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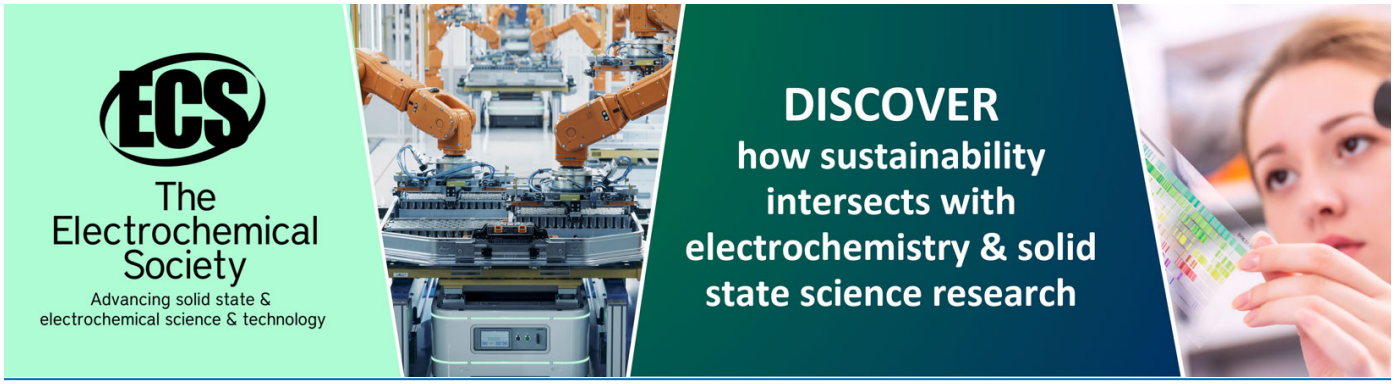

The use of waste products of the forestry sector for energy purposes in the central ecological zone of the Baikal natural area

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Abstract. We analyze the problems of using waste products of the forestry sector for energy purposes with the central ecological zone of the Baikal natural area as the case study. From the standpoint of the energy sector, the two main problems that hinder the spread of wood fuel are discussed: pricing and transport of the end product. From the standpoint of the forestry sector, the main problem is the transport of wood from logging sites. We investigate the influence of the annual amount of wood feedstock at wood processing enterprises on the optimal method of wood waste recycling. It is concluded that, at present, wide adoption of fuel pellets and wood chips proves impossible unless supported by state measures.

1. Introduction

The central ecological zone of the Baikal natural area has a special status with respect to the use of natural resources according to the Federal Law of the Russian Federation of May 1, 1999. "On the Protection of Lake Baikal" [1]. The inscription of Lake Baikal on The World Heritage List and List of World Heritage in Danger [2] also imposes prohibitive measures on activities that harm the environment [3]. All of this indispensably requires minimizing the human-induced impact, including the use of fuels that have environmental advantages over their conventional counterparts. Therefore, the use of wood fuel may be relevant in this area.

Among the wide range of technologies, it is biomass energy that is of great interest given Russia's circumstances. Deforestation without subsequent reforestation makes no good to the environment. Therefore, the use of plants and, above all, trees for energy production is possible only in three cases: sanitation harvest, the creation of dedicated energy plantations, or the use of wood waste from the forestry sector.

The use of wood from sanitation harvest is fully justified from an environmental point of view. However, its collection and transport are not economically feasible because of transport costs. In addition, the use of such wood fails to meet the conditions of reliability of heating. It cannot serve as the main source of energy.

The use of artificial forests, the wood from which is used for energy purposes, proves reasonable and is already practiced in some countries in Europe and North America [4-7]. There are no such forests in Russia. In the coming years, their creation seems to be not possible due to the large stock of wood from natural forests [8] and the large number of enterprises in the forestry sector, the by-products of which are sawdust, slab wood, wood chips, etc.

It is the wood waste generated by enterprises of the forestry sector that is of the greatest relevance because its use for energy purposes has a double effect: environmental (in terms of waste recycling), and economic (the manufacturer generates additional income from the sale or in-house consumption of the secondary product, and the consumer gets environmentally friendly fuel at a relatively low price). Thus, all three key aspects of the energy trilemma - energy security, energy equity, and environmental sustainability - are fully ensured [9].

2. Research methods

During the study, we used methods of mathematical statistics for the preparation of the initial data and the method of value engineering. To assess the feasibility of using wood fuel for heating, the metric of the levelized cost of energy, which is the ratio of the sum of all costs during the life cycle of the project to the energy also generated for the entire life cycle [10], which is determined as per the formula:

$$\mathrm{LCOH} = \frac{\sum_{t=1}^{n} (C_t + I_t) \cdot (1+r)^{-t}}{\sum_{t=1}^{n} H_t \cdot (1+r)^{-t}}. \quad (1)$$

Here C_t – operating costs per year t, million rubles; I_t – capital costs per year t, million rubles; r – discount rate; H_t – amount of heat produced per year t, Gcal; n – technology life cycle, number of years.

