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Review Article

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Renewable Energy By-products (REB) Adaptation Successes in Environmental Geotechnics: A Review

Onyelowe KC*

Department of Civil Engineering, Michael Okpara University of Agriculture, Umudike, P. M. B. 7267, Umuahia, Abia State, Nigeria

Abstract

The place occupied by Geotechnics and Geo-environmental Engineering in the 21st century renewable energy cycle has been reviewed and results have shown that for a complete, closed and perfect renewable energy process, the geotechnical engineering processes of soil stabilization, soil improvement and subgrade strengthening and the civil engineering procedures of concrete production should be credited and recognized. Biomass and the by-products of the renewable energy conversion process; fly ash, granulated slag, charcoal and ash have been in use in the stabilization operation without well positioned and full realization that these complete the cycle by kicking back the by-products which should have been disposed as solid waste thereby creating a loop, back into the renewable energy cycle. This is to justify that Geotechnical Engineering and its allied areas maintain a very important place in the renewable energy cycle by closing the loop that should been created should the by-products of renewable energy be disposed as solid waste.

Keywords: Renewable energy; Geotechnics; Lignocellulosic biomass; Plant based materials

Introduction

Renewable energy is the energy transformed from biomass (sugarcane bagasse, eucalyptus, palm kernel shell, coconut shells, palm bunch, snail shells, oyster shells, periwinkle shells, saw-dusts, wood wastes, municipal solid wastes, waste paper, waste ceramics and glasses, animal bones, groundnut shells, rice husks, etc.) as raw materials through the routes and schemes for conversion, which include conversion technology (gasification, hydrolysis, fermentation, pyrolysis, pelletising, direct combustion, etc.), to the products (bio-fuel, biogas; methane, ethane, ethanol, etc., bio-oil, bio-electricity, etc.) and by-products (ash, charcoal, granulated slag, fly ash, pulverized biomass, etc.), to the utilization technology (turbines, engines, reformers, cells, boilers, etc.), and to the utilization system (electricity, gas cleaning, automobiles, factories, etc.). This cycle of biomass conversion, which can be classified as thermo-chemical, physio-chemical or biological system contains negligible amount of sulphur, so their contribution to acid formation in soils is minimal and more importantly biomass contribution to global warming is zero [1]. Research results have shown that biomass comes from organic matter in trees, agricultural crops called the lignocellulosic biomass and other living materials that derive their energy from the sun as illustrated in Figure 1. The energy derived from the sun is transformed through the biological process of photosynthesis when the CO_2 from the atmosphere and water from the soil are combined to produce carbohydrates that form the building blocks of biomass which derives its source and origin from the trees, crops and soil. The biomass materials have been the building blocks of environmental and transportation Geotechnics and civil engineering as a whole. For centuries, the geotechnical engineer has sown its expertise in the fabric of making the environment and transport infrastructures reliable, serviceable, operation, stable and durable through the process of soil stabilization. This is the technology whereby the properties of the underlain weak soils are improved upon through various techniques and procedures which included mechanical method; dynamic compaction, chemical additives; cement, lime, fly ash(by-product of renewable energy), etc. treatment, and/or admixture stabilization; amorphous ash treatment (by-products of renewable energy), granulated slag treatment (by-products of renewable energy), pulverized biomass treatment (products of renewable energy) which include snail shells,

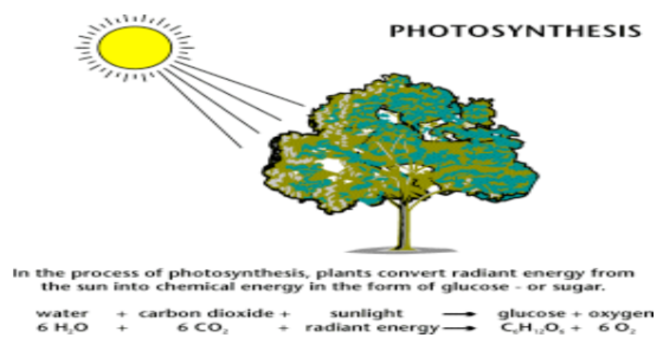

Figure 1: Solar and sustenance of biomass and bioenergy.

periwinkle shells, oyster shells, etc. The results of these investigations have been tremendous. The primary aim of this review exercise is to informatively kick the geotechnical engineer into the renewable energy cycle and to renew the cycle where the by-products of renewable energy (ash, slag, fly ash, etc.) are, instead of being disposed, brought back into the reusable technological cycle so that no products or by-products of renewable energy operation is laid waste.

