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State Policy in the Field of Waste Management: Effective Global Practices for Russia

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ABSTRACT

Globally, there are a number of successful practices and initiatives aimed at solving the problem of waste management and reducing its negative impact on the environment. The relevance of their application is due to the growing volume of waste accumulation, which is becoming a global environmental problem. **The aim** of the article is to identify possible economic benefits based on the analysis of the possibilities of applying global practices in the field of waste management in Russia. **Research methods:** economic and statistical analysis, comparison, generalization, synthesis, systematic approach. **The results of the study.** The article presents results of potential implementation of the "waste-free city" concept. Possible economic benefits have been identified when incinerators are put into operation in some regions, electricity is generated by incineration of waste sent to landfills, and traditional fuel is saved in the production of "green energy" at these plants. The benefits of using the reverse logistics mechanism have been determined. The introduction of reverse logistics practices encourages the solution of waste reduction tasks, sustainable competitiveness, and economic benefits. The results of effective deposit repayment programs implemented in many countries are summarized. **Scientific novelty.** Based on the results of the analysis, the authors substantiate the application of world practice in Russia. **Practical significance:** the research results can be applied to develop project activities, development strategies, and to adapt global practices to Russian realities, taking into account economic and environmental consequences, while choosing the most appropriate mechanisms to support effective waste management practices.
Keywords: waste management; international practice; closed-loop economics; incinerator; reverse logistics system; deposit system; circular economy

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INTRODUCTION

The changing geopolitical situation requires new approaches to deal with climate challenges. The major issues on the global agenda are co-operation on low-carbon development, drastic reduction of the anthropogenic impact on the climate and environmental protection. Russia is looking for new formats to implement ESG (environmental, social, governance) initiatives. ESG is a concept that enables the integration of environmental, social and governance factors into business objectives. Nowadays, the growing number of investors and regulators consider environmental sustainability as an integral part of modern businesses.

The depletion of natural resources has a significant impact on social development, and landfills pose environmental risks. Many countries are striving to transform the waste management industry to achieve economic growth while minimising environmental impact. They are implementing effective initiatives to reduce waste generation, ensure safe disposal and rationalise resource use.

LITERATURE REVIEW

The article by Chinese authors provides an overview and evaluation of the establishment of a "zero waste city" in China, it reports new results on the implementation of the "zero waste" concept and analyses the performance evaluation of the current level of solid waste management [1]. Many researchers focus on direct supply chains, however, little information about reverse supply chains was in consideration yet [2]. Some scientific articles present the reverse logistics system, identify its key processes [3–6], and its application as a strategic tool for economic benefits [7–9].

It is worth mentioning the argument in favour of importance of a deposit return mechanism for beverage and electronic packaging to solve many environmental problems [10]. The authors of one of the articles compare similar experience in Germany, Sweden and Australia [11]. Researchers also focus on the impact of waste collection and separation systems on the quality and efficiency of mechanical recycling of plastics [12].

ZERO WASTE CONCEPT

In the context of the circular economy, creating "zero cities" has become a goal for a growing number of countries and cities [13].

Many nations have achieved success in this direction. France has designed a national circular economy roadmap for 2019. Singapore has launched a master plan. Italy, the US and Japan have set the goal to achieve zero waste standards by the beginning of the 21st century. The European Union aims to ensure safe recycling of waste with priority to resource efficiency to achieve a win-win outcome for both economic development and the environment [14, 15].

China is one of the largest producers of solid waste, with reserves of approximately 60–70 billion tonnes. Over 10 billion tonnes are discarded each year and overall recycling rate is less than 55 per cent. The development of a circular economy in the People's Republic of China is focused on creating a multi-level, highly efficient recycling system [16, 17]

The waste-free city concept in China, based on international practices and innovative policies, promotes green development patterns through waste reduction and efficient resource use [18].

Incinerators make part of the waste free city concept, which involves the conversion of waste into electricity and heat. In 2023, China's electricity generation from renewable municipal waste totalled 13 GW, which is the highest indicator since 2010 and about 2 GW more than in 2022.[1] By the end of the year 2022, their daily incineration capacity reached 1 million tonnes, 3 years ahead of the target [19].

A well-proven clean energy solution are waste-to-energy technologies. They demonstrate high efficiency and are widely used in Japan, Switzerland, Finland, South Korea and the Northern Europe.

