On the issue of building an integrated waste management system: world practice and its application in the Russian Federation

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Abstract. The problem of municipal solid waste (MSW) in the world is increasing every year. According to the World Bank, more than 2 billion tons of municipal solid waste (MSW) are produced annually in the world. The paper shows that problem of waste management is growing all over the world. And if the developed countries have the opportunity to build an effective circulation system, then the developing countries, which are the majority, still solve this problem through open landfills and burial. It shows that only the presence of a balanced comprehensive program of the MSW management system will allow solving the problem of accelerated creation and effective functioning of the modern waste management industry.

1 Introduction

The urgency of the problem of the formation and processing of municipal solid waste (MSW) in the world is increasing every year. According to the World Bank, more than 2 billion tons of municipal solid waste (MSW) are produced annually in the world, which is approximately 0.74 kg per person per day. And this figure, according to the WB forecasts, will only grow by 2030 - 2.59 billion tons, and by 2050 it may reach 3.4 billion tons. Under the Paris Agreement, adopted by the United Nations Framework Convention on Climate Change in 2015 and signed in 2016, more than 80 countries have pledged to reduce emissions and improve waste management.

The paper shows that problem of waste management is growing all over the world. And if the developed countries have the opportunity to build an effective circulation system, then the developing countries, which are the majority, still solve this problem through open landfills and burial. The use of technologies provided by technology partners should be combined with the development of our own point technology solutions and their introduction to the world market. Only the presence of a balanced comprehensive program of the MSW management system will allow solving the problem of accelerated creation and effective functioning of the modern waste management industry.

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2 Methods

The World Bank study covered 217 countries. Table 1 presents data on waste generation for countries with different income levels, according to the World Bank classification, for 2016 and projections for 2030 and 2050. High income economies, which contain 16% of the population, account for 34% of the world's waste, while low income economies - 9% of the population and 5% of waste. Upper-middle income economies and lower-middle income economies account for 32% and 29% of waste, respectively. Obviously, there is a relationship between waste generation and a country's income level: daily waste production per capita in high-income countries will increase, according to the World Bank, by 19% by 2050, and in low- and middle-income countries - by 40% or more (see Table 2).

Table 1. Waste generation forecast in 2030 and 2050, million tons per year

WB country classification	2016 Nov.	2030 Nov.	2050 Nov.
High-income countries	683	781	879
Upper middle income countries	655	835	1004
Lower middle income countries	586	827	1233
Low-income countries	93	143	283

Source: Compiled by the authors based on World Bank research

Table 2. Waste generation forecast per capita in 2030 and 2050, kg per head per day

WB country classification	2016Nov.	2030Nov.	2050Nov.
High-income countries	1,58	1,71	1,87
Upper middle income countries	0,69	0,83	0,99
Lower middle income countries	0,53	0,63	0,79
Low-income countries	0,40	0,43	0,56

Source: compiled by the authors based on World Bank research

If we consider the generation of waste in a regional context (see Table 3), then the maximum volume falls on East Asia and the Pacific region (23%), followed by Europe and Central Asia (20%), South Asia (17%), North America (14%), Latin America and the Caribbean (11%), Sub-Saharan Africa (9%), the Middle East and North Africa (6%). The fastest growing regions in terms of waste generation are sub-Saharan Africa, South Asia, the Middle East and North Africa, where by 2050 the total waste generation will almost triple, double and double, respectively. In these regions, more than half waste is currently being discarded openly and the growth trajectories of waste will have enormous consequences for the environment and public health.

Table 3. Waste generation forecast in 2030 and 2050, million tons per year

Regions WB	2016 Nov	2030 Nov	2050 Nov
Middle East and North Africa	129	177	255
Sub-saharan africa	174	269	516
Latin America and the Caribbean	231	290	369
North America	289	342	396
South asia	334	466	661
Europe and Central Asia	392	440	490
East Asia and Pacific	468	602	714

Source: Compiled by the authors based on World Bank research

Analysis of the global waste structure shows that 44% of them are food waste, 17% - paper and cardboard, 12% - plastic, 5% - glass, 4% - metal, 2%, respectively, waste from wood, as well as rubber and leather , 14% - other categories of waste. Moreover, in countries with a high level of income, food waste (32%), as well as paper and cardboard (25%), prevail in the waste structure. Food waste also predominates in upper-middle-income, lower-middle-income and low-income countries, but its share in the waste structure is already significantly higher - 54%, 53% and 56%, respectively.

Worldwide, almost 40% of waste is disposed of in landfills, 19% of waste is recycled and composted, 11% is incinerated. At the same time, in high-income countries, 39% of waste is disposed of through landfill, 29% through recycling, 22% through modern incineration methods, and only 6% and 2%, respectively, through composting and open landfills. In low-income countries, 93% is in open landfills and only 3.7% in recycling and 3% in landfills.

