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THE LOGGING WASTE AS INEXHAUSTIBLE RESOURCE FOR ALTERNATIVE ENERGY

by

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The article shows that during the production and consumption of fuel wood for bioenergy projects in the organization of the Northwest and other regions of Russia there is the problem of lack of raw materials. It is established that the waste timber, during cutting on average, about 20% of the stock of standing timber. This value varies according to region, type forest resources and the skills, and technical equipment performer. Therefore, the main purpose of the article is a system evaluation of the use of forest residues in Russia. The authors present data on volumes of raw materials for production of wood chips and pellets on example, the Northwest region of Russia. Only about 30% of wood chips are now received from wood waste, bulk wood chips, and pellets produced from the wood of stems. Small volume of use of bark, twigs, branches, tops, stumps, and roots is due imperfection of processing technologies. Another important issue addressed in the article – the lack of standards and guides taxation inventory valuation and structure of the waste in many regions of Russia. This primarily relates to the hardwood. Research has shown that, depending on tree species, the structure and volume of waste are significantly different. Expert evaluation conducted by the authors shows that the proportion of forest residues from 5 to 20% of the stock of wood. It is found that in different forest types share twigs, branches, stumps, and roots vary considerably according to species of tree. But even within the forest reserves such as twigs, branches, and underground parts of the same species depend strongly on the age of stands and their completeness, and the differences may reach 2 to 5 times the size.

Key words: *northwest region of Russia, forest ecosystems, logging waste, alternative energy*

Introduction

More than a quarter of the world's wood is concentrated in Russia. At the same time each year about 200 million m^3 is harvested though the potential resource for timber harvesting is 2-2.5 times higher. The forest sector plays an important role in the Russian economy, but its effectiveness is not sufficiently high for various reasons. One of the main reasons is poorly developed network of roads and forest infrastructure. As a consequence a low level of forest residues is used. If the average for the whole Russian territory the share wastes considered to be 20% of the timber harvested volume we get that every year about 40 million m^3 of

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wood in the form of stem base, tops, twigs remain not used [1]. Taking into account all types of waste generated on the cutting area their total amount can reach 45-60 m^3/ha in terms of total clearing area (about 1.5 million hectares) will be at least 75 million m^3.

More than half of the forest resources are on the European part of Russia and about 30% of the wood is in the North-West Federal District. In terms of production of wood products this region occupies a leading position in Russia by volume of wood production. Northwest Russia is a major exporter of forest products to world market [2].

A lot of wood waste is produced due to the placement of logging and wood working capacities and lack of lumber-track development and forest infrastructure in general. Half of the harvested timber is realized as sawmill and veneer logs, but much of the hardwood is not used, because in North-West part of Russia we have not got so much hardwood forests and at the best case it is utilize as firewood.

Forests of Russia did not vary significantly by the composition of tree species. The dominant species is a larch (more than 38% of the forested area). About 70% of the forest area is occupied by *Coniferous species*. On the territory of the Leningrad Region also is dominated by conifers (pine and spruce). The structure of the forests of the Leningrad Region shows the high quality of forest resources: the proportion of pine 36.0%, spruce 33.5%, birch 22.1%, aspen and others 8.4% [3].

The predominance of *Coniferous species* continued in the Karelian Isthmus and the eastern part of the Leningrad Region. However, in the whole region the wood resources and the area occupied by *Deciduous species* (birch, aspen and alder) are markedly increased.

The forest area of Leningrad Region occupies about 5.8 million hectares. The annual prescribed cut is 12.3 million m^3 [4]. In recent year prescribed cut on the average on North-West region is used by about 43% and in the Leningrad Region by 50%. This volume of harvesting residuals content energy comparable with energy from other alternative sources – wind, hydro, and solar [5, 6].

Methodology of the research

In this paper calculations based on materials obtained in the field at the model areas, stationary objects with a long term observations (from 1929) and in numerous plots which laid down in the Leningrad Region and the neighboring Russian subjects.

