Business Model of Ecologically Balanced Reproduction of Fuel Resources from Waste

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Abstract. In modern conditions, the problem of waste processing is one of the most difficult and important. Traditionally in Russia, waste is processed by storing at landfills or burning. These methods are environmentally hazardous. The use of waste as raw materials is more promising. This requires new technological and economic developments. The purpose of the study is to form a new business model of ecologically balanced reproduction of fuel resources from waste, and the development of this business model both in technical, and in economic and organizational aspects. This business model will be an element of the development of a green economy. The basis of the research methodology was the concept of sustainable development. The study used methods of environmental, technological and economic analysis, data processing tools, organizational design, business modeling and forecasting. The main results of the research are the new business model of ecologically balanced reproduction of fuel resources from waste and the recommendations of its use at regional and municipal level. Economic and environmental effects were evaluated from the use of the proposed business model. The practical value of the results consists in the possibility of using them: by regional (municipal) authorities - when creating an enabling environment for the life of the population and organizing environmentally balanced waste processing; investors - when launching commercially effective projects of waste recycling.

1. Introduction

The evolutionary development of mankind, including production relations and productive forces, led to a sharp increase in consumption and, as a result, the accumulation of waste. According to [1] production and consumption wastes are understood as substances or objects formed during the production of products (works, services) or in consumption, and must be removed or intended for this process or are already subject to it in accordance with this legislation. It should be noted that during the development of society historically, the transformation itself was subject to both the waste itself and its species, as well as the ways of their processing and utilization. So, initially the waste did not require any special methods of their handling and processing, since they were an integral stage of the life cycle of the natural environment and were essentially organic in nature. Therefore, they were stored and rotted. In general, this kind of wastes
did not cause serious damage to the environment. It decomposed within 1-2 weeks before carbon dioxide and water. But when rotting, garbage collects around itself a lot of microorganisms, parasites and mechanical carriers of infection. Then, with the development of industry and the economy in the world, the structure of waste has undergone significant changes. As a result, the overwhelming majority of them began to occupy artificial components, which led to clogging and cluttering of the natural environment, as well as the entry of harmful chemical, biological and biochemical substances into it. All this could not but affect the life and health of the population. Therefore, at present, the issues on the need for waste recycling have been updated.

The most acute problem also increased in connection with urbanization. According to UN statistics, the amount of solid household waste (SDW) on average per capita is as follows: in large cities and megacities - up to 500 kg per year, in small towns - from 150 to 200 kg per year. And for comparison: in the US - from 350 to 700 kg per year, in European countries - from 200 to 500 kg per year, in Russia (according to Rosprirodnadzor) an average of 500 kg of waste per year. This dependence should be compared with the urbanization processes: the largest proportion of the world's inhabitants in 2017 account for the urban population - 54.7% of the total population. It should also be noted the annual growth of this indicator (for example, in mid-2016, according to the UN, it was 54.5% in the world, and in 2015 - 53.8%). As for Russia, the share of the urban population is also growing: in 2017 - 73.2% (104 883 814 people) versus 2016 - 72%. In the countries of the European Union this indicator is about 70%, and by 2030 can reach 80% by some estimates [2]. Thus, the trend of increasing solid waste in the world is predicted, and if, at the time of not taking appropriate measures for their disposal and processing, this can lead to global environmental problems. This is one side of the problem. On the other hand, many wastes are potential secondary raw materials for the production of products in demand on the market, and they are also a potential source of heat and power generation, since they contain valuable components. That is why since the middle of the last century research has been carried out to combat anthropogenic pollution of the environment and to solve the problems of MSW utilization in order to minimize harm from them, using waste repeatedly.

It should be noted that the problem of SDW utilization is topical on a global scale, including for the Russian Federation due to the limited land and resources, increased environmental hazards, reduced living standards, increased transportation costs, and so on. In the "Fundamentals of state policy in the field of environmental development of the Russian Federation for the period until 2030", one of the instruments for ensuring environmentally oriented economic growth involves the involvement of waste in economic circulation and the development of resource-saving. This problem can be solved through the justification of the business model of ecologically balanced reproduction of fuel resources from waste that allows them to be rendered harmless, utilized and eliminated, taking into account environmental, resource-saving and economic interests. That is why the authors of the article justify one of the ways of utilizing solid waste in the tubular-type portion modules.