Adaptations of REB in Environmental Geotechnics

According to the US Department of Energy (2005) has laid the foundation for the very source of renewable energy transformed from one form to another to benefit humanity (Figure 1). Energy is anything abstract or real that is put to use to better the living standard or condition of man. The renewable aspect of energy shows the cycles

***Corresponding author:** Onyelowe KC, Department of Civil Engineering, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia 440109, Abia State, Nigeria, Tel: +234 902 742 7974; E-mail: konyelowe@gmail.com

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and routes of conversion to its utilization. The cycles of renewable energy cannot be complete until experts have achieved a state where there are no by-products from the cycles; a complete cycle and circle. The solar energy that drives photosynthesis is stored in the chemical bonds of the structural components of the biomass. When biomass is burnt efficiently, oxygen from the air combines with the carbon in plants to produce CO_2 and water. The process is cyclic in that the CO_2 becomes available to produce new biomass. Biomass produces building materials, paper, fabric and chemicals which are all available as ash materials when burnt, geosynthetic materials, and chemical additives in the soil stabilization operation. There are typical biomass resources which include the forest, waste from wood processing industry, waste paper from educational institutions and paper mills, agricultural wastes, urban wood wastes, waste water and landfill, and other natural resources (Figure 2). Currently, the range of biomass utilization technology away from direct combustion, gasification, anaerobic digestion, methanol and ethanol products, are being discussed. That is the application of renewable energy and biomass by-products in soil stabilization and Geotechnics. Lack of formulation of sustainable engineering, policies and strategies in addressing the geotechnical and environmental challenges inhibit the development of biomass energy utilization which is indeed a precondition for the development and promotion of biomass Geoengineering. The mode of ash removal which is of particular interest to this work is a function of the combustion system which includes static grate, under screw, through screw, inclined grate, sloping or moving bed, suspension burning, and spreader stockers. In these mechanisms, ash is removed by manual or automatic process.

Direct combustion, which is used in many applications, is the most direct process for converting biomass into usable energy and into the by-products of renewable energy conversion cycle. Since pre-historical inhabitants of this planet learnt how to make fire, they converted biomass to useful energy by burning wood in a fireplace or woodstove. Ever since the earliest inhabitants of this planet burned wood in their fireplaces, direct biomass burning has been a source of energy for meeting human needs until the present time. Direct combustion is a thermo-chemical conversion process utilizing the following major feedstock: Wood, Agricultural waste, Municipal solid waste, etc. The energy produced by direct combustion process is heat and steam. Despite its apparent simplicity, direct combustion is a complex process from a technological point of view. High reaction rates and high heat release and many reactants and reaction schemes are involved. In order to analyze the combustion process a division is made between the place where the biomass fuel is burned (the furnace) and the place where the heat from the flue gas is exchanged for a process medium or energy carrier (the heat exchanger) as shown in Figures 3 and 4.

Figure 2: Biomass release cycle.

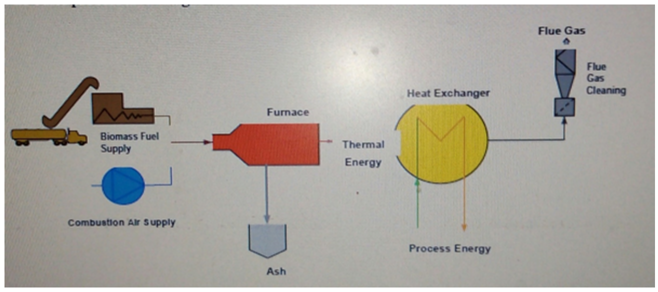

Figure 3: Principal scheme of a direct combustion system.

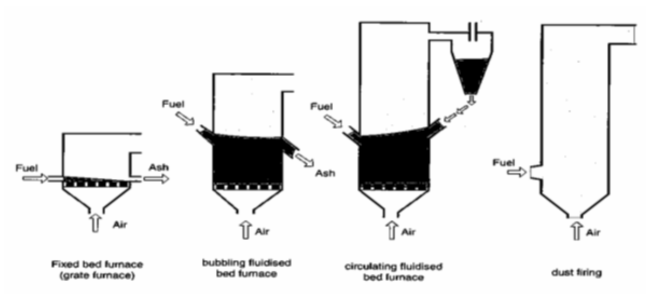

Figure 4: Direct combustion technologies.

The production of electricity from biomass as illustrated in Figures 5 and 6 can affect the environment in various ways, with potentially significant impacts that range in scope from the local to the global. Local impacts that must be managed include particulate and gaseous emissions from the conversion plant, solid waste (ash) disposal, increased demand for local water resources, noise, odour from some types of feedstock, physical intrusion and increased levels of traffic. On the other hand, some bio-energy production chains also present opportunities for improving local environments through reducing erosion and nutrient run-off from agricultural land, providing an effective disposal route for waste products and even increasing biodiversity. Today the most important environmental benefit of bioelectricity production results from its almost carbon-neutral production cycle. This means that as an alternative to fossil fuel-based electricity, bioelectricity can reduce anthropogenic contributions to global warming.

Figures 7-9 have shown the different biomass gasification reactor systems which bring to bear the amount of reusable by-products of this operation that has been ignored to be reengaged into the renewable energy cycle. Suffice it to state that the 21st century renewable energy operation can only break grounds of engineering records by complimenting the expertise of the geotechnical engineering in the reuse of its by-products to make a somewhat flawed and incomplete cycle a complete one.

REB Adaptation Methodology

Materials preparation has always been by the process of biomass pulverization to synthesize oyster shell powder, snail shell powder, periwinkle shell powder, egg shell powder, etc., or by direct combustion of biomass to synthesize palm bunch ash, palm kernel ash, coconut shell ash, rice husk ash, groundnut husk ash, sugarcane bagasse ash, straw ash, waste paper ash, snail shell ash, egg shell ash, periwinkle shell ash, corn cob ash, etc., or also direct combustion of municipal solid waste to synthesize ash particles or by relying on the by-product

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Figure 5: Routes for the conversion of biomass.

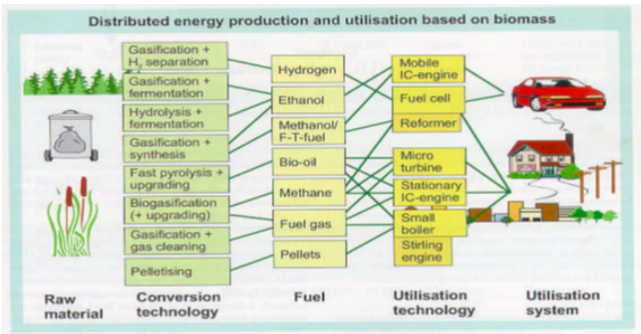

Figure 6: Potential paths for biofuel-based distributed energy production.

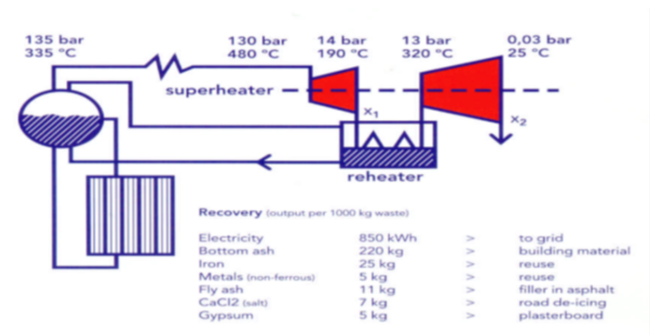

Figure 7: Flow scheme and characteristics of the new AEB Amsterdam new waste incineration unit.

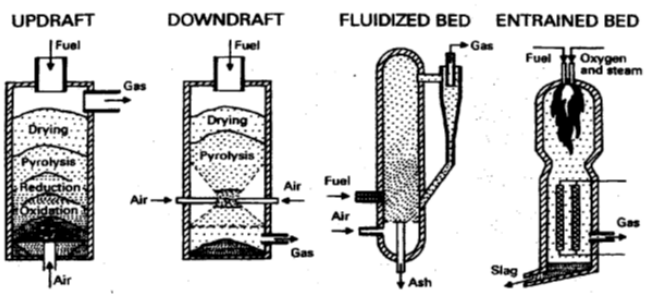

Figure 8: Schematics of different direct gasification reactors.

