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Research paper

Biomass resources assessment and bioenergy generation for a clean and sustainable development in Cameroon

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ABSTRACT

Cameroon is a central African country located at the bottom of the Gulf of Guinea. It has huge forest resources and over 70% of active population is employed in agriculture, fishery and livestock. Therefore, a lot of residues are generated from activities and most of them are not used for energy purpose. The goal of this paper is threefold: first, quantifying and assessing the energy potential of these residues; second, investigating the corresponding conversion systems; and third, analyzing the importance of biomass as a source of energy and its potential contribution to sustainable development of the country. Four biomass sources are considered in the study: forest residues, agricultural crop residues, animal manure and Municipal Solid Wastes (MSW). The potential of each source is estimated for the base year 2012. Our estimation shows that animal manure and organic fraction of MSW can produce almost 1 km^3 of biogas annually. Also, the total potential of electricity generation from all the sources is estimated to be about 67.5 $TWh.y^{-1}$, representing approximately twelve times the Cameroon's total electric production of 2010; implying that biomass sources could significantly contribute towards meeting the future energy requirement of the country. Depending on the type and quantity of biomass source, desired final energy, environmental impact and economic conditions, the conversion of biomass into energy can be achieved by thermo-chemical and biological conversion systems that are currently at different stages of research, development, demonstration and commercialization.

1. Introduction

Nowadays, supplying modern energy services to more than ten million of Cameroonians who still lack access to electricity and cook with traditional solid fuels is a major concern. Bioenergy can meet many times the present and future energy demand, so their potential is enormous. Indeed, access to energy is a pre-requisite of economic and social development because virtually, any productive activity needs energy as an input [1]. It increases employment opportunities, supports the provision of social services, and generally promotes human development [2]. Basic levels of electricity access (e.g. lighting, communication, healthcare, and education) provide substantial benefits for communities and households. Fossil fuels sources such as oil, coal, and natural gas have proven to be highly effective drivers of economic growth. However, an ever growing usage of fossil fuels confronts a certain threat to energy and environmental security of the planet [3].

Until now, despite its huge renewables potential, energy demand in Cameroon remains largely unsatisfied [4]. Of the 13 104 identified localities in the last census, only 2400 (about 18%) are electrified. Access to modern energy is very low, on a national average rate of 15% for electricity and 18% for domestic gas. Access to electricity is less than 10% in rural areas against about 50% in urban areas, which is a significant threat to the economy and peoples wellbeing [5]. The widespread issue of using fossil fuels and inefficient traditional biomass fuel for cooking requires urgent solutions to mitigate serious health and environmental issues (i.e. indoor air pollution, deforestation, acid rains, fossil fuels exhaustion, global warming and climate change). In Cameroon, about 19% of electricity generated comes from the combustion of fossil fuels in thermal power plants and more than 80% of populations still rely on traditional biomass [5,6]. This combustion pollutes the atmosphere and emits GHG [7].

Despite the availability of biomass resources in the country, much still has to be done in the economy to upgrade the living standard of the people. Persistent fluctuations (with an underlying trend of cost increases) in the prices of fuel, kilowatt-hour of electricity, food and other basic necessities have deteriorated the living conditions of the populations. In addition, domestic cooking gas is very expensive and cannot be afforded by most families on a regular basis; hence bioenergy should be promoted as an alternative solution. Particularly in rural areas, the lack of road infrastructure has made it almost impossible to access

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Abbreviations and units

AH	Annual amount harvest of the crop or product (t)
ARG	Amount of a residue generated annually ($t.y^{-1}$)
BY	Biogas yield per unit of VS
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
C_v	Current value
DM	Amount of dry matter (kg/head/day)
$EP_{residue}$	Total energy potential of residue ($J.y^{-1}$)
EP_{waste}	Energy potential of the biogas recoverable ($MJ.y^{-1}$)
EUF	Energy use factor (dimensionless)
F_v	Future (or projected) value
GDP	Gross Domestic Product
GHG	Green House Gas
h	Logging residue generation ratio
H	Logging residue recoverability fraction
IRW	Annual consumption of industrial round wood
LFG	Landfill Gas
LHV	Lower heating value ($MJ.kg^{-1}$)
LHV_{biogas}	Lower heating value of biogas ($MJ.m^{-3}$)
$LHV_{residue}$	Lower heating value of residue ($J.t^{-1}$)
MSW	Municipal Solid Wastes
Mt	Million tonne
n	Projected number of years
Nh	Number of animal (heads)
NIS	National Institute of Statistics
p	Wood processing residue generation ratio
P	Wood processing residue recoverability fraction
Q_{HR}	Energy potential of logging residues
Q_{PR}	Energy potential of wood processing residues
r	Growth rate
R	Recoverable fraction (dimensionless)
RETs	Renewable Energy Technologies
RPR	Residue production ratio (kg or tonne of residue per kg or tonne of product)
SAF	Surplus availability factor (dimensionless)
VS	Volatile solids (% of DM)
W_i	Annual production of round wood of category *i*

modern energy services.

