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THE BIOMASS OF CONIFEROUS PLANT SPECIES AS A BIOENERGY RESOURCE – MINI REVIEW

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Abstract: *The usage of biomass from coniferous species is one of the most sustainable methods for using renewable energy sources. Forest wood or biomass from the essential oil industry can be used as an alternative energy source. The conversion of biomass into an energy source includes mainly thermal methods (pyrolysis, gasification, combustion). Coniferous biomass can be transformed into extrudates, pellets, or composite in the form of solid fuels during conversion methods. The application of the techniques of the circular economy through the use of coniferous biomass will contribute to the ecological and socio-economic indicators of Bulgaria. This review may focus on the potential applications of biomass from the logging, wood processing, and essential oil industries, and mainly in the use of coniferous species.*

Keywords: *Bioenergy potential, Coniferous species, Alternative energy resources, Biofuels*

BIOENERGY POTENTIAL OF WOOD BIOMASS

The timber industry is generating the largest plant biomass source, although other sources, such as cereals, agricultural, urban, and industrial waste, are playing an increasingly important role in creating the energy balance. The gas formed during the decomposition of organic waste, with methane as the main component, is also a vital energy resource derived from biomass. Biofuels, bioenergy, and bioproducts are becoming increasingly popular as substitutes for fossil fuels. Their production is carried out by applying unique processes such as thermal distillation, and fermentation.

The Biomass Action Plan, emphasizing the main efforts of the Member States on development of available biomass resources, involves multiple waste products. However, its validation states that Europe can tackle its dependence on fossil fuels and energy imports by using biomass as a critical resource for ensuring sustainable energy and security of energy supply in Europe.

In the last few years, the European Union has attached great importance to two aspects of energy. One is "independence" (in terms of energy sources), and the second is reducing pollution (greenhouse gases, emissions). Both main energy goals could be implemented using renewable energy sources, such as biological materials.

Forests are one of the planet's main natural energy reservoirs (Bustamante et al., 2014), regulating the carbon cycle and climate change. The main problems related to the use of forest biomass for energy purposes are related to transportation from felling sites to processing plants. Most often, this is biomass collected in the clearings, and due to its volumetric nature, its transport is difficult (Puig-Arnavat et al., 2016), due to which up to 75% of it remains in the field. Depending on the proximity and conditions for carrying out transportation activities (road infrastructure), up to 15% of the wood biomass from the felling areas is used by the local population as an energy source (solid fuel). In countries where plant biomass is subject to organized transport from felling sites to fuel plants or the essential oil industry, it provides an average between 8 - 15% of energy needs (Kaliyan and Morey, 2009). It is due to the low bulk density and different moisture values, which create many difficulties for handling, transport, and storage (Nunes et al., 2014; Picchio et al., 2012; Puig-Arnavat et al., 2016; Rentizelas et al. al., 2009; Stelte et al., 2012; Verna et al., 2009). For this purpose, it is necessary to carry out many technological measures related to removing critical points when using biomass from coniferous species. Therefore, compaction and standardization of biomass have been applied to be used as a source of biofuel with a specific energy density (Sánchez et al., 2015).

In order to ensure the use of plant parts of coniferous and deciduous species of various compositions and properties, it is necessary to assess their energy density based on specific physical indicators. When using sawdust to produce pellets, it is often required to use a raw material with different moisture, complicating the matrix sequence in extrusion. For this reason, additional humidification is necessary to regulate the degree of moisture in the starting base (Ahn et al., 2014; Križan et al., 2015; Nizamuddin et al., 2016; Toscano et al., 2013). When using waste products from coniferous species (needles), lower-quality biomass characteristics for its use as an energy source have been reported (Lerma-Arce et al., 2017). It is primarily due to the higher levels of minerals in the branches that fall into the biomass.

The use of coniferous and deciduous biomass from the timber, wood processing, and essential oil industries is associated with generating a large proportion of minerals (Agar et al., 2018). According to some researchers with great interest in the application, as an energy bioresource are shrub species (Bados et al., 2017), which have a shorter growing season and at the same time provide good quantitative and qualitative characteristics of biomass.

The use of plant biomass and the involvement of additional binders improved the knowledge of the circular economy's aspects. The physical and chemical processes of interaction between the individual particles in the system are the subject of numerous analyses to understand the biomass's technological and energy characteristics. It can be achieved with the help of empirical equations in order to predict the functional interactions between the individual physical and mechanical characteristics of the biomass used.

"Energy Roadmap 2050" outlines the different scenarios for the sector's development, recognizing that due to the significant investments needed to replace obsolete infrastructure, it is essential for individual investors to have security in the direction they will continue to develop and regulates the sector. The scenarios for decarbonization of the energy sector proposed in the Roadmap indicated a particular share of energy from renewable sources (about 30% by 2030). The main percentage of wood biomass comes from residues from felling - roots, branches, tops, leaves, and needles (Fig. 1).

