Renewable Energy for Sustainable Food, Feed and Fibre Production: A Panacea to Nigeria's Energy Crisis.

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Abstract: Agriculture is the sole provider of human food. Most farm machines are driven by fossil fuels, which contribute to green house gas emission and, in turn, accelerate climate change. Such environmental damage can be mitigated by the promotion of renewable resources such as solar, wind, biomass, tidal, geo-thermal small-scale hydro, biofuels and wave-generated power. This is because, energy inputs are critical to agricultural production and long-term sustainability of global agricultural production will require renewable alternative energy resources. There are many systems that can provide on-farm energy resources from renewable sources. Solar energy, wind and small-scale hydro systems can provide on-farm as well off-farm energy resources. These renewable resources have a huge potential for the agriculture industry. The concepts of sustainable food, fibre and feed production lies on a dedicate balance of maximizing productivity and maintaining economic stability, while minimizing the utilization of finite natural resources and detrimental environmental impacts. It also emphasize replenishing the soil for future use. Hence, there is a need for promoting use of renewable energy systems for sustainable food production, for instance, solar photovoltaic water pumps and electricity, greenhouse technologies, solar dryers for post-harvest processing, and solar hot water heaters and so on. This article thus explains in detail the role of renewable energy in farming for production of safe and secure food for humans.
[Nnadi, F.N., Chikaire, J., Ajaero J.O.,Nwakwasi, R.N. and Oguegbuchulam, M.N.. Renewable Energy for Sustainable Food, Feed and Fibre Production: A Panacea to Nigeria's Energy Crisis. Nature and Science 2011; 9(11):76-82]. (ISSN: 1545-0740). http://www.sciencepub.net.

Keywords: Energy, solar, wind, biomass, agriculture, fossil fuel.

1. Introduction

Agricultural productivity has increased with increased use of energy from a variety of sources. Increasing use of inputs to production agriculture of fertilizer, irrigation and pesticides all require commensurate increases in the use of energy. Mechanization of agricultural tasks increases human productivity and improves the timeliness and quality of many operations and also relies on energy inputs. Increasingly the energy for all of these inputs to the agricultural production system has been derived from fossil fuels, particularly in the developed countries and increasingly in the developing countries. The requirements of fossil fuel based energy resources for post farm operations including processing, transportation, storage, wholesale and retail distribution and home storage and cooking far exceed production energy requirements in developed production systems (Mears, 2007).

The energy requirements for production agriculture, less than 3% of global energy use, represent a small portion of the demand for fossil fuels, but are a critically important input to the food, feed and fiber production system. Interest in reducing the dependence on fossil fuel for agricultural production increased dramatically just after the oil embargo of 1973. Many studies were undertaken to quantify the relationships involved in energy flows in various farming systems. Research and demonstration projects focused on reducing dependence on fossil fuel by conservation and replacing fossil fuel resources with solar energy and other renewable alternative sources (Mears, 2007).

Many renewable energy strategies such as solar thermal energy systems and electrical generation systems such as photovoltaic, wind and small-scale hydro can make a contribution to on-farm as well as off-farm applications. In addition there are possibilities to generate on-farm energy requirements from on-farm sources such as agricultural wastes and other biomass derived energy sources that are particularly effective fossil fuel replacement strategies as the resource is near the place of application.

Beyond the use of farm derived energy sources to meet on-farm energy requirements there are additional opportunities for agriculture to contribute to off-farm energy needs, particularly through biomass derived fuels. Biogas from anaerobic digestion and liquid fuels including ethanol and biodiesel can meet a substantial portion of global energy requirements on a sustainable basis. In order for this to occur the technologies developed must be based on consideration of all aspects of the production and utilization systems. Not only must the energy flows meet all needs on a renewable basis but ultimately all materials must be recycled to achieve long term sustainability.

2. The Situation In Nigeria

Nigeria's energy source for agricultural production include the use of human power to operate hand tools, animal power for drawn implement, and carbon fuel for motorized and mechanically driven post-harvest handling and processing machines, and pumps for irrigation (Onyema, 2010).

Table 1: Energy Sources Used For Agriculture In Rural Areas

Rate Of Coverage Of Agricultural Activities In Nigeria Using Energy Source (hour/ha)			
ACTIVITIES	**HUMAN**	**ANIMAL**	**CARBON-BASED**
Plowing	-	17.25	1.7-2.5
Ridging	80-250	6-8	1.0 -1.4
Harrowing	-	8.7	0.8-1.5
Fertilizer application	2-70	-	0.4-1.0
Spraying	2-3	-	0.4-0.5
Planting	100-500	6.8	1-1.5
Weeding	40-150	4.8	0.8-12

Source: Ozoemena and Onwualu 2008.