In determining the total amount of wood waste from logging, we take into account the total volume of timber harvested on certain forest areas, regions, and subjects of the Russian Federation. Potential reserves are estimated based on the value of the annual prescribed cut, *i. e.* the value that can be taken annually from forest ecosystems without damage to their condition and future growth. The actual amount of logging residues were determined on the basis of field studies taking into account the actual use of the annual prescribed cut of coniferous and deciduous species.

Logging residues includes tree tops, branches and twigs, bark, (the thickest part of the stem close to root), and stumps. The volume of these units was determined by the special tables with which and establishes the proportion of waste in the total volume of wood [7]. Direct measurement of exposed waste in the form of low-quality wood (diameter and length of the stems left on the cutting area).

The measuring of logging residues in the field work was carried out by the plots in accordance with OST 56-89-83, an industry standard, which shows quality of the product) and Guidance on the challenge of cutting areas [8]. Detailed surveys with the distribution of forest residues on tree species, size and category of fractions, were carried out on the routing course

[3, 9, 10]. To convert the stacked cubic meters in thick we used special coefficients established for improvement cuttings in young stands [7]. All initial data are obtained in the field directly.

In the calculations the taxation uniform standards for stock assessment and the structure of waste on individual subjects of the Russian Federation were used. For conditions of the Leningrad Region [7, 11, 12] the stock of waste for such hardwoods as alder and willow was determined from the tables accepted for aspen due to lack of a specific table.

Data on the fractional structure of phytomass mature stands, content of chemical elements and calorie content (specific heat of combustion) of various fractions of wood waste were used from various sources: reference books and publications [4, 7, 8, 13].

Results of the research

On average, logging residues are about 16-24% of the stock of growing forest. On every cutting area the structure of logging residues is about identical. Differences exist only in the ratio of individual fractions (tabs. 1 and 2).

Table 1. The structure of forest residues and their volume after clear-cutting (field work data)

The composition of the stand before cutting	Fractions of forest residues					The share of the volume of harvested wood [%]
	Stems [m^3ha^{-1}]	Branches [m^3ha^{-1}]	Tops [m^3ha^{-1}]	Sawdust [m^3ha^{-1}]	Total [m^3ha^{-1}]	
Pine forest						
9P1B	4.8	5.7	2.9	3.1	16.5	10.7
7P2S1B	4.2	8.3	3.4	3.7	19.6	12.1
5P2S2B1A	4.9	8.9	4.2	4.0	22.0	15.4
Spruce forest						
9S1B	3.4	11.7	6.8	5.2	27.1	21.8
7S2B1A	4.7	12.6	7.2	6.0	30.5	22.6
5S2B1P1As1Al	5.1	11.3	6.6	4.8	27.8	20.5
Hardwood-conifer forest						
9B1S	5.8	4.7	3.3	3.0	16.8	15.9
7B2S1P	5.0	9.1	4.1	4.5	19.6	18.0
5B2S2As1P	5.9	9.7	5.2	4.7	25.5	21.0
7As1S1B1W	8.8	11.3	5.4	6.2	31.7	23.7
5As2S2B1P	8.9	10.9	4.9	6.0	30.7	22.1

As one can see, the volume of logging residues on the experimental plots differs significantly. This value varies depending on many factors:

- silvicultural zones,
- characteristics of the forest fund,
- type and composition of the forest stand,
- the cutting area and harvesting season,
- method of cutting and the technology, and
- qualifications of executive and the unutilized technique.

