WOOD BIOMASS FOR ENERGY IN MONTENEGRO

by

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Wood biomass has got its place in the energy balance of Montenegro. A little more than 6% of the total energy consumption is obtained by burning wood. Along with the appropriate state measures, it is economically and environmentally justified to expect Montenegro to more than double the utilization of the existing renewable energy sources including wood biomass, in the near future. For the purpose of achieving this goal, "Commercial Utilisation of the Wood Residue as a Resource for Economic Development in the North of Montenegro" project was carried out in 2007. The results of this project were included in the plan of the necessary interventions of the Government and its Agencies, associations or clusters, non-government organisations and interested enterprises. The plan was made on the basis of the wood residue at disposal and the attitude of individual subjects to produce and/or use solid biofuels and consists of a proposal of collection and utilisation of the wood residue for each individual district in the north of Montenegro. The basic factors of sustainability of future commercialisation of the wood residue were: availability of the wood raw material, and thereby the wood residue, the development of wood-based fuel markets, and the size of the profit.

Keywords: *forest, wood processing, wood residue, energy potential, wood chips, briquettes, pellets*

Introduction

In Montenegro there is a large unused potential of the renewable energy sources, so that along with the appropriate state measures, it is economically and environmentally justified to expect Montenegro to more than double the utilization of the existing renewable energy sources including wood biomass, in the near future. For the purpose of achieving this goal, "Commercial Utilisation of the Wood Residue as a Resource for Economic Development in the North of Montenegro" project was carried out in 2007 [1]. The project was initiated by FORS Montenegro, the agency for the Regional Development of the North of Montenegro. The project has provided interested parties with the basic information on the market of solid biofuel made from wood biomass, the necessary investments for carrying out the projects of solid biofuel pro-

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duction works, the expected influences on development of the north of Montenegro, as well as the possible consequences of carrying out the proposed projects. The focus was on determining the quantities and characteristics of the wood residue at disposal and the possibilities for its utilisation in production of renewable biofuels (log wood, briquettes, pellets, wood chips), the economic justification for this production, and economic, sociological, and environmental influences this production might have upon the wider social community.

For the project purposes, the following has been analysed: the felling volume in the state and private forests, the wood residue from forestry and wood processing at disposal, its potential, spatial distribution and the existing ways of disposing of wood residue from forestry and wood processing. The total planned felling in Montenegro in the year 2007 represents a sum of the long-term and short-term concessions from the state forests, the foreseen sanitary felling, felling for the heating needs of the local population and calculated expected felling from the private forests. It amounts to something more than 560,000 m^3 which approximately represents equal amount of broadleaves and conifers. The total wood residue at disposal which might be potentially used for solid biofuel production amounts to slightly more than 400,000 m^3, more broadleaves (about 230,000 m^3) than conifers (170,000 m^3). The energy value of the total wood residue is equivalent to the energy value of 75,000 tons of oil. The values obtained are only rough approximation. There are differences from one region to another, so that detailed research should be performed for actual calculations. In addition, field research has been performed. Thirty companies, dealing with wood processing, were interviewed and 15 companies, of special importance for wood processing in Montenegro, were visited for the purpose of getting the direct insight into their activities.

For carrying out the plans of utilisation of the wood waste for the production of solid biofuel only a minor part of the wood mass thus calculated is at disposal. Major companies have their own plans about utilisation of the wood residue from forestry and wood processing and their "internal" consumption will increase with time according to their expansion. There is a lot of different ways to use the wood residue as a fuel, but the most efficient is its direct raw combustion in the burners of stoves or boilers with the degree of boiler utilisation from 60% for raw up to 80% for dried fuel [2].

A proposed plan of action is presented at the end of the paper. The plan includes the necessary interventions of the Government and its Agencies, associations or clusters, non-government organisations and interested enterprises. It is made on the basis of the wood residue at disposal and the attitude of individual subjects to produce and/or use solid biofuels and consists of a proposal of the collection and utilisation of wood residue for individual districts in the north of Montenegro.

