Analysis of Energy Value of Some Tree Species

Ljupčo Nestorovski, Mitko Nacevski, Zdravko Trajanov, Pande Trajkov

Abstract – Nacrtak

*This paper presents the investigation of five (5) characteristic forestry species (*Fagus ×moesiaca *(K. Malý) Czeczott,* Quercus petreaea *(Matt.) Liebl.,* Quercus pubescens *Willd.,* Carpinus orientalis *Mill.,* Pinus nigra *J. F. Arnold) that cover the major part of the total forest area, and account for around 70% of the total forest reserve in the Republic of Macedonia. These forestry species are also very common in other regional forests.*

The purpose of this investigation is to establish the energy value of these species at different trunk height and different parts of the tree (wood, bark) in order to determine the differences due to different cell structure.

The material for this investigation was collected in different regions of the Republic of Macedonia, and for each investigated species the material was collected at two different locations with different ecological conditions. Wood density parameters of tree species were also established for local conditions, and combined with the available sources from other countries. The article presents a harmonized approach to estimate the potential for energy production by different species, eliminating different ecological growing conditions.

The results of the investigation show that the conifers have higher energy value than broadleaved species, and that this difference is significant. There were no significant differences in the energy potential between different parts of the tree (1.3 and 5.3 m, branches), except for the bark. The energy potential of the selected species is significant, and with certain technological changes in the phase of forest utilization and in the process of transformation of wood into other kinds of energy (heat, electric, etc.), it is a significant basis for the improvement of the energy balance of the Republic of Macedonia, along with the use of the alternative, renewable and environmentally friendly energy.

Keywords: biomass, calorific value, alternative energy

1. Introduction – *Uvod*

The availability of energy is becoming a major issue since the demand for energy is growing every day. Concerning that fact, as well as the fact that the reserves of fossil fuels, such as oil coal and natural gas are limited, the world is turning towards discovering and using alternative, environmentally friendly, and renewable energy resources (Laponche et al. 1997).

One of these resources is forest biomass. Wood has been used as energy source since the early days. While in Western Europe the use of firewood decreased in favour of fossil fuels, large parts of the human population in South-Eastern Europe (SEE) still depend on wood as energy source. In the wake of Kyoto Protocol, the use of renewable resources for energy production has become a major issue in climate change mitigation (IPCC 2007). Forest biomass plays a major role in the biomass action plans of EU as well as in most national policies in Europe. This interest in increased utilization of forest biomass resources gave rise to questions on the potentials and limitations of forest ecosystems to produce biomass in a sustainable way. The importance of forests as a major source of global biodiversity has become well known during the recent decade, not only as a source for utilization of wood and other nonwood products, but also for providing a multitude of other ecosystem services and functions.

2. Objective of research – *Cilj istraživanja*

Forests contribute a substantial share of the energy balance in the Republic of Macedonia, where a significant share of the population heats with firewood or other biomass sources (75% of the heating energy is coming from firewood) (Kennedy 2004). According to the analysis of the World Bank, the Balkan region is, or will be very soon, in a position where the energy availability will be restricted due to the lack of investments in the energy sector (Kennedy 2004). The objective of this paper is to estimate the potential of biomass for energy production from forests and contribute to a more rational discussion about prospects and problems of forest biomass as an energy source. The data used in this paper come from the actual forest management plans and Statistical Yearbooks.

The Republic of Macedonia is a developing country in the south-east of Europe with a low level of energy resources and lack of capacities for energy production. It has no natural gas and fossil fuel resources, and has limited lignite reserves. Its total annual energy production is around 122 000 TJ, and the total annual energy consumption is around 218 000 TJ. 56% of the needs are covered by domestic resources, and 44% of the needs are met by import. The main energy production is from coal (around 70 000 TJ), followed by oil (around 40 000 TJ) and forest biomass (around 7 000 TJ).

About 85% of the electricity production is concentrated in two lignite fired thermal power plants (TPP), and the rest is covered by the hydro power plants. The electricity generating capacity is around 7 500 GW/year (Anon. 2009).

The goal of this investigation is to estimate and emphasize the energy potential of the forests, and to investigate the possibility to invest in this sector and produce energy in a modern, and economically and environmentally sustainable way.

3. Approach – *Pristup*

Forests in the Republic of Macedonia are mostly coppice, of low quality and of different species. The first task was to determine the tree species most commonly used for firewood production, as well as to estimate their energy potential. Also, since there are huge areas covered with artificially planted conifers, mostly with *Pinus nigra* J. F. Arnold, that are ready for sylvicultural measures (thinning), and there is no market demand for such assortments, to see whether it is possible to use them as energy wood. The next step was to determine different locations for each species, from where samples would be collected, in order to discover possible influence of ecological factors on wood energy potential. For each species, two locations with different ecological factors (altitude, exposition, soil and stand quality) were randomly selected and from each one of them, samples were collected to analyze the energy potential and wood density from different parts of the trees (1.3 m, 5.3 m, branches, bark and small branches) in order to investigate possible differences in potential and density.