However, out of the conventional energy source such as electricity, petroleum, gas, coal, and fuel wood, only fuel wood has any substantial sue in rural areas. For example, of the total households in Nigeria only 2 percent have access to power (through either rural electrification or self-generation) in 2007 (NBS, 2009). Those with low incomes have limited access to petroleum gas, coal and the tools that requires their use. Potential alternative energy source for the rural agricultural sector are biomass (including fuel wood, sawdust, crop and annual residue/waste and biogas), wind, solar power, and small hydropower.

Fuelwood

About 50 percent of Nigeria's total energy consumed for agriculture and other domestic food processing activities is from fuel-wood. The current reserve potential of 80 million cubic meters per year is reported to be poorly utilized (CREDC, 2008). Only a fraction of wood is effectively used with traditional stoves improved wood/solid fuel stoves and coal briquettes of various designs have been shown to have 10 to 20 percent thermal efficiency, while traditional stoves have 5 to 7 percent thermal efficiency (Sambo, 2010). The wood/fuel stoves can be sued for cooking, fish smoking, and preservation. Nevertheless, its unregulated consumption could result in environment decay such as deforestation, soil erosion, desertification and carbon emissions.

Table 2: Potential sources of energy for rural based agricultural production and processing activities

SOURCE OF ENERGY	**POTENTIAL/RESERVE**	**ENERGY CAPACITY**
Fuel wood	80 million m^3/year	6.0 x 109MJ
Saw dust	1.8 million tons/year	31,433, 00 MJ
Crop residue	83 million tons/year	5.3 x 10^{11}MJ
Animal waste	227,500 tons daily	2.2 x 10^9 MJ
Biogas	6.8 million m^3 daily	2.7 m^3 production 79.11 MJ
Wind	2.4m/s at 10m Height	5MW
Solar	6.25 hours daily	6.25-7.0KWh/M^2 per day
Small hydro power	0.143 billion tons	734.2MW

Source; Sambo, 2010

Crop Residue, Biogas, Animals And Human Wastes

Huge volumes of agricultural wastes in the form of livestock manure, corn cobs, cassava peelings rice husk, ground nut shells, sawdust, bagasse, human excreta and the resultant gas (BIOGAS) can be converted into potential sources of energy that can be plowed back into agricultural production and processing activities. This is achievable with the use of biodigester (Tejoyuwonu, 1982) Since 1 kilogram of fresh animal waste could produce about 0.03 cubic meters of gas, Nigeria can produce about 6.8 million cubic meter of biogas daily (Okafor and

Joe-Uzuegbu, 2010). Presently biogas is not widely used in Nigeria's rural economy due to poor knowledge of its energy potential as well as limited resource to purchase the required equipment for its conversion. Furthermore, even if the gas is produced, it may not be in a form that can be easily transported or converted into electricity, which is necessary to power farm equipment.

Wind Power

The use of wind power for rural agricultural production activities is practically adaptable for residents located along coastlines and in dry regions of Nigeria. This is useful in reducing the human energy involved in activities such as winnowing in rice mills. Since wind is not available in a sustained manner, it limits its usage for many farm activities in Nigeria.

Solar Energy

Nigeria receives an optimal supply of solar radiation (5.5 kilowatt hours per square meter unit). Of this amount, however, only about 0.005% is actually converted into energy. The energy challenge mentioned above could substantially be met by solar if 1 percent of the available solar energy can be tapped (FEC 1984) solar power has been successfully used in controlled drying of agricultural products, domestic cooking, and pumping water for irrigation in rural areas of China, India Finland, Kenya, and Bangladesh among others. The limiting factor in rural Nigeria is lack of technology and funding.

Small Hydropower

Small rivers and streams exist within rural areas in Nigeria, most of which maintain a minimum flow all year round. These streams and rivers can be used to develop hydroelectric energy for rural agriculture (ICEED 2002). Studies (Aliyu and Eleagba 1990), further confirm the great potential of small hydropower to improve on the energy deficits experienced in rural households in Nigeria.

