TECHNOLOGIES FOR RECOVERING LOGGING RESIDUES FOR BIOMASS ENERGY PRODUCTION

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Abstract

Potential wooden biomass sources include materials from thinning, selective sylvicultural systems and regeneration, coppice stands and short rotation forests (SRF) as well as logging residue. Additional materials can also come from sawmill wastes. Forest biomass can be differentiated as logging residue and fuelwood. Logging residue (branches, tops and waste wood) is a by-product of conventional logging operations and its advantage is that in many cases the extraction costs are covered by roundwood products. The volume of forest residue relative to the volume of timber harvested is very variable. Around 36% from coniferous and 42% from deciduous wood harvested in Bulgaria are potential fuel source for wooden biomass energy productive system. A principled technological outline for 2 MWh combined heating plant based on undersized and residue wood coming from logging and wood procession, comminuting to chips and converting them into steam and electricity is presented and described.

Key words: *wooden biomass, logging, wood processing, technological systems, electricity and steam production*

INTRODUCTION

Wooden biomass is one of the most effective and with highest potential renewable energy source (RES). In Bulgaria, when forested lands are more than 33% from the country territory, wooden biomass is most prospective source for energy productive systems due to own high-technological utilization.

European Union (EU) plays a leading role in realization of Kyoto Protocol aims and in 2002 with Directive 2002/358/CE it accepted them. Europe finds the ways to reduce energy dependence on conventional fuels and energy scarcity and all that give an impetus to rapid development of EU energy policy and legislation in special field of RES. Series of important normative documents, such as strategies, directives, green and white books, respectively, for energy policy and RES, green certificate trade policy, etc.

According to EU Action Plan in field of energy and climate changes mitigation is foreseen in 2020 the share of RES in energy consumption has to reach 20%. One of the particular aims in White book for RES is construction and installation of biomass thermal plants with capacity of 10 000 MWh [10].

The objectives of this paper are to present Bulgaria's current situation in the wooden biomass potential and the trends of the development toward biomass utilization for energy production, and particularly to offer methods for utilization of undersized and residue wood.

BACKGROUND

There are many studies focused towards biomass utilization, mostly in Scandinavian countries in forest on plains, lowlands, hills. In Central Europe and Balkans the forests are located mainly in mountains, often on steep slopes. The main problems are both difficult terrain conditions and small harvest volumes due to silvicultural requirements resulting in high biomass production costs. Therefore, Scandinavian biomass production systems is of limited applicability for the mountainous area, however, such comparison may only be made on the basis of case studies [8].

The importance of forest wooden chips as a source of biofuel will boost in future. Biomass production systems are typically organized around the chipping operation. The location of chipper can be in the forest – in the stump, around the forest road – at landing, at a central storage area or at the converting plant. Biomass can be transported as logging residues, roundwood, fuelwood, pressed bundles and chips.

The load density obtained and transport distances are the main factors determining efficiency of logging residue supply.

There are several basic technological systems in logging residue converting into fuel and energy:

⇒ Chipping at landing (collection point) and transportation of the chips to converting facility;
⇒ Bundling at stump or landing, transport of bundles to converting facility and chipping the bundles;
⇒ Loading loose uncommitted logging residue at landing and transport of them to the converting facility and chipping;
⇒ Loading fuel wood (produced by tops, branches, low-quality parts of stems) at landing, transport of them to the converting facility and chipping.

Chipping in the forest stand is practically avoided in mountainous conditions due to difficult transportation of chips from stand and need of reloading to truck.

The most common option in the production of woody biomass is chipping at the landing or around forest road and then transportation of chips to converting plant. Direct chipping into the truck is widely used at transportation. But closed work chain affects in the dependence between machine systems. Operational delays can be caused when the chipper waits for the truck and truck waits for the chipper as well. The challenge from a logistical point of view is to organize the whole process in such a way as to minimize these operational delays [8].

A characteristic problem in mountainous conditions is the limited area available around forest roads. Direct loading the trucks by the chipper requires close coordination between them and need for sufficient area. The number of machine units assigned to the operation must reflect both chipper capacity and transportation distance: excessive waiting erodes the productive edge of chipping at landing, and favours the other two methods [7].

One solution is the interrupted work chain, whereby the machines become independent from one another. However, additional costs are necessary for the loading of the truck. Another solution is the pre-concentration of material to be chipped at a central landing area. Larger quantities have a positive effect on both productivity and utilization of the chipper. Central landings near to the public road infrastructure also enable the use of non-specialized means of transportation (e.g. semi-trailer configurations with containers) for the transportation of woody biomass. The buffering effect of the centralized processing area is especially important in winter in the mountainous areas. The additional cost of preparing the centralized processing/storage area can be covered by these positive effects [8].

