Use of granulated wood waste and municipal solid waste as fuel: *review*

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Abstract. This research was focused on the combustion of granulated solid fuels from wood waste and household waste. Environmental considerations, as well as economic and resource factors, are frequently what drive the use of alternative fuels. The technical possibility of using an alternative fuels instead of the main one depends on the compliance of their heat characteristics, among which are the theoretical combustion temperature of the fuel and its calorific value. Alternative fuels are characterised by the instability of these properties. This is largely due to the uncertainty of their physicochemical properties, ignition potential, and emission profiles. The study shows that it is more reasonable to produce fuel granules (pellets) from biomass. They have many advantages over traditional fuels. Fuel pellets are considered to be environmentally friendly fuels, so enterprises that use them do not need quotas for greenhouse gas emissions. Pellets have an advantage over liquid fuels and coal, especially in terms of emissions. During combustion, along with a decrease in $CO_{2\ \mathrm{emissions}}$, sulphur dioxide emissions are reduced. If you burn two tonnes of pellets, then as many calories are released during combustion: 1400 m^3 of gas, 1370 litres of fuel oil, 1000 litres of diesel fuel and 3200 kg of wood. Fuel, pellets are safe to use. They can be stored in the immediate vicinity of the premises because they are biologically inactive materials that have undergone heat treatment. That's why pellets are an efficient alternative biofuel.

1 Introduction

At the modern stage of the development of society, waste management, along with other environmental problems, plays one of the leading roles in the system of environmental safety and sustainable development of the country [1]. Their solution is connected with the need to harmonise a set of environmental, economic, and social tasks and requires constant systemic efforts on the part of government authorities, scientists, and society. The growth in consumption, especially in large cities, leads to an increase in the volume of household waste formation (VO HWF). The existing waste management system, focused mainly on their disposal, is imperfect. It leads to pollution of the surrounding air and groundwater and, as a result, a decrease in the quality of life, which is not consistent with the principles of sustainable development and requires radical modernization. In industry, the domestic sector and vehicles, coal, natural and associated petroleum gas, wood, peat, lignite, refined petroleum products, biofuels, in particular bioethanol and biodiesel, agricultural waste and timber processing, process gases of metallurgical and chemical industries, municipal solid waste, sewage sludge, as well as derived fuel products (generator gas) and RDF (refuse-derived fuel), granular fuel produced from the combustible component of municipal solid waste, For the most part, these fuels can be alternatives to each other.

2 Materials and Methods

Municipal solid waste (MSW), which was produced around the globe in excess of two billion, is anticipated to multiply by 1.7 by the year 2050, according to the World Bank. In 2016, the EU-28 countries generated over 170 million metric tonnes of MSW in total, a level that has not changed since 2012 [2]. The results of this study demonstrate the necessity for more logical processing and management of solid waste. Waste is no longer viewed as a burden but rather as a source of energy and commodities in nations with a lengthy history of waste regulation and management. As part of the emerging idea of the "circular economy", the EC proposed the current EU trash hierarchy in 2015 [3]. Waste should be processed for reuse, recycled, recovered, and then disposed of in that order. Recycling has technical and financial restrictions, even though it comes before disposal in the hierarchy. According to this viewpoint, waste disposal is free and compatible with recycling for two reasons, according to Van Caneghem et al. [4]. Toxic compounds in trash can first be broken down and eliminated by improving operational efficiency (IOE). Recyclable products containing these compounds will cost more to recycle, and their quality can suffer as a result. The second benefit of IOE is that it not only recovers energy from trash that cannot be

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recycled due to technical or financial constraints, but also permits the recovery of specific resources like metals and minerals. IOE will therefore probably never be totally phased out, but there is still room for further energy and material recovery. Due to this, it is still necessary to conduct studies in this area.

In the context of population expansion and industrialization, which calls for new sources of energy from waste, waste management and the depletion of fossil fuels are important issues. For instance, the conversion of municipal solid waste, which would amount to 2.6 billion metric tonnes by 2030, could result in the production of waste fuel. The non-hazardous undesirable items that humans continuously produce are known as municipal solid waste, sometimes known as rubbish or garbage. The population has been expanding steadily over the past few decades, making it difficult to dispose of municipal solid trash. A record-breaking rise in the production of municipal solid trash was also caused by the 2019 coronavirus disease epidemic, which was followed by emergency lockdown and stay-at-home regulations in the majority of the world's nations. Because it can eliminate waste while also preserving the environment, waste-to-energy is a practical option that is gaining a lot of interest and attention globally. This review identifies current research gaps that need to be solved by future studies in the context of the aforementioned studies as well as recent advancements in waste-to-energy fuel gasification. This paper examines the work that has already been done on the burning of granular solid fuels derived from wood waste and domestic garbage.

