Usage of Woodworking Processing Industry Waste as a Fuel

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1 Introduction

One of the production development perspective directions is the processing of manufacture and municipal solid waste and second usage of resources. Nowadays, effective waste application is necessary for decreasing their harmful impact on the environment [1, 2].

Among the waste management area problems in Russia, there is an imperfection of the current waste management system in the legal, informational, and organizational spheres, poor cooperative relations development by the type of «industrial symbiosis» between the industrial enterprises (when one manufacture's wastes become raw material for another one), and poor highly efficient waste utilization industries development. Also, the ecological condition of the country is damaged a lot as a consequence of continuing legislation violations in the waste handling field: often, only landfill, not proper, disposal and decontamination occurs [3].

These problems require immediate government agencies', organizations', and enterprises' interference.

The purpose of this scientific work is to substantiate a waste applying economical expediency on enterprises.

The sub-targets of the work are to justify a woodworking industry waste processing and applying as a fuel efficiency, and to justify a waste processing efficiency in an enterprise's own division.

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2 Methods

Decrease and rational industrial waste usage are the waste management priority directions, which are encouraged by the state. According to the Federal Law of June 24, 1998, N 89-FZ «On industrial and consumer waste», there is a scientific substantiated combination of a society's ecological and economic interests, comprehensive raw materials resources processing for the purposes of waste amount decrease, and usage of activity regulation economic methods in the waste management area for the purposes of waste amount decrease and their involvement in economic turnover among the main principles of the state policy in waste management field [4].

One of the ways of applying wastes is to obtain energy from them.

Most of the woodworking factories give from 25 to 40% of waste materials which are not used after the production cycle.

Woodworking industry leavings are divided into 4 categories.

The first category includes slabs, tailings, and backing boards. Slab is the first board obtained in the process of cutting logs into boards. It can be only half sawn or not sawn at all.

The second category includes lump and longitudinal cuts, end faces, dry logs' pieces, wood details' scraps, and plywood sheets' ridges.

Finished material craps are referred to as the third category. Among them are fiberboard, plywood, veneer, chipboard, and other materials made from primary or secondary timber products. Often, this type of remains is left after building renovation or restoration.

The fourth category consists of shavings, wood dust, sawdust, and bark. These wastes serve as the materials for wood plates.

Moreover, all wastes are divided into reusable (they include large pieces, for example, slabs or lump cuts; this type of raw is easy to process and use for creating appropriate materials), and cull lumber (this type includes smaller fraction; for cull lumber processing, certain conditions and equipment are needed, so these materials are less in demand because their processing is more expensive) [5, 6].

The first category of waste may be applied for massive or bulky item producing like boards, parquet, pallets, box packaging, and also for small component part production in the furniture industry. Lump waste may be applied as a raw material for pulp-and-paper production manufacturing at the industrial enterprises of this direction. Wood chip is used as a filter at the treatment facilities [7].

A potential way to use wood industry scarps is to produce materials for heating such as fuel briquettes and fuel pellets.

Fuel briquette is a preparation form of different woodworking processing industry waste, peat, agricultural industry waste, and other materials for applying as a fuel; pressed waste of woodworking processing industry (sawdust, wood chips, etc.), agricultural industry (straw, husk, corn, etc.), peat, and charcoal.

The fuel briquette producing technology consists in the waste (as waste may serve sunflower, buckwheat husk, etc.) and finely milled wood waste (sawdust) pressing at a high-pressure process. Producing process may also assume raw material heating for obtaining the final product; however, it may not be needed. Completed fuel briquettes contain no binding agents in their structure except for lignin, a natural substance contained in plant cells [8].

Fuel briquettes are used at thermal power plants, steamships, industrial furnaces, railway transport, and low-capacity boilers. Also, they are demanded by the population for small square dwelling heating.

Fuel pellets are pressed under high-pressure natural raw materials of plant origin in the standard size cylindrical granule form [8].

As the raw materials for their production serve bark, sawdust, wood chips, other logging wood waste, agricultural waste (sunflower husk, straw, substandard flax, etc.), as well as organic packaging materials, cardboard packaging, etc.

Pellet producing process consists of 3 stages. The first stage is splitting. The point of this stage is in raw material milling to flour condition. The second stage is drying (the mass resulted must be thoroughly dried). The third stage is granulation. To compress the processed material into standard-size pellets, the special equipment—granulator—is needed. It heats the source material, therefore crushed particles of the material tightly glue together. The polymer lignin, which is contained in plant cells, performs here as the binding agent, as well as it does in fuel briquette producing, so no other chemical binders are required in the production process. The function of the granulator also comprises shaping the pellets.