The collected samples were then brought in the laboratory, where the energy potential and density of each species were established in absolutely dry condition, and statistically processed.

4. Results – *Rezultati*

4.1 Calorific values – *Kalorična vrijednost*

Calorific values of different species and different tree parts were established with calorimeter in the laboratory, where each species was chopped, dried and burned in the calorimeter. We also distinguished the differences in calorific values from different tree parts and different stand conditions, and concluded that there were no statistically significant differences within the same species (except for bark).

The results presented in Fig. 1 show that energy value of the wood is higher than energy value of the bark in broadleaved species, while the opposite applies to conifers.

The average calorific value of different species was established in MJ/kg (Table 1).

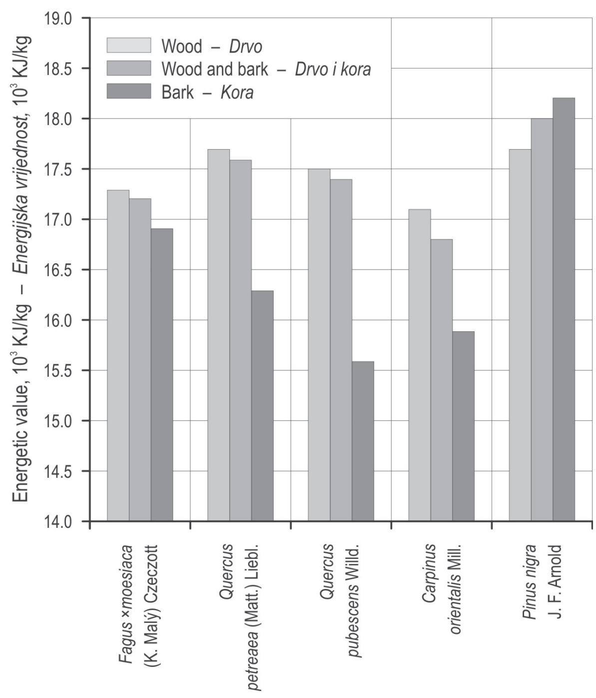

Fig. 1 Energy value of investigated tree species

Slika 1. *Energijske vrijednosti istraživanih vrsta drveća*

Table 1 Calorific value (t_0) of different tree species
Tablica 1. *Kalorične vrijednosti (t_0) različitih vrsta drveća*

Tree species – *Vrsta drveća*	Energy value, KJ/kg – *Energijska vrijednost*, KJ/kg		
	Average value *Srednja vrijednost*	Standard deviation *Standardna devijacija*	Coefficient of variation *Koeficijent varijacije*
Fagus × moesiaca (K. Malý) Czeczott	17 218.8	517.287	3.004
Quercus petreaea (Matt.) Liebl.	17 426.36	646.71	3.711
Quercus pubescens Willd.	16 971.78	909.257	5.358
Carpinus orientalis Mill.	16 688.14	756.3	4.532
Pinus nigra J. F. Arnold	17 924.70	446.081	2.489

The average calorific values are higher in coniferous (pine) then in broadleaved species. *Pinus nigra* J. F. Arnold has the highest calorific value, and *Carpinus orientalis* Mill the lowest.

4.2 Density – *Gustoća*

Wood density of different species was established based on the samples from the same trees and locations, in three different conditions: absolutely dry (0% moisture content), 12% moisture content and nominal density. These results were also compared with other previous investigations, and they were in the same range (Nacevski et al. 2002). The results are presented in Table 2.

Among the investigated species, *Quercus pubescens* Willd. has the highest density, and *Pinus nigra* J. F. Arnold the lowest.

4.3 Energy potential – *Energijski potencijal*

Wood assortments in the Republic of Macedonia are sold in cubic meters, so the potential of the investigated species was established in MW/m^3, as an equivalent of electricity, because it is the best way to present the comparison. The used ratio was 1 KWh = 3.6 MJ, or 3600 kJ (Nestorovski 2003, Chiani at al. 2010). *Quercus pubescens* Willd. has the highest energy content for 1 m^3, and *Pinus nigra* J. F. Arnold has the lowest. These differences are significant from species to species, having in mind their differences in wood density. The energy potential of the wood with 20% moisture content was established using the relation that for evaporating 1 kg of water, it is necessary to burn 2 kg of dry wood. The results are presented in Table 3 and Fig. 2.