3. Agriculture and Alternative Energy

In order to provide mankind's need for food energy resources must be available to agriculture in a form that is suitable for the application and in sufficient amount for the task. As food production is a very high priority activity relative to many other uses of fossil fuel energy it is rational for society to bear the costs required. However, as the price and scarcity of fossil fuel supplies increase it is prudent and will become essential to look for opportunities to meet the needs of production agriculture from renewable resources. In this regard there have been substantial efforts to understand the energy requirements for agriculture and the patterns of use as well as programs to develop and apply alternative energy technologies.

To meet energy requirements for agricultural production there are a number of technologies that have been studied and in many cases implemented. In some cases the energy requirements of the farm family and/or others living on the farm may be integrated with the systems being used to provide energy for production. An important aspect of most alternative energy sources is their distributed nature. Wind, solar energy, small-scale hydro systems and biomass based energy supplies all are localized resources. Wind, solar and hydro systems that can be developed and used at the local level will generally be economically competitive with fossil fuel sooner than applications that have to provide energy to distant needs.

Beyond meeting the need for on-farm energy requirements there is also potential for agriculture to provide energy resources for other societal needs. One example is the production of ethanol for use as a fuel or fuel additive. It is generally accepted that biomass derived energy, such as ethanol; biodiesel and biogas are particularly attractive agricultural based energy sources that can be transported and used on-farm as well as on-farm.

4. Alternative Sources for On- Farm Use

Historically production agriculture was completely dependent upon non fossil fuel based energy resources. Hunter-gatherer societies and some cropping systems depend only on human energy. The use of animal power for production agriculture shifts work from humans to animals but requires feed for the animals, which may be provided primarily from forage crops that can be produced on land that is better suited to forage crops than human food crops. Hydropower has been utilized as an energy source for grain milling, sawmills and other energy requirements. Wind power has been extensively relied on for water pumping and milling also. Early mechanization relied on steam power both for tractors and stationary power units for grain threshing and other operations. Biomass byproducts such as straw could be used as a fuel source as well as wood and at local. The use of biomass of any sort to provide energy for agricultural production has largely been supplanted by the ready availability of low-cost, easy handle fossil fuel, primarily petroleum and natural gas.

Biomass, such as wood, straw, crop residues and manure, contains stored energy. In some farming system, this energy is retained within the system so that little or none is wasted, and little external input of energy (e.g. from chemical fertilizer or fossil fuel powered machinery) is needed, feeding crop residues to livestock or fish is one example of this. the livestock or fish provide food as well as fertilizer, and in the case of cattle, draught power. Use of biogas digester takes this a stage further, making use of bacteria on the farm as well!

Mixed livestock/crop farms can be the ideal way of retaining energy within a farming system, but for those without livestock there are still many good energy-conserving strategies. Adding crop residues or compost to the soil recycles their nutrient into the next year's crop. It also boost water holding capacity and reduces erosion by wind or heavy rainfall.

A number of opportunities to use alternative, renewable energy sources in agricultural production and on farm processing are discussed in Goswami (1986). Wind power has historically been widely utilized for water pumping and is still found to be a practical energy source for this purpose in many locations. As the potential power that can be derived from wind varies with the cube of the wind speed the likely availability of adequate wind at the location and time it is required is a key element in the practicality of wind systems. Water pumping remains one of the most likely applications for wind power as there is the potential to store the water and as the pumping system can be driven directly by the wind machine. When the wind power resource is not completely reliable a hybrid system including another power supply can be used. However, in this case the energy cost savings alone must justify the investment in the wind generation system. So as long as fossil fuel based energy is available at relatively low cost it will generally be simpler and probably more economical to use only that energy source and not make the equipment investment necessary to utilize the renewable resource for part of the work.

In general there is an advantage when the mechanical power from the wind can be used directly without conversion to electricity and when storage of the energy, (or stored water) is not required or is already an integral part of the system. Wind generated electricity is becoming and will continue to become increasingly competitive with fossil fuel powered electricity generation in some areas, particularly where the power can be used on site and directly. While there are power losses in the conversion of mechanical power to electricity and conversion from electrical power to the final application the versatility of electrical power is often a compelling advantage. Also, if the point of application is near the electrical power distribution grid there is the option to use the grid system to purchase additional power when needed and to which surplus power can be sold when wind supply exceeds demand.

The direct use of solar energy on farms can meet many needs. Traditionally many agricultural crops have been dried using only solar energy but often fossil fuels are used to heat air for crop drying to reduce loses and to increase reliability and product quality. In the analysis discussed earlier, of the 1.39 kcal of energy required in the field to produce a kcal of food, 0.09 kcal of energy is used for drying, Stout (1979). A modern crop drying system that uses fossil fuel to heat the drying air and purchased electricity to operate fans can he replaced or supplemented by solar col1èt9rs for the heat input and/or a photovoltaic source for the electricity for the fans. A hybrid collector of photovoltaic cells incorporated in an air heater array is one example. In some cases it is possible to incorporate the solar collector air-heating component in various farm buildings in such a way as to significantly reduce the investment cost in the system.

In addition to crop drying there are other requirements for heat at modest temperatures that can be met with solar thermal collectors. Some animal housing units require heating arid, as with solar drying systems, if it is possible to incorporate the solar thermal collection system in the structure itself system economics can be optimized. Some food processing operators require process heat that can be provided with solar collection systems, whether the processing is on-farm or at an industrial processing site off-farm. Solar thermal energy is particularly suited to applications where hot water requirements are met by temperatures under 100°C and the food processing industry uses hot water for many processing applications and for space heating of facilities. One study on the technical and economic feasibility of solar energy indicates that 20% of the energy requirement of the food processing industry could be met with solar energy (Goswami, 1986).

Solar panels (also called photovoltaic or PV panels) are used to generate electricity from sunlight. The electricity can be used to power a water pump, normally used for village water supply, livestock watering and small-scale crop irrigation, e.g. vegetable plants in a home garden.

The water is pumped from underground into a tank, which must be large enough to store sufficient water to supply the village needs during cloudy weather.

Installing a solar powered water pump is a fairly expensive option (several thousand Euros or US dollars), although the system lat for a long time and are reliable. Before installing this kind of system, a detailed assessment must be made of water demand (including needs of people, livestock and crops) and availability (e.g. well yield). the site must also be carefully surveyed to ensure the system is designed correctly. Although solar powered water pumps are generally reliable and need little maintenance, if they do go wrong, skilled technicians are required to carry out repairs. Availability of this expertise is another factor in choosing whether to have such a system.

Agriculture produce has been dried by the sun and wind in the open air for thousands of years. In industrialized countries, drying of crops is mostly done by mechanized driers, which are quicker and give a higher quality product. However, these driers are expensive and require large amounts of fuel to work.

Solar driers are more effective than sun drying, but have lower costs than mechanized driers. Design of solar drier include quite simple boxes with glass covers, or more complex designs where heat is collected in one part of the drier, and then transferred to a box where the crop is placed. While various designs of solar drier have been proven to work, none are in widespread use in Africa, however, they may be in use in certain areas for drying certain crops, such as coffee and rice.

There is need for domestic energy requirements for on-farm residences including energy for space heating, water heating and food preparation. All of these needs can be met in whole or part with solar energy. Refrigeration needs for cold storage for farm production and for the residences can be met with solar thermal collectors powering absorption refrigeration systems. The technologies required for most of these applications and the economic harriers to their adoption are generally similar for on- farm applications and domestic residential applications. An important consideration in solar thermal systems is the relationship between system economics and the needed operating temperature of the system. In general for solar thermal collectors the efficiency of the collector decreases as operating temperature increases as most losses in the system are directly related to the difference in operating and ambient temperature.

Thus lower temperature applications, i.e. warm water rather than hotter water, will operate more efficiently and produce more useful energy relative to the capital investment. Therefore absorption refrigeration systems, which require higher operating temperatures than space heating or hot water for food processing, are inherently less economical than those applications.

Greenhouse production of seedlings, vegetables and ornamentals is a particularly highly productive yet energy intensive agricultural production system. Energy is required for heating the greenhouse in cold weather and often for mechanical ventilation systems as well as for operating equipment and cold storage for the crops. Increasing costs of both ventilation systems and electricity to power the fans have led to renewed 5
interest in natural ventilation systems but space heating is also needed in many locations. One of these, developed at Rutgers University Goswami (1986), utilized a floor storage/heat distribution system for the water heated in external collectors and a movable curtain system for insulation to reduce heat loss. The initial emphasis in the development of both the floor heating arid movable curtain system provide energy savings.

Curtain materials have been developed that provide appropriate levels of daytime shade and are deployed during high light periods o reduce heat stress on the crop as well as energy conservation on cold nights. Floor and bench heating systems have been found to benefit many crops as the grower can independently control the root zone and plant canopy temperatures. Benefits of root zone heating include better plant growth for some crops, improved disease control due to warmer and drier conditions under the plant canopy and increased energy savings in cases where warmer soil allows for cooler air temperature above the crop. These concepts have been widely applied in greenhouses worldwide even though the relatively low cost of fossil fuels have essentially eliminated the desire for the solar collectors to provide the heat. This case is an example of the integration of systems of crop production and energy management that develop synergies, which produce multiple benefits.

On-farm biogas plants utilize manure and other wet plant or food waste materials to generate methane, which can be used for cooking, heating, process heat or electrical generation. While there is an economy of scale in the use of biogas generators, there have been many workable designs developed for very small-scale applications, even for single-family use, particularly in China and India. Sims (2003) indicates that in both of these countries the trend is to progress from traditional small-scale family biogas plants to more efficient community or industrial operations. Large livestock facilities are attractive sites for biogas generation, particularly when the cropland supporting the livestock operation is close by, making the transport of the sludge left at the end of the biogas generation process to the fields easy. In such an integrated system the biogas generation basically harvests much of the potential energy in the waste while most the plant nutrients remain in the sludge and can be recycled to the productive fields.

Biogas is used for cooking and lighting in the hoe and is produced from animal manure and crop residues. the technology is most suitable for farmers who practices stall-feeding (zero grazing) of their livestock, as this gives them a regular supply of manure. The manure is mixed with water and then fed into a large tank. Here it is fermented by bacteria, producing gas (usually about 60%) methane, plus carbon-dioxide and other gases. The gas collected in a reservoir, connected by pipes into the kitchen of the home is used either in gas cooker or lights, helping families to save money on fuel. The gas also burns cleanly, so people cooking with it do not suffer from inhaling smoke.

Most designs of biogas digester need to be fed with manure on a daily basis. This obviously requires some labour and also requires an all year round supply of water, which can be a limiting factor. However, as well as providing gas for the home, the system also produce slurry from the digested manure, and this can be used as a fertilizer without needing any further treatment. This saves money compared to buying chemical fertilizer, and is less work than making compost. Biogas digesters also improve on-farm sanitation.

Small-scale hydropower

Many countries now have hydro-electric power stations, with large dams capturing water, which is used to drive turbines and generate electricity. However, small-scale versions of this technology also exist, which provide power to isolated rural communities. The small-scale system taps part of the water from a river and feeds it down a pipe which is sited on a steep gradient to increase the speed of water flow. The water then drives a turbine, generating a 24 hour supply of electricity, which is typically used for lighting, and for TVs and radios and in some cases for example providing light to a poultry farm, or power for a milk chiller or an agro processing operation.

Small-scale hydropower-also called micro-hydro or pico hydro is normally more expensive to set up than a diesel system of electricity generations, especially if imported equipment is sued. However, where local materials are used, it is possible to reduce the cost sustainability, and with proper training, all operation and management can be carried out by the communities, as well as repair or replacement of worn out parts. in the long run, the electricity produced by micro-hydro is very cheap compared to other sources. Assuming a year-round availability of water in the river a micro-hydro scheme is a reliable source of continual power, suitable for providing electricity to health centres school, as well as businesses.

Using waste charcoal dust to heat poultry brooders

During their first 30 days, young poultry chicks need to be warm. For those with electricity, heating lamps are one option. These can be powered whether from the national grid, from a generator or a renewable energy such as solar or micro-hydro. A cheaper alternative may be to sue fuel briquettes made from waste product. For example, charcoal dust-a waste product from charcoal making-can be mixed with sawdust, grass and other wastes to produce a fuel briquette that will burn slowly, over several hours.

Conclusion

Global agricultural energy productivity has been generally increasing over the years, due to generate improvement of crops, and other agricultural technologies. Animal and human power have been replaced with mechanization to achieve global food production. Fossil fuels have been sued for irrigation pumping power, fertilizer and pesticide production, processing and transportation and for other activities, but they are not completely sustainable forever. Therefore, alternative and sustainable sources for energy and for new materials have been identified. These renewable resources are technically capable for replacing fossil fuel for any application even though current economic fossil fuel for any application technologies unable to compete at current state of development. To achieve sustainability in food production and other aspects of production of material goods and services, not only must energy be derived from renewable resources but ultimately must be recycled.

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