Wood biomass in the Republic of Montenegro

The Republic of Montenegro is situated in the south-eastern Europe and bordering Albania on the East, Serbia on the North and Northeast, Bosnia and Herzegovina on the west, Croatia on the southwest, and the Adriatic Sea on the south. Montenegro covers the area of 13,812 km^2. It is dominantly a mountainous country incised by river gorges and deep valleys. Plains are found only in the southern parts of the country. The proportion of the land whose slope is smaller than 5% amounts to about 3.7% of the total area of Montenegro [3]. The climate in Montenegro is determined by its latitude, altitude, the presence of large water areas (the Adriatic sea, the lake of Skadar), deep incision of the sea into the land (the gulf of Boka Kotorska),

moderately high mountain hinterland in the vicinity of the coast (Orjen, Lovćen, Rumija), the field of Ulcinj in the extreme southeast and the mountain massive of Durmitor, Bjelasica, and Prokletije.

There are 21 districts on the territory of Montenegro which are divided into three regions: Southern, Central, and Northern region. The region considered within this project is somewhat wider than the Northern region and includes virtually all forest area in Montenegro. It refers to the economically less developed part of Montenegro with the population greater than 300,000 inhabitants. However, this area could overcome this economical disadvantage with better utilization of the natural resources at disposal.

Forestry in Montenegro

The diverse climate in Montenegro has a large influence upon forests and forest areas. We can distinguish between numerous different forest associations in Montenegro depending on geographic and climate conditions. The main commercial tree species in the Montenegrin forests are the conifers: fir (*abies alba*), spruce (*picea abies*), Scotts pine (*pinus sylvestris*) and Austrian pine (*pinus nigra*). The most important broadleaves in the Montenegrin forests are: beech (*fagus sylvatica*) and oak (Quercus sesiliflora). The other valuable species are found in smaller quantities. The main species make up mixed or single-species forests. Forests and forest lands in Montenegro cover about 710,000 to 740,000 hectares or 51% to 54% of the territory of Montenegro. The total stock of wood mass in the forests of Montenegro is estimated at 72 million m^3, out of which 29.5 million or 41% represents coniferous, and 42.5 million m^3, or 59% stands for broadleaved forests [3, 4] (see tab. 1).

Table 1. Wood stocks in Montenegro [3]

Ownership	Conifers [m^3]	Broadleaves [m^3]	Total	[%]
State forests	28,355,635	31,275,245	59,630,880	82.76
Private forests	1,171,920	11,253,899	12,425,819	17.24
Total	29,527,555	42,529,144	72,056,699	100.00

As for the ownership, around 60 million m^3 (59,630,880 m^3) of the forest fund is state owned. Economic forests cover the largest area (89.05%) whereas the rest belongs to protective forests and national parks, 7.7% and 3.25%, respectively.

The structure of the wood stocks in the state forests is the following:

– conifers 28,355,635 m^3, *i. e*. 47.55% of the total wood mass in the state forests, and
– broadleaves 31,275,245 m^3, *i. e*. 52.45% of the total wood mass in the state forests.

Wood stocks in private ownership amount to 12.425.819 m^3 where wood stocks of broadleaves dominate amounting to 90.57% of the total wood mass. The rest consists of conifers. The annual forest increment in Montenegro is estimated at 1.5 million m^3, out of which 0.7 million m^3 are conifers and 0.8 million m^3 are broadleaves The structure of the forest increment in Montenegro is presented in tab. 2 [5].

Table 2. Annual forest increment in Montenegro

Ownership	Conifers [m^3]	Broadleaves [m^3]	Total	[%]
State forests	664,792	575,589	1,240,381	83.29
Private forests	30,144	218,664	248,808	16.71
Total	694,936	794,253	1,489,189	100.00

The largest part of the increment (83.29%) originates from the state forests which make up 67.25% of forests and forest land in Montenegro and possess about 82% of the total wood mass. Based on assets it is prescribed how much wood over a certain time must, or can be cut in some stand*. The prescribed annual assets in Montenegro amount to slightly more than half the annual increment.

Table 3. Annual assets in Montenegro

Ownership	Conifers [m^3]	Broadleaves [m^3]	Total	[%]
State forests	406,813	264,494	671,307	82.30
Private forests	15,878	128,512	144,390	17.70
Total	422,691	393,006	815,697	100.00

By comparison of the increment and assets (see tab. 2 and tab. 3) the following conclusions can be made:

– the ratio between assets and increment in the forests of Montenegro amounts to about 55%,
– the ratio is approximately similar in the state forests (54.1%),
– the assets for the conifers in the state forests are somewhat higher and amount to 61.2% of the increment, while for the broadleaves they are about 50%,
– the ratio of the assets and the increment in private forests is higher and amounts to about 58%, and
– in private forests, the assets of broadleaves amount to 58.8% of the increment, and with the conifers about 52.7%.

