An analysis of the energy and raw materials structure of household and industrial waste management

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Abstract. This article explores the issue of developing the structure of fuel and raw material resources that provides for the disposal of various types of waste. In this case, the waste will be used as secondary raw materials or as fuel for the production of thermal or electric energy. The structure will significantly reduce the number of waste landfills in the country, which is especially important in the current situation of waste management. The scalability property of the structure makes it possible to apply it both to a group of enterprises and to an entire region. The most relevant publications examining the issues of waste management and processing are considered. As an example, we consider the current situation in terms of waste management in the Rostov region. The mutual arrangement of the largest waste landfills and industrial enterprises is given. A structure is proposed that ensures the rationalization of the raw material structure of each enterprise, as well as reducing the quantity and volume of waste landfills in the region.

1. Problem statement
Group of authors develops universal energy and raw materials structure of domestic and industrial waste management. This structure ensures the disposal of various wastes by using them as raw materials or fuels. The structure includes four key sectors – sources sector (research of the structure and logistic of enterprises in a particular region), analytical sector (in-depth analysis of the raw material component of specific enterprises, linking their fuel and secondary resources), distribution sector, generation sector (heat and electricity generation). The system analysis of raw materials structure of several huge enterprises of Rostov region from different industries was performed. In particular, enterprises of energy and metallurgical industry were considered. In addition, the potential of Rostov region in the field of waste use and processing was studied. Waste storage sites of several industrial enterprises were selected and their current status analyzed.

Analysis of enterprises waste structure was performed. Technologies for efficient, cost-effective and environmentally sound waste management have been proposed. In addition, linking waste structures of enterprises will allow their re-use in other enterprises.

The summary structure will be presented as a software product. The product will make it possible, through an analysis of the needs and capacities of enterprises, to ensure deeper recycling of waste and maximum rational use of raw materials. The main areas of waste management are incineration as fuel or reuse after sorting (locally or in a neighbouring plant).
2. Relevance of waste management research

This project will significantly modernize the fuel and energy complex and accelerate the implementation of the resolutions of the Government of the Russian Federation on reducing the amount of waste in the country. At the same time, the environmental situation in the regions will improve.

The essence of the project is to develop the structure of energy and raw materials logistics. This logistics will eliminate wastes of different types by using them as fuel or as useful raw materials. Everyone knows the critical situation with waste in our country. Therefore, the waste management approach should be improved. The cost of construction of one waste incineration can reach 25 billion rubles.

3. Study topic analysis

To date, there is a large number of scientific papers on waste management research. However, most of this work has some underreported coverage of existing technologies.

In particular, the work [1] analyzed the experience of waste treatment in different countries of the world. In order to solve the problem of recycling and recycling of garbage in Russia, it is recommended to learn from the experience of collection, transportation, recycling of waste in developed European countries and the USA. Article [2] describes a number of modern technologies for the storage and processing of solid household waste: preliminary sorting, sanitary ground filling, burning and other. Publications [3, 4] consider processing of food production wastes of agro-industrial complex. The articles propose the most appropriate technologies of agricultural processing and processing industry wastes in the conditions of the Voronezh region. Environmental management system issues based on ISO 14 000 standards are presented in the article [5]. Unfortunately, the technical and economic issues of the above-mentioned technologies using are not disclosed in any of the articles.

In the work [6] the problems of livestock waste disposal are considered. The most promising manure recycling technology is anaerobic processing with biogas producing. However, with anaerobic processing of manure in mesophilic mode, decontamination of the effluent doesn't fully occur. The proposed physical method of the effluent decontamination with the help of cavitation field, according to the author, needs to be further developed.

The introduction of waste management schemes into the most common energy schemes is today an important research. Due to the spread of steam-gas plants and various schemes of process schemes with them, the number of scientific works in this area is also increasing [7]. This is due to the advantages of these power plants. At the same time, automation of calculations is important, which gives rationalization of design works and flexibility in adjustment and operation [8].

In addition to steam-gas plants, research of microturbine technologies is under way. Such technologies have prospects in both small distributed energy and waste generation. Studies of possible performance characteristics of turbines are carried out [9] and studies of the perspective power systems on the basis of steam turbines are carried out [10].

The article [11] summarizes the experience in obtaining alternative fuel from solid domestic waste (SDW) by SDW processing enterprises in St. Petersburg for the subsequent sale of this type of fuel at cement plants. The regulatory and technical documents considered in the article are currently outdated. Article [12] analyzes the situation with waste processing in foreign countries and in Russia, considers the methods used for this, and also carries out a comparative analysis. It should be noted that some of the technologies have been missed. Article [13] considers the sources of solid waste generation by categories. Particular attention is paid to efficient recycling methods.

Publication [14] considers the problem of efficient processing of plant origin wastes at the enterprises of the timber industry complex and proposes a promising energy scheme for the production of thermal and electrical energy on the basis of such enterprises.