3. Results

According to official statistics [4], annual fluctuations in fuelwood production in Russia from 2009 to 2018 were insignificant. Annual production was about 12-15 thousand cubic meters of solid wood, almost 30% of them - in the Siberian Federal District. However, it is impossible to accurately estimate the annual volume of wood fuel production, since a significant portion of logging is done by the population themselves, including illegally.

Despite the fact that wood fuel is one of the most common in rural areas, it is almost never used at CHPPs. Recently, though, there have been discussions about projects to use wood for centralized use. A case in point is the boiler house in the town of Baikalsk, Irkutsk Region, which is located within the boundaries of the CEZ.

Restrictions on the use of wood fuel are due to a number of factors: the remoteness from the sites of production and transport infrastructure, the availability of a source of feedstock in place, high energy intensity of production, etc. The factors that make the use of wood fuel appealing are its relatively low cost, environmental friendliness, encouragement of the use of renewable fuels and the prohibition of some fossil fuels at the legislative level, as well as the possibility of recycling wood waste and generating additional income for forestry sector enterprises

3.1. Use of wood waste from the standpoint of the energy sector

According to the data collected during the expeditions of the Melentiev ESI, SB RAS, in 2017-2019 [11], despite the significant environmental advantages of wood fuel in the CEZ of the BNA, out of 109 boiler houses belonging to municipalities and the Ministry of Education of the Russian Federation, only 8 run on this type of fuel. These are mostly kindergartens and schools. In all eight cases, the wood fuel is represented by regular firewood. Firewood is currently used as fuel at small boiler houses in the Olkhonsky, Kabansky, Barguzinsky, and Pribaikalsky districts.

In general, the use of wood has both advantages and disadvantages (table 1).

3.1.1. Eco-friendliness. Wood fuel is a completely environmentally friendly fuel when one uses waste from the forestry sector and sanitation harvest, without the deliberate cutting down of natural forests.

Wood is a fuel with neutral greenhouse gas emissions, i.e., the amount of CO_2 emissions from burning wood is equal to the amount of its absorption during growth [12].

Table 1. Advantages and disadvantages of wood fuel.

	Firewood	Wood chips	Fuel pellets (briquettes)
Eco-friendliness	+	+	+
Fuel cost	–	+	–
Transport and storage costs	–	–	+
Ease of feeding during combustion	–	+	+

3.1.2. Fuel cost. The cost of wood fuel directly depends on the type of feedstock and the degree of its processing.

The lowest of those considered is the cost of fuel chips. It is usually a secondary product of production at logging and timber processing plants. There is practically no market for fuel chips in Russia. Oftentimes it is simply provided free of charge to the local population and interested businesses.

A more expensive fuel is firewood. Despite the low cost of processing, the production requires higher quality feedstock that could be used to produce lumber.

The most expensive fuel is fuel pellets and briquettes. The reason for their high prices is primarily two factors: their high energy intensity and high export prices. Significant reserves of wood waste, from which this type of fuel is produced, are often found in areas where there is no centralized electricity supply, which makes the production of biofuels low-profit. Another problem with the use of fuel pellets is their pricing in the domestic market. These products are in great demand in Europe and some Asian countries. The effective demand for pellets in the country does not match the global demand. Therefore, the market for pellets in Russia is unstable, most of the products are exported. The prices of those products that remain in Russia are dictated by export prices.

3.1.3. Transport and storage costs. Wood fuel and especially wood feedstock have a relatively low energy density. Therefore, its transport over long distances greatly increases the final cost. It is more efficient to use wood fuel only in areas relatively close to where the feedstock source is located. Permissible distance limits depend on the energy density of a particular type of wood fuel and the transport infrastructure of the area. Figures 1 and 2 show how the final cost of heat produced by the combustion of fuel chips and pellets varies depending on the method of transport (by rail or road). The final cost of heat obtained from the combustion of pellets, when transported over short distances, is higher than that of wood chips. As the distance increases, the final cost of heat obtained from the combustion of wood chips increases much faster due to the lower energy density. It grows especially fast when transported by road.

