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Forestry Biomass as Energy Source in Brazil

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Abstract

The demand for renewable energy is growing around the world. The participation of biomass, for the direct combustion of wood, charcoal, agricultural residues, among others, becomes more expressive. This opinion paper reports on the use of biomass as an energy source in Brazil, particularly the *Eucalyptus* genus.

Keywords: Renewable energy; Combustion; Chemical and energetic characterization

Introduction

Planet Earth has a large potential for energy that can be obtained from renewable sources, including wind, solar, hydro and biomass sources [1]. These sources play an increasing role in the mitigation of greenhouse gas emissions and provide an increasing fraction of primary energy in the world. Renewable sources are expected to significantly increase their share of global primary energy by 2050 [2].

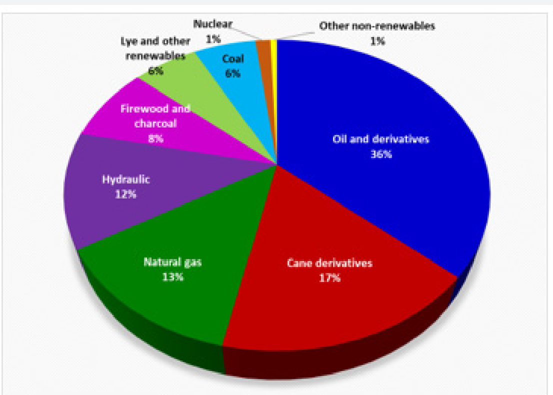

Figure 1: Brazilian Energy Consumption Matrix. Adapted from [5].

An energy source is considered as renewable when the natural conditions allow its replacement in the short term [3] and are derived directly or indirectly from solar energy [4]. Non-renewable energy sources are not restored by nature in a period compatible with its consumption [3]. In general, they are widespread technology, but have a high environmental impact. It is noteworthy that many industrial activities are dependent on fossil fuels, and those are exhausting and highly polluting sources of energy. Therefore, investments in renewable energy sources are indispensable. Renewable sources account for about 14% of the world's generated energy. Brazil's energy matrix differs from the world average, although energy consumption from non-renewable sources is larger than renewable energy. Firewood and charcoal, hydraulic, sugarcane and other renewable derivatives, totalize 42.9%, close to half of the Brazilian energy consumption matrix (Figure 1) [5].

Biomass is an important source of energy in Brazil, as it is very abundant. It is an alternative source of energy that offers significant economic and environmental gains, as it contributes to reducing dependence on petroleum derived fuels [6]. According to the principles of sustainable development, the use of biomass for energy is recognized as a mitigation measure of global warming, as it replaces fossil fuels and decreases the emission of greenhouse gases [7].

Biomass is distinguished using several raw materials, with different technologies for processing and transformation, playing a fundamental role in the environmental, energy and socioeconomic context [8,9].

In the world context, concerning the raw materials used as biomass supply sources, firewood predominates as a source of energy, followed by wood derivatives, such as charcoal and forest residues [10]. However, in Brazil, the use of sugarcane by-products (40%), such as anhydrous and hydrated alcohol, as well as sugarcane bagasse, followed using firewood and charcoal (19%) is predominant [5].

Biomass energy can be obtained from biochemical, thermochemical and physicochemical processes. Currently, there are numerous technologies for this conversion, resulting in a diversity of products that can be solid, liquid and gaseous. According to Patel et al. [11], among the thermochemical processes, the three main technologies used are pyrolysis, gasification and direct combustion.

Eucalyptus Genus

The *Eucalyptus* genus, belonging to the *Myrtaceae* family, which occurs naturally in Australia, has around 700 species adapted to the most diverse climatic and soil conditions [12]. Due to its relevant amplitude of edaphoclimatic adaptation and to its large number of species, the eucalyptus culture implanted in Brazil has emerged as a promising alternative for multiple use of commercial forest plantations [13]. Figure 2 shows an image of *Eucalyptus* trees.

Figure 2: *Eucalyptus* trees.[5].

The Brazilian forest sector has grown in recent years, from the application of new technologies, such as the genetic improvement of forest species, in addition to environmental factors favorable to forestry. This improvement made Brazil stand out in the forest productivity of planted species [14].

