



Small-Scale Biofuel Production: Assessment of Efficiency

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Abstract. Currently, the energy industry is tending toward a global expansion of the use of renewable energy sources, thereby contributing to economic development. In the Russian Federation, such transformation is particularly important in terms of enhancing the involvement of excessive wood waste in production. In this regard, processing wood waste into pellets has proven to be highly beneficial. Apart from increasing the efficiency of the harvested wood and reducing the fire hazard in waste storages, it also positively influences the structure of energy balance in specific regions, creating an impetus for the development of small businesses in the country. This paper aims to assess the economic effects of biofuel production together with the efficiency of processing wood waste into pellets as a factor in the development of small business in the Russian Federation. Net present value (NPV) is used as the main analytical tool to assess economic efficiency. A general scientific analysis of the open data is also applied, including analytical reviews of the Russian ministries and international organizations. As a result, the paper estimates the prospects of using wood biomass in the energy industry, provides options for establishing capacities of microenterprises engaged in pellet production, and considers the expected economic effect for various levels of capacity utilization. The scientific novelty of this paper is centered on the design of a biofuel production scheme from wood waste (wood pellets) for a small-business enterprise with minimum labor and production costs. The paper is highly practice oriented, as it substantiates the economic efficiency of pellet production by small businesses in the Russian Federation in accordance with current legislation and state subsidies. Overall, this paper provides enough evidence to seriously consider the prospects of wood pellet production in order to expand the share of renewable sources in the energy balance of the country.

Keywords: Biofuels; Economic efficiency; Renewable energy source; Small business; Wood pellets

1. Introduction

One of the most important trends observed in the global energy market is its gradual shift toward wider use of renewable energy sources (RES). This transformation is extremely beneficial for the Earth's climate, as the gradual abandonment of carbon-containing fuel and energy resources (FERs) leads to a significant reduction in carbon dioxide (CO₂) emissions. Though the decarbonization of energy is taking place worldwide, its intensity in different regions is determined by numerous factors, such as the level of

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technological development (Budyanto et al., 2011; Qosasi et al., 2019), the prospects of environmental legislation, the availability of natural energy resources, and the role of specific countries in the international division of labor (Konnikov et al., 2020).

Industrially developed countries widely promote respect for nature by developing and implementing technologies that preserve the environment, thus automatically transforming the fuel and energy balance (FEB), both within individual countries and globally (Nayaka and Bhushan, 2019; Shahbaz et al., 2020; Vankov et al., 2020). According to previous studies, the economic success of RES development depends on the utilization of various biomasses that can be processed and used as environmentally friendly biological fuels, thereby replacing primary FERs (Ugwua and Enweremadu, 2019).

Wood pellets have been gaining popularity in the global energy market since the second decade of the 21st century and have steadily increased in production and consumption, which is expected to exceed 40 million tons and a total value of more than \$9 billion by 2020. Significantly enough, the most drastic increase has been observed in the recent decade when the figures doubled. Despite certain fluctuations in statistics on production and consumption, the global demand for wood pellets is expected to increase to at least \$18 billion by 2027. Remarkably, almost half of the pellets' volume is produced in North America (the United States and Canada) and China. According to the 2020 data, Russia ranks fifth among world leaders, with an annual production of about 2 million tons (Gemco Energy, n.d.). The bigger picture shows that Russian pellet exports did not exceed 0.9 million tons in 2015. If such a pace of development is maintained, Russia will be able to move up to the second position among the world's leading exporters, following the United States, leaving Canada, China, and the Baltic States behind.

Europe is the main consumer of wood pellets in the world (Statista, 2019). In turn, North America is expected to see a growing demand for pellets by an average of 7–8% per year due to the gradual abandonment of the consumption of hydrocarbon FERs (Gemco Energy, n.d.).

Wood pellets are produced and consumed at greater rates, as the reserves of easily mined FERs are drying out, and the effects human activity cannot be neglected any longer (Picchio et al., 2020). As a response to these urgent problems, timber waste can be effectively used in the production of wood pellets, especially taking into account the fact that its share sometimes reaches more than 15% of the initial raw materials. What is more, environmental problems associated with the need to store these wastes are becoming less acute (Scherhauser et al., 2018).