2. The short literature revue and the purpose of the study

The problems of MSW utilization, as well as the optimization of the management system and the improvement of the economic mechanism of nature management, are devoted to the research of domestic and foreign scientists: Hornsby C., Rippa M., Vassilko C., Ulgiati S. [3], Pan, S.-Y., Chiang A., Chang E.-E., Lin Y.-P., Kim H., Chiang P.-C. [4]; R.R. O’Learv, P.W. Walsh [5], G.A. Davis, S.A. Wilt [6]; R.G. Mamin, T.P. Vetrova, L.A. Shilova [7], N.F. Abramov [8], A. Maslennikov [9], V.A. Kondratiev [10], Ya.I. Vaisman, V.N. Korotaev, Yu.V. Petrov [11], etc. At the same time, the questions of the justification of the business model of ecologically balanced reproduction of fuel resources from waste directed at the solution of ecological, resource-saving and economic problems are insufficiently studied and require their scientific justification.
The purpose of the article is to justify a business model of ecologically balanced reproduction of fuel resources from waste using the mining and chemical technology of their depolymerization.

3. Results and its discussion

According to the UN, by 2050, the global urban population is projected to almost double, which means an increase in the problems that accompany the urbanization process: both traditional urban problems, for example, uncontrolled growth of urban areas, abandoned areas, poverty, etc., and relatively new, associated with competitiveness, environmental safety, etc. In the Russian Federation, these trends are voiced at the highest level - in the President's Address to the Federal Assembly of 01.03.2018. So, there it is stated that the large-scale development of Russia is connected with the complex solution of various problems, including environmental ones. It is noted that in Russia there are about 22 thousand dumps. First of all, it is necessary to remove and remediate landfills in the city boundaries. And also to solve related issues and other issues of waste processing. All wastes can be classified according to different characteristics. We propose the following waste classification (Table 1).

We have summarized domestic and foreign experience in the field of processing of solid waste [12, 13] (Table 2). In particular, it is established that in Russia 96.5% of the waste from their total number is buried at landfills. Moreover, this territory exceeds 40 thousand hectares and annually increases by 2.5-4%. This trend is also characteristic of the largest industrially developed countries, where an average of no more than 25% of the waste is processed. However, there are countries where a rigid legislative base and active educational work have allowed to reverse this trend, they include: Sweden, Germany, Belgium, Switzerland, Finland. But it should be noted that in these countries not all solid waste is subject to processing.

The authors suggest to dispose of solid waste in tubular-type portion modules on the basis of the mining and chemical technology of depolymerization of waste and resource reproduction of fuels. This technology is patent protected and approved on a laboratory scale [14, 15, etc.]. The technology is described in detail in [16]. In a tubular reactor under the influence of high temperatures and pressure in the presence of a hydrogen-donor solvent, the parameters of the system are close to pseudocritical, dissolution of rubber and absolutely dry organics occurs, splitting the resulting mass into two components (synthetic oil and solid residue) in a centrifuge. When this method is implemented, BMP can be reproduced: scrap metal, synthetic oil, gasoline fraction, fuel oil and cement clinker.

Calculations were conducted using the example of a business model with a capacity of 10 tons of garbage per day. It is predicted that realizing the reproduced resources (except for synthetic oil, which will be consumed during processing), the annual income will be 25,000,000 rubles. Also, to justify the business model, investment and current costs were determined, a cash flow plan was drawn up, and key performance indicators were calculated: net profit margin was more than 32%; net discounted income - 58833616.7 rubles; profitability index - 1.99; The discounted payback period is 2.3 years. According to the calculations, this business model is effective.

The authors also carried out a comparative analysis of the proposed variant of MSW processing with the methods from Table 2. For calculations, the "Assessment tables" method and the following criteria were used: specific capital investments; the cost of renting a land plot; specific operating costs; specific incomes of the enterprise. Values of the criteria are presented in [12]. These criteria are unequal in their importance. To evaluate them, you can use the Saaty (MAI) hierarchy analysis method.

Let us compare the results with a dimensionless scale. The range of change of abstract units will be in the range from 1 to 10. We shall consider the largest sum of dimensionless units to be optimal. Instead of the given characteristics, we substitute the dimensionless units, multiply them by the corresponding weight coefficients, calculate the sums of these products, and find the maximum (Table 3).
Table 1. Classification of waste in terms of the possibility of their involvement in the business model of ecologically balanced reproduction of fuel resources from waste.