3 Results and Discussion

Environmental considerations, as well as economic and resource factors, are frequently what drive the use of alternative fuels. At low prices for natural gas, it was used in large volumes for blowing into blast furnaces to reduce coke costs. Coal dust took the place of natural gas after rising prices and supply issues. Bioethanol and diesel fuel made from vegetable raw materials can be alternatives to motor fuels of petroleum origin. Alternative fuel is often used as a backup when there are interruptions in the supply of the main fuel. Almost all boiler installations are equipped to use fuel oil instead of natural gas in case of interruption of its supply or in case of emergency pressure reduction. In the countries of Northern Europe, the replacement of coal in heat power plants with biofuels in order to reduce harmful emissions has become widespread. The technical possibility of using an alternative fuel instead of the main one depends on the compliance of their heat characteristics, among which are the theoretical combustion temperature of the fuel and its calorific value. For some types of bio-fuels that can be an alternative to natural gas, these parameters are shown in Table 1.

Attention is also paid to the state of aggregation, fractional composition, ash content, and moisture content of the alternative fuel. Coal, whose combustion temperature is close to that of natural gas or fuel oil, can be replaced by them with minimal intervention in the design of the heat unit or without it. The process of the reverse substitution of gas or fuel oil with coal requires the organization of systems for its storage, preparation, and transportation; replacement of burners; creation of ash removal and ash collection systems. When replacing the main fuel with an alternative one with a lower calorific value, it is not enough to supply the amount equivalent of heat equivalent to the main fuel to the heat unit. In order to maintain the performance of the heat unit for such substitutions, it is necessary to increase the combustion temperature of the alternative fuel to values close to those of the main fuel. This is achieved by enriching the air used for fuel combustion with oxygen and heating the air and fuel at the same time. In the general case, for a preliminary evaluation and comparison of the efficiency of the use of alternative and main fuels, it is possible to use the Carnot cycle expression:

$$\eta = 1 - \frac{T_2}{T_1} ,$$

where T_1 and T_2 – temperature burning and temperature departing gases respectively [2].

Along with other types of solid fuels, compressed pellets from various wastes are becoming increasingly popular for heating private houses. Since the demand for this type of fuel is steadily growing, the production of pellets is expanding. Fossil fuels extracted (coal, natural gas, and oil) from natural resources are non-renewable energy sources, the reserves of which are limited and, according to experts, will run out in the future. Taking into account this circumstance, most developed countries are rapidly increasing the production and consumption of alternative energy, in particular biomass. The leaders in the production of heat energy from biomass are Sweden, Denmark, Austria, and Finland. For instance, in Sweden, pellets power more than 100 district heating boilers. 60,000 or more private homeowners use household boilers that run on pellets. Due to government support, more than 4,000 boiler houses in Austria operate on biomass, which accounts for almost 90% of total energy consumption [5].

A solid energy carrier made from mechanically modifying biomass is what fuel pellets are, according to science (granulation of wood waste). Of course, wood waste can be burned and used directly to generate heat and energy. From an energy standpoint, it is preferable to process wood in a unique way—crushed and then granulated—rather than using it in its natural state. For this reason, fuel pellets are referred to as "enhanced" or even "refined" fuel. The following factors are also considered, in addition to appearance: The efficiency of burning pellets in a boiler furnace is higher because the amount of residue (ash) produced is less than 5–10% of the total volume of pellets burned. The granules don't harm the environment when they are burned, and they don't contain components that can spontaneously fire when the temperature is high and give people allergic reactions.