Since the pellets are produced without any chemical additives, they are currently considered the most environmentally friendly biofuel used. In addition, when burning, the pellets emit the same amount of CO₂ as during the natural decomposition of wood (Sippula et al., 2017). What is more, wood in general has been proven to exert less damage on the environment compared to fuel oil (Paolotti et al., 2017).

This paper aims to assess the efficiency of wood pellet production as a factor in the development of small business in the Russian Federation. To achieve this goal, the paper aims to do the following:

1. Evaluate the prospects of using wood biomass to maintain the country's FEB.
2. Develop a range of capacities potentially applied by the microenterprises engaged in pellet production.
3. Calculate the expected economic effects of different production capacities.

The scientific novelty of the research is centered on the design of biofuel production from wood waste (wood pellets) by a small-business enterprise with minimum labor and production costs.

2. Literature Review

The topic of RES is widely covered and discussed by the academic community. Such a large-scale concern is explained by the fact that many countries are actively looking for alternative raw materials to produce fuel pellets. Each state has opted for different materials, for instance, miscanthus (France) (Perrin et al., 2017), straw (China) (Song et al., 2017), forest biomass (Australia) (Crawford et al., 2016), plum pits (Poland) (Kostic et al., 2016), tea and oil palm waste (Malaysia) (Pua et al., 2020), tobacco (Chen et al., 2016), sugar beet (Poland) (Modelska et al., 2017), coffee waste (Lisowski et al., 2019; Colantoni et al., 2021), beans and potato peel (Obidziński, 2014; Minajeva et al., 2018), and olive pomace and olive tree (Barbanera et al., 2016). In particular, Thailand is currently experiencing a rapid increase in the production of wood pellets from fast-growing trees (Saosee et al., 2020).

Another good example is Canada, where large forests and wood biomass are typical, similar to in Russia, and thus, biofuels can be produced from wood waste (bark and branches, wood chips, scraps, sawdust, etc.) (Dupuis et al., 2021). As a huge benefit for all stakeholders, scientists have successfully investigated the effectiveness of bioenergy in remote settlements in Canada and have proven the feasibility of coordinated action between manufacturers and consumers of biofuels (Chen et al., 2016; Buchholz et al., 2017).

Though the issues of environmental and economic development are still relevant (Kichigin, 2017), the situation in Russia differs greatly from the Canadian case. The country does not get sufficient development of initiatives in RES (Shabunina et al., 2017), particularly due to a shortage of qualified specialists (Putinceva et al., 2020). Another problem faced by the industry is that small businesses involved in RES are not sufficiently supported (Khadra et al., 2020).

The combination of factors mentioned above highlights the relevance of discussing the issue of pellet production by small businesses as an RES option.

3. Materials and Methods

The production of wood pellets involves pressing and drying flour-like wood waste and subsequently shaping it into pellets. Throughout this process, lignin (a component of wood) softens and glues the prepared wood waste into dense cylinders, which makes the production process chemical free. The flow rate of wood waste per 1 ton of pellets amounts to 3–5 m³ of natural moisture waste (Abdoli et al., 2018). Pellets vary in diameter from 4 to 12 mm and in length from 20 to 50 mm.

When compared to other fuels, wood pellets:

- reduce emissions of air pollutants because wood biofuels are considered CO₂ neutral;
- provide a higher calorific value compared to firewood and wood chips (energy content of 1 kg of wood pellets is equivalent to 0.5 liters of diesel fuel);
- cost less compared to diesel fuel and electric energy;
- enable the use of the pellet boiler with all due convenience; and
- ensure conditions for the boiler houses to operate independently (Sippula et al., 2017).

The pellet production line includes zones for receiving, feeding, storing, drying, grinding, granulating (pressing), and cooling, as well as final packing. Production of 1 ton of pellets requires from 30 to 50 kW/h of electricity. Three types of packing are available: in bulk, in large bags (from 500 to 1200 kg), and in small packages (from 10 to 20 kg). Usually, large power plants opt for pellets to be shipped in bulk because the quality requirements are not very high, which allows them to purchase at a lower price. In turn, low-capacity boilers require small packages, which leads to an increase in the price per 1 ton of wood

pellets (Pantaleo et al., 2020).