Table 2. The structure of forest residues and their volume after a partial cutting (field work data)

The composition of the stand before cutting	Fractions of forest residues					The share of the volume of harvested wood [%]
	Stems [m^3ha^{-1}]	Branches [m^3ha^{-1}]	Crowns [m^3ha^{-1}]	Tops [m^3ha^{-1}]	Total [m^3ha^{-1}]	
Pine forest						
9P1B	3.2	3.0	2.0	2.1	10.3	12.3
7P2S1B	3.0	5.1	3.1	3.2	14.4	11.9
5P2S2B1As	4.1	5.3	2.7	2.8	13.9	14.2
Spruce forest						
9S1B	2.2	8.7	4.4	3.5	18.8	21.0
7S2B1As	3.0	8.9	5.1	3.8	20.8	21.6
4S2B2P1Al1W	3.6	7.3	4.2	3.0	18.1	19.8
Hardwood-conifer forest						
7B2S1P	2.3	6.0	2.7	2.8	13.8	18.7
5B2S2As1P	3.1	6.2	3.5	2.9	15.7	20.3
5As3S2B	5.7	7.9	2.8	3.3	19.7	23.1

The proportion of forest residues by a partial cutting is more than by a clear cutting (from the total growing stock). It is possible to explain it by the fact that both in the partial cutting sand clear cuttings the area allocated for official territories is about identical in which all trees regardless of their size cut down – loading platform, platforms for fuels and lubricants, forest strip (auxiliary), and main-line runs.

Inventory results show that on the cutting area in form of the waste from 17 to 32 m^3 phytomassis leaved after clear cuttings and on 35-50% less is leaved after partial cutting. Only about 30% from this amount is used for production of wood chips. Currently the great bulk of wood chips and pellets in Russia are produced from stem wood [2]. Small amount of bark, twigs, branches, tops, stumps and roots is due to a significant deconcentrating of this kind of raw and imperfect technology of collection and processing.

The total volume of logging residues is essentially dependent on the type of forest (yield class), tab. 3 [2].

The greatest amount of waste generated after cutting of spruce stands in the *oxsalis* forest type. The smallest amount of waste generated in *vaccinium* type of pine forests. In absolute values the differences reach two times the size. The share of waste from general stock of wood is 14-25.8%.

Our studies have shown that depending on the composition of forest stands and forest type the structure of the waste and volumes are significantly different. It is established that in one forest type the share of twigs and branches depends significantly on the composition of forest stands (dominant species).

The logging residues are formed also during the improvement cuttings. Depending on the type of improvement cutting (standage) the amount of waste is very different, tab. 4.

The twigs, branches, and other fractions reserves within the same type of forest are seen to strongly depend on the age of stands, density and felling intensity. These differences by type of improvement cutting can reach 5 times the size when the intensity of cutting is 20%

Table 3. Number of forest residues in the pine and spruce stands depending on the type of forest (field work data)

The composition of the stand before cutting	The volume of logging residues depending on the type of forest				Average amount of waste from general growing stock [%]
	Oxsalis [m^3ha^{-1}]	Myrtillis [m^3ha^{-1}]	Politrichum [m^3ha^{-1}]	Vaccinium [m^3ha^{-1}]	
9P1B	–	16.8	14.7	16.5	13.2
7P2S1B	–	19.6	16.2	17.8	16.9
5P2S2B1As	–	22.0	–	–	17.7
3P3S2B2As	29.7	24.6	–	–	19.3
9S1B	33.9	27.1	23.2	–	21.8
7S2B1As	30.5	27.2	–	–	23.1
5S2B1P1As1Al	29.0	28.5	24.8	–	20.6
Average amount of waste from general growing stock, %	25.8	21.3	17.1	14.0	–

With increase of improvement cutting intensity the volume of logging residues increases regularly.

Table 4. The number of logging residues generated after improvement cuttings in *myrtillis* tape of spruce forest m^3 per ha (field work data)

The type of improvement cutting	Cutting intensity [%]		
	20$^{(a)}$	30$^{(b)}$	40$^{(c)}$
Cleaning cutting, 10-20 years	1.2	1.8	2.5
Cutting-back, 21-40 years	3.7	4.4	7.6
Transit cutting, 41-60 years	7.0	10.5	13.1

(a) closing of leaf canopy, the density of 0.7-0.8, (b) closing of leaf canopy, the density of 0.8-0.9, and (c) closing of leaf canopy, the density of 0.9-1.0.

