EQUIPMENT AND TECHNOLOGIES OF COMBINED PROCUREMENT OF MERCHANTABLE WOOD WITH CUTTING WASTES UTILIZATION FOR ENERGY PRODUCTION IN BELARUS

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Abstract: *Current conditions and prospects of using wood fuel in Belarus are analyzed. The data on the annual economically available potential of wood fuel in Belarus and forecasts of its increasing are given. The projects of construction of small wood-fuel combined heat and power plants are considered. The technological processes of chip fuel production are presented. The domestically produced machines and mechanisms, used for wood raw materials procurement and comminution, for chip fuel transportation and storage, are analyzed. The recommendations for development of wood fuel productions in Belarus are given.*

1. Introduction

The energy consumption in the Republic of Belarus is about 33 million tons of standard fuel[3] annually, and only 15 per cent of this amount is covered by the own resources. The costs of purchasing the required energy resources and electric energy are about 2 billion € annually, that is equal to more than 30 per cent of the total amount of import of the Republic of Belarus, resulting in dependence of its economy on external factors. For 2006–2010, the challenge is issued to decrease the GDP energy intensity by at least 31 per cent, with GDP growth rates about 156 per cent (against 2005 level); in 2015, GDP energy intensity shall be decreased by at least 50 per cent, and in 2020, by 60 per cent. Meanwhile, along with measures for energy saving and introduction of energy-efficient technologies and equipment, a set of measures is implemented for maximization of utilizing local and renewable energy sources.

The total volume of forest stands in Belarus is about 1414 million m^3, that is about 243 m^3 per hectare. The average annual increment is slightly less than 30 million m^3, and the total volume of cuttings of all types is about 14 million m^3 only. In this respect, the matters of both logging volume increase and wood waste utilization for energy production, including utilization of logging, sawmilling, wood processing wastes and low-quality fuel timber, become especially important.

[3] 1 ton of standard fuel is equivalent to 29300 MJ

2. Wood fuel potential

To determine the potential of wood fuel resources in Belarus, the procedure was developed by the authors of this paper. On the basis of this procedure, the ***potential, technically available and economically available*** volumes of wood fuel were determined for the period up to 2015.

The possible *annual potential volume* (tons of standard fuel) *of wood fuel* (V(pot)), produced as a result of principal and intermediate harvesting, was determined using the formula:

$$V(pot) = \left(\sum_{(i)=1}^{(n)} V(i) \cdot K(i) + \sum_{(j)=1}^{(m)} V(j) \cdot K(j) + \sum_{(y)=1}^{(k)} V(y) \cdot K(y) \right) \cdot T(1) + \sum_{(e)=1}^{(n)+(m)+(k)} V(e) \cdot T(2), \quad (1)$$

where (i), (j), (y), (e) are the indices characterizing, respectively, the volumes of wood procured in principal harvesting, intermediate harvesting, forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality in exploitable forests, volumes of firewood used for heating; (n), (m), (k) are the numbers of cutting areas; V(i) is the volume of principal harvesting (m^3/year); K(i) is the wood waste generation coefficient for principal harvesting (0.16…0.29); V(j) is the volume of young stands tending cutting, thinning, selective sanitary cutting and other types of cutting (m^3/year); K(j) is the wood waste generation coefficient for young stands tending cutting (0.16…0.29), thinning (0.18…0.31), selective sanitary cutting (0.17…0.26) and other types of cutting (0.18…0.27); V(y) is the volume of cutting in forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality (m^3/year); K(y) is the wood waste generation coefficient for forest burnt-out places (0.01…0.1), windfalls and fallen wood areas (0.2…0.4), utilization of natural mortality in exploitable forests (0.16…0.28); V(e) is the volume of firewood for heating, procured in principal harvesting, young stands tending cutting, thinning, selective sanitary cutting, other types of cutting, in forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality; T(1) and T(2) are the factors for conversion from m^3 to the standard fuel tons with respect to wood waste and firewood.

The annual technically available volume (tons of standard fuel) *of wood fuel* (V(tech)), produced as a result of cuttings of all types, was determined using the formula (1), by multiplying the appropriate components by the wood waste extraction coefficients (0.45…0.6 for principal harvesting, 0.35…0.6 for intermediate harvesting, 0.65…0.8 for forest burnt-out places, 0.6…0.8 for windfalls and fallen wood areas, 0.2…0.3 for natural mortality).

In turn, *the annual technically available volume* (tons of standard fuel) *of wood fuel* (V(econ)), produced as a result of cuttings of all types, was determined by multiplying the *technically available volume* (V(tech)) of wood fuel by the coefficient, characterizing the economic reasonability of its using for the heat energy generation. This coefficient was determined, taking into consideration the wood fuel cost on the cutting area, hauling distance, transportation costs, wood fuel limit prices; according to the calculations and actual data from the enterprises, this coefficient is about 0.35…0.7.