This paper uses statistical methods, economic analysis, and synthesis of data on the effectiveness of business projects (Babkin et al., 2015, Babkin et al., 2019). The economic efficiency of the business plan for pellet production is calculated on the basis of the net present value (NPV). The research data are sourced from the Federal State Statistics Service, the Ministry of Energy, the Ministry of Industry and Trade of the Russian Federation, and the Institute of Energy Research of the Russian Academy of Sciences, along with results from previous studies on the use of wood biomass as a RES, published in leading peer-reviewed journals.

To evaluate the economic efficiency of wood pellet production at a small enterprise in Russia, the authors applied the following algorithm:

- 1) Drew up a brief summary of investment costs involved in setting up a microenterprise to produce wood pellets from the timber industry complex waste based on publicly available data on the cost of the necessary equipment and preparation of organizational documentation. To optimize investment costs, the authors assumed that such a small enterprise would be created with an already existing large sawmill.
- 2) Calculated the annual production capacity of a microenterprise within three modes of production (in one, two, or three shifts), based on the technical characteristics of the equipment (production capacity, required preventive repairs, maintenance, etc.), and the planned fund of the enterprise per year, based on the production calendar in Russia.
- 3) Evaluated the annual operating expenses for maximum production under the current tax legislation of the Russian Federation on the basis of publicly available information on the cost of consumables, packaging, electricity, etc.
- 4) Assessed the financial results in a pellet-producing microenterprise according to the minimum sale prices in the domestic biofuel market. At this stage, the authors assumed that the small enterprise would apply the preferential taxation system operating in the territory of the Russian Federation—“simplified taxation system.”
- 5) Calculated the present value for a typical project and determined its payback period according to the following formula:

$$NPV = x_0 + \frac{x_1}{(1+k)} + \frac{x_2}{(1+k)^2} + \dots + \frac{x_n}{(1+k)^n}, \quad (1)$$

where x_i is the cash flow of the project for the i -th period, and k is the required rate of return (as an assumption, the authors took the rate of return at a level of 10%).

4. Results

The initial launch of a microenterprise engaged in pellet production requires exact funds, permits for access to operating networks, and a range of specific technological capabilities (e.g., constantly renewable stocks of wood waste). It is also necessary to develop sufficient technical, technological, and logistical solutions that ensure the delivery of pellets to consumers according to the time, volume, and quality requirements.

Table 1 considers the economic aspects of launching a microenterprise as an external or internal organization at large logging plants, with the aim of optimizing investment costs (Table 1).

The production capacity of a business is determined by its operation mode (Table 2) and the hourly capacity of the line (300 kg of wood pellets per hour). Considering that an average household boiler consumes 3–5 tons of wood pellets per season, a pellet-producing enterprise must have at least 100 regular customers or an exporting wholesale customer, even if operating in one shift.

Table 1 Business plan provisions for the pellet production line with a 300 kg/h capacity

Initial priority investments	Funds, thousand rubles
Cost of equipment with installation (dry raw materials)	3 640.0
Working capital	280.0
Organizational expenses	40.0
Total expenses	3 960.0

Designed by the authors on the basis of data on the cost of equipment and their economic calculations.

Table 2 Production capacity of the production line with a 5-day working week

Indicators	Unit of measure	Operating mode		
		1 shift	2 shifts	3 shifts
Planned fund of working time per year	hour	2 100	4 200	6 300
Scheduled repairs and maintenance breaks	%	5.0	10.0	12.0
Working hours per year	hour	1 995	3 780	5 544
Production per 1 hour of work	ton	0.3	0.3	0.3
Possible production (maximum per year)	ton	598.5	1 134.0	1 663.2

Designed by the authors on the basis of technical data on the operation of equipment and their economic calculations

Business-related operating costs (Table 3) are classified into semiconstant and semivariable. Note that one production worker per shift is enough to maintain the entire line. In accordance with Chapter 34, "Insurance Premiums," of the Tax Code of the Russian Federation, insurance contributions are calculated on the basis of the wage fund at 31.4%, including statutory pension insurance at 22%; compulsory social insurance at 2.9%; compulsory health insurance at 5.1%; and compulsory social insurance for accidents at work and occupational diseases at 1.4% (due to group XIII, professional risk) ([Tax Code of the Russian Federation, 2000](#)). The estimated useful life of production equipment is 120 months when working in one shift, 90 months for two shifts, and 60 months for three shifts. The price of 1 m³ of sawdust is 150 rubles, and 4 m³ of sawdust produces approximately 1 ton of pellets. The price of packaging and other materials (for production of 1 ton) is 280 rubles, electricity is 1 thousand rubles, and transportation costs are 800 rubles.