The experience of advanced European countries, as well as Japan and the United States in the field of MSW management demonstrates that the best method of disposal of garbage today is a combination of recycling what is recyclable and incinerating everything else. Burial, especially at uncontrolled landfills, is the lot of lagging countries.

According to Eurostat data for 2018, the level of processing and thermal treatment of MSW in the EU countries averages 77%. The structure of MSW management methods in the EU-28 is as follows: 31% - recycling into secondary raw materials, 29% - thermal processing, 23% - landfill, 17% - organic waste composting.

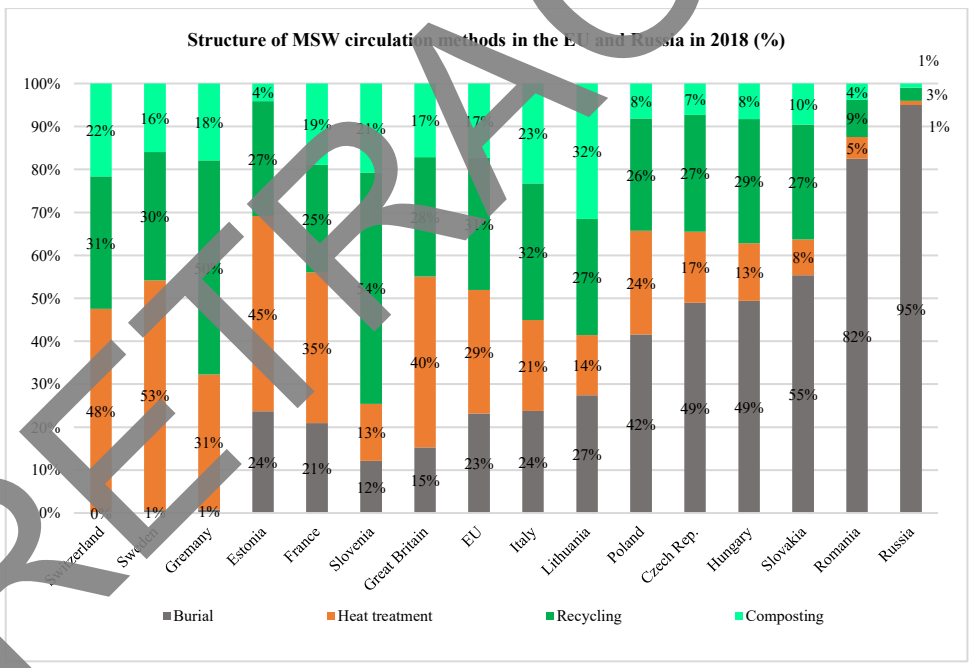

Fig. 1. Structure of MSW treatment methods in the EU and Russia. Source: compiled by the authors based on (https://ec.europa.eu/eurostat/databrowser/view/ENV_WASMUN__custom_120617/default/table?lang=en)

Table 4 shows the availability of national waste management legislation in countries with different income levels. This table shows that 86% of countries reported the existence

of a formal national law or guidelines. Obviously, legislation on waste management systems exists primarily in high-income countries.

Table 4. Existence of national legislation on MSW management in the countries of the world according to the World Bank classification (for 2016)

WB country classification	**Total number of countries**	**Number of countries with legislation on MSW management**	**Number of countries without legislation on MSW management**	**Number of countries with a lack of information**
High-income countries	78	75	2	1
Upper middle income countries	56	47	4	5
Lower middle income countries	53	47	1	5
Low-income countries	30	18	1	11
Total	**217**	**187**	**8**	**22**

Source: Compiled by the authors based on World Bank research [1]

The principles and methods of national legislation on waste management are different: the degree of severity of waste management (emission limits), the degree of assistance to entrepreneurs in waste processing and the creation of low-waste technologies, the requirements for recycling waste and the maximum possible disposal of valuable components contained in waste, regulation of control composition of waste, etc.

For example, in the United States, environmental legislation is aimed at stimulating resource conservation and minimizing the amount of waste in places where it is generated. Waste recycling is now legally fixed in accordance with the rules developed by the Environmental Protection Agency (EPA), in particular, a norm of 25% of waste subject to necessary sorting before incineration is established for the reuse of paper, cardboard, glass, ferrous and non–ferrous metals, plastics. In addressing environmental issues and, in particular, with respect to waste management, a large role in the United States is assigned to work with the public - the formation of an environmentally minded society.

The main EU waste legislation is represented by the Waste Framework Directive 2008/98 / EC and EU regulations on waste transport. Its essence lies in the observance of 7 basic principles: the use of a hierarchy of priorities in the field of waste management (the highest priority is the prevention of waste generation, then preliminary waste treatment for their reuse, waste processing as secondary material resources, waste disposal methods for energy purposes and the least preferred is burial); sufficiency of production facilities and equipment for waste disposal and disposal; implementation of the best available technologies without excessive financial costs; maximum proximity of production facilities (equipment) for disposal (placement) of waste to the sources of their generation; taking measures to prevent damage to the environment and human health; introduction and financial responsibility of the manufacturer for the entire life cycle of the product and its packaging, even after the end of its use by the consumer; introduction of the polluter pays principle.