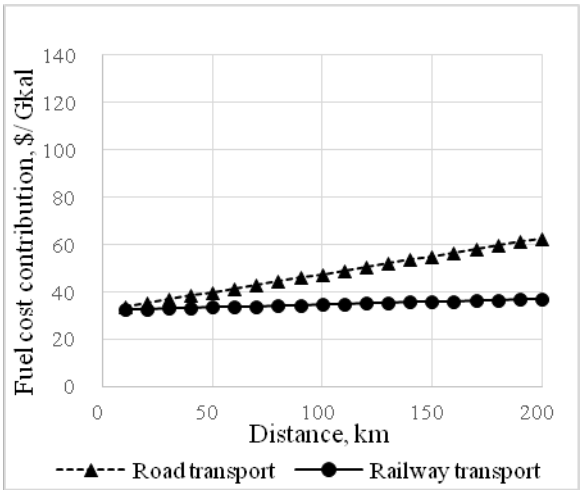

Figure 1. Changes in fuel components of wood pellets in the cost price of heat depending on the distance and way of freight transportation.

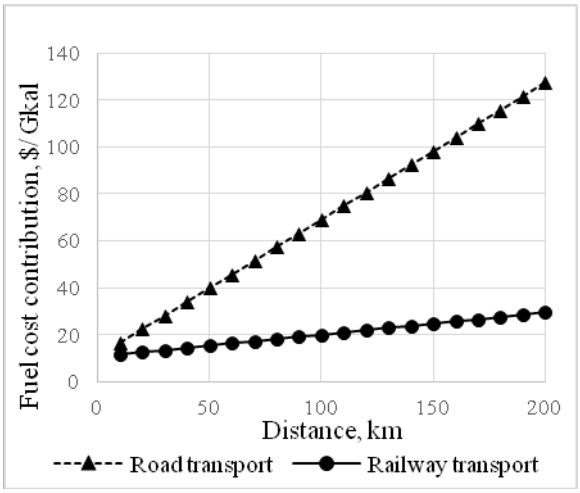

Figure 2. Changes in fuel components of wood chips in the cost price of heat depending on the distance and way of freight transportation.

3.1.4. Ease of feeding during combustion. The convenience of feeding during combustion is due to the possibility of its automation. With standardized sizes of fuel pellets and wood chips, such feeding is quite possible, while when using firewood, it is difficult.

3.2. Use of wood waste from the standpoint of the forestry sector

Wood processing, as is known, involves huge losses of wood. At the logging stage, waste (stumps, limbs, needles) can reach several tens of percent of the original volume. Further, only 60% of all wood approved for processing becomes lumber. The remaining 40% is distributed as follows: about 12% - sawdust, 6% - end trimmings, and 22% - slab wood and sawn wood edge trimmings. It is advisable to use this wood waste for energy purposes in the form of fuel chips or pellets (briquettes).

3.2.1. Law on the recycling of wood waste. Since 2015, the State Duma has been working on amendments to the law on the mandatory recycling of wood waste. It is expected to be considered in 2022. For recycling purposes, it is supposed to introduce a ban on the burning and burying of wood left as a result of industrial activities. All the residues obtained will have to go back into the production chain with the subsequent result as a finished product, a component for other goods, or energy generated. Without waiting for amendments to the federal law, amendments to the republican law "On the organization of reception and shipment points of wood in the Republic of Buryatia" have been effective since October 1, 2019 in the Republic of Buryatia. According to the amendments, each wood processing company within one year must completely recycle its wood waste on their own or ensure its transfer for further processing. As a result of this amendment, one can already consider the creation of new and enlargement of existing pellet plants in the Republic of Buryatia. A case in point is Baikalles LLC, which in 2020 increased its production capacity of 8 to 10 thousand tons of pellets per year.

3.2.2. Influence of the volume of wood waste from the forestry sector on the method of recycling. For each particular wood-processing facility, the choice of wood fuel recycling method depends on the annual stable amount of wood waste. The production of pellets involves considerable costs, their energy density is high, the product has a high market price. The production of wood chips does not involve considerable costs, its energy density and market value are very low. Therefore, it is advisable to transport it only for short distances. The market for pellets is wider because of the possibility of transport. Therefore, in the case of large volumes of wood processing (and, consequently, waste), their

production is more profitable. It allows one to recover a large capital investment. In the case of small production facilities, the capital investment in pellet production, where wood is chopped, dried and, pressed, fails to be recovered. Therefore, in this case, it is advisable to resort to wood processing with less added value - to shred the wood into chips without additional drying and pressing.

