The use of solid household waste as fuel in the housing and utilities sector

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Abstract: The development of civilization is accompanied by a steady increase in the amount of waste and industrial production. Improvement of technology and production technology increases the variety of chemical compounds and their danger to the environment. The problem of processing and disposal of solid household waste (SHW) is becoming more and more urgent not only for megacities, but also for small settlements. The vast majority of solid waste in our country is stored in natural or specially organized landfills. Landfills of solid waste without preliminary processing occupy huge territories, thus removing fertile lands from economic circulation for many decades. Landfills are characterized by a high concentration of carbonaceous materials. For various reasons, fires often occur, as a result of which the products of incomplete combustion pollute the environment. Solid waste landfills are a source of pollution of surface and ground waters due to the drainage of landfills with atmospheric precipitation. In addition, landfills are home to stray animals, rats, mice, birds, insects and parasites. All of them are the cause of the spread of viruses. Because of this, there is a danger of the spread of infectious diseases [1]. In order to reduce the volume of solid waste, harmful emissions into the atmosphere, the number of rodents and birds, and put an effective barrier to the spread of various infections, it is necessary to improve the production and put the project of a mini-plant for processing solid household waste into operation. Thus, the work considers a technological scheme and a set of equipment for processing solid household waste into gas fuel. Calculations of technical and economic indicators are given.

1. Introduction
In any city or settlement, the task of recycling and neutralization of solid waste is always an economic problem. It is vitally important to organize the processes of removal, processing and disposal of solid waste so as not to violate the ecological safety of the city, the normal functioning of the city economy with public sanitation and hygiene, as well as the living conditions of the population as a whole.

Solid and industrial waste is a rich source of secondary resources, including ferrous, non-ferrous and rare metals. SHW contains renewable carbon-containing raw materials, therefore it is considered as a “free” energy source for fuel energy. SHW recycling is a profitable business all over the world. In industrialized countries, they learned how to recycle household waste, obtaining valuable substances and heat from it [2].

Foreign experience of such countries as Germany, Belgium, France and the Netherlands shows that the rational processing of solid waste makes it possible to use up to 90% of the waste products. Now there are a number of ways to store and process solid waste: sorting, earth filling, incineration, biothermal composting, low and high temperature pyrolysis.
Russia annually produces about 4 billion tons of various types of waste. The amount of solid waste is 63 million tons/year, an average of 445 kg per person. The approximate composition of SHW in Russia is shown in the diagram in Figure 1.

![Figure 1. The approximate composition of solid waste in Russia.](image)

Russia recycles on average 10% – 15% of its garbage. SHW is processed only by 3% – 4%, industrial waste is processed by 35%. Most of the garbage is taken to landfills – there are about 11 thousand of them in Russia. According to various estimates, about 82 billion tons of waste are buried in them.

In the city of Penza, with a population of 520 thousand people, about 2000 tons of solid waste are taken to landfills every day. Only the capacity of one landfill in the village of Chemodanovka near Penza is 7 million 425 thousand tons. Annually, more than 300 thousand tons of solid waste are brought there. In 2019, the facility processed 356 thousand tons of garbage (Figure 2).

![Figure 2. Photo of the Chemodanovsky landfill in the Bessonovsky district of the Penza region.](image)
So, in this regard, there is an acute problem of processing and disposal of solid waste. For large cities and megacities with a population of more than 1 million people, this problem is generally solved. In the suburban area, there are factories that take garbage from the city, process it and dispose of it, but what should small and middle cities do?

2. Materials and methods
In middle-sized and small towns, the problem is more acute and they are trying to solve it in different ways. But the lack of sufficient funding for municipalities does not allow purchasing modern equipment and building a plant. In most cases, SHW is sorted and buried in repositories. At the same time, significant areas of land are allocated for landfills and taken out of agricultural use. There is a real danger of environmental pollution, since under natural conditions, many substances decompose for tens of years.

In order to reduce the volume of solid waste, harmful emissions into the atmosphere, the number of rodents and birds, and put an effective barrier to the spread of various infections, it is necessary to improve the production and put the project of a mini-plant for processing solid household waste into operation. This plant will perform many tasks:
1. Deep processing of garbage and solid waste.
2. Development of a scheme for the production and use of combustible gas.
3. Reducing the cost of collecting and removing garbage.
4. Reducing the consumption of energy resources for the processing of solid waste.
5. Decrease in the volume of solid waste utilization.
6. Reducing the concentration of harmful substances in burial grounds.

The project is aimed at solving the problems of solid waste recycling in small towns, reducing the volume of landfills and landfill areas, eliminating unauthorized dumps, and, ultimately, reducing the harmful impact of solid waste on the environment.

SHW contains a significant proportion of combustible components - wood, plastics, rubber, plant waste. The combustion of such components in the classical way leads to the emission into the atmosphere of significant volumes of harmful substances containing products of incomplete oxidation, sulfur, phosphorus, nitrogen and their compounds. To organize deep processing of garbage, it is proposed to subject all fractions containing hydrocarbon components to thermal decomposition without oxygen and then burn the resulting gas in a conventional boiler house.

As a result the volume of waste disposal that is not subjected to thermal processing is reduced 2 – 3 times. This will reduce labor costs for the disposal of solid waste residues and reduce the area of the landfill. The combustible gas which is emitted as a result of processing, is an environmentally friendly fuel and almost does not pollute the atmosphere when burned.

Furnaces are used to process solid waste at existing plants; natural gas or fuel oil is used as fuel. An electric drive is used to mechanize work, increase productivity and process significant volumes of solid waste. Electricity consumption for the drive of equipment, lighting of buildings and structures, the operation of filters for cleaning combustion products can be very significant.