The highest difference between energy potential in absolutely dry and 20% moisture content was established in beech and coniferous species, while other species were more stabile.

5. Conclusion – *Zaključak*

Energy potential of the selected species is considerable. *Pinus nigra* J. F. Arnold has the highest energy potential with 18 018.51 KJ/kg, followed by *Quercus petreaea* (Matt.) Liebl. with 17 646.89 KJ/kg, *Quercus pubescens* Willd. with 17 391.61 KJ/kg, *Fagus ×moesiaca*

Table 2 Wood density
Tablica 2. *Gustoća drva*

Tree species – *Vrsta drveća*	Density, kg/m^3 – *Gustoća*, kg/m^3		
	Moisture content 0% *Udio vode 0 %*	Moisture content 12% *Udio vode 12 %*	Nominal *Nominalna*
Fagus × moesiaca (K. Malý) Czeczott	703	726	645
Quercus petreaea (Matt.) Liebl.	782	800	736
Quercus pubescens Willd.	946	952	809
Carpinus orientalis Mill.	876	895	702
Pinus nigra J. F. Arnold	582	615	512

Table 3 Energy potential
Tablica 3. *Energijski potencijal*

Tree species – *Vrsta drveća*	Energy potential, MWh/m³ – *Energijski potencijal*, MWh/m³	
	Moisture content 0% *Udio vode 0 %*	Moisture content 20% Udio vode 20 %
Fagus × moesiaca (K. Malý) Czeczott	3.36	2.11
Quercus petreaea (Matt.) Liebl.	3.78	2.90
Quercus pubescens Willd.	4.45	4.16
Carpinus orientalis Mill.	4.06	3.40
Pinus nigra J. F. Arnold	2.90	1.50

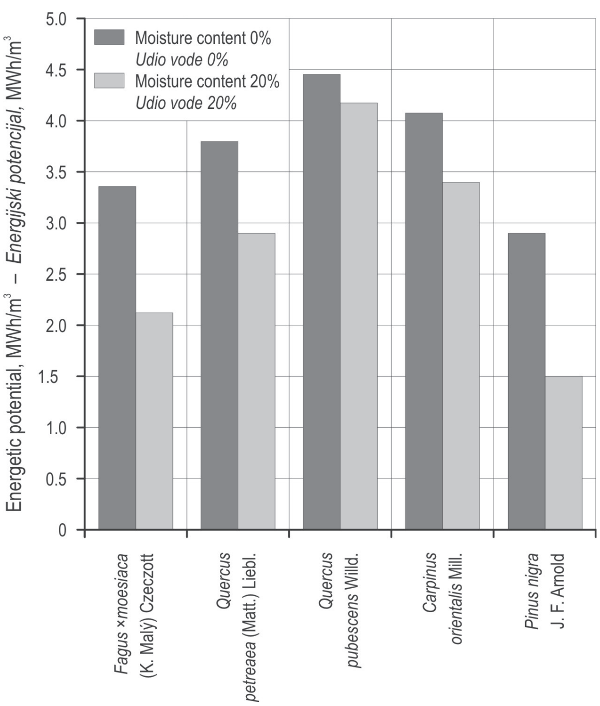

Fig. 2 Energy potential of wood
Slika 2. *Energijski potencijal drva*

(K. Malý) Czeczott with 17 204.93 KJ/kg and *Carpinus orientalis* Mill. with 16 841.05 KJ/kg.

Due to the difference in wood density, these values are different when converted into MW/m^3, so *Quercus pubescens* Willd. has the highest value with 4.45 MW/m^3 (0% moisture content) and 4.16 (20% moisture content), followed by *Carpinus orientalis* Mill. with 4.06 and 3.40 MW/m^3, *Quercus petreaea* (Matt.) Liebl. with 3.78 and 2.90 MW/m^3, *Fagus × moesiaca* (K. Malý) Czeczott 3.36 and 2.11 MW/m^3, and *Pinus nigra* J. F. Arnold. 2.90 and 1.50 MW/m^3, respectively.

Energy produced from forest biomass is considered environmentally friendly, with low production of GHG and ash (Kovacevik at al. 2011, Nestorovski 2012).

Having in mind the obligations towards EU to gain at least 20% of the energy from environmentally friendly and sustainable resources, it is recommended to invest in this sector, as one of the most prospective for energy production in the following period, and help reducing high CO_2 emissions, instead of using fossil fuels.

6. References – *Literatura*

Anon., 2009: Statistical Yearbook: Energy Balance for Republic of Macedonia 2009. Ministry of economy, Republic of Macedonia.

Azievska, M., 2008: Second national communication on climate change. Ministry of environment and physical Planning of Republic Macedonia, 118 p.