Drying of the stored chips at landing results in a decrease of subsequent energy consumption of production system as well as increased utilization of truck capacity in transportation.

Bundling represents an additional process and therefore increases the total cost of chips. But it has the advantage as an independent operation and restricts a lot of organizational problems related to chipping at forest landings [7]. In Scandinavian countries the harvest residues are bundled with special machines to increase the load density of logging residues at transportation and to increase productivity when chipping. The bundlers are built on forwarder chassis and work is carried out in the forest stand [1, 3, 5, and 6]. In mountainous conditions the bundler was designed and built for a truck chassis to work on the forest road [4]. In Scandinavian countries bundler technology for chips is very common and a viable economic alternative (e.g. 18% of forest wood biomass is produced in this way in Finland), but an Austrian study showed the opposite [4]. Different hourly machine rates are significant and they are often just 40–50% of the Central European level [1, 3, 4, 5, and 6]. It is due to higher level of machine utilization, shorter relocation distances and larger harvest areas.

Chipping at the conversion plant allows independence between the chipping and transportation processes. The biomass is transported in the form of logging residue, whole trees or cut-to-length form. Transporting loose uncommitted residue is the simplest method, which avoids investing in costly equipment. However, this system is constrained by the difficulty of fully exploiting vehicle payload and is not suitable to the handling of fine slash [8]. The use of stationary large-scale chippers allows all types of biomass to be chipped at high production rates. This advantage increases with the number of round wood used, but it is also related to high up-front capital costs [2].

THEORETICAL ANALYSIS

Principal technological systems for wooden chips obtaining from logging residue

⇒ Logging residue after whole trees felling and prime processing at landing

This technology is based on skidding whole trees form stand to landing with cable or grapple skidders, and tractor-mounted cableways. Residue obtained from prime processing is collected in large piles, than is chipped and blown in truck and are transported to converting facility. During storage for several months in large piles wooden residues can partially dried.

The key advantage of this system is that the felling and extraction costs are associated with the conventional production (logs, pulpwood, fuel wood, etc), and the biomass is relatively inexpensive. From forest protection point of view, removal of wooden material susceptible to biological attacks is positive. Disadvantages are the removal of nutrients, and therefore this system cannot be used in forest stands with nutrient deficit;

⇒ Logging residue after cut-to-length procession

The logging residue obtained from harvester felling is transports by forwarder to the landing and a truck-mounted larger-sized chipper blows the material directly into trucks that carry the chips to the converting plant. Additional expenses are incurred for the logging residue transportation to the landing.

Another possible technology is bundling of residue by forwarder-mounted machine, forwarding bundles to the landing, loading and transports them to converting facility by trucks where they are chipped by large-scale chipper.

The technology is limited to trafficable terrain.

Forest protection and nutrient removal requirements are the same as for above mentioned technology;

⇒ Whole tree chipping

All trees harvested in a thinning operation is converted to wood chips. The felling and processing is carried out with a harvester or manually with chain saws. The logs as well as residues are taken by the forwarder to the landing, while whole trees respectively - by small skidders. Logs, fuel wood, etc. when available are loaded in trucks. After a storage period of one month or more logging residues are chipped by a tractor-mounted chipper and transport to converting plant.

The logs production from thinning in small diameter trees results marginally economic efficiency. In Scandinavian countries this is subsidized as a silvicultural treatment [2].

On steep slopes whole tree transport is possible only by cableways.

Efficiency of chip delivery for fuel is in close connection with further reduction in transport costs and delays. This is a live question due to boosted forest biomass volumes for energy purpose in the future and increasing transport distances.

The truck transport can be more effective by two ways: increasing truck payload capacity and increasing load density. The first one may be boosted by road trains, consisted by semi-trailers or trailers, but that worsens the vehicle mobility in forest mountainous conditions. An increase in load density can reached after preliminary air-drying of wooden chips at landing. In that way it is spent storage area and energy for drying in converting facility.

Principal technological systems for converting wooden chips into energy

Biomass is organic non-fossil material from biologic origin, part of which can be usable for energy production. Biomass divides into **primary biomass** - vegetal material, which can utilize directly or after processing for energy production; and **secondary biomass** - residue biomass from logging and wood processing, pulp and paper industry, thremmatology, food industry, etc.

Among all RES wooden biomass residue characterizes with highest potential. Wooden biomass easily can convert into industrial fuel. The annual technical potential of Bulgarian wooden biomass estimates at 48 PJ or 1,15 Mt o.e., incl. logging residue 44,4 PJ or 1,064 Mt o.e. and wood processing residue 3,6 PJ or 0,086 Mt o.e.[9].