[1] URL: Statista/ https://www.statista.com/statistics/963246

Russia is also planning to build more waste-to-energy project plants. The RT-Invest Group's waste-to-energy plant put in operation in the Moscow region has become a revolutionary event for the country's energy sector and for the preservation of environment in Russia. It produces energy from non-recyclable waste, which is processed after the obligatory industrial sorting and selection of useful fractions. The thermal power plant will be able to process 700 000 tonnes of household waste and generate 520 million kWh of "green" energy per year,[2] which is enough to supply 80 000 inhabitants with electricity.[3]

Waste-to-energy plants are currently under construction in Solnechnogorsk, Naro-Fominsk and Bogorodsk districts of the Moscow Region, as well as in the Republic of Tatarstan. Five new plants with a total processing capacity of about 3.3 million tonnes of waste per year will be able to produce more than 2,200,000 MWh of "green" energy, reduce CO_2 emissions by 3.8 million tonnes per year and improve the quality of life of more than 18 million people.[4]

The new project of waste incineration to provide heat and electric power envisages the construction of two plants in Moscow and four in the Moscow region by 2029.[5] All this contributes to elimination of landfills, so it seems reasonable to complement environmental projects with rehabilitation measures of degraded land [20].

Let us determine the potential benefits of incinerating one tonne of garbage:

- production of 300 550 kWh of electric energy;
- production of 600 kWh of thermal energy (515 Gcal) [21];
- saving 0.5 tonnes of coal or 0.25 tonnes of natural gas[6];
- avoids greenhouse gas (GHG) emissions of 2–10 tonnes (in terms of CO_2). One tonne of waste emits from 0.05 to 0.15 tonnes of methane, which has a greenhouse effect more than twice that of carbon dioxide.[7]

In addition, the storage for the remaining waste after incineration is environmentally safe and requires 10–12 times less space.

Let us make a calculation of the approximate benefits of incinerators in some regions using their performance indicators:

- the plant commissioned in the Moscow region, which will be able to process 700 thousand tonnes of municipal solid waste (MSW) per year, which were left after sorting and found unsuitable for recycling, generate 520 million kWh of green energy per year (742.9 kWh per each tonne of waste incinerated).
- the plant commissioned in Kazan, which will process 550 thousand tonnes of MSW and generate 55 MW of energy; it is planned to generate 690 kWh of electricity from each tonne of waste.[8]

Let us look at the regions that, according to FinExpertiza's calculations, will generate the largest and smallest amounts of waste per capita[9] in 2023 (*Table 1*).

As it was revealed, Voronezh Oblast, Bashkortostan and Dagestan discard significantly more solid municipal waste to landfills than other regions analysed: (952 075.0 tonnes, 842 766.1 tonnes and 686 717.6 tonnes respectively). We shall use the example of calculation for a waste-to-energy plant in Moscow region to determine the approximate benefits of building high-capacity incinerators capable to process annually 700 thousand tonnes of household waste and generate 742.9 kWh of green energy per tonne of waste incinerated. The results show that in the Voronezh region

[2] URL: https://www.bigpowernews.ru/markets/document117585.phtml

[3] URL: https://neftegaz.ru/news/energy/873211

[4] URL: https://neftegaz.ru/news/energy/873211

[5] URL: https://www.vedomosti.ru/economics/articles/2019/12/15/818744

[6] URL: https://meganorm.ru/Data2/1/4293852/4293852448.pdf; URL: https://files.stroyinf.ru/Data2/1/4293784/4293784075.pdf

[7] URL: https://belfes.ru/wte/

[8] URL: https://protatarstan.ru/news/razumnoe/musor-energiia?ysclid=m65i00w1bs216306617

[9] URL: https://finexpertiza.ru/press-service/researches/2024/bolshe-musora/

the energy production will be 707 296 487.7 kWh (952 075.0 t * 742.9 kWh) (*Table 1*).

In other regions, the benefits are calculated on the basis of the capacity of the plant under construction in Tatarstan (550 thousand tonnes of solid waste per year, 690 kWh of electricity per 1 tonne).

As we mentioned earlier, burning 1 tonne of waste saves 0.5 tonnes of coal or 0.25 tonnes of natural gas. Let us use these data to estimate the benefits (*Table 2*).