The forests owned by the state in Montenegro are given for utilisation to the legal subjects registered for performing activities in forestry, as well as for other activities as determined by the Law on Forests of Republic of Montenegro, under the conditions and in the way foreseen by this Law, through the system of concessions. The data on concessions for the year 2007 are given in tab. 4 (420,688 m^3). In addition, certain quantities should be added for sanitary cuts (3,233 m^3) as well as for the cuts that the local rural population would use as a fuel. There are no such elaborate data for the private forests as there are for the state forests. It can only be assumed

* Asset – wood stock or surface area foreseen for cutting by the management foundations in a ceratain year is called annual assets

Table 4. Calculated gross volume of forests in the north of Montenegro planned for felling in 2007

Ownership	Tree species volume [m^3]		
	Broadleaves	Conifers	Total
State forests (concessions + needs of the rural population; fuel + expected sanitary cutting in 2007)	198,871	264,763	463,634
Private forests	89,958	11,115	101,073
Total	288,829	275,878	564,707

that the same state policy is applied for the private forests as well. It means that the plan of felling in the private forests is around 70% of the established assets.

The calculation has been made under the assumption that the wood from the sanitary felling and the fuel wood for the population originate from the broadleaved forests.

Wood processing in Montenegro

Both wood industry and forestry represents significant economic activities in Montenegro though their significance is mostly based on their potential and not accomplishments in these fields. The raw material resources and numerous previously constructed capacities are a basis for considerably higher level of production and more significant proportion within the domestic product, export, and employment. The mentioned plants were mostly built or modernised in the eighties and until recently they have all been in the hands of the state. Over the last few years the priorities of the Government of Montenegro, in the area of wood processing, are the restructuring and privatisation of these enterprises but also the stimulation of development of small and medium enterprises in the rural areas which would be based on other products of forests, apart from processing of technical wood [6].

In the frame of the field research, visits have been organised to the key enterprises of the wood processing in Montenegro. It refers to the privatised enterprises, once bearers of the wood industry. The quoted firms in the year 2007 processed approximately 300,000 m^3 of timber, which is more than 50% of the total wood mass (from the state and private forests) foreseen for cutting in the year 2007. The raw material that they utilise mostly comes from the state forests based on long-term concessions. The situation in these firms varies and depends on the time elapsed from the instant of privatisation, the state at the time of privatisation, human resources situation, as well as the plans and ambitions of the new owners. The best firms have already activated the existing technologies and they are on the way to return to the former volume of the production. The others mostly engage in sawmill processing, while their works and energy installations are still in the reconstruction phase. At the moment, they dispose of surplus wood residue which might be used for production of solid biofuel. In addition, these firms dispose of a certain quantity of stacked wood which they have pulled out of the forest together with the logs, and which they are now selling to the population and other enterprises. It is important to remark that the quantities of wood residue and stacked wood for selling will be decreasing, due to increasing degree of finalisation in the wood industry.

Wood residue

Along with analysing quantities, the utilisation possibilities and the problems related to disposing the wood residue it is necessary to separate handling the wood residue stemming from forest felling and the wood residue stemming from wood processing not forgetting the wood ending in industrial or communal waste. In this paper, we will consider only the part of sources of wood residue as a possible feedstock for the production of solid biofuels.

Forestry

In the forestry sector when we calculated the amount of wood that could be used for heating, we took into account bulky branch substance, stacked wood, whole trees from sanitary cuts, and specially cuts for fuel for the local rural population. Table 5 represents the data on the calculated heat at disposal which might be reached by burning this wood, as well as the equivalent energy value in oil.