Table 3 Annual operating business-related expenses, thousand rubles

Indicators	Operating mode (production of pellets, tons)		
	1 shift (598.5 t)	2 shifts (1.134.0 t)	3 shifts (1.663.2 t)
Labor compensation fund	600.0	1 200.0	1 800.0
Accruals to the labor compensation fund	188.4	376.8	565.2
Rent (including utilities, except electricity for pellet production)	280.0	280.0	280.0
Depreciation	364.0	485.3	728.0
For reference: amount of accrued depreciation for 1 month of equipment operation	30.33	40.44	60.67
Management services	300.0	300.0	300.0
Advertising expenses	200.0	200.0	200.0
Total semifixed expenses	1 932.4	2 842.1	3 873.2
Sawdust cost	359.1	680.4	997.9
Cost of packaging and other materials	167.6	317.5	465.7
Electricity	598.5	1 134.0	1 663.2
Transportation costs	478.8	907.2	1 330.6
Total semivariable expenses	1 604.0	3 039.1	4 457.4
Total operating costs	3 536.4	5 881.2	8 330.6

Designed by the authors on the basis of their economic calculations

If production is carried out in one, two, or three shifts, with the general line load at 75%, the designed capacity is reached in the second operation year (Table 4). According to Chapter 26.2, "Simplified Taxation System," of the Tax Code of the Russian Federation, the tax can be calculated as 15% of the difference between income and expenses, but not less than 1% of the annual revenue. The estimated price for 1 ton of wood pellets is taken as the lowest in the domestic market—7 thousand rubles per 1 ton. At the same time, the alignment of internal and external prices for wood pellets increases the efficiency of a microenterprise, making the biofuel business more attractive.

Table 4 Net profit of a small enterprise engaged in pellet production in 1 shift, thousand rubles

Indicators	1 shift		2 shifts		3 shifts	
	First year (75%)	Second year	First year (75%)	Second year	First year (75%)	Second year
Production of pellets when working in 1 shift, ton	448.9	598.5	850.5	1 134.0	1 247.4	1 663.2
Company revenue	3 142.3	4 189.5	5 953.5	7 938.0	8 731.8	11 642.4
Production cost, including:	3 135.4	3 536.4	5 121.4	5 881.2	7 216.3	8 330.6
Semifixed expenses	1 932.4	1 932.4	2 842.1	2 842.1	3 873.2	3 873.2
Semivariable expenses (75% in the 1st year)	1 203.0	1 604.0	2 279.3	3 039.1	3 343.1	4 457.4
Gross profit	6.9	653.1	832.1	2 056.8	1 515.5	3 311.8
Tax under the simplified taxation system	31.4	98.0	124.8	308.5	227.3	496.8
Net profit	-24.5	555.1	707.3	1 748.3	1 288.2	2 815.0

Designed by the authors on the basis of Tables 1–3

The NPV of the project (Table 5) indicates that, by varying the level of the workload at a processing line and managing the operating costs, it is possible to ensure effective pellet production at an enterprise. Working in one shift will pay off in six years, which is reduced to five years once a subsidy to compensate for transportation costs is obtained. The payback period is significantly reduced if the work is performed in two or three shifts, provided that there is a sales market, primarily exporting. Additionally, a state subsidy up to 80% of the transport costs is available, which amounts to at least 400 thousand rubles annually.