| Characteristic | Types of waste |
|---------------|----------------|
| By object of education | Industrial, are formed during the implementation of production processes; at extraction and enrichment of minerals; when cleaning off process gases and wastewater by industry by type of production non-toxic and toxic metal, non-metallic, combined extremely dangerous, highly dangerous, moderately dangerous, low hazard industrial waste household waste coming from the cultivation of plants, livestock, fish and dairy farms, etc. | |
| According to the aggregate and physical state | Liquid: water in the territory of enterprises, drains: storm sewage; Domestic where there is no centralized sewerage and water supply | Non-toxic and toxic non-metallic, combined extremely dangerous, highly dangerous, moderately dangerous, low hazard industrial waste household waste coming from the cultivation of plants, livestock, fish and dairy farms, etc. |
| Raw material for secondary material resources (BMP) | Real - BMP, for the use of which effective methods and capacities for processing have been created, and also a sales market Potential - other types and by-products that are not fully used and can be a reserve of WMR for industry | Additive or completely in place of primary raw materials and materials |
| On the way of using waste as a BMP | Raw materials or materials that can be used in another technological cycle Raw materials or materials with new properties that are absent from primary raw materials | |
| In the direction of use | Are subject to involvement in economic circulation | |
| On the impact on the environment | Have a harmful effect explosive; oxidants; waste with a high degree of flammability; flammable; | |
| Classification proposed by the Research Institute of the General Plan of Moscow | Organic | food, wooden, leather and bone Inorganic Paper, plastic, metal, textile, glass and rubber | |
| By classification of substances (composition) | Energy heat, noise, radiation, electromagnetic, ultraviolet radiation, and the like. | |
| By organization level | Not covered by centralized assembly and disposal Wastes in a garbage dump or burial on landfills | |
| By methods of processing | Compostable Thermally recyclable, including combustible | |
| Based on origin | Mineral and chemical origin | |
| On the obtained effect | Effects: ecological, economic, social, energy, climatic, integrated | |
Table 2. Main methods of solid waste processing in the world.

| Method                                      | Description                                                                 | Advantages                                                                 | Disadvantages                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Garbage dump or burial at the polygons      | the most common in the world; can be carried out: waste sorting (extraction of valuable components and fractions from them for secondary use); earth filling | low costs for implementation; utilization of a wide range of waste; possibility of further reclamation | environmental pollution; occupy a large territory; search for new places and their absence; growth of transportation costs; Land can not be used for other purposes; subsequent reclamation; does not comply with the "Basics of state policy in the field of environmental development of the Russian Federation for the period until 2030"                                                                                                                                                                                                                       |
| Natural methods of MSW decomposition        | composting (biothermochic fermentation (with the production of fertilizers, biofuel, fuel, etc.), anaerobic fermentation (with the production of biogas) | production of BMP; return organic substances to the natural biogeochemical circuit; restoration, support of the balance of nutrients of the earth; return to land use land from landfills; reduction of environmental pollution; growth of economic indicators in housing and communal services | significant investment and current costs of sales and services; sorting and preparation of waste; odor from fermentation; labor intensity of MSW processing, as regular hedging and shoveling of heaps of garbage is necessary; the possibility of spreading harmful substances with improper preparation and sorting                                                                                                                                                                                                 |
| Burning                                     | reduces the volume of solid waste; the proven effectiveness of the method on the basis of its broad approbation; availability of equipment; the service life of the equipment is relatively large; high level of automation; reduction of harmful impact on the environment of solid waste; energy reproduction effectively neutralizes waste; reduces the amount of debris; possibility of using the energy potential of organic waste | reduction of harmful impact on the environment of solid waste; energy reproduction effectively neutralizes waste; reduces the amount of debris; possibility of using the energy potential of organic waste | significant investment and current costs of sales and services; The possibility of atmospheric pollution by harmful emissions during the combustion process                                                                                                                                                                                                                                                                                                                                          |
| Thermal processing of MSW                  | low-temperature pyrolysis ("liquefaction" and gasification of solid waste, where drying processes, dry distillation (pyrolysis), gasification and burning of the coke residue take place, with the release of gaseous products) high-temperature pyrolysis (plasma processing), where high temperature allows the production of a harmless vitrified product and useful energy | effectively neutralizes waste; reduces their volume; production of BMP; universality of use without preliminary preparation of solid waste; small size; possibility of creating mobile process modules | significant preparatory work is needed; Used equipment that, if used for prolonged periods, is prone to frequent breakdowns and failure; the practical implementation of the method has rendered that the technology is currently economically and energetically ineffective in comparison with other methods of thermal processing high power consumption                                                                                                                                                                                                 |

Compiled by authors.
Table 3. Rationale for the efficiency of the choice of the method for the processing of solid waste.

| Criteria                     | Weight coefficient | The proposed method | Method of MSW processing | Composting |
|------------------------------|--------------------|---------------------|--------------------------|------------|
|                              | B_k               | P                   | B_k*P                    | P          | B_k*P    | P       | B_k*P |
| Specific capital investments | 0.27              | 4                   | 1.08                     | 7          | 1.89     | 1       | 0.27  | 3     | 0.81  |
| Cost of land lease           | 0.1               | 10                  | 1                        | 1          | 0.1      | 10      | 1     | 9     | 0.9   |
| Specific operating costs     | 0.24              | 3                   | 0.72                     | 10         | 2.4      | 1       | 0.24  | 4     | 0.96  |
| Specific income of the enterprise | 0.39          | 10                  | 3.9                      | 1          | 0.39     | 4       | 1.56  | 3     | 1.17  |
| Total                        | 1                 | -                   | 6.7                      | -          | 4.78     | -       | 3.07  | -     | 3.84  |

Calculated by authors.