Our study provides the maximum theoretical potential of energy that can be recovered if adequate waste to energy plants could be built, and use is made of the potential landfill gas for energy production. After the introductory Section, the ensuing Section presents the general methodology conducting the work. Section 3 summarizes the key findings while Section 4 presents an overview of biomass conversion technologies. Section 5 analyses the contribution of bioenergy to sustainable development of Cameroon while the last Section followed by the references concludes the study.

2. Methodology and data

This section presents the general approach used to assess the potential of biomass resources considered in this paper; these can be classified into: (i) woody biomass, (ii) agricultural crop residues, (iii) animal manure, and (iv) municipal solid wastes (MSW). Annual productions of crops, woody biomass, livestock and human population data for the base year 2012 were mainly obtained from statistical handbook of National Institute of Statistics (NIS) [8] of Cameroon (2013) edition.

2.1. Woody biomass

Forests residues are generally classified as logging residues and wood processing residues. Logging residues are generated during the harvesting operations and include stumps, roots, branches, and sawdust. Wood processing residues arise from saw-mill and plywood processing operations and include discarded logs, barks, saw-dust and offcuts [9,10].

Logging operations generating logging residues usually take place in remote locations making it difficult to collect the residues for energy utilization. There are also technical, ecological and environmental considerations that limit the quantities of forest residues that can be practically recoverable for energy [9]. The amount of logging residues that can be practically harvested is estimated using logging residue recoverability fractions. This is the fraction of the generated logging residues that can be realistically harvested for energy application and is estimated to be about 25% in developing countries [11]. Residues are also generated during processing of wood and are estimated using wood processing residue recoverability fraction. Available literature indicates that up to 42% of wood processing residues can be recovered from sawmills in developing countries for energy application [11]. The procedure for estimating the energy potential of forest residues proposed by Smeets and Faaij [12] was used. The energy potential of logging residues was calculated using equation:

$$Q_{HR} = \sum_{i=1}^{n} (W_i \times h \times H \times LHV) \tag{1}$$

Where, Q_{HR} is the energy potential of logging residues and W_i is the annual production of round wood of category *i*. Factors *h* and *H* are respectively, logging residue generation ratio and logging residue recoverability fraction. Factor *h* was assumed to be 0.6 [12,13] and *H* is estimated to be about 25% in developing countries [11]. The energy potential of wood processing residue generated was estimated using equation:

$$Q_{PR} = IRW \times p \times P \times LHV \tag{2}$$

Where, Q_{PR} is the energy potential of wood processing residues and IRW annual consumption of industrial round wood. Factors *p* and *P* are respectively, wood processing residue generation ratio and wood processing residue recoverability fraction. Factor *p* is the fraction of logs that is converted into residues during the processing of wood and depends on the efficiency of sawmills. We used a *p* value for developing countries of 70% [13]. Factor *P* is estimated to be about 42% in developing countries [11].

In natural forests, a significant amount of biomass, from non-marketable felled trees, is left on the ground. The exploitation required to make paths, develop means of access and harvest commercial timber leaves a significant amount of biomass. This abandoned biomass is approximately 70% of harvested logs [14]. In addition to biomass that has been left on the forest floor, sawmill residue can be found, notably scraps in the form of flitches (non-marketable short strips of varying sizes).

Cameroon produced an estimated 11.4 Mt of fuelwood, 214 kt of charcoal and 301 kt of sawdust and wood chips in 2009 [14]. The main consumers of fuelwood are households (especially, those of rural area), of which 82.6% use wood in the form of fuelwood, charcoal, sawdust or chips, as their primary and sometimes unique cooking energy source.

2.2. Agricultural crop residues

In general, crop residues are classified as primary and secondary residues. Primary residues are generated during harvesting and primary processing of the crops in farms and crop plantations [9]. The amount of primary residues that can be realistically harnessed is estimated using recoverable fraction of biomass. The actual values of recoverable