Chiani, F., Corradi, C., Perugini, L., Rappuoli, V., Valentini, R., Angelova, E., Nestorovski, Lj., 2010: Biomass availability in the territory of republic of Macedonia, MOEPP, 2010.

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Kennedy, D., 2004: FYR Macedonia Energy Policy Paper. Report No. 29709 –MK, The World Bank, 1–32.

Kovacevik, G. P., Melis, C., Nestorovski, Lj., 2011: Forestry biomass use for energy production in Macedonia. 19th European biomass conference, Berlin.

Laponche, B., Jamet, B., Colombier, M., Attali, S., 1997: Energy efficiency for a sustainable world. ICE editions, Paris.

Nacevski, M., Nestorovski, Lj., Iliev, B., Trajanov, Z., 2002: Quality analysis of the wood from domestic and foreign tree species, Ministry for education and science, Skopje.

Nestorovski, Lj., 2003: Comparative Analysis of the energetic potential of forests as an renewable resources and the possibilities for its utilization in Republic of Macedonia. Skopje.

Nestorovski, Lj., Nacevski, M., Trajkov, P., Trajanov, Z., Kovacevic, G., 2011: Analysis of the Energetic Potential of Forests in Republic of Macedonia. 19th European biomass conference, Berlin.

Nestorovski, Lj., Nacevski, M., Trajkov, P., Trajanov, Z., Danilovic, M., 2012: Analysis of the Ash Quantity During Beech Wood Combustion. Forest Review 43: 12–14.

Sažetak

Analiza energijskih vrijednosti nekih vrsta drveća

*Predmet je ovoga istraživanja pet karakterističnih šumskih vrsta drveća (*Fagus × moesiaca */K. Malý/ Czeczott,* Quercus petreaea */Matt./ Liebl.,* Quercus pubescens *Willd.,* Carpinus orientalis *Mill.,* Pinus nigra *J. F. Arnold), koje pokrivaju najveći dio ukupne šumske površine i koje sudjeluju s oko 70 % u ukupnoj drvnoj zalihi šuma Republike Makedonije, a i često se nalaze i u ostalim šumama u regiji.*

Svrha je ovoga istraživanja utvrditi energijsku vrijednost navedenih vrsta drveća na različitim visinama debla i u različitim dijelovima stabla (drvo, kora) kako bi se vidjele razlike koje su posljedica različite stanične strukture.

Materijal je istraživanja prikupljen iz nekoliko područja Republike Makedonije, a za svaku je istraživanu vrstu materijal prikupljen na dvjema različitim lokacijama različitih ekoloških uvjeta. Gustoća drva istraživanih vrsta drveća također je utvrđena s obzirom na lokalne uvjete i uspoređena s dostupnim vrijednostima za ostale države. U radu je prikazan harmonizirani pristup utvrđivanju energijskoga potencijala različitih vrsta drveća eliminacijom utjecaja nejednakih ekoloških uvjeta rasta.

Rezultati istraživanja pokazuju da četinjače imaju veću energijsku vrijednost nego listače te da je navedena razlika energijske vrijednosti signifikantna. Nisu utvrđene signifikantne razlike u energijskom potencijalu različitih dijelova stabla (na 1,3 m i 5,3 m, grane), osim za koru. Energijski potencijal istraživanih vrsta drveća značajan je i uz određene promjene u pridobivanju drva te u procesu transformacije energije drva u ostale oblike energije (toplinu, električnu energiju itd.) respektablina je osnova za unapređenje energetske bilance države alternativnim, obnovljivim i okolišno pogodnim izvorom energije.

Ključne riječi: biomasa, kalorična vrijednost, alternativni izvori energije

Authors' address – *Adresa autorâ*:

Prof. Ljupčo Nestorovski, PhD.*
e-mail: nestorovski@sf.ukim.edu.mk
Assist. prof. Zdravko Trajanov, PhD.
e-mail: ztrajanov@sf.ukim.edu.mk
Prof. Pande Trajkov, PhD.
e-mail: ptrajkov@sf.ukim.edu.mk
Ss. Cyril and Methodius University in Skopje
Faculty of forestry
16 Makedonska brigada 1
1000 Skopje
MACEDONIA

Prof. Mitko Nacevski, PhD.
e-mail: nacevski@fdtme.ukim.edu.mk
Ss. Cyril and Methodius University in Skopje
Faculty of Design and Technologies of Furniture and Interior
Bul. Aleksandar Makedonski bb
1130 Skopje
MACEDONIA

*Corresponding author – Glavni autor

Received (*Primljeno*): February 5, 2014
Accepted (*Prihvaćeno*): April 8, 2014