So, the variant offered by the authors is more advantageous in comparison with other ways of processing of solid waste, since the sum of the estimates in this version is 6.7.

4. Conclusion

Thus, the effectiveness of the thermal method for the processing of solid waste has been proved. From the proposed options, the most optimal method of waste utilization was chosen according to the proposed selection criteria. As a result, the considered mining and chemical technology of depolymerization of waste and resource reproduction of fuels is the most preferable. Based on it, the business model of ecologically balanced reproduction of fuel resources from wastes is proved, which showed financial and investment efficiency: the profitability index is 1.99, the discounted payback period is 2.3 years, and the net present value is 58833616.7 rubles. The novelty and topicality of the proposed option will allow to find consumers after the end of R & D and production development, and this technology is easily scalable.

5. References

[1] Federal Law of June 24 1998 No. 89-FZ "On production and consumption wastes"
[2] Nikulin A A 2013 Alternative energy from garbage. In: Utilization of energy from waste - innovative technologies Krynica Zdroj (Poland)
[3] Hornsby C, Ripa M, Vassillo C and Ulgiati S 2017 A roadmap towards integrated assessment and participatory strategies in support of decision-making processes The case of urban waste management Journal of Cleaner Production 142(20) 157-172
[4] Pan S Y, Chiang A, Chang E E, Lin Y P, Kim H and Chiang P C 2015 An innovative approach to integrated carbon mineralization and waste utilization Aerosol and Air Quality Research 15(3) 1072-1091
[5] O'Leary P R and Walsh P W 1995 Decision Maker's Guide to Solid Waste Management U S Environmental Protection Agency – EPA
[6] Davis G A and Wilt C A 1997 Extended Product Responsibility: A New Principle for Product Oriented Pollution Prevention The University of Tennessee Center of Clean Products and Clean Technologies
[7] Mamin R G, Vetrova T P and Shilova L A 2013 Innovative mechanisms of waste management (Moscow) MSSU 136
[8] Abramov N F 2007 Sanitary cleaning of territories from household wastes Solid household waste 7 10-13
[9] Maslennikov A 2005 Waste sorting enterprises Solid household waste 6 10-12
[10] Kondratiev V A and Tverdovskaya H A 2006 Features of cleaning waste from plastics Solid household waste 9 24-25

[11] Vaisman Ya I, Korotaev V N and Petrov Yu V 2001 Landfills for the deposit of solid household waste Perm, Perm State Tech University 150

[12] Vertakova Yu V, Zvyagintsev G L, Babich T N and Polozhentseva Yu S 2017 Estimation of the economic efficiency of an innovative project to create an enterprise for a new mining and chemical technology of depolymerization of waste products Organizer of production 25 (2) 79-91

[13] Vertakova Y V, Babich T N, Polozhentseva Y S and Zvyagintsev G L 2017 Prospects for development of hydrocarbon raw materials resources reproduction In: IOP Conference Series: Earth and Environmental Science. "Innovations and Prospects of Development of Mining Machinery and Electrical Engineering - Materials Science", 092031

[14] Emelianov S G, Zvyagintsev G L, Kobelev N S, Nazarova D G, Nazarov A N and Larichkina D O 2011 Plasma-chemical method for processing solid household and industrial waste Pat. RU 2478169

[15] Emelianov S G, Zvyagintsev G L, Kobelev N S, Hlyamov S V, Kretov S I, Zvyagintsev K G, Nazarova D G, Larichkina D O, Hudokormov N N, Kozub A V, Novoselov A V and Filatova T V 2015 Way processing of organic and polymeric waste Pat. RU 2496587

[16] Vertakova Y V, Zvyagintsev G L, Babich T N and Polozhentseva Y S 2017 Feasibility basis for use of new solid household waste processing equipment. In: IOP Conference Series: Earth and Environmental Science "Innovations and Prospects of Development of Mining Machinery and Electrical Engineering - Mining Ecology" 042026

[17] Vertakova Yu V, Vatutina O O 2012 Evaluation of the economic efficiency of innovation-oriented integrated structures and the choice of managerial decisions to improve the effectiveness of interactions Izvestiya South-Western State University 1-2 (40) 112-117

[18] Vertakova Yu V 2009 Using the Network Approach to Ensure the Stability of the Development of Entrepreneurial Structures in the Conditions of the Economic Crisis. Innovative Herald Region 2 36-43

[19] Kuzbozhev E N, Babich T N, Nekrasova A S 2011 Integration of the state economic policy and strategic development plan of the enterprise Economic Analysis: Theory and Practice 24 15-20

[20] Polozhentseva Yu S, Fomenko V V and Litvinova O V 2014 Substantiation of strategic guidelines for the development of the region's industry Proceedings of the South-Western State University 2 (53), 60-70

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