In the year 2015, the total area of trees planted in Brazil was 7.8 million hectares. Of these, 5.6 million hectares were occupied by *Eucalyptus* plantations. The largest planted areas are in the states of Minas Gerais (24%), São Paulo (17%) and Mato Grosso do Sul (15%) [15].

The main species cultivated in Brazil are *Eucalyptus grandis*, *Eucalyptus urophylla* and *Eucalyptus camaldulensis* [15]. The most widespread hybrids in Brazil are from the cross *Eucalyptus urophylla x Eucalyptus grandis*. According to Gonçalez et al. [16], the objective of the crossbreeding between these two species is to obtain plants with high resistance to water deficit (characteristic of *E. urophylla*) and high potential of rooting and growth in the field (characteristics of *E. grandis*). Combining the inherent characteristics of the two species, we obtain a hybrid with good characteristics adaptive to the most different conditions.

When selecting the genetic material to use, besides the final use of the wood, the soil and climatic requirements must be considered, which depend on the technological characteristics [17].

Wood Combustion (Direct Burning)

Combustion is defined as a rapid chemical combination of oxygen with a combustible material, being an oxidation reaction. For energy purposes, direct combustion occurs mainly in stoves (cooking of food), ovens (metallurgy, for example) and boilers (like steam generation). Although very practical and sometimes convenient, the process of direct combustion is usually very inefficient. Other problems are the high humidity of the fuel material (20% or more in the case of firewood) and the low energy density of the fuel (firewood, straw, residues etc.) which makes it difficult to store and transport [18].

The combustion of wood is a complex process consisting of a sequence of homogeneous and heterogeneous reactions. The procedure takes place in six consecutive well defined stages: drying, volatile emission, ignition of volatiles, burning of volatiles in flame, extinction of the flame of volatiles and combustion of carbon residue [19].

The reaction for combustion of wood with air can be presented as follows:

$$Wood + air = \underbrace{CO_2 + SO_2 + H_2O}_{1} + \underbrace{N_2 + O_2}_{2} + \underbrace{CO + H_2 + CH_2 + soot}_{3} + \underbrace{ashes}_{4}$$

In which,

1 – are products of complete oxidation: CO_2, SO_2, H_2O. The sulfur content of the wood is always low, its value being negligible;

2 – Excess air ($N_2 + O_2$) and likely the moisture of the fuel and air;

3 – Gas products ($CO + H_2 + CH_4$) and solids (soot) of incomplete combustion;

4 – Non-combustible mineral fraction of biomass (ashes).

According to Brutti et al. [20], among the main chemical reactions of wood combustion, are the combustion of carbon and hydrogen, according to equations:

a) $C + O_2 \rightarrow CO_2$ + heat of reaction → carbon combustion;

b) $2H_2 + O_2 \rightarrow 2H_2O$ + heat of reaction → hydrogen combustion;

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In addition to the use of biomass as a solid fuel for the energy conversion through direct burning, pyrolysis and gasification also appear as differentials for better handling and burning of fuel [21]. The gas resulting from the gasification process can be used in the generation of electric energy by means of internal combustion engines, boilers and steam generators for steam turbines [22].

Properties of wood that affect combustion (direct burning)

The quality of wood depends on the combination of physical, chemical, anatomical and mechanical characteristics of a tree or its parts that allow to define its best use. According to Vital et al. [23], wood characteristics, such as moisture, basic density, biomass dry mass and lignin mass, structural and elemental chemical composition, calorific value, volatile matter content, ash and fixed carbon are properties generally used in the determination of their energetic potential.

The energetic evaluation is carried out with the purpose of promoting the classification of superior genotypes, since they are relevant for decision making in the implementation of reforestation projects aiming at the use of biomass as an energy source. The attributes of wood serve to promote differentiation between genetic materials [24,25].

In addition to the genotype, several factors can affect wood properties. The conditions of the site, age, plant spacing, fertilization, silvicultural practices are known. It is necessary to know the interrelationships of these factors so that this raw material can be improved, since these factors cause considerable physiological changes in the tree and, consequently, alter its energetic properties [26].

Thus, the main properties of the wood aimed at energetic use are high basic density, high calorific value; high lignin content; low ash content and low humidity [27].