A similar hierarchy was approved by the Ministry of Natural Resources of Russia in accordance with Law 89_FZ "On Production and Consumption Waste", according to which

the greatest preference is given to the return of waste to material circulation, and those waste that cannot be used as raw material must be neutralized with the generation of energy. Whereas landfill is the least preferred waste management method. Nevertheless, the regulatory framework for the management of solid waste is still far from perfect and is being finalized. The previously existing laws did not meet the requirements of environmental protection, did not use the experience of foreign countries in environmental protection activities.

Today, against the background of global data, Russia looks like this. According to various sources, from 60 to 70 million tons of MSW are generated annually in Russia, of which, according to Eurostat, 95% are subject to burial, 3% - recycled into secondary raw materials, 1% - heat treatment and 1% - composting (Fig. 1).

In recent years, our country, as in many other issues related to advanced technologies, has been striving to catch up with the leading countries that have been dealing with these issues for decades. Priority has been given to the ways and methods of European waste management policy, the result of which has been very successful. In the EU, the average value of recycling as raw materials is about 47%, while in Germany this figure reaches 68% of municipal waste, and there is a clear trend towards an increase in this share (Fig. 2). Although it should be noted that a number of wastes cannot be recycled, including used personal hygiene products, some types of plastics, composite packaging, contaminated paper and plastic wrap, paper and polymers that have gone through several stages of recycling, and a small fraction of waste.

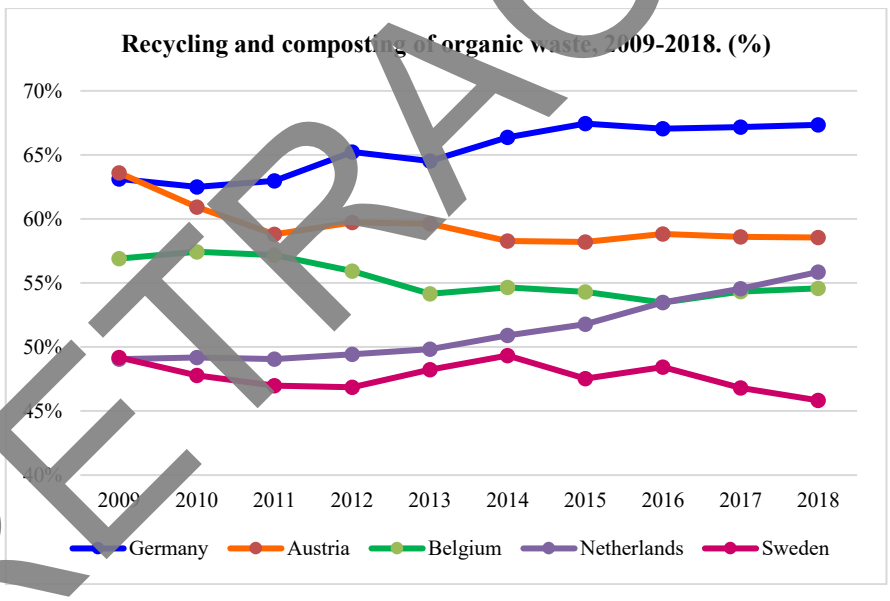

Fig. 2. Top 5 Western European countries - leaders in terms of recycling. Source: compiled by the authors based on Eurostat data (https://ec.europa.eu/eurostat/databrowser/view/ENV_WASMUN__custom_121348/default/table?lang=en)

3 Results

In 2019 as a part of the solution to the problem with solid waste, the Federal project "Integrated Solid municipal Waste management System" was developed with a deadline of implementation until 12/31/2024. Its implementation involved the introduction of separate

waste collection, which was supposed to increase the volume of waste to be recycled to 60% or incinerated to 36%, respectively, to reduce the volumes exported to landfills or illegal landfills. For this purpose, it was planned to put into operation 31.7 million tons of solid waste recycling facilities, as well as 23.1 million tons of waste disposal facilities and their fractions remaining after processing. The total budget of the project amounted to 296.2 billion rubles. in mixed financing from the state (101 billion rubles.) and the rest - from extra-budgetary sources.

According to the passport of the national project, effective waste management includes annual monitoring of 5 indicators:

- the number of all unauthorized landfills identified as of 01/01/2018 eliminated within the city boundaries (in pieces);
- the number of liquidated most dangerous objects of accumulated environmental damage (in pieces);
- the number of commissioned industrial and technical complexes for the processing, utilization and disposal of waste of I and II hazard classes (in units);
- the share of MSW aimed at disposal in the total volume of generated MSW (in%);
- the share of MSW directed to treatment in the total volume of generated MSW (in%).

There are different opinions on the progress of the "garbage reform" implementation.