Table 5. Available energy value of wood that will be at disposal for burning in Montenegro in 2007

Origin	Species				Heat at disposal [GJ]	Equivalent tons of oil
	Broadleaves		Conifers			
	Volume [m^3]	Mass volume [t]	Volume [m^3]	Mass volume [t]		
Long-term concessions	60,029	54,026	77,426	45,294	1,012,259	24,101
Short-term concessions + private forests	123,421	111,079	40,807	23,872	1,351,294	32,174
Total	183,451	165,106	118,233	69,166	2,363,561	56,275

The values in tab. 5 have been obtained on the basis of the following assumptions:

- the volumes of the bulky branch substance and the stacked and cellulose wood at disposal have been calculated on the basis of the Proposal of the Decision on Concessions from the year 2007 and the data given in [7],
- the moisture content of the felled wood is 60%,
- density of the raw broadleaves (beech taken as representative) amounts to 900 kg/m^3,
- density of the raw conifers (fir taken as representative) amounts to 585 kg/m^3,
- lower heating value of raw broadleaves (beech taken as representative) amounts to 9.90 MJ/kg [8, 9],
- lower heating value of raw conifers (fir taken as representative) amounts to 10.54 MJ/kg [8, 9],
- lower heating value of crude-oil amounts to 42.00 MJ/kg,
- forest residue makes 40% of mass of trunk of broadleaves [10], and
- forest residue makes 30% of mass of trunk of conifers [10, 11].

For the rest (tiny branch wood, stumps, and roots), however attractive it might be at first sight, there are neither technical nor human resources potentials, nor economic justification to exploit it. However, it is still possible in the future to be utilized with according changes in the legal regulations, state policy, and the public attitude toward the renewable energy sources.

Wood residue from the wood processing

The wood residue in the wood processing is divided into: bulky, tiny, and bark. Table 6 represents the data on the proportion percentage of the residue at wood processing in different technologies of the latter. These percents do not include the bark and a part of the wood residue which is specially designated for different reasons and can not be used (scatter, shrinking, and similar).

Table 6. Available wood residue in wood processing (average values)

Wood processing technology	Typical final product [%]		Available wood waste [%]	Losses* [%]
Sawmilling broadleaves	Sawn timber	50	43	7
Sawmilling conifers	Sawn timber	65	30	5
Veneer production	Veneer	47	45	8
Plywood production	Plywood	41	53	6
Particleboard production	Particleboard	90	5	5
Final processing of wood	Furniture	35	65	–

* The wood residue that for different reasons can not be used (scatter, shrinking, and similar)

Each mechanical or chemical processing is directed to production of certain assortments and products and it has its production balance with respect to the input raw material. When calculating the available wood residue it has been assumed that all the available technical wood is processed only into sawn timber. Wood residues from the production of veneer, panels, furniture, joinery, *etc*. are excluded from the calculations. In these enterprises there is usually a balance between the technological needs of thermal heat and energy potential of wood residues that occur there [12]. Amounts that remain are low and decrease with increasing degree of finalization of these plants.

The values in the tab. 7 have been obtained on the basis of the previously given assumption in calculating the energy value of forest biomass.

Table 7. The assumed energy value of the wood residue in the sawmills in 2007

Wood species	Volume of the wood residue [m^3]	Mass volume [t]	Available heat [GJ]	Equivalent tons of oil
Broadleaves	47,420	42,678	422,515	10,060
Conifers	55,176	32,333	340,789	8,114
Total	102,596	75,011	763,304	18,174

Expected wood residue in Montenegro in 2007

The available quantities of the wood residue from forestry and the primary processing are not particularly large (see tab. 8).

Table 8. The assumed energy value of the wood biomass from forestry and the sawmills in Montenegro in 2007

Origin	Volume [m^3]	Available heat [GJ]	Equivalent tons of oil
Forestry	301,684	2,364,806	56,305
Wood processing	102,596	763,304	18,174
Total	404,280	3,128,110	74,479

Besides, it is almost evenly distributed across the whole territory of the area considered. An exception is Pljevlja where almost 30% of the total residue from the primary processing of wood is concentrated. All this should be taken into account when making potential plans about its utilisation.

Interest for biofuels production

On the basis of the field research performed, it has been found out that a major part of the sawn timber (at that moment) was sold without drying and finalisation, so that the wood residue originating from the sawmill processing was not necessary on site for production of the heat energy or heating. The wood residue is a particular problem for small firms located in the urban areas. Due to non-existence of the market, tiny residue is piling at the site of the firm, being dumped or, with compensation for the transport costs, transported to the communal waste disposal site (where existent). Bulkier residue is sold or transported away.

Neither of the cities visited has a separate depository for wood residue nor is this residue utilised for heating, briquette or pellet production. Kolašin may serve as a good example trying to solve the heating issue in the town centre by utilisation of the wood residue from the wood processing companies in the town and its surroundings [13]. When the project ends, this might be the example for some neighbouring cities, with continental climate, placed in the valleys rich in forests. Limitations for carrying out such projects are the low price of other sources of energy (electricity in particular), high investments in boiler plants and the heating network, high costs of introducing distance heating into households, as well as lack of interest on part of the authorities.