Pellet producing process is technologically more complicated than the fuel briquette producing process: it requires high-quality raw materials and thorough pre-processing because it may affect the product's quality, its transportation, and storage options hereinafter [9, 10].

In terms of calorific value, fuel briquettes and fuel pellets quantitatively exceed the values of unprocessed woodworking waste.

The comparison of different fuel types calorific value is performed in Table 1. Consequently, fuel briquette or fuel pellet application as a fuel is physically more effective than just burning raw, unprocessed leavings that emerge during wood processing.

On the Alabuga Special Economic Zone (Tatarstan, Russia), the Kastamonu Integrated Wood Industry factory is situated. This factory is specialized in the production of MDFs, chipboards, laminate floorings, door skins, and glossy panels [11, 12]. The enterprise has its own power supply system: two gas turbine units and energy blocks operating on the wood waste of the production. On the factory territory, a waste processing complex is planned to be built. The capacity of this complex is supposed to be about 30,000 tons per year.

Building this complex has advantages for both the factory itself and the country as well.

According to the regional normative act, the Territorial scheme in the waste management sphere of the Republic of Tatarstan, 9053.4 tons of industrial waste emerged on the enterprise in 2017. If during the wood processing only 60% of all waste becomes raw materials and 40% becomes waste (among them 14% is slabs, 12% is sawdust, 9% is trimmings and small pieces, and the rest are bark and end face cuts), then about 3168.690 tons of the enterprise wastes are the first category wastes

Table 1 Comparison of the calorific value of different fuel types

Fuel type	Measurement unit	Specific combustion heat			Equivalent		
		kcal	kW	MJ	Natural gas (m^3)	Diesel fuel (l)	Fuel oil (l)
Natural gas	1 m^3	8000	9.30	33.50	–	0.777	0.825
Wood chips	1 kg	2610	3.00	10.93	0.326	0.253	0.269
Sawdust	1 kg	2000	2.30	8.37	0.250	0.194	0.206
Wood charcoal	1 kg	6510	7.50	27.26	0.814	0.632	0.671
Dried wood ($W = 20\%$)	1 kg	3400	3.90	14.24	0.425	0.330	0.351
Fuel briquettes	1 kg	4600–4900	5.35–5.70	19.26–20.52	0.575–0.613	0.447–0.476	0.474–0.505
Fuel pellets	1 kg	3465–4320	4.00–5.00	14.51–18.09	0.433–0.540	0.336–0.419	0.357–0.445

(slabs), 2716.020 tons is sawdust, 2037.015 tons are trimmings and small pieces, and 1131.675 tons are bark and end face cuts.

The amount of energy obtained due to waste burning may be calculated by Eq. (1):

$$Q = m \cdot q, \tag{1}$$

where

Q fuel energy (kW);
m mass of the fuel (kg);
q specific combustion heat (kW/kg) [13].

The equivalent amount of natural gas required to obtain the same amount of combustion heat is calculated by Eq. (2):

$$\rho \cdot q = \frac{Q}{V}, \tag{2}$$

where

ρ fuel density;
V fuel volume.

In this calculation, the natural gas amount was assumed to equal about 0.7614 kg/m^3 ($\rho \approx 0.7614$ kg/m^3); 1 m^3 of natural gas specific combustion heat was introduced in Table 1.

To calculate the cost-saving due to waste incineration instead of natural gas burning, Eq. (3) is used:

$$C = P_{\text{ng}} \cdot V, \tag{3}$$

where

C cost of natural gas required to obtain energy;
P_{ng} 1 m^3 of natural gas cost.

Therefore, if all these wastes obtained during a year use as a fuel in the factory energy blocks, waste combustion produce 28,110,807 kW of energy. At the cost of natural gas equal 6.00781 rubles for 1 m^3 (the natural gas cost for legal entities and businesses in the Republic of Tatarstan, for which annual gas consumption limit amounts from 10 to 100 million m^3), the enterprise cost saving due to production waste using as a fuel will amount 18,371,198.27 rubles (Table 2, in the energy obtained from trimming, small pieces, bark and end face cuts combustion calculating the wood chips specific combustion heat is assumed).