It should be remark that at present residential sector in Bulgaria is major consumer (86%) of wooden biomass mostly as fuelwood.

The most serious interest for energy production provokes secondary biomass. Possible applications of wooden biomass are as follows.

Direct firing

One of the methods for converting of biomass into energy is direct firing in furnace to obtaining thermal energy and cogeneration.

Accordingly Directive 2004/8/CE of European Parliament **cogeneration** is a process of combining production of electrical and thermal energy by one the same primary source in combined heating plants (CHP). Cogeneration compared to traditional electrical production provides energy usable both for heating and electricity. Therefore, it saves funds and fuels as well.

The major source of residue biomass in Bulgaria is wood residue coming from logging and wood processing. The surveys point approx. 1 600 000 t/year wood residue in Bulgaria [9]. Bulgarian market offers wide range of furnaces and boilers for direct firing of wooden biomass from 25 to 1100 kW. Logging residue as branches, bark, tops requires preliminary comminution and it is suitable for small local heating installation, small or medium enterprises (SME) or municipal buildings such as schools, hospitals, sport and recreation centers, etc.

The caloricity of wooden biomass residue depends crucially on its moisture content varying in wide range - from 10% for wood processing residue to 50% just after felling in stand. The caloricity of dried wood is approx. 4300 kcal/kg, while that of the air-dried wood is approx. 1500-1700 kcal/kg. The approximate ash content is 1-1,5%. Wood processing residue, such as slash, small parts are dried and suitable both for direct firing and further processing into secondary, named refined biomass.

Refined wooden biomass

One of the fast-growing wood processing technologies is that for production of palettes and briquettes.

Pelettes and briquettes can produce from residue after logging, wood processing and pulp and paper industry. Logging residue is less suitable for mentioned products due to high moisture content. *Briquettes* are products obtained by pressing of vegetal biomass (wood or agricultural) without agglutinate substation, formed as cylinders with following characteristics: diameter 5,2-7,7 cm; moisture content under 12%; ash content under 2%; caloricity approx. 4200- 4500 kcal/kg and length approx. 25 cm. *Advantages:* cheaper than palettes (bellow 100 €/t), due to lower up-front capital costs; most widespread in Bulgarian market at present; higher caloricity and less ash content than fuelwood. *Disadvantages:* no suitable for automatic feed on fire place, stoves, as well as heating systems equipped with different capacity boilers. *Pelettes* are made by wood and/or agricultural wastes pressed without agglutinate substation. Pelettes are small cylinders, obtained under high pressure and temperature. The lignin plays role of natural agglutinate substation, which liquates at temperature over 100°C and that allows of the material to get different form. The main parameters of palettes are as follows: moisture content under 10%; caloricity of 4300-4500 kcal/kg; approx. length of 2 cm; diameter of 6-12 mm; approx. ash content of 0,9-1,5%. The caloricity of pelettes is approximately equal to that of coal briquettes and only 2,1-2,2 times lower than caloricity of gas oil. The ash content is significantly lower than that of coal briquettes (5-10%) and than that of fuelwood (2-4%). Therefore, after firing of 1 t pelettes remains only 10 kg of ash. *Advantages:* compact, easy to handle and transport, automatic feed allowed and relatively high energy value; easy to maintain modern heating systems which are based on pelettes as fuel allow high efficiency ranged between 80 and 85%. There is in pelettes very lower content of sulphur and other noxious substances than in coal and petrol products. *Disadvantages*: high-technology equipment, required high up-front capital costs and therefore they are more expensive (approx. 200 €/t) than briquettes and fuelwood; shortage of sufficient home manufacturing at present; at present no standards and hence, no quality guarantee. Pelettes are not yet popular as fuel in Bulgarian market due to high up-front capital costs combining with lower purchasing capacity of Bulgarian inhabitants compared to that of "older" EU-member countries. Despite that different home manufacturers produce palettes and speed up of that production is expected.

At present in Bulgaria two projects focused towards construction of heating systems based on wooden biomass residue are made in Bansko and Razlog. The latter is based on specific wood residue. The biggest industrial project for wooden biomass utilization is installed 11 MW boiler based on wood bark in Svilocell Co. near Svishtov.

Production of Electricity from Wooden Biomass

A principled technological outline for CHP uses undersized and residue wood by comminution to chips and converting them into steam and electricity is shown in Fig. 1. Wooden biomass from thinnings with diameter up to 80 mm and length over 100 mm, logging residue (branches, tops, etc.) with length ranged between 0,5 m to 1,5 m and wood processing residue with length over 300 mm and up to 20 mm thick are in use.