Discussion

The problem of rational and full utilization of logging residues and wood waste, wood working as a secondary raw material becomes crucial in many countries around the world. This problem is most actual today in Russia.

The total amount of wood waste used in our industry is not more than 9%, mostly they are top and other parts of the stems [2]. There are a great number of utilization areas of such materials: energy, construction materials, road construction, furniture, *etc.* In Russia the method of thermal biomass processing in gas-generator with receipt of gaseous fuel tests for a long time. Feedstock for gas-generator can be not only wood waste but also any carbon-containing wastes such as peat, bark, vegetable wastes from agriculture, municipal, and household wastes. The resulting gas has a high caloric content (8.5 m^3 gas generator is equivalent to 1 kg of heating oil) [4, 13].

Pellets production is widespread. Increased pellets production associated also with the Kyoto agreement to comply of environmental regulations. The pellets in Russia are less popular than in Europe but the situation is gradually changing. The increase of pellet production in Russia is connected with the development of wood industry. The rapid energy price increase is second important point.

The one kilogram of wood pellets on caloric is known to replace 0.5 liters of diesel fuel. Pellets have a high calorific value, increase the efficiency of boilers, easily stored, do not ignite spontaneously. Thus pellets emit 50 times less CO_2 and 20 times less ash than coal. Pellets are the cleanest fuel burned almost completely. Pellets ash is only 0.7% and the calorific value is 1.5 times higher than normal wood. Thus the ash can be used as fertilizer [2].

Despite the availability of promising scientific and technological development on deep processing of wood waste the analysis of current industry and economy state of Russia analysis allows to determine as the primary the method of briquetting. This is due to not only the level of industry readiness but also the growing demand by housing and communal services of the country for an ecologically clean fuel.

The geographic dispersion of waste wood, wood working enterprises, the remoteness of cutting areas sites from pulp and paper mills, the lack of efficient technologies on wood waste processing are reasons of poor wood wastes utilization.

Wood wastes have a high caloric content (specific heat of combustion). The calorific value of wood is comparable with peat and brown coal, tab. 5.

Table 5. Specific heat of organic compounds combustion

Raw	Calories combustible materials [kJlkg^{-1}]
Slate	9600
Peat	12100
Wood (moisture 12 %)	12400
Brown coal	13000
Bituminous coal	27000
Heating oil	40600
Petrol	44000
Natural gas [kJl/m^{-3}]	33500

(Source: Krankina. *et. al.*, 1999)

The burning of 1 ton of wood waste can save 0.2-0.3 tons of heating oil or 250-300 m^3 of gas.

Regulatory heat engineering parameters heater are about 12500 kJl/kg. When using briquettes the efficiency of heater reaches 76%. The fuel component of one Gcal development of thermal energy by means of fuel briquettes from waste wood is equal to 219.55 rub. per Gcal, and in heating oil and coal is equal to 271 rub. per Gcal and 263 rub. per Gcal, respectively. [2] Evident the use of briquettes from wood waste is economically justified. In this case wood chips are more efficient and environmentally safer than coal and heating oil.

The elementary chemical composition of different species wood is almost identical. On average, absolutely dry wood regardless of the species contains 49.5% carbon, 44.2% oxygen (with nitrogen), and 6.3% hydrogen. The nitrogen in the wood contains about 0.12% [13]. Growth conditions virtually no effect on the major elements content. Chemical composition of forest residues and the content of the basic substances are presented in tab. 6.

Table 6. Organic matter content in the different species wood [13]

Organic matter	Organic matter content in the main tree species [%]			
	Pine	Spruce	Birch	Aspen
Extractivesubstances	7.89	5.06	3.80	4.47
Cellulose	56.50	55.17	47.20	47.80
Lignin	27.05	27.00	19.10	21.67
Pentosans	10.45	11.24	28.70	23.52

On average we can assume the wood of conifers contains 48-56% cellulose, 26-30% lignin, and 23-26% hemicellulose.