Table 5 Calculation of NPV for the production line with a 300 kg/h capacity

Indicators	1 year	2 year	3 year	4 year	5 year	6 year
Number of equipment shifts	1	1	2	2	3	3
Production capacity, thousand tons	75%	100%	75%	100%	75%	100%
Production capacity, thousand tons	0.449	0.598	0.850	1.134	1.247	1.663
Investment, million rubles	3.960	-	-	-	-	-
Estimated revenue, million rubles	3.142	4.189	5.983	7.938	8.732	11.642
Operating expenses, million rubles	3.135	3.536	5.121	5.881	7.216	8.330
Net present value, million rubles	0.007	0.653	0.832	2.057	1.515	3.312
Present NPV, million rubles	0.007	0.593	0.687	1.545	1.035	2.056

Designed by the authors on the basis of Tables 2–5 and their economic calculations

Overall, a small pellet-producing enterprise provides a significant reduction in storage costs and allows for gaining income from processing wood waste even at low prices, despite the necessary initial investments in basic equipment.

In the study, the main causes of medication error found are information overload and

fatigue. To overcome the first of these, suggestions made include using computerized systems to reduce errors in reading the handwriting of the doctors and in drug labeling. To minimize fatigue, rearrangement of shift hours as well as rest time is suggested.

5. Discussion

Today, the feasibility of using various types of RES is an important issue on the research agenda worldwide. For instance, Italian scientists conducted a study on the pellet market in Italy (Pantaleo et al., 2020) and assessed its profitability in accordance with different raw material prices, moisture levels, and transportation costs. As a result of this comprehensive research, the profitability of production was proven to increase alongside improving biomass quality. This study is similar to the one carried out by the Italian counterparts. However, the results presented in this paper differ greatly, as the main goal here was to assess the economic efficiency of pellet production in small businesses in the Russian economic environment.

It should be noted that the use of wood pellets in industrial production and everyday life is quite economical. At lower consumption, they emit more heat energy than alternative fuels (Table 6), and the efficiency of boilers when operating on wood pellets can reach up to 90%.

Table 6 Specific heat of combustion of some fuels

Type of fuel	Unit	Specific heat of combustion			Equivalent		
		kcal	kw	MJ	Natural gas, m ³	Diesel fuel, l	Fuel oil, l
Electricity	1 kWh	864	1.0	3.62	0.108	0.084	0.089
Diesel fuel	1 l	10 300	11.9	43.12	1.288	-	1.062
Petrol	1 l	10 500	12.2	44.0	1.313	1.019	1.082
Natural gas	1 m ³	8 000	9.3	33.5	-	0.777	0.825
Liquefied gas	1 kg	10 800	12.5	15.2	1.350	1.049	1.113
Hard coal (W=10%)	1 kg	6 450	7.5	27.00	0.806	0.626	0.665
Brown coal (W=30 40%)	1 kg	3 100	3.6	12.98	0.388	0.301	0.320
Charcoal	1 kg	6 510	7.5	27.26	0.814	0.632	0.671
Peat	1 kg	2 900	3.6	12.10	0.363	0.282	0.299
Wood pellet	1 kg	4 100	4.7	17.17	0.513	0.938	0.423
Dried wood (W=20%)	1 kg	3 400	3.9	14.24	0.425	0.330	0.351
Sawdust	1 kg	2 000	2.3	8.37	0.250	1.194	0.206

Nonetheless, the results obtained by the authors do not contradict previous studies published in the leading international journals and can be applied in further research on the effectiveness of waste-related RES. This paper may be used in the comparative assessment of various technologies involved in the production of wood biofuels that depend on such variables as raw materials, regional subsidies in the Russian Federation, or even different countries of the world.

6. Conclusions

According to the results obtained from this paper, Russia shows sufficient potential to transform the energy balance toward a wider use of RES, including wood biomass, which, for now, remains largely unclaimed, posing a fire-related threat to storage areas. The economic calculations allow for the conclusion that pellet production in micro-business conditions is viable. In addition, with a production capacity of 300 kg/h, it would pay off

within six years, even at a minimum selling price, and if a transportation subsidy were acquired, this period would be reduced to five years. Taking into account real global prices, investments in the wood pellet business may turn out to be twice as lucrative, provided that no force majeure takes place and that proper competitiveness of Russian production is ensured. Having considered three modes of capacity utilization, we can conclude that profit can be obtained in the second operation year and, with greater capacity utilization, in the first year.

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