According to above mentioned technological outline undersized wood and logging residue *1*, as well as that coming from wood processing *2* with air-dried moisture content varying between 18 and 20% are feed by belt conveyors *3* and *4* to disc chippers *5* and *6*, where they comminute to chips with length up to 25 mm. The dimensions of inlet opening of chippers are width of 350 mm and height of 325 mm, and disc diameter is 2100 mm. The productivity of each chipper is 20-30 m^3/h. The mass of a cubic meter depends on tree spices and moisture content and it is ranged between 250 and 580 kg.

Thanks to centrifugal fans *7* and *8* and pneumatic pipelines *9* and *10* the chips are collected in intermediate vertical hoppers *11* and *12*. By pneumatic installation *13*, chips are delivered to vertical hopper *14* which feed the steam generator. From the hopper *14*, by the feeder *15* and belt conveyor *16* chips are delivered to the furnace of steam generator *17*, where they burn. The wooden biomass capacity of steam generator is 10 t/h.

The needed air for maintaining the firing process passes by the fan *18*, while the needed water for steam generator receives from pipeline *19*. In the furnace incoming air warms up by the air heater *20*. Passing through the air heater the exhausted gas directs to dust-catcher *21*. The exhausted gas uptake (i.e. steam generator draught) provides by fan *22* and smokestack (chimney) *23*.

The productivity of boiler is 6 t/h steam with temperature of 467ºK and pressure of 1,3 MPa. The generated steam delivers by high-pressure pipeline *24* into the turbine *25*, which drives the generator of electricity *26*. By the transformer *27* the electric energy with power of 2 MWh joins to the grid. The steam for technological purpose takes away by reservation of steam intake from the connector *28* of turbine *25*.

It should be notice that in Bulgaria the only one CHP is located in pulp and paper plant near city of Stamboliyski.

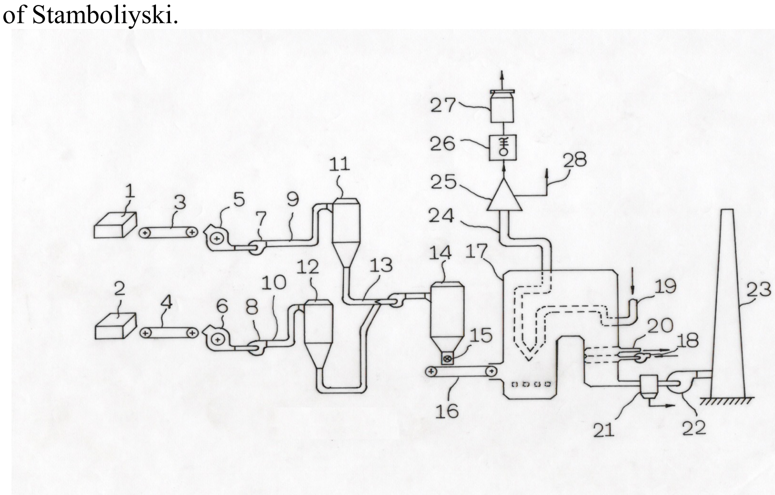

Figure 1. A principled outline of electricity and steam production from wooden biomass

Economics

According to Decision of State Commission for Energy and Water Regulation (SCEWR) in Bulgaria the electricity produced by CHP with power up to 5 MW buys up from electrical distributing companies at 110 €/MWh. SCEWR motivates this preferential price for green energy with undeveloped market and shortage of large-scale CHP, based on biomass as fuel. According to Energy Law the price of electricity coming from biomass and other RES power plants is preferential and it calculates as 70% from mean selling price of electricity in previous year in order to stimulate construction of small power plants based on RES. Bulgaria strives for increase the share of RES up to 11% from domestic energy consumption in 2010. In own decision SCEWR gives an account of expenditure for investments in construction and exploration of CHP, including joining to the grid, location and wooden biomass residue prices varying between 35 and 65 €/t. At present in Bulgaria the rate of investments in up to 5 MW CHP based on wooden biomass are approx. 1800 €/kW installed power.

CONCLUSION

The effective utilization of domestic energy sources and potential of RES are a real opportunity for diversification of energy supplies in Bulgaria. The contribution of RES for energy production based on biomass converting into thermal and electrical energy will be significant in the future.

The major and significant features of RES are sustainability, competitiveness and security of supplies. Therefore, it is needed to compose a ***portfolio of technologies*** – well-founded both in technical and economic aspects technologies for wooden biomass utilization for energy production including following considerations:

⇒ ***species and condition of wooden biomass*** – sustainability, reliability and security regarding the volumes, supply, prices;

⇒ ***converting technologies*** – high-efficient technological equipment according to final product;

⇒ ***economic efficiency*** – relevant costs and profit.

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