Only three firms which have participated in the questionnaires or have been visited during the field research possess the installations for briquette or pellet production:

– briquette equipment in the company “Mi-Rai” though the production is not operating at the moment,
– briquette production in the company “Vraneš” whose construction has been partly financed by FORS Montenegro, and

– pellet production located within the site of the sawmill "Brezna" in Plužine; the basic raw material should have been old sawdust at the factory site.

Based on the collected information, there is an interest for production of solid biofuel for the market among the polled and visited firms. "Vektra-Jakic" firm from Pljevlja, for instance, has plans to use its surplus of wood residues, which are not used in the company's energy plant, for the production of pellets. Another one is the firm "Boj-Komerc" from Andrijevica which has the same idea.

A large number of smaller companies showed interest in the production of briquettes. The lowest capacity (100 kg/h), which would not be equipped by a grinder, *i. e*. which would use sawdust only, might produce around 500 t of briquettes annually. In order to achieve this, it is necessary that the sawmill processes at least 5,000 m^3 of logs. In Montenegro there are not so many firms having such an annual production, so that a precondition for building briquette plant is the co-operation and interest association of a larger number of private firms which would jointly produce briquettes at one location.

Organisation of the collection and utilisation of wood residue

The proposal of organization of the collection and utilization of available wood waste is made on the basis of the available quantities, their allocation and minimum commercial production capacity for each type of wood based fuel. When defining the way of organisation of the collection and utilisation of wood residue, the outset have been the following elements:

– in the districts in which there is at least one major wood processing company, this enterprise is chosen for pellet or briquette production, and the other smaller manufacturer would sell the surplus of their wood residue on the commercial basis to the enterprise chosen,
– in the districts in which only small wood processing companies exist, having expressed an interest for the surplus of their wood residue to be used for production of wood based fuel, one smaller enterprise is chosen as the activity bearer, and the other enterprises would, also on the commercial basis, sell wood residue to the enterprise chosen, and
– in the districts in which small enterprises previously have not shown an interest for co-operation in utilisation of wood residue for production of wood-based fuels, but had a problem with the disposal thereof, communal depositories will be formed for all wood residue from small sawmills and it will be utilised as fuel in small heat generating plants producing heat energy for heating schools, kindergartens, or local administration buildings.

Briquette production

In Bijelo Polje there is one bigger ("ŠIP Lim") and several smaller manufacturers which produce sawn timber and have a big problem with wood residue, especially sawdust because of the pollution of the environment. The enterprise "Vraneš" has been chosen to be the activity leader for the production of wood-based fuels in this district. Based on the available quantities of waste coming from the production process in this enterprise as well as the wood residue generated in the Danilovgrad district which is in immediate vicinity of Nikšić, it is estimated that the enterprise "Mi-Rai" could produce around 500 tons of briquettes annually. Net heating value of briquettes is between 17 GJ/t and 18 GJ/t (4.6-5.0 MWh) for moisture content of 10%.

Profitability of briquette production included the analysis of production costs, the total income obtained by sales of the planned quantity of briquettes and the profit. Production costs

have been established on the basis of data obtained from the manufacturers in Serbia and Bosnia and Herzegovina (in 2007) (see tab. 9). More details can be found in [1].

Table 9. Calculation of the production costs of briquettes at a representative example of production of 2,000 t per year

Type of cost	Raw material*	Electricity costs	Labour costs	Other costs	Production cost of briquettes [€/t]
Specific costs [€/t]	20.00	6.60	12.00	3.40	42.00

* Transport of raw material is included

Specific costs are calculated based on the following input data and assumptions:
- needed amount to produce one ton of briquettes is 1.2 tons of dry or 5.45 m^3 of bulky wet sawdust [14]. It includes eventually losses and the amount of sawdust that is used for drying,
- calculated price of wet sawdust ex works was 2.5 €/m^3 or 11.4 €/t of same material; transport costs (1.2 €/m^3) should be added to this price,
- specific electricity consumption is about 110 kWh/t [15],
- an average price of electricity for enterprises was 60 €/MWh in 2007,
- personnel costs amount for 4 worker for 12 month were estimated at 24,000 € or 12 €/t of produced briquettes, and
- other cost includes production services, financial duties, packaging, non-material costs…

The quoted calculation implies that the manufacturer has no own raw material at disposal, but buys it completely at the market. The real situation in the field is different since the enterprises possess a part of the raw material, and the rest up to the foreseen capacity will be provided in accordance with the proposed model of collection and utilisation of wood residue. However, for the purpose of getting insight into the profitability of the production the least favourable example has been chosen, since if the production pays off under such circumstances, then it can be assumed to be even more profitable under more favourable circumstances.