The basic density is considered as one of the most important parameters among the physical properties of wood, since it affects most of the other properties. Its effects, however, are interactive and difficult to assess alone [28]. The advantage of using wood with high basic density is to store higher energy content in a smaller volume, which also contributes to the increase of its energetic density [25,29].

The calorific value is an excellent parameter for evaluating the energy potential of biomass fuels [30]. Woods with high calorific value have the largest amount of energy available in the form of heat. However, it is necessary that the wood is previously dry, since much of the energy produced during the thermochemical process is directed to evaporate the free water present, reducing the energy potential [31].

Moisture is an important factor that must be considered in any biomass aimed at combustion, and it is always preferable to use wood with the lowest possible humidity [23]. The main effects of high humidity on wood aimed for energy are the reduction of useful calorific value, reduction of the temperature in the combustion chamber with consequent loss of equipment efficiency and productivity, increase in biomass consumption and atmospheric emissions [32].

Another factor relevant to energy use is energy density, defined as the amount of useful energy released by a fuel per unit volume when subjected to combustion. The knowledge of the energy density of a given biomass allows to evaluate its potential for energy generation, considering that loads with higher energy densities contribute positively to the optimization of transport and reduction of costs.

The chemical composition of the material is also very relevant for energy use, because when thermally degraded, wood undergoes a transformation process, in which all its primary components (cellulose, hemicellulose and lignin) are drastically altered, which affects the energetic properties [33].

For the energy production, it is desirable that the wood presents high levels of carbon and hydrogen and low levels of oxygen due to the correlations between these elementary components and the calorific value. High concentrations of oxygen in the biomass favor a decrease in the calorific value [34], while high levels of carbon and hydrogen contribute to an increase in the calorific value of biomass fuels [35].

According to Bufalino et al. [36], the extractives can be determinant in the choice of the wood use, because, besides influencing the organoleptic properties, they can affect several other properties, such as density, permeability, retractability and energetic value.

The wood extractives contain several chemical compounds, but they do not constitute the essential wood structure, for example, polyphenols, oils, fats, resins, starch and waxes. As its name says, it refers to what can be extracted by some process. The phenolic origin of some extractives may act to increase the calorific value of wood, due to the presence of high carbon content [37].

The immediate chemical analysis of an energy source provides the contents of volatile materials, fixed carbon and ash (residual material), which influence the burning properties of the fuel, since the volatile constituents burn rapidly and the fixed carbon burns more slowly [38].

The higher the ratio volatile materials/fixed carbon the greater the intensity of combustion. Volatile materials dissipate rapidly during combustion: the higher the volatile material content, the lower the ignition temperature of the biomass. Although biomass ignites faster, it will have reduced burning time, which contributes to the reduction of energy efficiency [39].

The content of volatile materials and fixed carbon is directly related to the calorific value, increasing the time of burning of the energy source. The volatile materials and the fixed carbon content of the wood are dependent on each other, since the percentage of ashes in their constitution is generally low [28,40].

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Ashes or minerals are inorganic constituents that do not participate in the combustion process of the biomass, representing about 1% of the dry mass of wood. A high percentage of ash is harmful to the energetic purpose. Minerals are undesirable, therefore, a residue is formed, since they not degraded in the thermochemical process; consequently, they contribute to the reduction of the calorific value.

One of the important characteristics to select biomass that presents/displays energetic potential is its thermal stability. Techniques such as thermogravimetric analysis (TGA) make it possible to understand the decomposition of biomass as a function of heating in thermochemical conversion processes [41]. The thermogravimetric analysis consists of analyzing the variation of the mass of samples in a system under the control of temperature and atmosphere, which can vary both with temperature and time, allowing to obtain information on composition, thermal stability, as well on the ranges of temperatures at which decomposition is more pronounced [42].

The evaluation of the energetic properties and efficiency of the material allows to obtain more competitive materials compared to other sources of energy. The energy density is an important parameter to be determined, since it influences the transport of the material, the amount of biomass consumed in the burning process and the size of the biomass storage silo of a machine, when the amount of energy required is associated with the characteristics of the material [43-45].

Conclusion

Waste Wood biomass, particularly the *Eucalyptus* genus, have are a good energy source in Brazil. The wood must have certain properties in order to show efficiency in the direct burning (combustion) process.

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