About potential opportunities for the development of solid biofuel production in Russia

N V Ozerova, I V Korolev, A A Zavyalova and N V Vasilyeva
Department of Engineering Ecology and Labor Safety National Research University "Moscow Power Engineering Institute" 14, Krasnokazarmennaya str., Moscow, 111250, Russia
E-mail: nozerova73@mail.ru

Abstract. The article considers the possibilities of expanding existing woodworking enterprises due to state subsidies for the development of renewable energy. It is proposed to use wood waste and lignified agricultural waste (straw) together as raw materials for the production of solid biofuels. An assessment of the reduction of CO$_2$ emissions at a woodworking enterprise when replacing traditional fuels with solid biofuels is given.

1. Introduction
Due to the sharp rise in the price of gas fuel, as well as the signing of a number of agreements in the European Union, including the Paris Climate Agreement, the European "Green Agreement" in the near future, the demand for biofuels in Europe will continue to grow. One of the aspects of the "Green Deal" proposed by the European Commission in December 2019 is to reduce net greenhouse gas emissions by 55% by 2030 compared to 1990 levels [1].

Now Russia accounts for almost 5% of carbon dioxide emissions in the world, it is the fourth largest in the world after India, China and the USA – Figure 1. For convenience, choose the equivalent of this substance and count it in tons [2].

Almost 80% of all carbon dioxide emissions come from energy (heat and electricity generation), industrial production and transport. At the same time, 24.2% of emissions are generated by energy consumption in industry. The metallurgical sector alone accounts for 7.7% [3].

It is believed that the burning of biofuels releases as much carbon dioxide (CO$_2$) as was previously absorbed during photosynthesis during the life cycle of a plant (tree), and therefore the process of burning wood and lignified agricultural waste is considered neutral. Biofuels, along with solar, wind and water energy, belong to renewable energy sources (RES). In order to achieve these goals by 2030, it will be necessary to increase the mandatory target share of renewable energy sources in the EU energy balance to 40%.

The EU will not achieve the renewable energy target by 2030 if it does not increase the annual increase in the share of renewable energy sources in final energy consumption from the current 0.7% (recorded in the period from 2005 to 2017) to 1.1% [4].

In addition, the new version of the directive of the European Parliament and the Council on energy efficiency requires mandatory reduction of energy consumption by 2030 at the EU level: by 39% and 36% for primary and final energy consumption, respectively, compared with the current figure of 32.5% (for both primary and final energy consumption). This goal will become mandatory [5].
Figure 1. The largest producers of CO₂ emissions in the world in 2018 (by share of emissions).

However, in the near future, the "digital economy" will account for more than 10% of total global energy consumption. Already, according to various estimates, information and communication technologies (ICT) spend from 3 to 9% of the total energy consumption. In 2018, the internal costs of organizations in the Russian Federation for the "digital economy – the creation, distribution and use of digital technologies and related products and services reached 1952.8 billion rubles, or 1.9% of GDP – Figure 2. As the costs of the "digital economy" increase, the total amount of energy consumption increases [6].

Figure 2. Internal costs for the development of the digital economy as a percentage of GDP.

Despite the increase in energy efficiency of the data centers and communication networks sector for many years, the energy consumption of the sector has been growing extensively due to the growth in the number of viewing devices and subscriptions of VoD services, the popularity of videoconferencing and the Internet of Things, as well as the development of big data technologies at
the state level and the widespread introduction of artificial intelligence technologies. For example, only in Russia up to 50% of the urban population use paid subscriptions on the Internet [7]. According to the forecasts of digital technology developers, the growth of the share of ICT in global electricity consumption will increase to 20% by 2030.

Thus, the declared transformation of the EU and Russian energy in the direction of the development of renewable energy sources (RES), the cost of which is constantly decreasing, will help to implement the "Green Deal" and develop a circular economy, whose share in the global economy is estimated at 9% [8]. The scale of renewable energy use is slowly but steadily growing: their share in the total volume of primary energy resources, predicted by experts for 2020 [9], was achieved already in 2010, but mainly due to the development of solar and wind energy.

By 2035, Russia plans to put into operation more than 12 GW of generation capacity based on renewable energy sources.

Special attention should be paid to the development of small distributed energy for agricultural and forest areas – a network of autonomous generating facilities with a capacity of 1-50 MW with a power storage system for local consumers based on solid biomass combustion. Some generating companies using biofuels may be protected by measures of state support for renewable energy sources (priority of purchase, special tariffs). According to the expert's estimates, up to 80% of the population of agricultural areas and remote territories can be provided with heat and electricity in 2-3 years at reduced tariffs instead of decades needed to create traditional infrastructure at reduced tariffs [10].