The chemical composition of the bark is markedly different from the chemical composition of wood. Compared with wood the bark contains more ash, extractives substances and lignin, but less cellulose and hemicelluloses (pentosans). The chemical composition of main tree species bark is shown in tab. 7.

Table 7. The chemical composition of the tree species bark [13, 14]

Species	Part of the bark	Content of organic matter [%]				
		Water-soluble	Cellulose	Lignin	Hemicelluloses	Other
Pinus	phloem	20.84	18.22	17.12	28.44	15.38
	cortex	14.20	16.43	43.63	12.76	12.98
Spruce	liber	33.08	23.20	15.57	18.95	9.20
	cortex	27.91	14.30	27.44	14.80	15.55
Birch	phloem	21.40	17.40	24.70	20.30	16.20
Aspen	phloem	31.32	8.31	27.70	18.80	13.87

Conclusions

Timber reserve in the Russian Federation is about 82 billion m^3, it is more than a quarter of world reserves. In compliance with the principles of sustainable forest management in Russia every year you can harvest from 500 to 550 million m^3 [15]. Over the past five years on average for the year 190-230 million m^3 is harvested. Therefore, there is an essential reserve for increasing the volume of lumbering. The main causes of prescribed cut under utilization are lack of forest infrastructure in many regions of Russia and lack of wood working capacities.

The forest sector plays an important role in the economy and especially in those regions of the Russian Federation in which the share of forest products in total production about 50%. Just in these regions the bulk of forest residues are concentrated. The use of these residues for the biofuel production is stimulus to economic development of forest regions, decision social concerns and environmental safety. Russia joined to the Kyoto agreement on climate change prevention. So it is advisable to use of biofuel as a renewable energy source because the emissions of GHG are considered to be zero in this case.

Wastes generated from timber harvesting are an effective energy resource. If the waste to transform into fuel chips the one conventional ton of heating oil can be received from 11-15 bulked cubic meters of fuel wood chips (or 3-5 cubic meters thick) [7]. According to experts a thick cubic meter of fuel wood equivalent to 2 MW/h. To meet the annual heat demand by separate cottage about 20 MW/h *i. e.* 10 think cubic meters or about 20 bulked cubic meters of wood chips are required. If the average share of waste considered to be 20% of the harvested timber volume (about 200 million m^3 per year) it is only through the use of forest residues can be made annually not less 200 million MW/h of energy.

There is another important point. Coal, heating oil, gas must be transported to the consumer for many thousands of kilometers. The fuel wood is concentrated frequently on a short distance from the consumer and is no less efficient source of energy which besides is rapidly renewable natural resource. For these reasons the share of transportation costs in the cost of wood chips is only a small part.

Wood waste also has a different value. It is a holocoenotic value. We mean the role of waste as a source of organic and mineral substances. With each withdrawal of timber from the forest ecosystem a significant amount of chemical elements are taken there from. It is not necessary to fill up a stock of nutrients in the ecosystem at the expense of fertilizers and other improvement measures because the essential part of wastes leaves in cutting area. Thus the maximum utilization of forest resources is economically feasible and effective, but however we harm to forest communities because we reduce and impair their food allowance. That is why every generation of forests will be weaker. Less productive and less diverse.

Under intensive forest management the optimal forest productivity through timely and effective economic measures can be maintain. In Sweden, Finland, Switzerland and Austria, in countries where a small area of forest it is real. However, it is impossible in spacious forests of Russia. Canada. Here forest area per capita is 50-100 times more and forest infrastructure is less developed than in any European country.

In Russia, waste wood is not fully utilized. But it does not mean. They do not benefit. Waste – is an organic substance. staying on the ground cutting is involved in the biological cycle. It is an undoubted benefit to the forest ecosystem. With regard to waste wood as an alternative energy source. then in the near future they will be sorted and recycled. The main direction – the use of mobile units.

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