According to the comments of the Minister of Natural Resources and Environment of the Russian Federation D. Kobylkin within the framework of the International Forum "Clean Country", which took place in the Skolkovo Technopark in December 2019, it was planned to complete the "adjustment of industry regulation" by March 2020. Within the framework of the international forum "Clean Country", held in the Skolkovo Technopark in December 2019, the first results of the implementation of the national project "Ecology" were summed up, including in relation to the MSW management system: in 2019, the newly created company "Russian Environmental Operator" became the integrator of the MSW management system, and FSUE "RosRAO" became the federal operator for the management of waste of I and II hazard classes. According to the Ministry of Natural Resources and Environment, 16 unauthorized landfills were liquidated during the year (this is 100% of the planned indicator of the national project for 2019 and 8% of the planned minimum value of the indicator following the implementation of the national project for 2024), 17 objects of accumulated environmental damage. Wednesday (100% of the plan for 2019 and 64% of the planned level in 2024). Thus, in 2019, all 33 planned objects were reclaimed.

However, it is precisely the systems (formation of a regulatory and methodological basis for the reform, training and advanced training of personnel, the creation of a system of engineering and technical centers, a unified information system on waste, technologies for their disposal, financial instruments, etc.) for waste management have not been created. In a systematic way, all this was laid down in the main law in the field of waste management N 89-FZ of 24.06.1998 "On production and consumption waste". The reasons are different, among them – according to the head of the working group "Environmental Protection" of the Public Council under the Ministry of Natural Resources of the Russian Federation A. Fedorov – the lack of qualified personnel in this area, as well as the absence of a real waste accounting system, including by hazard classes. In particular, in Moscow in 2016-2017, the data on the amount of waste from the Moscow City Government and Rosprirodnadzor differed by 10 times. The data of the State Register of Waste Disposal Facilities also differed from the data of Rosstat, which led to lower payments to the budget for environmental impact.

According to the Accounting Chamber, which published a report on the progress of the waste reform in September 2020, the situation in the field of waste management remains unfavorable: the level of waste processing does not exceed 7%, and more than 90% is sent

to landfills and landfills, which do not meet the requirements of environmental legislation. According to Rosprirodnadzor, at the time of the formation of the national project "Ecology" on the territory of the constituent entities of the Russian Federation, there were 8,323 landfills, including 916 landfills in urban districts. And the national project "Clean Country" involves the elimination and reclamation of only 191 landfills (more than 700 landfills within the city boundaries are not covered). Consequently, the goal set by the President - to eliminate landfills within the city boundaries - will not be achieved.

The report of the Accounting Chamber on the implementation of the waste reform published in 2020 showed that the situation in the field of waste management has practically not changed. Only 7% of the waste was recycled, while 90% was still sent to landfills that did not meet the requirements of Russian legislation in the field of nature protection. At the time of the launch of the national project “Ecology”, there were 8,323 landfills on the territory of the Russian Federation, 916 of them in urban districts. Whereas the national project “Clean Country” aimed to eliminate or reclaim 191 landfills in urban districts, thereby leaving 700 landfills uncovered. That is, the goal set by the President of the Russian Federation – to free cities from landfills – cannot be achieved.

It should be noted that the capacity of official landfills in 49 regions will be exhausted by 2024, given that the volume of MSW is growing by 1-2% per year. Whereas the creation of new landfills in most regions of the Russian Federation is difficult. The federal project "Integrated system of MSW Management", aimed at creating a high-tech infrastructure for waste processing and disposal, turned out to be non-operational, its target results and indicators were not coordinated with the regions, as a result, 42% of the subjects of the Russian Federation did not confirm the possibility of its implementation. Its parameters require revision, as well as the inclusion of a mechanism to encourage the population to use reusable goods, containers and packaging, which could reduce the amount of waste generated.

Regional waste management programmes need to be reviewed. Their specific consideration showed that only in 39 regions measures are being taken for separate waste collection, in 33 regions the volume of MSW management capacity is maintained at the required level, in 19 regions private companies are involved in the waste management sector, and only 9 regions use the best technologies available in the Russian Federation for this sector.

The critical point is the financing of waste reform in the regions, the main funds go in the form of payments from the population, the amount of which depends on the norms of accumulation of MSW and existing tariffs. At the same time, as the analysis showed, the standards differ significantly even in comparable areas – in 2019, tariffs for services of regional operators ranged from 244 to 1411 rubles per cubic meter. As a result, in 2019-2020, regional operators were unable to collect the planned amount of funds, so on July 1, 2020, there was a risk that 22 regional operators in 19 regions of the Russian Federation would terminate their activities to serve more than 15.1 million people. At the same time, funds allocated from the state budget for the construction of waste sorting and recycling facilities were not brought to the regions, as well as control over the commissioning of facilities for which funds were allocated in 2018 was also not carried out. The result is that this industry is not considered by business as attractive for investment. The most difficult situation is in large cities, where the proportion of solid waste is the most significant. For example, on the territory of the Moscow region is generated 20% of MSW generated in the Russian Federation. The resource of the polygons operating in the Moscow region will be exhausted within the next 3-4 years. At the same time, the use of landfills leads to a significant increase in the risk of oncological diseases. Even with proper operation of MSW landfills, which implies preventing fires, recycling leachate, neutralizing landfill gas, the likelihood of oncological diseases as a result of the impact of the MSW landfill is on