Based on these characteristics, pellets are most frequently used to heat buildings and cottages in

European nations. The fact that wood heat is seen as being far more pleasant than heat produced by light fuels like natural gas or oil accounts for the success of pellets as a "house" fuel. Moreover, boiler houses at the communal level and even small enterprises operate on pellets in Europe. The consumption of pellets in the EU countries is constantly growing, which was also announced at the bioenergy conference held as part of the Ligna + exhibition in Hannover. According to research by some marketers, a sharp jump in demand for this type of product is expected in the near future. Good-quality pellets have an excellent calorific value [6]. About 5 kW of heat energy is released from burning 1 kg of such fuel. Accordingly, to get 1 kW of heat, we need to burn about 200 grams of pellets. The average consumption of granules per unit area is easy to determine based on the fact that 100 W of energy is required to heat each 1 m^2 area. There is one important condition: the height of the ceilings should be within 2.8–3 m. 100 W of heat will be obtained from 20 grams of granules; it seems like a simple calculation [7].

However, not everything is as simple as it seems at first glance. The figures presented above are correct if the pellet boiler has absolute 100% efficiency, and this does not happen in real life. In fact, the efficiency of pellet boilers, although higher than that of traditional solid fuel boilers, is still only about 90% [8]. This means that after burning 1 kg of pellets in the furnace of the unit, not 5 kW of energy will be received, but 5x0.90 = 4.5 kW. And vice versa, in order to release 1 kW of heat in pellet boilers, 1/4.5 = 0.222 kg, or 222 grams of fuel, is consumed. This is the first nuance. The second nuance is that 100 W of heat per 1 m^2 of room is required when the ambient temperature is the lowest, which lasts for 5 days. On average, during the heating season, the cost of heat energy is half as much. This means that the specific heat transfer per unit area is only 50 watts. It will be incorrect to determine the consumption of pellets for 1 hour relative to 1 m^2. The figure will turn out to be small and inconvenient. It would be more correct to calculate the weight of pellets that must be burned per day [9].

Since a watt is a unit of power related to 1 hour, then 50 W x 24 hours = 1200 W, or 1.2 kW, will be needed per day for each square of the room. For this purpose, it is necessary to burn the following number of pellets per day:

1.2 kW / 4.5 kW / kg = 0.27 kg or 270 grams

Comparative characteristics of the heat of combustion MJ/kg by type of fuel are presented in Table 1.

Waste and loss of raw wood products occur throughout the entire production process in the wood processing sector. 21% of the overall mass of wood and roughly 14% of the logging stock are made up of logging-related wastes [3]. Despite the fact that it doesn't contain any dangerous elements, unrecycled wood can have a severe impact on the environment. This occurs when sizable amounts of wood waste that haven't been treated start to disintegrate and emit methane into the atmosphere. Landfills that are developing cause the release of greenhouse gases as wood rots and pollutes the air with dust when there is wind.

Table 1. Comparative characteristics of the calorific value MJ/kg by type of fuel

Type of fuel	Heat combustion MJ / kg	% Sulfur	% Ash	Carbonic gas, kg/GJ [a]
Coal	from 15 to 25	from 1 to 3	from 10 to 35	60
Engine oil	42.5	0.2	one	78
Fuel oil	42	1.2	1.5	78
Wood chips woody	ten	—	2	0
Wood granules	17.5	0.1	one	0
Peat granules	ten	0	twenty	70
Granules from straw	14.5	0.2	four	0
Household waste granules	15.62	0.41	16.1	40.12
Natural gas	49–53 (35–38 MJ/m^3)	–	–	57

[a] “0” means that when a product is burned, the amount of CO_2 does not exceed the amount that is formed during natural decomposition, and the amount of other harmful emissions is negligible.

It is advisable to use wood waste for energy production since the heat output of fuel, which is obtained from wood biomass, is quite consistent with traditional fuel (for example, one ton of coal can replace 4.2 m^3 of such waste) [4]. Direct combustion to produce energy [7] or processing wood biomass to create fuel products like pellets or briquettes are two ways to use it. The following are some benefits of using biomass as fuel: renewable nature, low ash content, low emissions, and preservation of the atmospheric CO_2 balance.

When it comes to recycling household waste, many researchers like to talk about the European experience. One country that is often cited as an example is Sweden. It not only recycles 99% of the waste generated in the country but even imports it from other countries. Any discarded item is considered solid waste. These could be containerized gaseous gases, solid, liquid, or semi-solid materials. Notwithstanding a World Watch Institute survey, there are roughly 1.3 billion tons of municipal solid waste generated globally each year (MSW is measured before landfill, so the data about it contains materials that are subsequently redirected to recycling). Furthermore, it is anticipated that by 2025, their number will rise daily. Governments all around the world are increasingly concerned about the disposal of solid waste. Municipalities and governments still make previous management efforts. Innovative ideas are on the way.