If we suppose that in the new waste processing complex fuel pellets will be produced and wholesale price will be 5000 rubles per ton, then fuel pellet production from this enterprise wastes only will earn revenue equal to more than 45 million rubles per year (Eq. 4):

Table 2 Energy retrieving by incineration of waste

Waste structure	Specific combustion heat q (kW/kg)	Waste amount (fuel mass) m (kg)	Amount of energy obtained Q (kW)	Equivalent amount of natural gas V (m^3)	Waste type instead of natural gas combustion cost-saving C, thousands of rubles
First category wood processing wastes	3.9	3,168,690	12,357,891	1,328,805.48	8076.23
Sawdust	2.3	2,716,020	6,246,846	671,703.87	4082.49
Trimming, small pieces, bark and end face cuts	3.0	3,168,690	9,506,070	1,022,158.07	6212.48
Total	–	9,053,400	28,110,807	3,022,667.42	18,371.20

$$I = P_{\text{pell.}} \cdot m, \tag{4}$$

where

I revenue;
$P_{\text{pell.}}$ sale price for 1 ton of pellets;
m mass of waste obtained at the enterprise [14].

Not only this enterprise waste processing but also other waste processing (which are obtained beyond the enterprise) will contribute to quick payback and profitability of the complex (its productivity planned to be equal to 30,000 tons per year). Also, at the use of own produced pellets by the factory itself, the amount of energy received may be greater than the amount of energy gained by unprocessed waste combustion, since the calorific power of pellets is greater than the dried wood, sawdust, or wood chip calorific power. The amount obtained, which is calculated as the product of pellet specific combustion heat (in this calculation by Eq. (1), it is supposed to be equal to 4.5 kW/kg) and the waste amount of the enterprise (9053.4 tons), is equal 40,740,300 kW that is equivalent to 4,380,677.42 m^3 of natural gas (the calculation is proceeded by Eq. (2)).

Also, we may suppose that at the new waste processing plant, not only wood-working processing waste will be handled, but, for example, polyethylene, plastic, paper, cardboard wastes too.

3 Results

In 2017, the Kastamonu company sent more than 350 tons of waste for processing to external specialized organizations, gained due to it extra profit equal to more than 2.5 million rubles [11]. Therefore, we consider two versions: to send wastes for processing into external organizations, or to realize processing in the own enterprise department. The cost-effectiveness of each of the two versions is compared in Fig. 1.

In the calculation, the profit is defined by Eq. (5):

$$\mathrm{Pr} = I - \mathrm{Cost}, \tag{5}$$

where

Pr profit;
Cost cost.

The new object building payback period is defined by Eq. (6):

$$T_{\mathrm{pp}} = \frac{\mathrm{TIC}}{\mathrm{NCF}}, \tag{6}$$

where

T_{pp} payback period;
TIC total investment costs;
NCF net cash flow per planning interval.

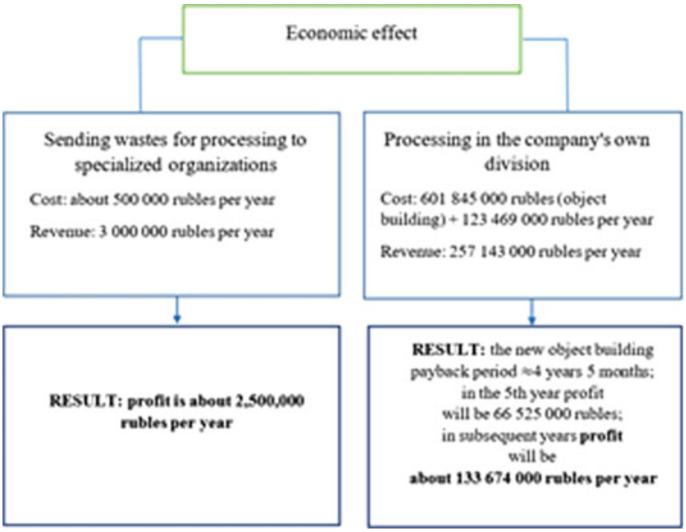

Fig. 1 The economic effect comparison

Therefore, from the scheme performed in Fig. 1, we can see that the waste processing complex building will be paid for itself in less than 5 years. Processing realizing in volumes supposed by the capacity of the complex will start to make a profit in a larger size than just sending wastes into external organizations. Thus, this project realizing is economically effective.

4 Discussion

Based on all of the above, we may make a conclusion that the implementation of effective waste applying undertakings favorably affects not only a country's ecologic conditions, but the economic stability of enterprises too because the waste removal, obtaining of extra energy, and revenue source items are solved. Enterprises should not neglect the waste issue because effective applying of processing technologies may favorably impact a company's financial results [15].

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