average 5 times higher than from the operation of thermal processing facilities (research data for the state of New York). Thus, this problem affects 14% of the population of Russia or 19 million people (the entire population of Moscow and the Moscow region). The emergence of fires at landfills means special damage to health, on average in the Moscow region, 40-50 thousand tons of MSW are burned per year, which means emissions of dioxins and furans of about 50-70 g annually.

The experience of selected large cities, both European and non-European, shows that zero waste disposal can be achieved through an integrated approach, the essence of which is the reuse of waste as raw materials and fuel (Fig. 3).

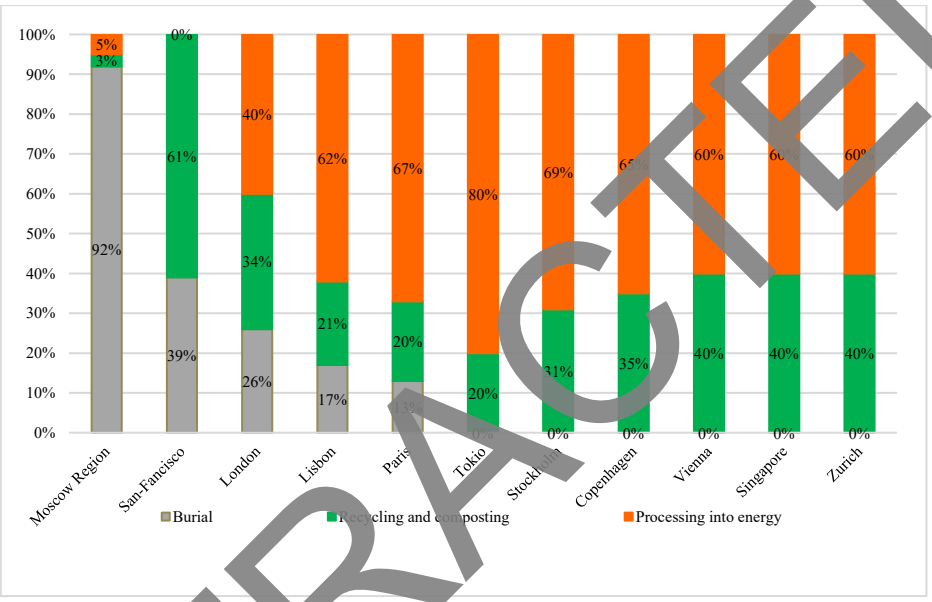

Fig. 3. Waste management in some large cities. Source: Governments and Waste Management Companies

To form a new waste management system in the Moscow region, a pilot project "Energy from Waste" was launched, implemented by “RT Invest”. The project provided for the introduction of separate waste collection by the population; organization of waste sorting for the selection of secondary and organic fractions for reuse; incineration of waste that cannot be recycled with energy generation; organization of safe waste disposal with landfill gas collection, as well as filtrate purification. Thus, the approach used both in Europe and in China, the use of waste as raw materials and fuel, was chosen. According to calculations, the implementation of this project will reduce the volume of waste disposal in Moscow and the Moscow region by 25% and will provide 335 MW of "green energy" annualy.

The most significant factor for this project, in particular, and for the formation of a new integrated waste management system in Russia, in general, is the choice of technology for thermal neutralization of non-recyclable fractions with energy generation. The formation of a new, in fact, for Russia industry today - the waste management industry will largely depend on this choice. Abroad, in economically developed countries, this industry has been developing for about 40 years, while in Russia this process should proceed principally faster, proceeding from the already existing strict necessity. Therefore, the main introductory developments of the new industry are the need to act quickly, simultaneously develop all elements of the industry - from waste collection to their final processing, each of which requires its own technology, as well as affordable cost - since available financial

resources for a limited period of time are finite. The financial feasibility of building the industry in a short time, as well as the need to ensure a level of localization of at least 55%, determines the approach to the choice of technologies used. The main idea is that all possible technologies are at different stages of the life cycle - laboratory experiment, pilot production, industrial production. Outdated technologies can be purchased cheaply, but they do not meet the requirements imposed in Russia today, the newest technologies are expensive, and most importantly, they are still poorly developed and may have their own specific limitations. Therefore, the best solution is to choose technologies that have potential for not the next 10 years, at least. And in the future, to isolate the zones where to point to create their own technological solutions that will be in demand, including at the global level.