For the rhythmic work of plants for the processing of solid waste, significant amounts of energy are required. Energy costs are paid by the municipality. This item of expenditure falls on the city budget and must be fulfilled first.

To meet environmental requirements, high-temperature pyrolysis is used in the processing of household and industrial waste (Figure 3).
Figure 3. Boiler for high-turbulence waste incineration.

Pyrolysis is a thermal destruction of the original substance, in which, in the course of reactions, there is a destruction of the normal structure of the substance into the simplest molecules. Distinctive features of the fast pyrolysis method are:

1. closedness of a continuous technological production process;
2. relative "purity" of the end products of pyrolysis;
3. maximum power consumption of the process in comparison with other technologies;
4. release of a significant amount of thermal energy.

Pyrolysis processes have become more widespread than traditional gasification, due to the fact that a significant amount of thermal energy is released during the process. Pyrolysis is applied to solid household and industrial waste - plastics, rubber (including automobile tires), wood, cardboard, paper, fabrics, and other organic waste. By recycling such garbage for disposal, it is possible not only to reduce the volume of garbage disposal in our country, but also to make a significant contribution to improving the environmental situation in the country [5].

3. Results and Discussion

From an environmental point of view, the pyrolysis process leads to more efficient results compared to incineration. The volume of gases to be treated is much less than that with direct incineration of waste. The technological scheme of processing and disposal of industrial and solid waste will reduce emissions of harmful substances into the soil, water and air [6].

In order to reduce the cost of operating a mini-plant, it is proposed to include a gas turbine unit in its composition. Combustible gases obtained as a result of thermal decomposition will be used as fuel in the gas turbine unit. The same gas will be burned in a boiler house to create a high temperature and process solid waste (Figure 4).
Figure 4. Technological scheme of the processing.

The capacity of the plant will be 200 tons garbage per day. In the most unfavorable conditions, the share of garbage will be 40%. 80 tons will be buried in the burial ground. The organic part is 120 tons. 80% becomes the gas fraction. The gas output will be 96 thousand cubic meters per day. At the price of natural gas of 5.38 rubles/cubic meter, the cost of the received fuel will be 517 thousand rubles. With round-the-clock operation, the plant will produce about 28 million cubic meters of gas for a total of 15 million rubles every month.

The installed capacity of the plant's equipment is 260 kWh, the load factor is 0.6, and the working time is 24 hours a day. The electricity consumption for the plant's own needs is 3744 kWh/day. The plant consumes 112 thousand kWh of electricity per month, with an electricity tariff of 4.7 rubles/kWh. The amount of expenses will be 530 thousand rubles.

The cost of the plant for the purchase of electricity is about 6 million rubles per year. This money is paid to energy supply organizations during the operation of the plant. This amount of savings remains in the city budget and can be used to solve other vital tasks for the city.

Gas piston and gas turbine units can be used to generate electrical energy required for the plant's own needs. In the process of processing solid waste, the technical process includes the operations of drying and heating raw materials. Significant amounts of thermal energy are required. In existing plants, gas-fired furnaces are used. This is another item of expenditure of the city budget [7].

To generate electrical energy, gas turbine installations are used, which have a high exhaust gas temperature at the output. Thus, gas turbine plants are easily integrated into the technological cycle of the plant. They use the heat of the exhaust gases, increase the efficiency of fuel combustion and reduce the cost of operating the plant. In addition, the gas turbine plant is a multi-fuel plant. It can run on motor fuel, natural gas and synthesis gas.

When calculating the gas consumption for a gas turbine plant, we find from the tables that 1 kWh is equal to 3.6 MJ. The volume of generated electricity is 405 thousand MJ. The efficiency of the gas turbine unit is quite low and is 30%. The amount of heat released during the combustion of gas will be 1340 thousand MJ. The specific heat of combustion of synthesis gas is 30 MJ/kg. The gas turbine unit will require 44.67 thousand cubic meters of gas per month.

The pyrolysis heating boiler has an average heat output of 320 kWh. It consumes 256 cubic meters of gas at an 8 – hour cycle. The consumption per day will be 768 cubic meters. If the plant
continuously operates 8 boilers, the gas consumption per day is 6144 cubic meters. The gas consumption for all boilers of pyrolysis plants per month is 184 thousand cubic meters. Thus, the total consumption of synthesis gas for the plant's own needs will be 228 thousand cubic meters per month.

The plant spends about 1% of the generated gas to provide the technological cycle with heat and electricity: it costs 150 thousand rubles. Taking into account mandatory payments, staff salaries, and environmental protection measures, you can expect monthly operating costs of about 1 million rubles. At the same time, the plant produces 28 million cubic meters of gas fuel every month.

The net profit of the plant will be 14 million rubles per month or 168 million rubles per year. If the transport is included in the structure of the plant, the profit will be significantly reduced, but the plant will still give profit.

4. Conclusion

Thus, the mini-plant will provide itself with electricity and fuel. This will allow you to avoid building a gas pipeline and power transmission line, to reduce capital construction costs and to locate the plant in any convenient location.

Manufacturers offer several options of equipment for thorough recycling of garbage. The average price of a factory with additional equipment is 3 million dollars. This will be approximately 240 million rubles. The payback period of the mini-plant with an annual profit of 168 million rubles will be 2 years.

One such plant is enough for district centers with a population of up to 100 thousand people. The needs of the regional center with a population of about 0.5 – 1 million people will be fully covered by 2 – 3 landfills with 4 – 5 such plants. Currently, the Penza region needs 35 such plants; the whole country needs several thousand plants.

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