Bearing in mind the quantities of briquettes which individual enterprises can produce, for the production profitability calculation, the production lines have been chosen of the following characteristics (see tab. 10):
- briquette press of capacity of 200 kg/h and 350 kg/h, and
- sawdust kiln dryer of capacity of 350 kg of dry mass per hour (this is the minimum capacity of a kiln dryer found at the equipment manufacturers).

On the basis of projection of the total profit for individual manufacturers (tab. 10) it can be concluded that the investment into technological equipment will yield a profit in the period between 2.5 years at the enterprise NVO “Pljevlja drvo”, and 4.9 years at the other manufacturers. The credit costs have not been taken into account in the quoted calculations, since it has been assumed that the acquisition price of the equipment does not represent more serious costs for the manufacturers and that they can either finance it on their own or with the assistance of non-interest loans approved by the Agency for Small and Medium Enterprises of the Government of the Republic of Montenegro. The analysis of the investment pay-back period shows the pay-back time to decrease with the increasing production capacity.

Table 10. Basic characteristics, prices and profitably of the lines for briquettes production

Name of enterprise	Annual briquettes production [t per year]	Investment cost [€]	Selling price [€/t]	Total income [€]	Production cost [€/t]	Total profit [€ per year]	Simple pay-back time [Year]
NVO "Pljevlja drvo"	2,000	138,600	70	140,000	42	56,000	2.5
"Vraneš", Bijelo Polje	500	68,100	70	35,000	42	14,000	4.9
"Mi-Rai", Nikšić	500	68,100	70	35,000	42	14,000	4.9
Total	3,000	274,800	70	210,000	–	84,000	–

Pellet production

With respect to the quantities of wood which it will obtain on the basis of long-term concessions in the Pljevlja district "Vektra-Jakić" has been suggested to be the main bearer of pellet production in this district. Since the transportation distance is not long, the proposal is that all the quantities of the wood residue from Žabljak should be directed into the production of the enterprise "Vektra-Jakić". Bearing in mind the development needs of the enterprise, with respect to the utilisation of wood residue originating from the forest as well as from the technological process of primary processing of wood, it is estimated that out of wood residue around 5,000 t of pellets could be produced annually. The enterprise "Boj-komerc", having its wood processing works in the districts of Berane and Andrijevica, has been suggested as the main bearer of the utilisation of wood residue for pellet production in these districts (2,000 t at annual level), with respect to the capacities as well as the readiness of the enterprise owner to start pellet production. The heating values of pellets are between 17 GJ/t and 18 GJ/t (4.6-5.0 MWh) for moisture content of 10%.

The calculation of profitability of pellet production has been performed by the similar methodology as the one applied in the calculation of the profitability of briquettes. The specific production costs of determining the manufacturing price at a representative example are presented in tab. 11. Calculations were made under the assumption that the manufacturer is supplied with 10% of the necessary raw material from the market (according to the proposed model of utilisation of wood residue it represents the case of supplying the enterprise "Jakić-Vektra" by wood residue from Žabljak).

Table 11. Calculation of the production costs of pellets at a representative example with the production of 5,000 t per year

Type of cost	Raw material	Electric energy costs	Labour costs	Amortization of the basic assets	Loan repayment costs	Other costs	Production cost of pellets [€ per t]
Specific production costs [€ per t]	6.75	10.20	15.60	21.16	11.00	15.29	80.00

Specific costs are calculated based on the following input data and assumptions:
- needed amount to produce one ton of pellets some is 1.2 tons of dry or 5.8 m^3 of bulky wet sawdust; it includes the amount of sawdust that is used for drying,
- calculated price of 1 m^3 of the wood residue recalculated to 15% of moisture content (grinding and drying included) is 10 €/m^3 (48 €/t),
- specific electricity consumption is about 170 kWh/t [1],
- an average price of electricity for enterprises was 60 €/MWh in 2007,
- personnel costs amount for 10 worker for 12 month were estimated at 78,000 €,
- amortization of the basic assets in the amount of 10%, and
- other cost includes production services, water, fuel, non-material costs.