Based on these preconditions, within the framework of the Energy recovery pilot project, the grate combustion technology, which is very widespread, including in Europe, was chosen as a thermal neutralization technology, which has a number of proven advantages. In particular, the technology is optimal for working with unsorted MSW with a changing morphology, while most alternative technologies require preliminary preparation of raw materials and a stable morphology. The technology is well developed, at the moment there are more than 1.5 thousand grate installations in the world against, for example, 200 fluidized bed incinerators and 50 pyrolysis and gasification projects, including plasma. Today, more than 90% of all commissioned facilities for the thermal treatment of MSW use grate combustion technology. It is very important that this technology shows higher - relative to alternative options - energy efficiency, in particular, 600-800 kWh of electricity is generated from a ton of MSW on the grate (taking into account consumption for the plant's own needs), while gasification and pyrolysis give 0-500 kWh. The specific capital cost per ton of installed capacity is $ 500-1000 versus 1500-3000 for alternative technologies. This technology makes it possible to build factories with a capacity of up to 1 million tons, which is very important given the volumes of MSW that are produced, in particular, by the Moscow region. Alternative technologies do not allow the construction of such large facilities, the capacity of plants operating on pyrolysis and gasification technologies does not yet exceed 10-100 thousand tons per year. Comparative characteristics of thermal neutralization technologies are shown in Table 5.

Table 5. Comparative characteristics of thermal neutralization technologies

	Grate combustion	Fluidized bed incineration	Gasification	Plasma gasification	Pyrolysis
Principle of operation	Waste incineration on a moving grate, steam turbine	Waste incineration in a pseudo-liquefied state when mixed with sand, steam turbine	Waste processing into synthesis gas, purification and supply to GTU	Processing of waste into synthesis gas and liquid fuel by means of an electric arc (plasma)	Conversion of waste into synthesis gas and liquid fuel through anaerobic thermal decomposition
Number of factories	1500	200	120	20	20
Plant capacity, thousand tons / year	100-1000	100-300	20-100	20-50	20-75
CAPEX, $ / ton	500-1000	500-1000	1000-2000	2000-3000	1000-1500
Efficiency	28%	25%	23%	n / a	n / a
Waste preparatio	not required	sorting, grinding, drying, homogenization			

n					
Flaws	Significant slag volume	Waste stream uniformity requirements, large slag volume	Requirements for uniform waste stream, low energy efficiency, high cost	Unused technology, significant energy consumption for own needs	Low efficiency for MSW, suitable for high-energy waste

Source: compiled by the authors

The named advantages of grate technology are confirmed by world experience, in particular, by the fact that it dominates in economically developed countries (Fig. 4, 5).

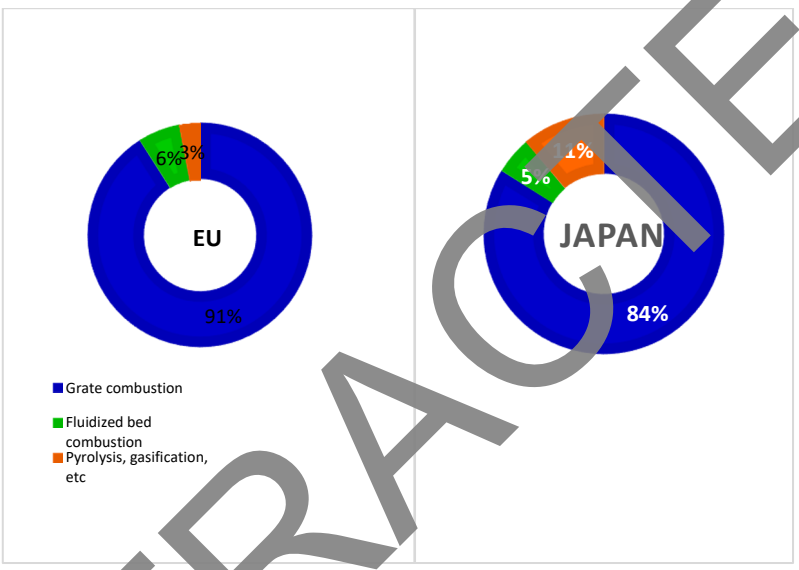

Fig. 4. The structure of the use of thermal neutralization technologies. Source: compiled by the authors based on CEWEP, WTERT, ecoprog

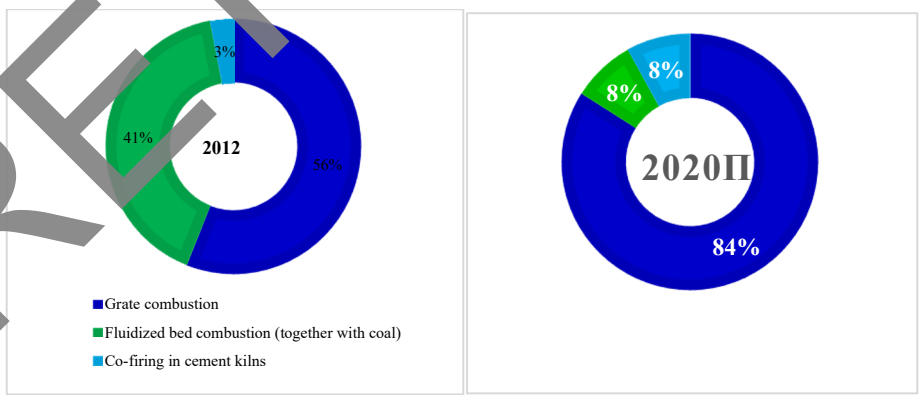

Fig. 5. Increasing grate incineration in China. Source: Compiled by the authors based on Credit Suisse Research