As part of the system analysis, the main technologies for waste management were identified. Some of them are applicable in the proposed structure, on the basis of several large enterprises of Rostov
4. System analysis of the existing energy and raw materials structure in Rostov region

Analysis revealed that the largest amount of waste is concentrated in industrialized parts of Rostov region - in the south-west and the center near Rostov-on-Don. In total in the territory of the area more than 400 various factories, the plants and producers of agricultural products are located. Within the framework of the system analysis, only the largest enterprises are considered as having the greatest influence on the environmental and economic situation in the region. In this regard, it is proposed to include the following enterprises in the structure: Novocherkasskaya SDPP (State District Power Plant), Taganrog Metallurgical Plant (Tagmet), Taganrog Boiler Building Plant (TKZ). Each of the above-mentioned enterprises received comments that were caused by irregularities in waste management.

In addition to analyzing the production structure, a waste circulation analysis was performed. According to the Ministry of Natural Resources, more than 250 illegal waste disposal sites with a total area of about 1000 Hectares are located in the territory of the region [15]. The location of enterprises and the largest waste landfills was analyzed, and the possibility of linking them into a single waste management structure was assessed.

Figure 1 shows the mutual location of the largest landfills and industrial enterprises in the Rostov region.

![Figure 1. Mutual arrangement of the largest landfills and industrial enterprises in the Rostov region](image)

It is proposed to link the existing waste landfills and raw materials structure of each the enterprises into a single cluster ensuring waste disposal and maximum rational use of raw materials. More than 1.6 million tons of waste generated in the region – it’s about 355 kg per 1 person [16]. Almost all of this waste is disposed of by removal to landfills or illegal landfills.

Taking into account the average composition of waste (Figure 2) in Russia [17-19] industrial enterprises will receive about 24% of food waste, 21% of paper and cardboard, 17% of plastic and 13% of glass, 11% of metals, 14% of other waste (wood, leather, textiles). This is more than 380,000 tons of food waste that can be used as raw materials for biofuels and biogas; 330,000 tons of paper and paperboard that can be used as a fuel for energy generation; 270,000 tons plastic and 200,000 tons glass for reuse as raw material; 160,000 tons of metals for use as secondary raw materials in production; 220,000 tons of other waste (wood, leather, textiles) for use as both raw material and fuel.
Figure 2. The average composition of waste in Russia.

In addition, existing waste landfills were analyzed. In particular, ash and slag removal in Novocherkassky city district (Figure 3). According to the data of the territorial scheme of waste management [20], this ash and slag sink is classified as an open site with a soil coating intended for waste storage.

Figure 3. Satellite image of ash dump
Novocherkasskaya state district power station.

The operating organization is Novocherkasskaya SDPP, which has started storage of waste there since 2008. The total capacity is 7081870 tons, today there is about 4231549 tons of waste. Total area – 320000 m².

5. Project realization
The structure includes four key sectors – sources sector, analytical sector, distribution sector, generation sector. Each sector is responsible for a stage leading to more efficient and complete waste management (Figure 4).
Project implementation will be implemented as a software product based on waste management methodology. The program takes into account and predicts logistics and waste volumes. The program also creates a system that ensures the interaction of industrial enterprises for the most complete and effective reuse of waste. The program scales the structure and its flexibility to specific consumer conditions (enterprise, region, district, country). The structure being developed ensures consistency between consumer needs and waste usability.
The scalability of the program consists in the recommendation of energy complexes configuration, depending on the waste type and the location of industrial enterprises. First of all, the analysis of potential consumers and the possibilities of waste sources is taken into account. At the larger level (region, country), a comprehensive analysis of the structure, type and volume of waste by territory is needed. The next step will be to create a functional and mathematical model of the developed structure. The result of the model will be a complete structure of fuel and raw materials logistics for a particular object or group of objects.

6. Structure at the Rostov region
The existing structure in Rostov region is shown in Figure 5.

![Figure 5. Existing structure in the Rostov region.](image)

There are a large number of waste landfills containing useful raw materials for industry (both secondary and fuel). There are several large enterprises (Novocherkasskaya SDPP, TKZ, Tagmet).

Novocherkasskaya SDPP is the main object of generation in the Rostov region. Accordingly, it provides Taganrog plants with electricity. At the same time during power generation SDPP has waste - exhaust gases discharged into the atmosphere, often without purification; Slag sent to gold mills, the number of which grows every year; Ash, the overwhelming amount of which is also directed to gold boilers and only a small amount is used for cement production. Tagmet supplies metal to TKZ, which provides SDPP with boiler equipment and heat exchangers.

Within the framework of the structure being developed (figure 6), the following activities are proposed. It is proposed to ensure sorting of waste and combustible waste to be sent for combustion to SDPP, non-combustible to bioreactors, and others - to be disposed of. It is possible to dispose of in slag melt or in hydrothermal destruction plant.
Figure 6. The proposed structure in the Rostov region.

It is proposed to pass the exhaust gases through plants providing extraction of sulphates from them (for cement production) and nitrates (for fertilizers). Ash is directed to cement production. Slag is directed to production of slag or slag melt with electrolysis device. This ensures the production of metals, which in turn are sent to Tagmet and TKZ. Metal sorted on polygons is also directed there.

7. Conclusions
Taking into account the above, the proposed structure rationalizes production by optimizing the raw material structure of an enterprise or enterprises group. Waste of various types is disposed of in parallel and thermal and electrical energy is generated. The scalability of the program allows it to be used for cities, regions and countries.

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