2. Materials and methods

The purpose of our work was to assess the prospects for expanding the raw material base for the manufacture of solid biofuels in Russia as a source of "green" generation in Russia and Europe. Biofuels will play an important role in the future energy supply, regardless of technological development or climate goals. Biomass will account for at least 8% and up to 35% of the total primary energy supply by 2050 in all the presented baseline scenarios and mitigation scenarios, and its contribution increases in mitigation scenarios. In scenarios that meet the ambitious Paris-style climate goals, bioenergy will account for 26-35% of primary energy in 2050 and 32-50% in 2100, mainly used in the transport and energy sectors. After 2050, the use of bioenergy is increasingly combined with carbon capture and storage (CCS), providing so-called negative emissions, which are very important when it is necessary to meet strict emission limits of ambitious climate goals [11].

According to the Federal Forestry Agency, up to 25% of the world's wood reserves (102.2 billion m$^3$) are concentrated in our country [12]. More than 30 million tons of logging waste are generated annually, including crown waste, stumps and roots, bark. More than 200 million m$^3$ of wood waste from timber processing complexes and wood processing plants is generated [13].

In recent years, the number of enterprises owned by various owners producing solid biofuels has been increasing. Thus, the production of fuel pellets in Russia reached 2 million tons. Only the export of fuel pellets from Russia in 2020 increased by 19.1% YoY to 2.3 million tons [11]. In the case of the implementation of the strategic scenario for the development of the forest complex of the Russian Federation, the annual production of pellets in Russia by 2030 may increase to 2.7-5.1 million tons - depending on market conditions in European developed countries [14].

In addition to wood waste, straw is the raw material for producing solid biofuels. According to Rosstat, in 2020, agricultural enterprises and peasant farms in the Russian Federation collected 85.9 million tons of wheat grain, 0.3 million tons of triticale, 20.9 million tons of barley, 4.1 million tons of oats [15]. At the same time, more than 50 million tons of crop waste – straw was produced. To restore fertility, from a third to half of the formed straw is plowed. Potentially more than 25 million tons of straw can be removed from the fields. After a part of the straw (no more than 25%) is used as bedding for animals and feed additives, more than 12.5 million tons of straw remains unclaimed.

The calorific value of 1 ton of straw dry matter is equivalent to 445 kg of crude oil. Wheat straw is used for the manufacture of agricultural pellets, since the calorific value (15.5 MJ / kg) is comparable to the calorific value of wood waste (14.6 - 15.9 MJ / kg) – Table 1,2. However, their ash content can
reach 5%. In addition, straw ash softens at a temperature of 800 °C, unlike wood ash, which has a softening temperature above 1100 °C, which contributes to the rapid contamination of furnaces with ash and slag agglomerates. Energy value of straw [16].

| Type of straw | Heat of combustion, kWh | Equivalent amount of furnace fuel, l | Ash content, kg |
|---------------|-------------------------|-------------------------------------|----------------|
| Wheat         | 4 032                   | 396                                 | 57             |
| Barley        | 4 116                   | 406                                 | 48             |

Table 1. Energy value of straw [16].

Table 2. Comparative energy value of straw [16].

| Energy carriers | Units of measurement | Equivalent amount of furnace fuel, l | Calorific value, MJ |
|-----------------|----------------------|--------------------------------------|---------------------|
| Straw           | kg                   | 24.3                                 | 14.2 – 17.2         |
| Firewood        | kg                   | 23.5                                 | 14.6 – 15.9         |
| Fuel oil        | kg                   | 50.0                                 | 40.2 – 42.7         |
| Diesel fuel     | kg                   | 52.0                                 | 42.0               |

To assess the efficiency of biofuel use, the calculation of pellet production was carried out using the example of the woodworking enterprise LLC "Belozerskles", which harvests and processes 230 thousand m³ of wood per year [17]. When processing wood, the following amount of waste is generated – table 3.

| Type of waste | Thousand m³ |
|---------------|-------------|
| Bark          | 12.6        |
| Wood chips    | 54.7        |
| Sawdust       | 24.2        |
| Total         | 91.5        |

Table 3. The amount of waste of the company [17].