The grate technology is included in the manual on the best available technologies "Thermal waste disposal" ITS 47-2017 officially published by Rosstandart. In particular, on

page 128 it is indicated that "The incineration method is used in modern enterprises and is considered the most versatile, reliable and effective in comparison with other thermal methods of waste disposal." And also on page 183 “As an example of BAT, a scheme of layered grate combustion of MSW can be considered. A system for generating electrical energy can be organized in it ”.

The implementation of a project to convert MSW into energy based on the use of grate combustion technology requires a technological partner. In particular, a number of companies are represented on the market for the construction of thermal processing plants (Fig. 6).

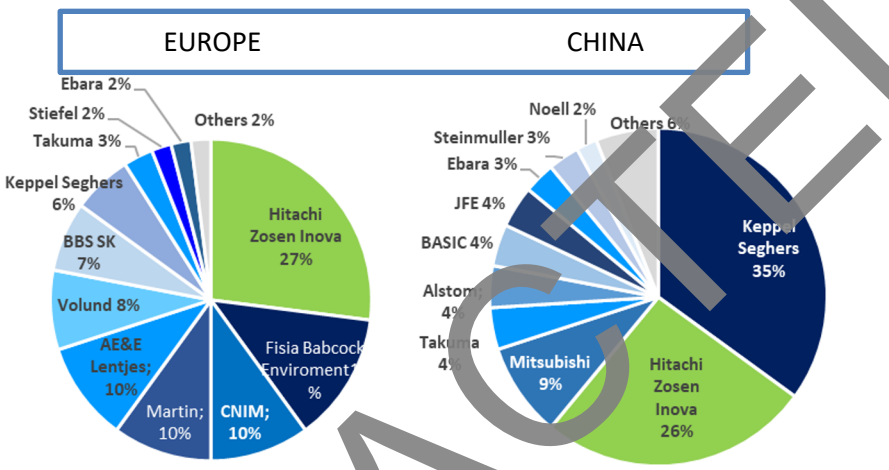

Fig. 6. Market shares of construction of plants for thermal processing of MSW, 2000-13. Source: Hitachi Zosen Inova

The Swiss company Hitachi Zosen Inova has a 27% share in Europe in the construction of heat treatment plants, being the largest company in this market. Its position in China is also very significant. Inova was founded in 1823, in 2010 100% share was acquired by the Japanese corporation Hitachi Zosen, founded in 1881. By combining the technological expertise and experience of two companies, each of which is a leader in its own country, a global market leader for equipment for the thermal processing of MSW was created. During its history, the joint company has built more than 500 factories around the world, including 235 in Asia, 250 in Europe and 44 in North America. At the moment, the company operates 12 factories with a total capacity of 3.9 million tons of solid waste, 395 MW of electricity and 285 MW of heat. The company is ready to localize in Russia unique technologies and know-how in all processes of thermal waste disposal, including the grate and flue gas cleaning system.

One of the main problems of the thermal processing of MSW, which causes discontent among the population and environmental organizations, is the emission of dioxins. This problem was urgent in the mid-1990s: it was discovered that, despite the high temperatures in the furnace and boiler, thermal waste treatment plants are a large source of dioxins. This is due to the fact that when the flue gases are cooled in the boiler at temperatures of 250-400 ° C, dioxins are re-formed. After this opening, the gas cleaning systems of all ZEUs were necessarily improved and in 2000 a strict standard for dioxin emissions (0.1 ng / m3 of flue gases) was introduced. Now the problem of dioxins has been solved - modern methods of gas cleaning allow bringing the level of emissions closer to zero. In particular, if in 1990 in Germany 400 g of dioxins were emitted for 6 million tons of processed MSW, then by 2000 dioxin emissions decreased by about 1000 times, and amounted to 11 million

tons of processed MSW - 0.5 g. For comparison, Table 6 presents figures for different sources of dioxin emissions.