Bearing in mind the foreseen quantities of pellets for individual producers, the technological equipment has been chosen of the following characteristics:
- 2.2 t/h of pellets for the enterprise "Jakić-Vektra" from Pljevlja, and
- 1.0 t/h for the enterprise "Boj-Komerc" from Berane.

On the basis of the projection of the total profit for individual manufacturers (see tab. 12) it can be concluded that the discounted pay-back time would range from 7.05 years at the enterprise „Jakić-Vektra" from Pljevlja to 11.32 years at the enterprise "Boj-Komerc" from Berane.

Table 12. The basic characteristics and acquisition price of the technological equipment for pellets production

Name of enterprise	Annual briquettes production [t per year]	Investment cost [€]	Selling price* [€/t]	Total income [€]	Production cost [€/t]	Total profit [€ per year]	Simple pay-back time [Year]
"Vektra", Pljevlja	5,000	1,058,200	110	550,000	80	150,000	7.05
"Boj-Komerc", Andrejevica	2,000	678,900	110	220,000	80	60,000	11.32
Total	7,000	1,737,100	110	770,000	80	210,000	

* Selling price represents the price at the factory

Wood chips, communal "waste" and heat generating plants for heat energy production on the basis of wood biomass

Wood chips production pays off observed both from the aspect of proportion of the profit in the selling price and from the aspect of utilisation of the initial raw material in production of this sort of fuel. Moisture content affects greatly on heating value of wood chips. Net heating value of wood chips is 12.6 GJ/t (3.5 MWh) or 3.2 GJ/m^3 (0.89 MWh) for 30% moisture content.

Namely, besides the fuel (stacked) wood, bulky and tiny branch wood can be used for the production of wood chips, as well as the residue generated in forest when producing wood assortment, which in such circumstances can not be used and sold as fuel wood.

The technological process of wood chips production is not too complicated. Specially designed machines ("grinders") are used for this purpose. The machine is mobile, and

such machine of medium capacity can process around 8 m^3 of staacked wood and thus produces around 20 m^3 of wood chips (in diffuse state) for 1 hour of operation. The market price of the machine with the tractor and all the accessories amounts to 66,000 € (tab. 13).

Table 13. Profitability of production of wood chips

Communal depository	Annual production [m^3]	Investment cost* [€]	Selling price [€ per m^3]	Total income [€]	Production cost [€ per kWh]	Total profit [€ per year]	Simple pay-back time [Year]
Kolašin	18,000	66,000	10	180,000	8	36,000	1.83
Rožaje	18,000	66,000	10	180,000	8	36,000	1.83
Plav	12,000	66,000	10	120,000	8	24,000	2.75
Total	48,000	198,000	–	480,000	–	96,000	–

* The principle has been adopted of one grinding machine for one district

Wood chips could be used as fuel in urban heating plants. The Rožaje district has on its territory a wood processing enterprise "Gornji Ibar" still out of order as well as a certain number of smaller sawn timber producers. Based on the data collected in the field research, the estimate is that in this district with around 3,000 m^3 of wood residue of the heat generating plant of capacity of 1.5 MWh is proposed. In the Kolašin district a project has already been made of the heat generating plant of 1.5 MW power on wood biomass [16]. Due to small quantities of wood residue generated in the Mojkovac district, as well as the vicinity of these two towns (ca. 50 km), it has been recommended that the wood residue from Mojkovac should be transported to the Kolašin district. In the district Plav (AD Bor) there is one bigger enterprise engaged in wood processing and several smaller enterprises. The proposal is given of forming so-called communal depository in which wood residue would be collected for the heat generating plant of the power of 1.0 MW.

For the purpose of calculating the profitability of wood chip production the selling price has been taken in the amount of 10 € per loose m^3 or about 43 €/t. The data obtained from manufacturers from Austria indicate the profit range of around 20-30% of the selling price, depending on the moisture of wood chips, and the profit has been determined at 2 €/m^3.