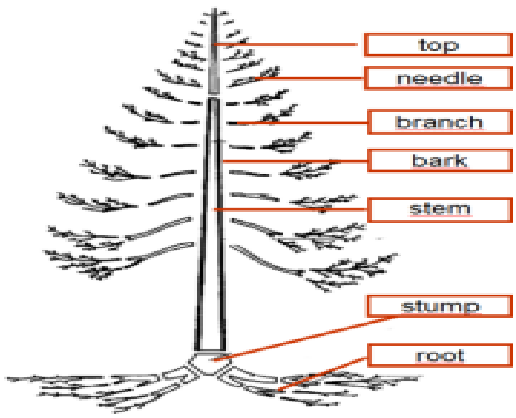

Fig. 1. Coniferous biomass sources (AEA, 2011)

The ratios between the usable and non-usable parts of the biomass differ, making it challenging to prepare a plan for the use of biomass. Primarily, 52% of the total amount of biomass from coniferous species is in the stem, and the remains as stumps are about 21 - 26%. Residues from felling (top, branches) generated on average between 16 and 18% and bark from trunks up to 8% (Sánchez et al., 2015).

The National Action Plan for Energy from Renewable Sources of 2010 states that "biomass is a renewable source with the greatest potential in Bulgaria." It lists biomass as the primary source of renewable energy with a share of 34%. This plan was subsequently developed under the Model for National Renewable Energy Action Plans.

CONIFEROUS BIOMASS AND ITS APPLICATION AS A BIOENERGY RESOURCE

Biomass is the fourth largest energy source globally, after coal, oil, and natural gas. Among energy biomass, wood species are the primary source, with total wood fuel needs of about 70% in rural areas and about 35% in urban areas. In recent years, there has been an increasing interest in artificial ecosystems, which include coniferous species. Their ecological and aesthetic participation increased their natural habitat and created conditions for their broader use (Lehtimäki & Nurmi, 2011). The application of afforestation measured in different terrains also changes the forest ecosystems and created conditions for changing biodiversity. On the other hand, the increasing coniferous species share made them valuable source in the biorefinery, bioenergy, and biofuels processing (Križan et al., 2015).

The primary way to use coniferous biomass as an alternative bioenergy source is its processing in the form of electricity through its joint combustion with the help of coal or pellets. Bioconversion and gasification methods can also be used (Bustamante et al., 2014). Modern applications of bioenergy have been overgrowing over the last decade. These include mainly heating systems in buildings, pellet stoves, large-scale industrial use of bioenergy in the processing industry (14%), transport (9%), and electricity for district heating (8%). The use of biomass to produce biological chemicals and polymers added about 1% of the generated biomass (Saygin et al., 2014).

The usefulness of coniferous biomass is related to paper production (up to 60%), but all residual waste products have many advantages over other plant biomass. Coniferous biomass requires smaller amounts of additional materials for gluing as the wood part (stem) has a higher density than some other plant biomass (reed roots, wheat straw, and others). The higher density of coniferous biomass reduces transport costs and also allows its year-round applicability. An essential condition for the inclusion of coniferous biomass in bioenergy resources is the relatively low ash content and well-known genetic and silvicultural cultivation methods, increasing populations and wood yield (Nunes et al., 2014).

The more efficient conversion of soluble carbohydrates (mainly hemicellulose) and lignin into cellulosic liquids, and hence into electricity through gasification methods, is an important lever in managing the principles of sustainability when using biomass. In this way, higher amounts of other chemicals, including liquid fuels, can be generated (Van der Stelt et al., 2011).

Despite the great potential for electricity and liquid fuel production from coniferous species biomass, it is mainly converted into energy through many technological operations. It is often subjected to combustion in coal combustion plants for energy production, production of wood pellets (briquettes), wood gasifiers for generating gas, electricity and liquid fuels, other chemicals, and bioconversion plants (Sánchez et al., 2015).