Table 6. Estimation of dioxin emissions from main sources

№	Name	Units	The values
1	Forest and meadow fires, peatland fires	ng DE * / kg	0,5-19
2	Burning agricultural residues in the fields	ng DE * / kg	0,5-20
3	Incineration of MSW in the open air		
3.1	PVC free		4,4-14
3.2	With a PVC content of 0.2%		17-79
3.3	With a PVC content of 1.0 - 7.5%		200-2000
4	Fires in open landfills	ng DE * / kg	23-1000 66-518
5	Incineration of MSW at energy utilization plants (ZEU)	ng DE * / m3	0,1 0,4-0,3

* DE - dioxin equivalent

Source: the table was compiled on the basis of the data of the international project on the elimination of persistent organic pollutants (PCP), which identified the main sources of dioxin emissions in the context of the Stockholm Convention on PCP. Added to the table are EU standards (2000/76 / EC) for dioxin emissions (0.1 ng DE / m3

The presented data indicate that the emissions of dioxins at modern EPPs are significantly lower than emissions from all the listed sources.

4 Discussion

Thus, the following conclusions can be drawn.

The problem of waste management is growing all over the world. And if the developed countries have the opportunity to build an effective circulation system, then the developing countries, which are the majority, will solve this problem through open landfills and burial.

Russia, which signed the decree on the adoption of the Paris Climate Agreement on September 23, 2019, launched a garbage reform in the same year, using European approaches to waste management. However, this reform did not bring the expected results: burial remains the priority method of MSW management in Russia (95%).

The high capital intensity of waste conversion projects into commercially attractive products, as well as the need for preliminary R&D implementation, makes them unattractive in the Russian Federation.

Recommendations for improving the waste management system include the following:

- expand measures of financial support for investment projects and develop an effective mechanism for attracting extra-budgetary funds;
- create a unified MSW accounting system;
- improve the mechanism of extended producer responsibility;
- adjust regional programs for waste management, taking into account the prevention and reduction of waste generation;
- form a separate approach for the infrastructure of millionaire cities.

The construction of a new industry involves the introduction of new technologies covering the entire waste management chain - from separate waste collection to their final processing, in a very short time and within limited funds. This determined the approach to the choice of technologies used, primarily at the stage of thermal neutralization of non-recyclable fractions with the generation of energy, since ensuring safety at this stage causes the greatest worries among the population. No less important was the factor as the target - to ensure the level of localization - not less than 55%.

The grate combustion technology selected for the implementation of a pilot project in the field of waste management in the Moscow region is a technology that is most consistent with the requirements put forward in Russia, including legislative ones. It should be consistent with innovative principles outlined in [2-8].

It is well developed and efficient, as the experience of European countries shows, demonstrates the best energy efficiency, is characterized by low unit capital costs, proven environmental safety. In addition, the technology - unlike alternative ones - is adapted to work with unsorted MSW, which is very important for Russia, where so far the sorting of waste by the population is extremely inactive. It also allows to build factories with a capacity of up to 1 million tons per year, which is an obvious advantage in the context of huge volumes of waste generated in Russia. The advantages of the chosen technology are confirmed by its inclusion in the handbook on the best available technologies for thermal waste disposal.

For the implementation of the pilot project "Energy from waste" in the Moscow region, Hitachi Zosen Inova, the leader in the European market for the construction of plants for the thermal processing of MSW, became a technological partner. The decision was largely determined by the company's willingness to localize unique technologies for thermal waste disposal in Russia.

The use of technologies provided by technology partners should be combined with the development of our own point technology solutions and their introduction to the world market. Only the presence of a balanced comprehensive program of the MSW management system will allow solving the problem of accelerated creation and effective functioning of the modern waste management industry.

References

1. Silpa Kaza, Liza Yao, Perinaz Bhada-Tata, Frank Van Woerden. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050 http://datatopics.worldbank.org/what-a-waste/ , P. 89
2. V.A. Ermakov, et.al., Revista Espacios. **4.** 42. 1–12 (2019)
3. A.I. Kashirin, et.al., Journal of Advanced Research in Dynamical and Control Systems **11**. 10 204–211 (2019) DOI: 10.5373/JARDCS/V11SP10/20192792
4. A.I. Kashirin, P.A Kashirin, Journal of Contemporary Issues in Business and Government **26**. 1. 205-216 (2020). DOI: 10.47750/cibg.2020.26.01.026
5. A.I. Kashirin, S.V. Chemezov, V.V. Strenalyuk. *The formation of innovative leadership on key product features based on unique technological competences* // Springer Nature Switzeland, LNNS p. 417- 426 (2020). DOI: 10.1007/978-3-030-40749-0_50
6. Hiển Nguyen Hoàng, et.al., International Journal of Energy Economics and Policy **5** (2022) DOI: doi.org/10.32479/ijeep.13408
7. A.I. Kashirin, P.A. Kashirin, A.S. Semenov. *Diversification mechanisms and their effectiveness* /E3S Web of Conferences. – 2023, ERSME-2023 DOI: https://doi.org/10.1051/e3sconf/202337605010
8. A.I. Kashirin, A.S. Semenov, V.V. Strenalyuk, E.O. Pavlov. *Management of technological competencies for the purpose of innovative development* /E3S Web of Conferences. – 2023, UESF-2023 DOI: https://doi.org/10.1051/e3sconf/202338909001