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# ECONOMIC EFFECTIVENESS OF LOGGING RESIDUE BUNDLING AND CHIPPING

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**Abstract.** The paper contains research results into the time consumption and costs of fuel woody biomass production, in the form of bundles and chips from logging residues. The tests were conducted in adult pine stands and machine technologies for wood harvesting and extraction were used. The share of logging residues in the total tree biomass was assessed based on measurements carried out on three experimental plots in adult pine stands. The costs calculations contained fixed and variable cost categories. The share of the woody biomass which forms logging residues in the total above-ground tree biomass was 15%. The time consumptions of the energy wood harvesting, using machine technologies, were 0.447 h/m$^3$ for wood chips and 0.481 h/m$^3$ for residue bundles, and the costs amounted to 53 PLN/m$^3$ and 70 PLN/m$^3$, respectively.

**Key words:** energy wood, wood chipping, bundling of logging residues, costs, biomass

## INTRODUCTION

The increasing energy consumption, the need to counteract the climate change and to protect fossil fuel resources require the use of renewable energy sources. In the Polish conditions biomass seems to be the most promising resource of renewable energy. According to the statistical data [Leśnictwo... 2008] the total area of clear-cut areas in forests managed by State Forests (i.e. 78% of all Polish forests) was 26 016 ha in 2006 and it should be stressed here that this figure refers to pine forests mostly. In course of final fellings in pine stands, after extracting the round wood assortments, tree parts in the form of branches and tops are left behind, and they have to be either removed or milled before the new tree generation can be planted. This material is a potential source of energy and it is intensively used in countries like e.g. Sweden, giving about 100 TWh of eneregy per year [Wikström 2007]. The harvesting of this material for energy purposes doesn't harm the environment, provided it is conduced according to rules aiming at preserving the biodiversity and the ash (after the biomass is burnt) is returned to the site. In areas with high nitrogen atmospheric deposition, the extraction of logging resi-

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dues can even improve the nitrogen balance [Lundborg 1998]. The problem of the selection of technology for logging residue harvesting has to viewed in the light of machine accessibility. The choice of technology often depends on which machines, enabling the extraction, chipping or bundling of the energy material, are at the disposal of the forest manager. On the one hand such machines enable to reach high productivity, but on the other hand they cause high costs, which calls for research into the effectiveness of energy wood harvesting.

## MATERIALS AND METHODS

The field tests aiming to assess the share of logging residues in the tree biomass were conducted in Dąbrowa Forest District on two experimental plots in pine stands of 96 and 100 years of age, growing on a fresh mixed coniferous site. The volume of the tree stands was 278 and 298 $m^3$/ha. The average dbh was 33 and 37 cm, and the average tree heights amounted to 26 and 23 m, respectively. The share of the logging residues in the above ground tree biomass was assessed according to the Urich II method.

The energy wood harvesting technological processes in final fellings were applied in two variants and consisted of the following operations:

Variant A
- felling, delimbing and cross cutting into wood assortments with the use of a Timberjack 1270D one-grip harvester
- extraction of round wood with a Timberjack 1010D forwarder
- pre-concentration of logging residues with a Timberjack 1010D forwarder
- chipping of logging residues with a Bruks 805 chipper
- trucking of wood chips in containers up to a distance of 50 km.

Variant B
- felling, delimbing and cross cutting into wood assortments with the use of a Timberjack 1270D one-grip harvester
- extraction of round wood with a Timberjack 1010D forwarder
- bundling of logging residues with a Timberjack 1490D bundler
- extraction of bundles with a Timberjack 1010D forwarder
- trucking of bundles up to a distance of 50 km
- chipping of bundles at the heating plant.

The time consumption and costs were assessed according to methods and formulas described by Różański and Jabłoński [2003, 2005]. The technological tests were carried out on the same areas where the biomass measurements were conducted.

