and could be a significant source of renewable energy.[2] Large conventional dams, however, have caused serious environmental damage.[3] They will have to be retrofitted or taken down, while smaller systems with advanced turbine designs are set up (up to 25 MW). According to DOE, advanced systems can be applied at more than 80% of existing hydropower projects, and can also be built at small existing dams that have not been previously used to produce power.[4] Advanced hydro designs reduce the impact of turbines on fish, facilitate upstream fish migration, and mitigate sediment and water quality problems. River-run systems – which harness the power of moving water without dams or reservoirs - are also a small, low-impact alternative that could be developed where dams are removed or at new sites. Estimates of potential sustainable hydro resources from existing dams range from 77 to 82 gigawatts (GW). This includes 62GW from retrofitted existing hydropower projects and 15-20 GW from fitting advanced systems onto other existing small dams.[5] These hydropower sources could provide between 337 and 359 billion kWh per year, or 8.5 - 9 %of current electricity use[10].

Biomass

Biomass is the burning of organic matter – typically agricultural crops and grasses – to produce heat or electricity. Biomass, unlike solar and wind, does produce significant carbon dioxide emissions. These emissions, however, can be balanced out by planting new crops, which take up carbon dioxide as they grow. The carbon emission to carbon uptake ratio, the location of the two processes, and the effects on local soil and water quality, are important issues that must be considered in determining what forms of biomass are sustainable. For biomass to be a significant source of non-carbon emitting renewable energy, crops must be grown with little cultivation and fertilizer, transported only over short distances, and grown and harvested in a way that does not degrade the land. Grasses - such as switch grass and big blue stem - are low impact possibilities for biomass. If produced and used correctly, biomass could contribute significantly to meeting the World energy needs. According to a recent NREL study, biomass could produce 17-28% of the world electricity by 2020.[6]

What about Variability and Intermittency?

Despite the abilities of renewable technologies and the vastness of the resource, renewable energy is still often depicted as far too variable and inconsistent to meet our energy needs. This, however, is an incorrect picture. Advanced hydro and sustainable biomass are already capable of producing base load power, and offshore wind has similar potential. For PV and land-based wind - although it is true that “the sun doesn’t always shine and the wind doesn’t always blow” - it is possible to harness these sources of energy in a way that substantially reduces the problems of intermittency and variability[7].

A recent analysis by the International Energy Agency (IEA) - an intergovernmental body of twenty-six countries committed to advancing security of energy supply, economic growth, and environmental sustainability- concluded that intermittency is not a technical barrier to renewable energy.[7] To deal with variability and intermittency,[8] IEA recommends distributed generation, links across geographic areas, a diverse mix of technologies harnessing different resources, and the continued development of storage technologies.

Significant advances along these lines have already been made. The first three measures alone can allow non-hydro renewable technologies to well exceed 20% of generating capacity by 2020 without impacting grid reliability or stability. In the longer term, storage remains the most significant issue. Presently, the best options for storage are hydroelectric pumped water and compressed air. Hydroelectric pumped storage moves water from lower to higher reservoirs when extra electricity is being produced, and releases it when that energy is needed. These systems are well-established, low in cost, up to 80% efficient, and have an enormous capacity for storage. Also, because energy is stored in times of excess generation, pumped storage systems do not compete with hydro generation.[9] Using advanced hydro technology, these systems can also have minimal environmental impact. Air compression systems work on a similar principle, compressing air and storing it in airtight underground caverns during times of less demand, and releasing it to run turbines when needed.[3] These technologies have undergone significant developments recently, being designed to store energy from wind farms. In the longer term, the development of extensive regional grids will increasingly stabilize geographically distributed generation, and the production of hydrogen will likely become an important energy storage mechanism.[3]

Are renewable technologies more expensive?

Despite all their advantages, renewable technologies are still often rejected as too costly. But this fails to take two very important factors into account. In the last fifty years, federal support worldwide for nuclear power and fossil fuels has far surpassed support for renewable technologies. This imbalance has resulted in unequal technology development and commercialization. In addition, while the costs of renewable technologies are decreasing substantially, the costs of nuclear power and conventional fuels continue to be underestimated[11].

Where do we go from here?

Presently, there are many artificial regulatory barriers limiting the immediate growth of renewable energy technologies. If we are truly to move towards these technologies, adjustments to the way renewable energy is produced and sold, and the establishment of long-term purchase agreements between renewable energy producers, utilities, and large end-users are necessary. Changes like this can be affected from the local, state and national level. In addition, cities and states can develop renewable portfolio standards (RPS) which mandate a certain percentage of energy generation come from renewable technologies, and states can also put in place financial incentives that encourage the development of renewable technologies[4].

CONCLUSION

The technical advantages of this approach include:

– Provides a source of methane that could be used as a replacement for natural gas that is obtained from cracking;
– Potential for the use for carbon dioxide from the biogas to grow algae for the production of solid fuels, biodiesel, food products, and other products;
– Utilizes waste carbon sources in a manner that reduces the water requirement for energy production;
– Reduces climate change by recycling and utilizing huge amounts of methane and carbon dioxide which would otherwise be released into the atmosphere from landfills;
– Reduces the potential for groundwater and surface water contamination from landfills;
– Potential for producing bio-solids that can be used as fertilizers; and,
– The concept could be developed for implementation at other places or organizations with large volumes of food waste in any city or locality regardless of location, or local climatic conditions..

RECOMMENDATIONS

Energy sustainability means using less carbon from fossilized sources such as natural gas, coal and petroleum, and utilizing and recycling biologic forms of carbon that already exist in the environment. The coupling of anaerobic digestion with carbon dioxide utilization via alga-culture will represent a giant step forward in achieving this goal. The success of the pilot plant here will allow the PIs to seek funding from both Nigeria and International sources in order to reproduce this concept not only at other sites but also in large urban areas where cities are seeking to think green, which requires them to think smart.

REFERENCES

1. Archer, Christina L. and Mark Z. J, (2005) "Evaluation of global wind power," Journal of Geophysical Research, Vol. 110,
2. Brown, E, (2006) "Near-Term Practical and Ultimate Technical Potential for Renewable Resources," Draft, NREL,
3. Chaudhari, M, Frantzis, L & Tom E H, (2004) "PV Grid Connected Market Potential Under a Cost Breakthrough Scenario, The Energy Foundation and Navigant Consulting.
4. Elliot, D.L.and M.N. Schwartz, (1993) Wind Energy Potential in the United States, Pacific Northwest Laboratory.
5. European Council on Renewable Energy, (2004) "Renewable Energy Scenario to 2040,".
6. Farrell, A, Daniel K, and Frank L, (2006) Managing Greenhouse Gas Emissions in California, The California Climate Change Center at UC Berkeley.

7. Gul T, and Till S, (2005). “Variability of Wind Power and Other Renewables: Management Options and Strategies,” International Energy Agency (IEA).

8. Japan Times, (2005). “Reactor increase not needed to cut CO2 drastically,” The Low Carbon Society Scenarios toward 2050 Program authored the study.

9. Kammen, D, and Sergio P, (2004) “Assessing the Costs of Electricity,” Annual Review Environmental Resource,.

10. National Renewable Energy Laboratory (NREL) (2005), Power Technology Energy Data book.

11. Shell International, (2001). Energy Needs, Choices, and Possibilities: Scenarios to 2050, Global Business Environment.

12. Yen-N, Dora, (2005) “California Wind Resources,” Draft Staff Paper, California Energy Commission.