The average price of steam coal in Russia was 2 400–2 600 Rubles in 2022 and for the steam coal for thermal power plants of the Far East in 2023 was 3 000–3 400 Rubles per tonne.[10]

In 2023, the price of coal on the Russian market was in average about 30 USD per ton, which is about 4 times lower than the world price (120–130 USD per tonne).[11] Accordingly, for the estimation

[10] URL: https://www.bigpowernews.ru/news/document112113

[11] URL: https://spimex.com/upload/iblock/6b2/dniqsmvg2087.pdf

Table 1

Calculation of the volume of electricity generation from waste intended for disposal in 2023 (kWh)

Region	Share of disposed MSW, including treated (sorted) MSW in the total mass of generated MSW (%)	Population (persons)	MSW per capita (in Kg)	MSW sent for disposal (tonnes)	Electricity generated (kWh)
Voronezh region	96.0	2 279 349.0	435.1	952 075.0	707 296 487.7
Bashkortostan Republic	86.8	4 070 980.0	238.5	842 766.1	626 090 963.7
Dagestan	100.0	3 221 002.0	213.2	686 717.6	510 162 524.7
Republic of Adygea	91.7	499 288.0	605.8	277 363.8	191 381 001.8
Novgorod region	91.8	573 687.0	501.7	264 217.6	182 310 164.0
Yamalo-Nenets Autonomous Okrug	98.2	514 174.0	453.5	228 980.7	157 996 687.6
Sakhalin Region	98.6	459 063.0	430.1	194 678.8	134 328,368,.1
Republic of Buryatia	99.8	973 275.0	127.2	123 553.0	85 251,555.4
Mari El	99.0	671 088.0	217.6	144 568.5	99 752,238.3

Source: compiled by the authors.

Table 2

Calculation of savings of non-renewable natural resources for 2023

Region	Amount of MSW sent for disposal (tonnes)	Coal savings (tonnes)	Natural gas savings (tonnes)	Coal savings (mln. Rubles)	Whole sale prices of gas (Rubles / 1000 m^3)	Natural gas savings (thousand m^3)	Natural gas savings (mln. Rubles)
Voronezh region	952 075.0	476 037.5	238 018.7	1 428.1	5.751	297 523.4	1 711.1
Bashkortostan Republic	842 766.1	421 383.1	210 691.5	1 264.1	5.002	263 364.4	1 317.3
Republic of Adygea	277 363.8	138 681.9	69 340.9	416.0	5.873	86 676.2	509.0
Novgorod region	264 217.6	132 108.8	66 054.4	396.3	5.555	82 568.0	458.7
Amur Region	308 619.8	154 309.9	77 155.0	462.9	4235	96 443.7	408.4
Kaliningrad region	458 469.4	229 234.7	114 617.3	687.7	5.582	143 271.7	799.7
Yamalo-Nenets Autonomous Okrug	228 980.7	114 490.4	57 245.2	343.5	3.154	71 556.5	225.7
Sakhalin Region	194 678.8	97 339.4	48 669.7	292.0	3788	60 837.1	230.5
Dagestan	686 717.6	343 358.8	171 679.4	1 030.1	5.873	214 599.3	1 260.3
Mari El	144 568.5	72 284.2	36 142.1	216.9	5.168	45177.6	233.5

Source: compiled by the authors

of savings we will use the indicator 3 000 Rubles per tonne.

One tonne of natural gas contains approximately 1 250 cubic meters of gas (density 0.8 kg per cub/m). To calculate savings, we will take into account the wholesale prices of gas (RUB/1 000 cub/m) in accordance with the Ordinances of the Federal Antimonopoly Service of Russia 910/23[12] dated 28.11.2023, 816/22[13] dated 16.11.2022 and 818/22[14] dated 16.11.2022 (*Table 2*).

The results of the analysis indicate that incineration of the municipal solid waste sent to the plants instead of landfills will lead to the following resource savings: 476 037.5 tonnes of coal worth 1 428.1 million Rubles and 238 018.7 tonnes of

[12] URL: http://publication.pravo.gov.ru/document/0001202312010032

[13] URL: http://publication.pravo.gov.ru/document/0001202212010069

[14] URL: http://publication.pravo.gov.ru/document/0001202212010058

natural gas worth 1 711.1 million Rubles are in the Voronezh Region; 421 383.1 tonnes of coal worth 1 264.1 million and 210 691.5 tonnes of natural gas worth 1317.3 million Rubles are in the Republic of Bashkortostan; 229 234.7 tonnes of coal worth 687.7 million Rubles and 114 617.3 tonnes of natural gas worth 799.7 million Rubles are in Kaliningrad Oblast.