The possible *annual available volume* (tons of standard fuel) *of wood fuel* (V(wood)), produced as a result of sawmilling and wood processing, can be determined using the formula (2), proposed by the authors of this paper:

$$V(wood) = \left(\sum_{(u)=1}^{(r)} (V(u) \cdot K(u) - P(u)) \right) \cdot T(3), \quad (2)$$

where (u) is the index characterizing the direction of merchantable wood consumption; (r) is the number of directions of merchantable wood consumption; V(u) is the volume of consumption of merchantable wood for (u)th production (m^3/year); K(u) is the wood waste generation coefficient for (u)th production (0.18…0.39 for sawmilling, 0.2…0.6 for wood processing); P(u) is the volume of consumption of wastes from (u)th production for technological purposes (m^3/year); T(3) is the factor for conversion from m^3 to the standard fuel tons with respect to wood waste in sawmilling and wood processing.

The investigations, carried out on the basis of the procedure proposed, indicate that the annual economically available wood fuel potential for the enterprises of forestry complex is about 6.8 million m^3, and in 2015 it will increase by 55 per cent.

In this connection, the plans are developed, stipulating both increase of consumption of wood fuel on small power engineering plants, and construction of 16 small combined heat and power plants (CHP plants) with about 1.2 million m^3 annual consumption of wood fuel. The enterprises of the Ministry of Forestry and "Bellesbumprom" Concern will be the principal suppliers of wood fuel for these power plants.

3. Promising systems of machines and equipment

In cooperation with "Minsk Tractor Plant" Republican Unitary Enterprise, a series of wheeled logging machines for principal and intermediate harvesting was developed, including harvesters, forwarders, trailing trucks with handlers, various logging tractors. Production of similar machines was implemented also by "Amkodor" Open Joint-stock Company (see Figure 1). The specific feature of these machines is a wide application of imported components and equipment, including hydraulic handlers, shear-and-grapple felling units, components of hydraulic actuators and automated control systems.

a *b*

Figure 1 – Wheeled logging machines: a) harvester ("Amkodor" Open Joint-stock Company); b) forwarder ("Minsk Tractor Plant" Republican Unitary Enterprise)

For implementation of technologies of combined procurement of merchantable wood with utilization of cutting wastes for energy production, the before-mentioned enterprises have also launched production of mobile chippers with barrel-type units ("Jenz GmbH", Germany; "Kesla OYJ", Finland), having the capacity about 40...100 m^3 loose per hour (see Figure 2).

a *b*

Figure 2 – Mobile barrel-type chippers with hydraulic handlers: a) driven by the stand-alone motor MR-40 ("Minsk Tractor Plant" Republican Unitary Enterprise); b) driven by the forwarder motor, with the collecting bin "Amkodor-2902" ("Amkodor" Open Joint-stock Company)

In cooperation with "Minsk Automobile Plant" Republican Unitary Enterprise, a road train for chips transportation was developed, with 80 m^3 loose turn volume (see Figure 3a). Also, the development of a chip truck with removable containers, having the turn volume about 35…40 m^3 loose, is at the final stage now (see Figure 3b). Wheeled front loaders are also produced in Belarus, having 400…6000 kg capacity, with removable process equipment, able to handle both round timber and chip fuel, with the load height up to 5.93 m.

a *b*

Figure 3 – Trucks for chips transportation ("Minsk Automobile Plant" Republican Unitary Enterprise): a) road train MAZ-5516+MAZ-8561; b) chip truck with "multilift" container handling mechanism MAZ-6501

4. Technological processes and economic effectiveness of chip fuel production

The availability of domestically produced logging equipment, in combination with foreign machines widely used in Belarus ("Farmi Forest Corporation", Finland; "Heizomat GmbH", Germany; "Vermeer Corporation", the USA), gave an opportunity to implement several technological processes of logging with chip fuel production at the cutting area and at intermediate or interseasonal storages. For the flowchart of the most typical existing technological process of chip fuel production, see Figure 4.