The study showed that provided the current price conditions with a volume of wood waste less than 300 cubic meters / year, it is advisable to deliver wood waste to larger wood processing companies, and in the case of a volume of wood waste more than 300 cubic meters / year - to produce wood fuel on one's own. When the volume of wood waste is more than 5,000 cubic meters/year (figures 3, 4), the levelized cost of heat energy at the site of production (exclusive of transport costs) becomes stable. For pellets, it stabilizes at about $7.5 and $9.5/Gcal for the Irkutsk region and the Republic of Buryatia, respectively. The difference is due to the values of limit electricity tariffs in these constituent entities of the Russian Federation [13-14]. The levelized cost of heat (thermal energy) obtained from the combustion of fuel chips, for both subjects varies at the level of 0.5 $ / Gcal.

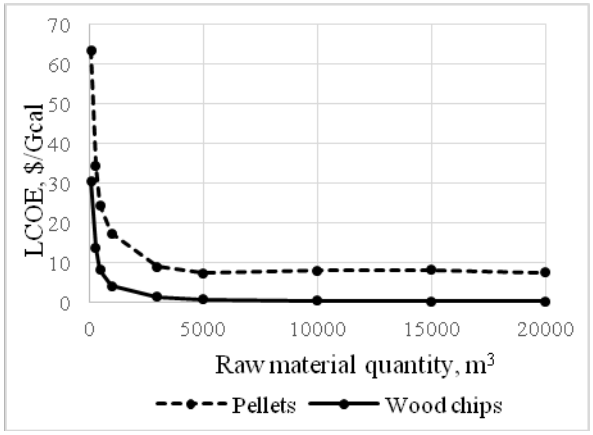

Figure 3. Change in the levelized cost of thermal energy obtained from the combustion of fuel chips and pellets, depending on the annual volume of feedstock in the Irkutsk region.

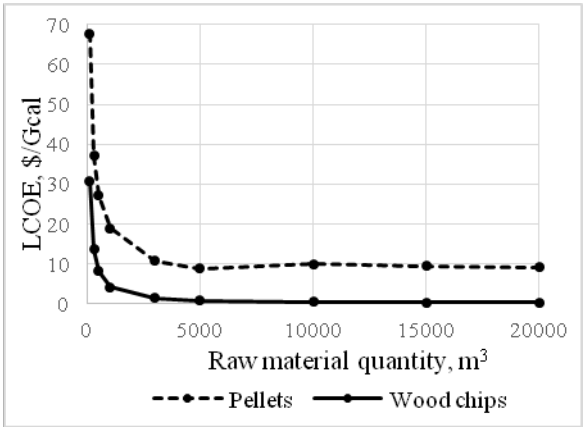

Figure 4. Change in the levelized cost of thermal energy obtained from the combustion of fuel chips and pellets, depending on the annual volume of feedstock in the Republic of Buryatia.

4. Discussion

The following problems stand in the way of widespread adoption of wood fuel: high transport costs, insufficient information base on the volumes of wood waste, inefficient management.

The transport factor is the biggest issue with the use of wood fuel. This is associated not only with the transport of finished products but also with the transport of wood from logging sites. Every year a huge amount of "logging residues" (wood culls, twigs, and top logs) are burned in thousands of cubic meters during logging site cleanup, making a huge contribution to greenhouse gas emissions and carbon release. A large amount of substandard wood simply rots in the forest.

The insufficient information base on the volumes of wood waste and its composition makes it difficult to plan its use, especially in the long term. In 2020, as part of the research work on the implementation of the federal targeted program "Protection of Lake Baikal and the socio-economic development of the Baikal natural area for 2012-2020" the administrations of all municipal districts located in the Central ecological zone were sent inquiries regarding the state of the woodworking industry. Informative answers were provided only from the Olkhonsky District of the Irkutsk Region and the Barguzinsky District of the Republic of Buryatia. The rest of the municipalities responded either with statements of having no information or that there were no wood processing plants within their territory. The information about the absence of wood processing plants in some cases was not reliable. Often unrecorded wood is linked to the disastrous nationwide problem of illegal logging.

An important factor influencing the development of production and consumption of wood fuel is the strict export orientation of producers. However, exporting always entails additional risks associated with currency fluctuations, technical and political barriers, and the need to transport products over long distances.

5. Conclusion

Given the following factors:

- The high cost of pellets;
- The high cost of transporting wood fuel;
- The need to remove wood waste from logging sites;
- Pricing;
- The need to replace the furnaces;
- The relatively low cost of firewood and coal.

In most of the central ecological zone of the Baikal natural area, the adoption of fuel pellets and wood chips for use by the population is currently impossible. It is possible to expect the creation of centralized boiler houses, but only if backed by state incentives. The Strategy for the Development of the Forest Sector of the Russian Federation to 2030 [15-17] implies the implementation of measures to convert a number of existing municipal boiler houses from fuel oil and coal to wood fuel. Despite the fact that such a measure is unlikely to lead to wide adoption, it may well set a new trend for the use of pellets for heating.

Acknowledgments

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