The conversion of coniferous wood biomass into pellets increases the bulk density and thus reduces the costs of processing, transport, and storage (Gilbert et al., 2009; Kaliyan and Money, 2010; Stasiak et al., 2017; Van der Stelt et al., 2011; Zhou et al., 2016). The value of moisture in the source biomass is important for converting biomass into pellets (Calderon et al., 2017). Coniferous biomass is processed by pressing a homogeneous wood powder mass through small holes (6 - 9 mm) in a matrix sequence (matrix). High pressure raises the temperature of the dried biomass and increases the plasticizing properties of lignin, which in turn creates a consistent partial bonding. It provides a certain hardness of the resulting pellets, which has a critical energy adaptation to fuel quality. The obtained pellets are used for combustion in installations (stoves, furnaces) for burning solid fuels. Pelletizing and briquetting technologies are processes in which the previously crushed plant biomass under the action of pressure (from 10 to 20 MPa) is transformed into pellets or briquettes with a compact shape and high density, which are suitable for further manipulation and use. The technological lines include grinding, sieving, drying to a minimum set of moisture, pressing, cooling, storage and packaging. Bio-pellets have a cylindrical shape with a 6-10 mm diameter and a length of 10-30 mm. In addition to reducing transport costs, it also helps to fully automate the combustion process, whether for single-family homes or large heating and power plants. For these reasons, there has been a significant increase in the production of bio-pellets over the last decade in various EU member states (Bados et al., 2017).

Under other conditions, coniferous biomass can be used in co-incineration with coal (briquettes). It can be done by replacing coal (up to 20% of the amount) or be included in the composition of fuel mixtures for pellets (on average between 35 - 40%), which reduces harmful emissions from burning coal or other synthetic mixtures in production of some types of solid fuels. In order to use coniferous biomass, it is necessary to dry and grind it into fine particles before including it in the pellet or coal matrix. In this case, biomass can be used more often in households, as industrial energy requires high calorific value and larger amounts of biomass, which further complicates the process's technological sequence (Kaliyan et al., 2009).

Bio-briquettes technology is another important process. The briquettes differ in size and are much larger as they resemble chopped firewood. These dimensions make them unsuitable for automated combustion in small combustion plants. The heat released during combustion can be used both directly and to produce steam to produce electricity from reciprocating engines or turbines. A common practice in burning biomass is to mix it with organic fuels or household waste. The ash from the combustion of pure biomass is used to fertilize the soil (Beringer & Schaphoff, 2011).

Coniferous biomass can be used as an energy source in gas production through ethanol (so-called bioconversion). The conversion of coniferous biomass by converting lignocellulosic materials into ethanol will increase the alternatives for the recovery of coniferous waste. Bioconversion methods are based on a series of technological operations related to pre-treatment (grinding), saccharification, fermentation, and distillation. Pre-shredding (grinding) of coniferous biomass increases the active area of the material (biomass). Thus, most hemicelluloses will be converted into monosaccharides in order to diffuse through the fibrous cellulose and lignin structure. The bioconversion increases the porosity of the biomass, which makes it more easily accessible to the action of cellulases. The treatment of cellulose and lignin with cellulases completes the bioconversion method. The sugars thus formed are broken down by yeast (fermentation), and the ethanol formed is concentrated by distillation (AEA, 2011).

It is necessary to reduce the total share of the wood waste (both from the logging, wood processing, and essential oil industry) for its efficient use. About 47 to 50% of the coniferous species biomass falls into the residual lignocellulosic products in Bulgaria. In coniferous species, the main log is mainly used, and the adjacent branches and crown fall into the biomass group. It represents a substantial raw material potential, which is not widely used in Bulgaria (Argus Media, 2015).

Although it seems perfect at first glance, investing in green energy production through the utilization of waste biomass has some disadvantages. Operators of installations for the incineration of waste biomass (from household waste, wood waste, etc.) and the production of electricity and steam often face problems related to the high cost of raw materials. Despite the already achieved higher efficiency of this installation, providing raw material at affordable prices and transporting it to the facility can be so expensive that it makes the whole endeavor meaningless. To produce one kilowatt of electricity, a biomass plant needs 1.5 to 2 kg of biomass. In most cases, the raw material price is not high, but often the transport costs significantly increase its cost. For the cost-effective operation of an installation for combustion or gasification of biomass, the raw material price should not exceed 60 BGN per ton. It is achievable when the raw material is delivered from no more than 30 km.

CONCLUSIONS

The use of coniferous biomass as a model of bioenergy resource ensures sustainable development of the bioenergy industry. Biomass processing and recovery technologies are an approach to moving the economy towards a more sustainable base. Biomass is an internal energy source and can significantly reduce dependence on imports of solid and liquid fuels. The widespread distribution of wood biomass and its involvement in energy production offers local, regional, and national energy independence opportunities. Through its use and adequate application, the economic performance of the regions can be improved through the use of agricultural residues, which will stimulate rural development in the fields of farming, forestry, and related service industries by creating new products and markets.

On the other hand, the use of renewable energy sources will improve many environmental indicators. Bioenergy resources can regulate nitrogen dioxide emissions, sulfur dioxide, greenhouse gas levels, soil conversion, soil erosion, carbon subsidies, and water resources in the region.

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