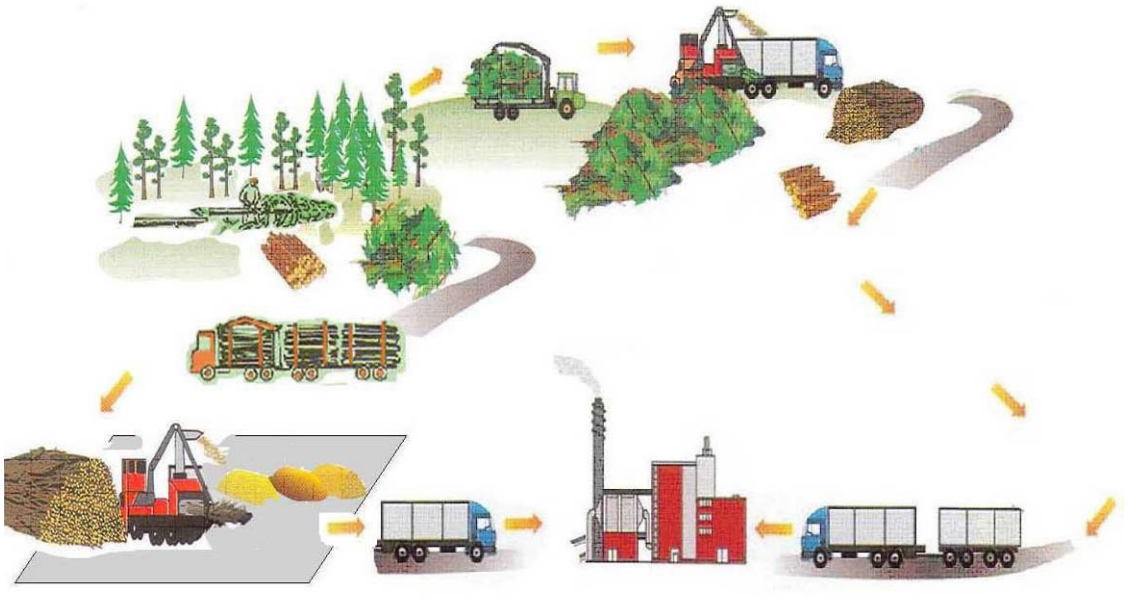

Figure 4 – The flowchart of technological process of chip fuel production

For provision of small CHP plants, both existing (Belarusian State District Power Plant, 22 200 m^3; Osipovichi small CHP plant, 34 000 m^3; Vileika small CHP plant, 60 000 m^3; Pinsk small CHP plant, 88 000 m^3) and planned for putting into operation in 2008 (Petrikov small CHP plant, 26 300 m^3; boiler plant in Rossony, 30 000 m^3; small CHP plant of "Mostodrev" Open Joint-stock Company, 38 000 m^3; Pruzhany small CHP plant, 60 000 m^3) with wood fuel, it was necessary to choose the most rational technological process and machine system.

As a result of solving this problem by several departments and organizations, and with no practical experience, the actual cost of chip fuel production for CHP plants in Belarus varies greatly. For example, for Vileika small CHP plant (where the fuel supply system was developed by the authors of this paper), the cost of chip fuel is about 15 €/m^3 solid; for the Belarusian State District Power Plant, this cost is about 22 €/m^3 solid, and for Osipovichi small CHP, about 28 €/m^3 solid.

5. Conclusion

The multiple technical and economical investigations, carried out by the authors with regard to the conditions existing in Belarus, give an opportunity to make the following conclusions.

1. At present, various technologies of combined procurement of wood and chip fuel production, both of them based on fully mechanized systems and involving mechanized work, can be implemented in Belarus. However, principal technical and economic indicators of these technologies are lower than those in countries with highly-developed forestry.

2. The technological processes, providing procurement and hauling of wood on cuttings of principal and intermediate harvesting as assortments, will become predominant, because of their better economic effectiveness indicators and maximum compliance with the requirements of forest certification.

3. Within the combined process of wood raw materials procurement, it is most reasonable to use mobile machine systems for chip fuel production. This machine system shall include: load-haul-dump machines; mobile barrel-type chippers, driven by a stand-alone motor, having the capacity at least 40 m^3 loose per hour; chip trucks, having turn volume more than 35 m^3 loose, or road trains, having turn volume about 70…80 m^3 loose; a bucket front loader, with bucket volume at least 5 m^3 loose.

4. As a rule, for fuel timber, comminution at interseasonal storages is most reasonable. For logging wastes, comminution at intermediate storages, located near all-weather roads, with the delivery distance not exceeding 5 km, and for sawmilling and wood processing wastes, communition at the source is most reasonable. Meanwhile, the required conditions of effectiveness of these processes are as follows:

- concentration of cutting areas;
- large volumes of cutting wastes and low-quality timber at intermediate storages, located near all-weather roads;
- scheduling of chip fuel hauling for the final consumer;
- finished products transportation distance should not exceed 50 km.

5. As a whole, for production and delivery of wood fuel in Belarus, about 228 logging tractors, 762 load-haul-dump machines, 167 chippers and tractors for their transportation, 620 chip trucks, 74 chip loaders are required.

6. The further improvement of the system of providing the power engineering plants in Belarus with wood fuel shall include:

- investment support of the enterprises for purchasing the equipment (subventions, credits on easy terms) and tax benefits;
- formation of wood fuel market, and stabilization of prices for the long-term period;
- development of domestic engineering industry, with regard to the machines and equipment for production and delivery of chip fuel;
- development of repair facilities and establishing of service facilities for special equipment;
- construction of new forest transport roads and proper maintenance of the existing ones.

7. At present, some experience of wood raw materials combined procurement and chip fuel production has been accumulated in Belarus. Positive results are obtained, confirming reasonability of involving the renewable wood resources in power engineering. There is hope that the prime cost of wood fuel procurement in Belarus can decrease as a result of implementation of international; experience, improvement of logging machines system and increasing their reliability, and implementation of advanced European technologies, matching the natural, industrial, social and economic conditions in Belarus.