Despite the expected benefits, it is worth noting, that the capacity of some incinerators will be used not in full 100 per cent, so it is possible to consider bringing additionally more solid municipal waste for incineration from some neighbouring regions. The choice of the most appropriate technology depends on the capital investment and the capacity of the plant.

Since legislative changes back up a closed-loop economy increasingly, it is reasonable to envisage a growing number of waste-to-energy plants. The implementation of the waste-free city concept in Russia contributes to more waste recycling, economic benefits and the prevention of negative environmental impacts.

PRACTICAL APPLICATION OF REVERSE LOGISTICS

Reverse logistics is a strategy with a great potential to promote sustainable development [22]. It plays an important role for the adoption and implementation of the circular economy concept in supply chains. Reverse logistics was developed in the USA, Canada, China, Germany, India and other countries as an essential instrument within the framework of the growing e-commerce and technological innovation. It contributes to developing strategies for an effective take-back and recycling policy, when the priority is set for recycling, resales at reduced prices, donations and the establishing of reserves for recycling.

The concept of reverse logistics ensures revenues for companies and the implementation of its tools in projects could be a potential solution to waste management problems and contribute to the reduction of CO_2 emissions [23].

The reverse logistics process is developing worldwide, wherever new systems being developed to improve it [24]. Currently, more and more research has been conducted in this area. Many scientists support the introduction of Industry 4.0 principles [25, 26], which can accelerate the development of a circular economy with implementation of modern production technologies and waste use.

Sophistication and innovations in reverse logistics contribute to establishment of the circular economy, by means of supporting sustainable practices and minimising waste. In some countries, such programmes and roadmaps have become significantly popular. Russian model of economy based on the export of raw materials is unsustainable, and one of the reasons for this is the social and environmental problems caused by the high growth of waste [27].

In this context, the following aspects should be under consideration:

- the volume of the global reverse logistics market was amounted to $ 1.07 trillion USD in 2023 and 1.22 trillion USD in 2024, by the year of 2033, it is expected to grow by around $ 3.68 trillion USD, which is 13.1 per cent higher than in 2024;
- the Asia-Pacific market contributed over 52.14 per cent of the revenue in 2023 and was valued at $ 560 billion, moreover, by 2033, it is expected to be around $ 1.970 billion;
- Middle East and Africa market will grow at a compound annual growth rate of 13 per cent from 2024 to 2033;
- E-commerce is accounted for more than 56 per cent of the segment's revenue share in 2023;
- the share of repairable returns is expected to grow at a compound annual growth rate of 6 per cent from 2024 to 2033.[15]

The expansion of e-commerce is the driving force for the growth of reverse logistics. The volume of e-waste is increasing: the global pro-