Wet MSW has a caloric content of roughly 4900 kJ/kg, while fuel pellets have a caloric content of 16800 kJ/kg [6]. On average, 15–20 tons of fuel pellets can be produced from 100 tons of raw garbage. Granulation, which increases the amount of organic matter in waste by eliminating inorganic components and moisture, can be a very effective way to provide enriched fuels for thermochemical processes other than incineration, such as pyrolysis and gasification. Both the production of energy and the heating of boiler plants are possible with pellets. For home and industrial uses, they can also be a useful alternative to coal and wood. The amount of waste recycled has increased over the past several decades; for instance, in the US, out of the 4.4 pounds of trash removed daily, one and a half pounds is recycled and another half a pound is burned, but nevertheless, about 50% of the waste is buried in landfills. Currently, it is conceivable to create a fuel that is comparatively clean and more energy dense than coal while reducing the quantity that ends up in landfills by roughly 10% utilizing the granulation approach. Baby diapers are a good example of a material that this technique is particularly suited for because they are hard to recycle or disintegrate slowly in landfills.

Environmental effects:

- Financial gains: large and prospective consumer markets;
- Advantages for resource conservation;
- Substantial decreases in SOx, NOx, and CO2 are taking place, as well as the entrainment of chlorine combustion products like HCI from plastic trash in landfills, making recovered granular SRF elements part of the solution rather than the problem for the environment.

Positive selection is made for the material that can be granulated, and a tiny portion of the residue is set aside for disposal. Crushed, made, and kept in storage silos are materials that can be used to make fuel pellets. To ensure simple drying and separation, the materials are separated into fractions of sizes ranging from 25 to 40 mm during the first grinding. The materials are dried at a moisture content of 50 to 25%, either on dry land that has been sun-paved or in a mechanical dryer. Hot air is used to speed up drying, while hot fractions are run through a cell mill for further size reduction and to lower the humidity from 25 to 15%. Fuel is a dried, combustible substance with a calorific value of roughly 12.6 MJ/kg and a size range from 25 to 40 mm.

The fuel can be made suitable for granulation by further grinding it in a secondary grinder, and it can then be mixed with high – BTU additions such as carpet scraps, plastic film, or other acceptable plastic materials. They are processed through pellet mills to provide finished fuel pellets with a range of diameters, from 10 mm to 25 mm, that are appropriate for a variety of uses. These pellets of fuel are solid and odorless. Because of their greater bulk density, they are more enduring and simpler to carry. They can be stored for up to three years without experiencing substantial biological or chemical deterioration. In comparison to other fuels, it is simpler to transport, store, transport, and burn due to its high bulk density and consistent dimensions.

4 Conclusion

Thus, scientific research and experiments showed that it is more reasonable to produce fuel granules (pellets) from biomass. They have many advantages over traditional fuels. Fuel pellets are considered to be environmentally friendly fuels, so enterprises that use them do not need quotas for greenhouse gas emissions. Pellets have an advantage over liquid fuels and coal, especially in terms of emissions. During combustion, along with a decrease in CO_2 emissions, sulphur dioxide emissions are reduced, and this, in turn, will reduce the death of plant materials due to a decrease in acid rain.

When burning fossil fuels, carbon dioxide accumulated over millions of years is released, and when wood pellets are burned, wood releases as much CO_2 as it took in during growth (closed carbon exchange). If you burn two ton of pellets, then as many calories are released during combustion: 1400 m^3 of gas, 1370 litres of fuel oil, 1000 litres of diesel fuel, and 3200 kg of wood. The ratio of fuels to 1 m^3 of gas is: 1.6 kg of coal; 1.7 kg of fuel pellets. In terms of calorific properties, 1.7 tons of fuel pellets are needed to replace 1000 m^3 of gas. Fuel pellets are safe to use. They can be stored in the immediate vicinity of the premises, in the back rooms and basements, because they are biologically inactive material that has undergone heat treatment. Pellets are an efficient alternative to biofuel. They are environmentally friendly and much cheaper than gas, which makes them an attractive energy source.

Acknowledgments

This research was prepared as a part of the Program “Priority 2030” in Belgorod State Technological University named after V.G. Shukhov. The research was performed using equipment of High Technology Center at BSTU named after V.G. Shukhov.

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