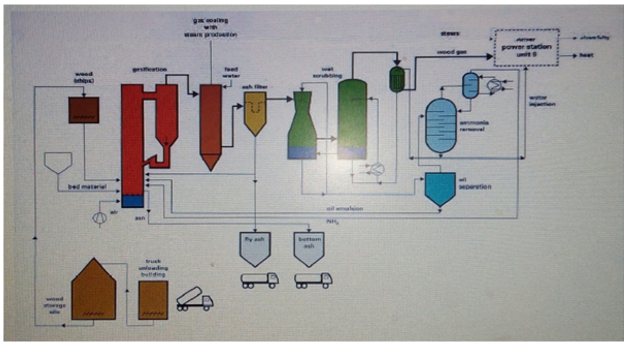

Figure 9: Biomass gasification reactor systems.

of renewable energy cycles of biomass conversion, which are ash, charcoal, fly ash, and granulated slag. These materials are all eco-friendly and green engineering materials [2] and are also in use as partial replacement for cement, which production contributes to global warming by contributing to CO_2 emission. The methods of application and adaptation were the conventional geotechnical engineering laboratory exercises in accordance with BS 1377-2 and the stabilization methods used to study the effects of these products of renewable energy on the strength, consistency, grading, swelling potential, subgrade, etc. properties of lateritic soils in accordance with BS 1924-2.

Results of REB Adaptation in Geotechnics

Results from the foregoing reviews and currently reviewed literature have shown that groundnut husk ash which is a product of direct combustion of biomass was applied on the soil stabilization procedure results showed that the swelling potential and strength properties of the stabilized soil improved consistently, which proved that the products of the biomasses were good admixtures in soil stabilization [3]. Also, rice husk ash has been in use in the stabilization of soils and research results showed that rice husk ash is a good admixture to soil [4]. Amu and Bamboo leaf ash and forage ash respectively to improve the strength properties of lateritic soils in a stabilization procedure [5]. Cassava peels were also used by previous researchers as partial replacement for cement because of its high pozzolanic properties in the stabilization of lateritic soils and results were good and satisfied the material condition to be used as both an admixture and also as a pozzolana [6]. Periwinkle; as ash or powder has been in use as admixtures and as partial replacements for cement for its high pozzolanic properties in the stabilization of soils for engineering construction purposes and results have shown that it meets the materials requirements as soil strength additives [7]. Quarry dust on the same hand, has been used in various construction purposes which included its application in the production of light weight concrete, asphalt, concrete and sand-crete blocks, interlocking stones, pebbles, and most of all is its wide usage in the stabilization of weak soils and results have shown that QD is a good material for use in soil stabilization and in other engineering application [8]. The effect of corn cob ash on the properties of lateritic soils has also been investigated and results showed that it improved the strength properties of the treated soil [9]. Waste paper ash; a product of wood processing and paper mills and educational institutions is not left out for its application has also given good results in the stabilization of soils for pavement engineering [10]. Palm bunch ash in micro and nano scale has been used in the stabilization process also and results have been consistent with previous results with other forms of biomass [11]. At the same time, naturally occurring clay was applied in the stabilization of lateritic soils as a pozzolana and results were also recorded to be positive [12,13]. Most populous amongst the biomasses being in use in the stabilization of soils is the sugarcane bagasse and straw ash which has been used my many researchers in the field of geotechnical engineering in soil stabilization and results showed that bagasse ash satisfied the material requirement for use as admixture in soil strength improvement [14]. Conversely, lime which is a product or oxide found in high amount in amorphous materials resulting from the direct combustion of biomasses has equally been in use in the stabilization operation and because of its role in the hydration process, cation exchange reaction and pozzolanic and carbonation reaction, there is resultant long tern strength gain by the stabilized soils [15,16]. Other agro-waste and bio-waste materials find their way as ash in this procedure also [17]. Then lastly, fly ash and granulated slag which are the direct by-products of the renewable energy cycle of biomass conversion have been applied in the stabilization of soils as replacement for cement and the results from these investigations have been satisfactory [18].

Concluding Remarks

The foregoing has the following to conclude:

(i) Modern biomass utilization technologies, mainly the gasification, bio-oil or biofuel and anaerobic digestion, give the advantage of separating the usable energy and the reusable fly ash, slag ash, charcoal, etc., which are the by-products of the renewable energy cycles.

(ii) Biomass technologies, such as biomass gasification and anaerobic digestion, that use locally available resources, would enable poor rural areas to access the electricity produced in a decentralized power plant and at the same time access stabilized transportation facilities and infrastructures achieved by applying the by-products of the energy cycle in environmental and transportation geotechnics to improve on the mechanical and geotechnical properties of soils used as subgrade material in airfield and highway pavements.

(iii) Finally, Geotechnical and Geo-Environmental Engineering can only recount on the successes recoreded by renewable energy by providing a platform where the by-products of the renewable cycle are kicked back into the reusable energy cycle making a complete cycle of renewable energy operation.

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