[15] URL: https://www.precedenceresearch.com/reverse-logistics-market

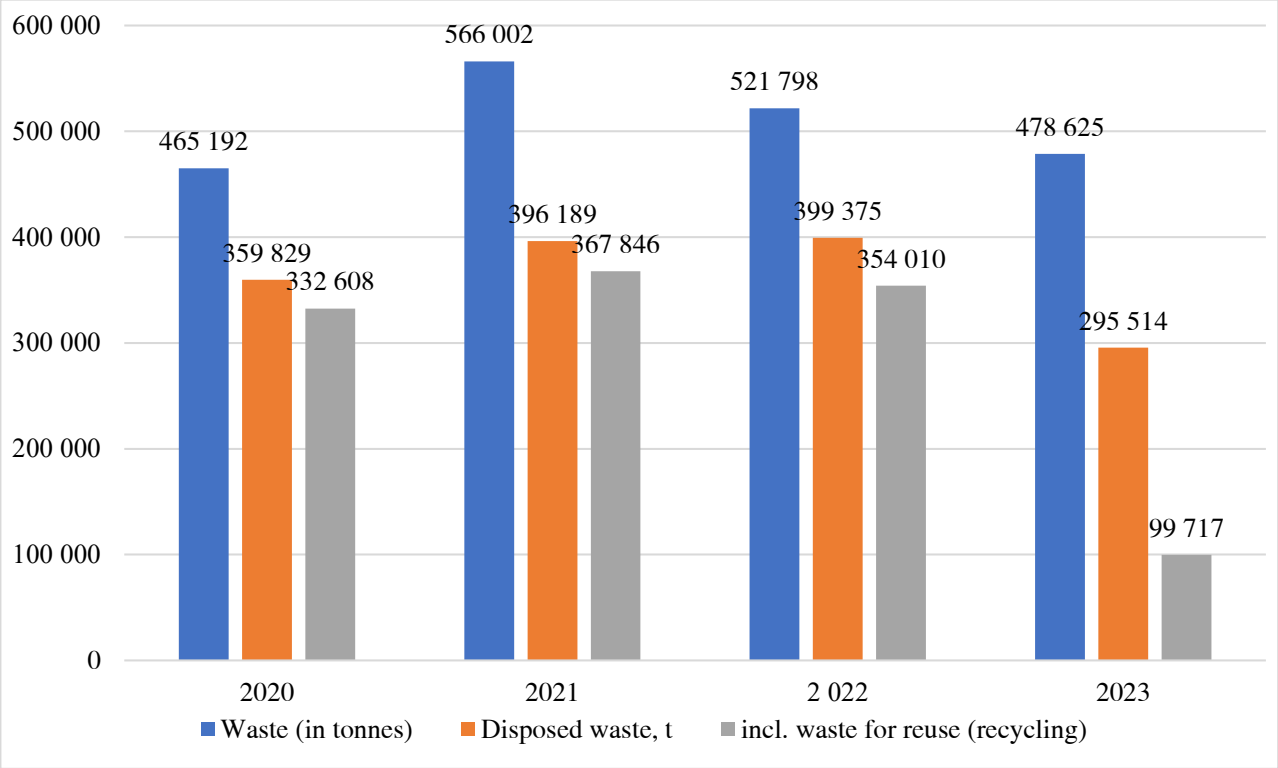

Fig. 1. **Dynamics of the movement of electronic waste (t)**

Source: compiled by the authors on the basis of: URL: https://rpn.gov.ru

duction in 2022 will be 62 million tonnes (7.8 kg per capita); 22.3% (13.8 million tonnes) will be reported as properly recycled.[16] The volumes of electronic waste is expected to reach 74 million tonnes by 2030.[17]

The analyses of research and analytical data indicate that the implementation of reverse logistics mechanisms contribute to the following:

- they bring down costs, reduce e-waste, increase profitability through product recovery;
- they maximise profits (through repair, resale, reuse) which otherwise might have been lost;
- they recover and recycle products (e-waste producers are responsible and obliged to process recycling).

The authors conducted an analysis for the period 2020–2023 (*Fig. 1*), which indicates that the volume of e-waste collection in Russia has increased.

Figure 2 shows the dynamics of waste generation and waste recovery by type of "Manufacturing" economic activity: production of computers, electronic and optical hardware). With regards to this type, the volume of waste recovery is decreasing.

Thus, the application of reverse logistics will contribute to the growth of waste recovery and recycling. At the same time, the following aspects should be taken in consideration.

1. It is possible to recover critical materials and metals from waste, but this requires investments and equipment. For example, the content of gold, silver and palladium in electronic components, cable contacts, microcircuits range from 179.86 to 3694.51 mg/kg, from 809.0 to 12320.51 mg/kg and from 96.25 to 117.49 mg/kg respectively. The

[16] URL: https://www.genevaenvironmentnetwork.org/resources/updates/the-growing-environmental-risks-of-e-waste/

[17] URL: https://forbes-ru.turbopages.org/forbes.ru/s/mneniya/476085-zoloto-iz-musora-perevernet-li-novaa-tehnologia-pererabotku-othodov-elektroniki