## RESULTS

The results of the weight measurements of sample trees on the experimental plots are presented in Figure 1. An average adult tree consists of 72 kg of branches and 67 kg of twigs with needles. Assuming there are 300-400 trees per ha, this gives 21.6-28.8 t of branches and 20.1-26.8 t of twigs with needles per 1 ha. The share of the woody biomass which forms logging residues in the total above ground tree biomass is 15%.

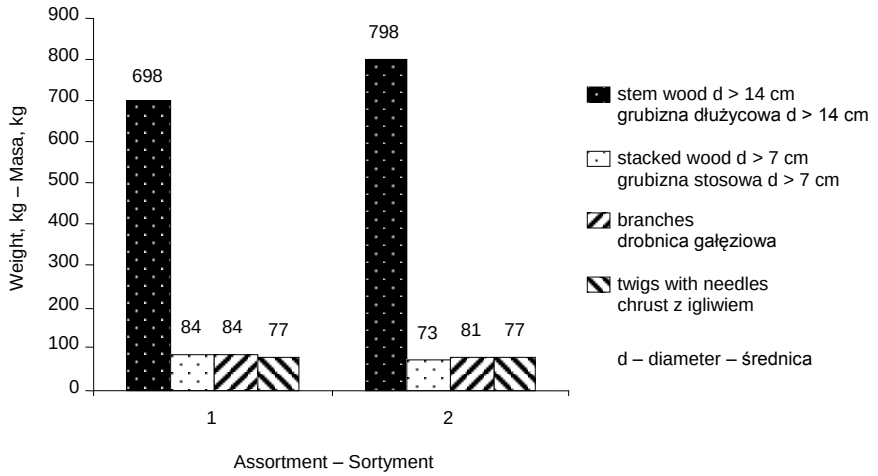


Fig. 1. Weights of wood assortments on experimental plots 1 and 2
Rys. 1. Masy sortymentów drzewnych na powierzchniach badawczych 1 i 2

The time consumption values and costs broken down into technological operations in the two variants tested are presented in Table 1. The comparison of the time consumption values of the energy wood harvesting variants showed that the technology in which the bundles were produced was by 8% more time consuming than the variant in which the wood chips were produced. The productivities of the energy wood chips and logging residue bundles amounted to 2.23 $m^3$/h and 2.08 $m^3$/h, respectively. Among different technological operations that were analysed, that of trucking the energy material to the heating plant was the most time consuming one. Then, the relatively most time consuming operations were those of bundling the residues on the clear-cut area (without pre-concentration of the logging residues) and the pre-concentration of logging residues with a forwarder. It can be assumed that an operation of pre-concentrating logging residues prior to the operation of bundling would have increased the time consumption of the whole process even further (with an expected decrease of the time consumption of bundling), because the field observations have shown that the relatively large time consumption of the bundler resulted from the need to move over the area and to collect the material.

The cost analysis of the two technologies showed that the variant with logging residue bundles was by 30% more expensive than the logging residue chip production technology. In the former variant, the costs of bundling played the dominant role, making 14% of the total technology costs. Taking into account the observed productivity of bundling (13 $m^3$/h), high hourly costs can be expected, up to a level of 370 PLN.

In the variant in which the logging residues were harvested in the form of chips, the costs of pre-concentrating the material and of chipping dominated, and they amounted to 31% and 29% of the whole process costs, respectively. A comparison of the costs of pre-concentrating the residues and their chipping with the costs of bundling without a pre-concentration operation showed that the cost values were similar, and the difference did not exceed 0.12%. However, the variant with the operation of bundling requires the bundles to be chipped at the heating plant. It should be stressed that the last

Table 1. Time consumption values and costs of the harvesting, extraction and trucking of logging residues