Along with the communal waste grounds, mini heat generating plants would be constructed, utilising wood residue for production of heat energy for heating of public buildings and town centres, depending on the projected power of the plant. The necessary investment for a heat generating plant of 1.5 MW power amounts to around 1,000,000 € combined with the distribution network. This value of the investment costs does not include the costs of installations in the objects to be heated. Within the framework of this study, the proposal is that the costs of installations in their objects should be paid by the users themselves.

The total heat energy production of such plant for 3,000 hours of operation amounts to 4,500,000 kWh. According to the study made for the heat generating plant in Kolašin the production cost is 0.045 €/kWh. The quoted production costs cover the raw material acquisition (10 €/m^3), labour, and electric energy costs. On the basis of the above, the selling price ensuring a satisfactory profit has been determined at 0.055 €/kWh. In the analysis of the profitability of

heat energy production, the production costs have been taken from the study made for the city of Kolašin.

With respect to the simple pay-back time for the construction of a heat generating plant on biomass of 1.5 MW, with the sales price of 0.055 €/kWh and the planned profit of 45,000 € per year 22.2 years are needed. With respect to the very long payback time it is necessary that the Government or the district authorities finance the greatest part or the complete investment (tab. 14).

Table 14. Profitability of production of heating energy on the basis of wood biomass

Name of the producer	Heat plant power [kW]	Investment cost [€]	Heating energy production [kWh per year]	Selling price [€ per kWh]	Total income [€]	Production cost [€ per kWh]	Total profit [€ per year]	Simple pay-back time [Year]
Kolašin	1,500	1,000,000	4,500,000	0.055	247,500	0.045	45,000	22.2
Rožaje	1,500	1,000,000	4,500,000	0.055	247,500	0.045	45,000	22.2
Plav	1,000	900,000	3,000,000	0.055	165,000	0.045	30,000	30.0
Total	4,000	2,900,000	12,000,000	–	660,000	–	120,000	–

Recapitulation of the values of the total production of fuels based on wood biomass in the region is given in tab. 15.

Table 15. Planned value of fuels and energy based on wood residue in the north of Montenegro

Fuel based on wood biomass	Planned quantity	Selling price	Heating value [kWh/kg]	Unit price [€/kWh]	Total value [€/year]
Pellets [t per year]	7,000	110 €/t	5.0	0.0220	770,000
Briquette [t per year]	3,000	70 €/t	4.8	0.0146	210,000
Wood chips [t per year]	11,200	43 €/t	3.5	0.0123	480,000
District heating [MWh]	12,000	0.055 €/kWh	–	0.055	660,000
Total	–	–	–	–	2,120,000

Conclusions

On the basis of wood residue at disposal and the attitude of individual subjects to produce and/or use solid bio fuels, a proposal has been made of the collection and utilisation of wood residue for each individual district in the north of Montenegro.

briquette production at three sites with a total annual production of about 3,000 tons. Approximate purchase price of the equipment is around 300,000 €. In briquette production

satisfactory profit is achieved which can be fully stimulating for the enterprises proposed to start production of this kind of wood based fuel. An additional factor which has stimulating effect upon the manufacturers is the short simple (undiscounted) pay-back time, ranging from 2.5 to 4.9 years [1].

Pellet production at two sites with a total annual production of around 7,000 tons. Approximate purchase price of the equipment is around 1,800,000 €. In pellet production a forecast of the possible profit indicates its percentage to amount to 27.2% of the selling price, which should also represent a stimulating factor for determination on part of enterprises recognised as the major bearers of production of this kind of fuel. The reason why some fears might appear with the manufacturers is a relatively long simple payback time ranging from 7.05 to 11.3 years [1].

The construction of three heat generating plants (total power 4 MW) in the districts of Kolašin (1.5 MW), Rožaje (1.5 MW), and Plav (1 MW). Communal waste grounds would be formed in their vicinity, to which sawdust and other wood residue would be transported from small sawmills found in the surroundings of these towns. Wood chips would also be brought here, which would be prepared from the forest residue by the rural population. This would influence the development of the rural areas and inclusion of the population from these areas relatively rich in forests into the process of supplying of city heat generating plants for energy production. Annually production of thermal energy would be about 12,000,000 kWh, and approximate purchase price of the equipment is around 3,100,000 € [1].

The proposed investment will allow the opening of 46 new jobs, and a number of them on the collection of wood residues and wood chips production.

Based on the conclusions drawn, the plan is proposed of the necessary interventions of the Government and its Agencies, associations or clusters, non-government organisations, and interested enterprises.

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