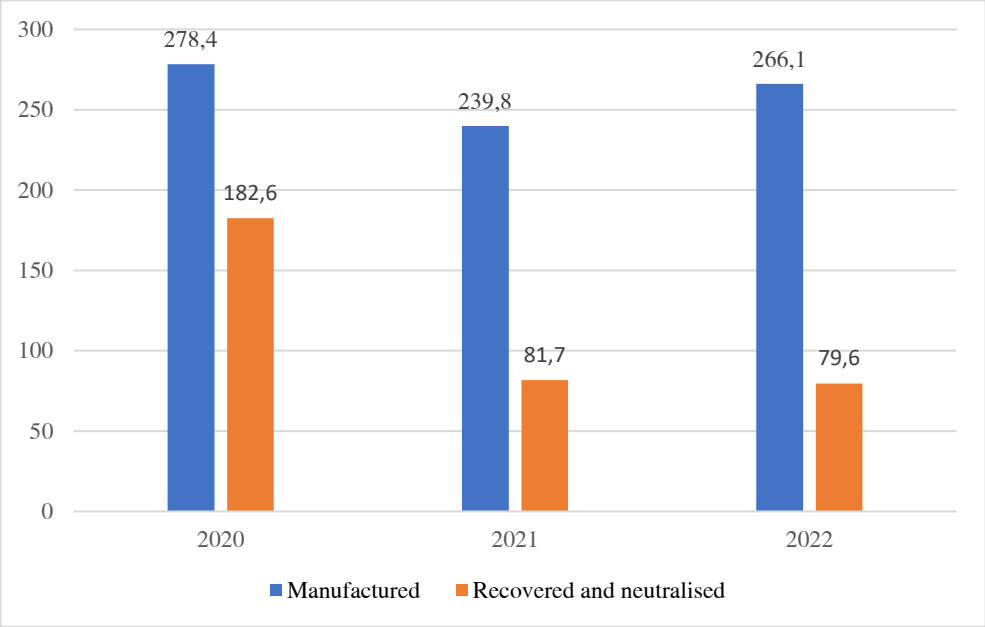

Fig. 2. **The dynamics of waste generation and disposal by type of economic activity "Manufacturing" (production of computers, electronic and optical products – in tonnes).**

Source: compiled by the authors on the basis of data from the Federal State Statistics Service. URL: https://rosstat.gov.ru/storage/mediabank/oxr_bul_2023.pdf

economic value of recycled precious metals in 1 tonne of e-waste is up to 2 292.94 USD, with a gold content of 98 per cent [28]. Extracting metals from e-waste is environmentally friendly and 13 times less expensive than mining. 85–90 per cent of the materials used to produce refrigerators can be recycled.[18]

2. Electronics manufacturing and e-waste disposal generate high greenhouse gas emissions. Recycling products reduces the carbon footprint and is beneficial to avoid greenhouse gas emissions.

3. Analytical studies, application of data analysis, adequate tracking technologies and introduction of management systems of supply chains will help to improve understanding of needs [29]. Manufacturers can develop a system of target indicators to evaluate the reverse logistics policies.

The following measures are recommended to develop the introduction of the reverse logistics mechanism in Russia:

- improving legislation;
- informing the society about the importance of waste recycling and recovery;
- developing technology for effective reverse logistics management;
- introducing environmentally friendly practices;
- investing in infrastructure, developing recycling technologies.

The authorities improve legislation in the area of waste management and expand the ecological education activities implemented within the framework of State programmes. Adoption of legislative and regulatory documents will not require additional expenditure from the budget. Private investors are able to invest in infrastructure, development of recycling technologies within the framework of public-private partnership subsidies and privileges from the budget of the National Project "Ecological Wellbeing" for 2025–2030. It is planned to allocate about 600 billion Rubles for environmental projects by 2030 and for programmes to finance lending

[18] URL: https://www.mckinsey.com/capabilities/sustainability/our-insights/sustainability-blog/implementing-decarbonization-what-consumer-companies-should-know

to small and medium-sized enterprises by 2025 it is planned to allocate 57.6 billion Rubles in 2025 and about 238.0 billion Rubles in 2030.[19]

Thus, implementing the above mentioned measures: economic benefits, sustainable competition, reducing waste and greenhouse gas emissions etc. encourage Russian companies to adopt reverse logistics.

DEPOSIT RETURN SCHEME

Resource management and circular economy policies in the EU are constantly improving. Germany has a highly efficient deposit-refund system (DRS): thanks to a high deposit value and a convenient network of return points, DRS system provides a record 98 per cent return rate for a single-use drinks packaging. Germany was the first country in Europe to introduce the deposit-refund system in 2003, which is evaluated the most successful in the world[20] with approximately 3 billion disposable containers[21] discarded each year. This policy increases the amount and a whole variety of recycled plastic raw materials, including for the production of various containers. It also promotes effectively the development of a circular economy and helps to minimise waste.

The authors present here the following global statistics in the analysed area.

