Renewable and Sustainable Energy Reviews 72 (2017) 625–638

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Biomass and bioenergy potential of cassava waste in Nigeria: Estimations based partly on rural-level garri processing case studies

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ARTICLE INFO

Keywords:
Biomass
Bio-energy
Cassava
Renewable energy

ABSTRACT

Advocating production of bio-energy from agricultural crop wastes has double benefits of minimizing land usage and threat to food security. These benefits are specially needed now that issues of greenhouse emissions, deforestation and human over population of the world dominate international discuss. Cassava being a major food crop in Africa, its waste constitutes the major candidate for bio-energy production thus motivating the aim to review its history, production, food value, economic value and bio-energy value. Cassava waste is noted to be suitable feedstock for bio-fuel production from the 1st Generation, 2nd Generation and integrated processes unlike the other Nigerian crop residues that are mainly suitable for the not-yet-viable 2nd Generation bio-fuel production. A procedure for estimating *cassava non-food biomass*(CnFB) from harvest data is established. The procedure entails use of statistical sampling and regression analysis to establish scaling factors for transforming the data to CnFB. A real case study reflected very accurate and statistically significant error indices. For example, the factor for converting mass of harvested cassava for food production to waste is $R_w = 0.5263$ (R^2 = 0.9875 and *t*-Test = 0.0896) while the factor for estimating mass of peels alone is $R_{12} = 0.1735$ (R^2 = 0.9951 and *t*-Test = 0.1680). The other factors for converting mass of dewatered cassava pulp to waste were established for the case study community as follows; $m_w = 33.7675$ Kg per bag (R^2 = 0.9611 and *t*-Test = 0.0665), m_3=32.0599 kg per bag (R^2 = 0.9865 and *t*-Test = 0.1944) and $r_w = 1.0508$ (R^2 = 0.9464 and *t*-Test = 0.2539). The factors and literature data were used to make long-term projections of CnFB potential of Nigeria. The implications of the projections to the programs of the Nigeria Energy Policy - which pertain to renewable energy integration in the national energy mix, emission reduction and rural electrification via distributed generation - were discussed.

1. Introduction

1.1. The global energy outlook

The today's astronomically high global energy demand is mainly caused by human population. Before and during miasma theory of human medicine, population grew marginally because of poor understanding of human epidemiology and poor understanding of the importance of improved sanitation and personal hygiene in reducing human mortality. The scientific breakthrough in medicine following the replacement of miasma theory with germ theory in the sixteenth century led to the better understanding and control of human epidemics. This mainly caused the surge witnessed in global human population. More on trends and projections of world's population growth can be found [1].

The surge in human population led to a surge in the cumulative human energy requirements. It is known that energy consumption is affected by other factors in addition to population; for example, the gross national product (GNP) [2] and GDP [3] are related to energy consumption. Other factors (in addition to GNP) like energy price, gross output, technological development and energy efficiency are being linked via econometric models to energy demand [4]. The human energy requirements of the pre-industrial revolution era of Europe was relatively small and was easily sustained by world's energy resources irrespective of less awareness of the need for efficient energy conversion processes. This was because of two reasons: (i) the human population was small and so was its energy demand relative to the world's energy resources and (ii) the energy requirement was rudimentary (e.g. cooking, heating, blacksmithing, etc), in other words, lacking in energy-demanding technology and mechanization. According to [5], the final energy use per capita increased in most countries between 1990 and 2005 due to growing wealth which led to

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http://dx.doi.org/10.1016/j.rser.2017.01.031
Received 5 November 2015; Received in revised form 22 November 2016; Accepted 8 January 2017
1364-0321/

Table 1
The global proven reserves of major fossil fuels for 2013 and the length of time (t_L) the reserves would last if production were to continue at the 2013 rate [7].

Fossil fuel type	World reserve	t_L
Oil	1687.9×10^9	53.3
Natural gas	$185.7\times10^{12}m^3$	55.1
Coal	0.891531×10^{12}tonnes	113

increased per capita demand for energy-using goods and services. Further, the key points of the summary by [5] of world's energy consumption trends between 1990 and 2005 include that the global final energy use increased by 23%. The International Energy Agency (IEA) have projected a rise in oil demand from 76 million barrels per day in year 2000 to 94 million barrels per day in 2010 [6].

The emergent industrial revolution about three hundred years ago in Europe has enveloped almost the whole world and has evolved to modern-day high energy consumption in technological manufacture and usage of the machines like machine tools, computers, mobile phones, cars, trains, planes, turbines, miniature power plants, solar panels, satellites, construction and mining machinery, military vehicles and ammunitions, cookers and the list goes on and on. The rapid advancement of technological development in the twentieth century was necessary to cope with the rapidly rising energy need of the rapidly rising population of progressively more modern and more per capita-energy-consuming humans. The scale of energy need was conveniently sustained by massive exploitation of the non-renewable fossil fuels. The non-renewable energy resources are finite and fast depleting because of exponentially increasing world energy demand [4]. The proven global reserves of major fossil fuels for 2013 and the length of time (t_L) the reserves would last if production were to continue at the 2013 rate are summarized in Table 1. The table highlights the finite and fast depleting nature of fossil fuels.

1.2. The Nigerian energy outlook

Nigeria is endowed with abundant primary energy resources. Crude oil, which is the most important of the resources was discovered in commercial quantities in 1956, produced from 1958 and made increasingly more important than the other sectors of Nigerian economy since early 1970s. As a result, gross domestic product (GDP) and external trade increasingly became dominated by crude oil; for example, crude oil accounted for 32.9% and 64.63% of the total external trade in 1970 and 2002 respectively and accounted for ***7.1%*** and ***40.6%*** of the GDP in 1970 and 2002 respectively [8]. Adaramola and Oyewola [9] have noted the report of the statistical bulletin for the year 2009 of the Organization of Petroleum Exporting Countries (OPEC) which gives the proven crude oil and natural gas reserves in Nigeria as 37.2 billion barrels and 5292 trillion standard cubic meters respectively. They also noted that the tar sand and coal reserves are estimated at about 30 billion barrels of oil equivalent and 639 million tonnes respectively. The Nigerian energy reserves, summarized from the Nigeria Renewable Energy Master Plan (2009) by Shaaban and Pentinrin [10], are shown alongside a more modern estimate of natural gas and crude oil reserves in Table 2.

A more recent estimation [7] gives the Nigerian proven oil and natural gas reserves for 2013 as 37.1×10^9barrels (t_L = 43.8 years) and $5.1\times10^{12}m^3$ (t_L > 100 years) respectively. Ojolo et al. [12] believe that if the undiscovered reserves are taken into account, the Nigerian crude oil would run out in the next 50 years and the proven natural gas reserves would run out in the next 115 years. The expected durations of these primary energy resources may be much shorter due to rising population and government efforts for economic growth and industrialization. The Energy Commission of Nigeria (ECN) has projected the trends of Nigerian energy demand based on four expected economic scenarios as measured by the total GDP. The four scenarios are GDP growth rates per annum of 7% (reference), 10% (high growth), 11.5% (optimistic) and 13% (optimistic). The projection is given graphically in Fig. 1(a). The duration that the sum of the reserves in Table 2 can sustain each of the energy demand levels in Fig. 1(a) is presented in Fig. 1(b) to highlight that energy reserves depletes fast with rise of energy demand. Alternative detailed discussion of the Nigerian energy economy covering the energy crises, the trends for energy demand, and depletion time of primary energy reserves can be found [13].

Table 2
Nigeria fossil fuel energy reserves.

Resource type	Reserves [10]		Reserves [11]	
	Natural units	Energy units (Btoe)	Natural units	Energy units (Btoe)
Natural gas	187 trillion SCF	4.19	180.1 trillion SCF	4.0354
Crude oil	36.22 billion barrels	5.03	37.1 billion barrels	5.1522
Tar sand	31 billion barrels equivalent	4.31	–	–
Coal and lignite	2.175 billion tonnes	1.52	–	–

1.3. Renewable energy as the sustainable remedy

In addition to the problem of finite and fast depleting nature of fossil fuel, emissions and effluents associated with its utilization are harmful to the environment. The carbon in fossil fuels has been locked up underground for several geological eras. This carbon gets released as CO_2 when burnt and pollutes the atmosphere. The CO_2 plays a negative climatic role by increasing absorption of terrestrial solar radiation and thus enhancing terrestrial release of the long-wave heat radiation that heats up the biosphere. This so-called green house effect has been the reason for melting of the polar ice and the concomitant rise in ocean levels among other harmful climatic changes. The global final energy use increase of 23% between 1990 and 2005 is associated with slightly higher rise (about 25%) in the associated CO_2 [5]. The year 2005 sector by sector proportioning of the total final energy consumption of 285 EJ and CO_2 emission of 21Gt by [5] shows that manufacturing holds the highest share thus reflecting higher percentage in CO_2 emission than the percentage of the manufacturing energy. This means that global dependence on fossil fuels only presents a bleak future. A study of Nigeria in isolation from the rest of the world suggests that GDP per capita and population have positive and significant impact on CO_2 emission [14]. The other green house gases associated with fossil fuel exploitation and usage are Methane, Sulphur oxides and nitrogen oxides. Usage of fossil fuels has additional demerits of release of particulate pollutants like smoke that are harmful to health and reduce visibility.

Development based on fossil fuels is basically unsustainable. There is therefore a call for sustainable development based on renewable energy sources. This call is widespread as apparent in a number of international and United Nations declarations that include the following; (1) the Earth Summit of 1992 which pledges to stabilize greenhouse-gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system, (2) the Kyoto protocol of 1997 which commits its Parties by setting internationally binding emission reduction targets under the principle of common but differentiated responsibilities, (3) the Copenhagen Accord of 2009 which sets the long-term goal of limiting the maximum global average temperature increase to no more than 2 degrees Celsius above the pre-industrial levels, and (4) the recent Paris Agreement of 2015 (negotiated at the COP21) which sets to limit the global average temperature to well below 2 °C above the pre-industrial