Tabela 1. Pracochłonności i koszty poniesione na pozyskanie, zrywkę i wywóz surowca energetycznego

| Operation<br>Operacja | Time consumption<br>Pracochłonność | | Costs<br>Koszty | |
|---|---|---|---|---|
| | variant A<br>wariant A | variant B<br>wariant B | variant A<br>wariant A | variant B<br>wariant B |
| | h/m$^3$ | | PLN/m$^3$ | |
| Felling, delimbing, bucking<br>Ścinka, okrzesywanie i wyrzynka | 0.021 | 0.021 | 6.36 | 6.36 |
| Forwarding of logs<br>Zrywka drewna okrągłego | 0.033 | 0.033 | 5.64 | 5.64 |
| Pre-concentrating of logging residues<br>Zrywka pozostałości zrębowych | 0.097 | – | 16.59 | – |
| Chipping<br>Zrębkowanie | 0.033 | – | 15.41 | |
| Bundling<br>Pakietowanie | – | 0.076 | – | 28.33 |
| Forwarding of bundles<br>Zrywka pakietów | – | 0.026 | – | 5.07 |
| Trucking of chips<br>Wywóz zrębków | 0.263 | – | 9.53 | – |
| Trucking of bundles<br>Wywóz pakietów | – | 0.296 | – | 10.67 |
| Chipping of bundles<br>Zrębkowanie pakietów | – | 0.029 | – | 13.55 |
| Total<br>Razem | 0.447 | 0.481 | 53.53 | 69.62 |

operation (chipping of bundles at the plant), due to its high cost (13.55 PLN/m$^3$) significantly increased the cost of the whole process of harvesting logging residues in the form of bundles.

## CONCLUSIONS

1. The technological processes of forest fuel harvesting in the form of chips and bundles produced from logging residues had similar time consumption values.

2. The production of bundles from logging residue bundles in the forest, with their subsequent chipping at the heating plant were 30% more expensive than the production of chips from logging residues in the forest.

## REFERENCES

Różański H., Jabłoński K., 2003. Analysis of selected technological processes of fuel wood chip harvesting. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 2(2), 81-90.

Różański H., Jabłoński K., 2005. Economic effectiveness of crushing logging residues with a Meri Crusher MJS-2.5 DT with a farm traktor Valtra T-190. Zesz. Nauk. AR Krak. 419, 75-81.

Leśnictwo 2007 [Forestry 2007]. 2008. GUS. Inform. Oprac. Stat. Warszawa (www.stat.gov.pl) [in Polish].

Lundborg A., 1998. A sustainable forest fuel system in Sweden. Biomass Bioener. 15, 4/5.

Wiktröm F., 2007. The potential of energy utilization from logging residues with regard to the availability of ashes. Biomass Bioener. 31, 1.

## EFEKTYWNOŚĆ PAKIETOWANIA I ZRĘBKOWANIA POZOSTAŁOŚCI ZRĘBOWYCH

**Streszczenie.** W pracy przedstawiono badania na temat pracochłonności i kosztów poniesionych na pozyskanie surowca energetycznego w postaci zrębków i pakietów wyprodukowanych z pozostałości. Badania prowadzono w rębnych drzewostanach sosnowych, zastosowano maszynowe technologie pozyskiwania i zrywki drewna. Udział pozostałości zrębowych w pozyskiwanej biomasie drzew określono na podstawie badań przeprowadzonych na trzech powierzchniach badawczych w rębnych drzewostanach sosnowych. W określeniu kosztów wykorzystano metodę ich obliczania z podziałem na koszty stałe i zmienne. Udział pozostałości zrębowych w całkowitej biomasie nadziemnych części drzew wynosił 15%. Pracochłonność pozyskiwania drewna energetycznego w technologii maszynowej ze zrębkowaniem pozostałości zrębowych wynosiła około 0,447 h/m$^3$, przy koszcie ok. 53 zł/m$^3$ zrębków. W technologii pozyskiwania surowca energetycznego w postaci pakietów wykonanych z pozostałości zrębowych pracochłonność wynosiła 0,481 h/m$^3$, a koszty kształtowały się na poziomie około 70 zł/m$^3$.

**Słowa kluczowe:** drewno energetyczne, zrębkowanie drewna, pakietowanie pozostałości zrębowych, koszty, biomasa

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