In 2023:

- In the UK, 70 per cent of PET-bottles[22] were processes for recycling, in Sweden the amount was 90–95 per cent;
- In the USA, 890,000 tonnes of bottles were collected, 2.7 per cent more than in 2022, with a recycling rate of 33 per cent[23];
- Germany and Finland have high rates of collection of PET bottles: 98 and 97 per cent respectively[24];
- In Russia, the recycling rate is up to 25 per cent[25].

In 2024:

- Belgium and the countries of the Arabian Peninsula were the leaders in terms of plastic waste per capita (147.7 kg per capita);
- Russia had 33 kg of plastic per capita.[26]

Our country has adopted The Ecoplatform Programme to recycle plastic bottles and aluminium cans: over 13 million of them were collected in 2022 and more than 19 million in 2023.

Thus, thanks to the deposit-refund system, which has proven to be effective, countries have achieved a high level of collection and reuse of plastic bottles.

However, in Russia the current economic mechanisms do not fully generate the recovery of secondary resources, including the lack of incentives for recycling costs [30]. The introduction of efficient deposit-refund system will contribute to the reduction of plastic waste, increase collection and recycling, save energy and raw materials for the production of new containers.

It is worth noting that complete transition to a closed-cycle economy practically solves the problem of waste recycling. Capital investments in Russia are channeled to put in operation additional capacities: incinerator plants and modernised landfills, but domestic recycling rates are still lower than in the countries, which adopted earlier the concept of a closed loop economy. Besides, the current tariff system does not adequately stimulate the use of environmentally friendly methods of waste management: the environmental fees are 3–4 times lower than the cost of delivery of PET bottles to the recycler [31].

[19] URL: https://digital.gov.ru/ru/events/53021/; URL: https://rlw.gov.ru/press/document/19261

[20] URL: https://www.tomra.com/en/reverse-vending/media-center/feature-articles

[21] URL: https://www.statista.com/statistics/1316967/pet-collection-rates-by-country-europe/

[22] PET bottles are plastic containers of various colours, volumes and shapes for all purposes.

[23] URL: https://www.jdsupra.com/legalnews/2023-u-s-pet-bottle-recycling-national-6916540 products/Demo

[24] URL: https://www.statista.com/statistics/1316967/pet-collection-rates-by-country-europe/

[25] URL: https://drgroup.ru/components/com_jshopping/files/demo_.

[26] URL: https://plasticovershoot.earth/wp-content/uploads/2024/04/EA_POD.pdf

It is also worth noting, that promotion of "environmental awareness" in the society is a very important factor. This applies not only to separate waste collection. From 2019, the environmental fees raised for producers of plastic packaging allow them to inform consumers on the amount of the pollution charges about it in a separate space on the labels and save on environmental payments [30].

Although the completion of the circular economy is developing gradually, some industries have already made significant progress by means of introducing related initiatives and activities. The development of the circular economy will require radical changes, breakthrough innovation and unprecedented collaboration between countries, industry leaders, stakeholders, researchers and consumers.

CONCLUSIONS

In conclusion, it is worth noting, that the given article proposes to implement in Russia an effective international experience in terms of introducing the "city without waste" concept. The concept is based on a new model of urban development and aimed at reducing the amount of solid waste, safe disposal with minimal environmental impact, efficient use of resources, which will contribute to the formation of "green" models of development.

The authors have identified economic benefits from the possible commissioning of incineration plants in some regions of Russia and the generation of electricity from the incineration of waste from landfills.

The research work also demonstrates that the mechanisms of reverse logistics become an integral part of supply chain management: it can help companies reduce storage and distribution costs, as well as ensure a payback of the economic benefits related to returned products. Reverse logistics has become particularly important with the development of e-commerce. It contributes to the growth of e-waste recycling. The concept requires the development of new regulatory tools, the formation of normative and legal acts.

The article also provides recommendations for the implementation of the deposit return system (DRS) in Russia, aimed at promoting a closed-loop economy and reducing waste generation. As practice indicates, deposit return system has become effective and is widely popular in many countries, providing financial incentives for the return of used containers to be recycled or reused. In this era of developing new ways of managing waste, deposit return system is regarded as a good choice for more structured plastics recycling.

Thus, the implementation of successful global practices in Russia, such as the "city without waste" concept, reverse logistics mechanisms and deposit return systems will contribute to the development of a circular economy, as they all aim to reduce the environmental impact of production and consumption by extending the life cycle of products and materials and fulfilling efficient recycling methods.

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