This amount of waste 91.5 thousand m³ or 81 thousand tons/year is about 50% of the initial raw materials. From these wood waste it is possible to produce fuel pellets in the form of pellets in the amount of 91.5 thousand m³ of pellets. The technological capacity of the enterprise allows processing an average of 11.4 m³/h of waste, based on the number of working hours per year. For the production of 1 ton of pellets, an average of 5 m³ of waste is needed, so the number of pellets is 2.28 t/h. The enterprise consumes 3668.4 thousand kW per year for production and economic needs [17]. Electricity consumption per hour is 458.6 kWh. The selected pellet line "Pellet Park" consumes 613.4 kWh, taking into account the amount of energy consumed before the introduction of the pellet line, the total amount of energy is 1118 kWh.

According to the calorific value of pellets, approximately 1.5 kg of pellets (mini-CHP on pellets) is required for the production of 1 kWh, which is 1677 kg/h of pellets. An enterprise can produce 2280 kg/h of pellets from existing waste, and 1677 kg/h is needed to generate electricity to meet the needs of the enterprise, therefore, this amount of pellets can be produced on a pellet line, and the surplus can be sold to other organizations. Calculate the amount of CO₂ generated by the annual consumption of this enterprise, powered by the central CHP. The total amount of energy consumed per year will be $E_{ob} = 8944000$ kW*year. The amount of carbon dioxide (CO₂) emissions according to the calculator [18] averages $F1 = 4024.8$ t/year of CO₂. The calculation of the amount of CO₂ generated during the production of the same amount of energy when replacing fossil fuels with biofuels (pellets) is carried out taking into account the required number of pellets:
Calculations of CO$_2$ on the carbon dioxide (CO$_2$) emissions calculator [18]:

$$L = E_{oh} \cdot 1.5 = 8944000 \cdot 1.5 = 13416 t / \text{yrar}$$ (1)

$$F2 = L \cdot 68 = 13416 \cdot 68 = 912 kg / \text{yrar}$$ (2)

Calculate the difference in CO$_2$ emissions:

$$R = F1 - F2 = 4024800 - 912.288 = 3112.5 t / \text{yrar}$$ (3)

Therefore, when replacing fossil fuels with pellets, this enterprise reduces the amount of CO$_2$ per year by 3112.5 tons.

3. Results
We conducted experiments on pressing pine sawdust with crushed wheat straw, followed by heat treatment at a temperature of 180° C. Agro-wood briquettes were obtained. Extractive substances of wheat straw (37%) were caramelized under the influence of temperature and provided the properties of binders in briquettes. As a result, it was found that the addition of crushed wheat straw in the production of wood briquettes in an amount of 10-20% by weight improves the strength properties of briquettes.

The calculation of the efficiency of the use of pellets showed that when replacing fossil fuels with pellets produced at the enterprise in question, the amount of CO$_2$ per year decreases by 3112.5 tons. Using the example of a woodworking enterprise, it was shown that when processing its own wood waste and lignified agricultural waste, it is possible to ensure the energy independence of the enterprise, receive a state subsidy for the development of renewable energy and reduce greenhouse gas emissions, as well as profit from the sale of solid fuels on the domestic and international market.

4. Discussion
The ban on the export of untreated wood from Russia from January 1, 2022 will help load the timber processing enterprises of the Far East and Siberia and contribute to the opening of new woodworking enterprises. The volume of roundwood exports from the regions of the Far Eastern Federal District is 4.7 million cubic meters per year, and local processing capacities are underutilized by 3 million cubic meters, the remaining 1.7 million cubic meters can be directed to new capacities [19].

5. Conclusion
We have proposed to produce agro-wood briquettes at the existing production facilities of fuel briquettes using lignified agricultural waste - cereal straw. Agro-wood fuel briquettes can be used for most types of furnaces and central heating boilers. The great advantage of briquettes is the constancy of temperature during gorenje for 4 or more hours. It is also possible to use pellet lines for the production of pellets. This makes it possible to replace fossil fuels used at thermal power plants and thermal power plants with ecological solid biofuels, which improves the ecological situation and thereby slows down climate change. It is recommended to use biofuels primarily in areas of coal mining and in areas capable of providing themselves with biofuels. At the same time, with the reduction of the environmental burden from emissions, the issue related to the disposal of wood and lignified agricultural waste is being resolved.

References
[1] Effort Sharing: Member States’ emission targets Retrieved from: https://ec.europa.eu/clima/policies/effort_en
[2] Svyatoslav Ivanov. Paris Agreement: why Russia ratified it and why business was so afraid of it Retrieved from: https://hightech.fm/2019/09/24/paris-agreement
[3] Comparison of Russia, USA and China in terms of carbon dioxide emissions Retrieved from:
