



Implementation of Eco-Industrial Park for Effectual Establishment of Circular Economy in Russia

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ABSTRACT

In recent years, waste management has become a major concern in Russian cities. This can be addressed through the circular economy. Developing Eco-Industrial Parks (EIP) can be considered an innovative infrastructure of a circular economy. EIP is based upon the principles of industrial symbiosis involving the exchange of material and energy flows, sharing of infrastructural facilities, and provision of municipal utility and other services. Researchers have found that most industrial symbiotic interconnections originated spontaneously, the main driver being the increasing commercial benefits of such interchange. Still, the authors were able to identify pre-designed EIP through their examination of global practices. This paper proposes a five-stage methodological approach to EIP organization. This methodology was applied to create a model of an EIP in the Voronezh Region, one of the fastest developing regions in Russia. Implementation of this model is intended to help solve a set of environmental, economic, and social problems of a region. The approach to creating EIPs described in this study can be used in other places to improve resource efficiency and reduce waste disposal. Because Russia's garbage disposal rate currently exceeds 90% per year, this is one of the country's top sustainable development priorities.

INTRODUCTION

Innovative infrastructure based on a circular economy is a concern of many cities around the world. This demand is mainly driven by the lack of raw materials, an increasing volume of hazardous waste, intensifying unplanned landfills, and the lack of energy resources. Disposal of waste is a problem in many cities of Russia and a solution is immediately required towards the establishment of energy-efficient infrastructure. Developing a circular economy for industrial processes will reduce resource consumption and eliminate unauthorized landfills and dumps. EIP in Russia integrates the concept of circular economy, which is crucial for the sustainable development of the country (Zhou et al. 2017, Pakhomova et al. 2017).

The basic premise of ensuring an ecosystem's sustainability is to keep its constituents in a closed loop. Despite the fact that the entire biosphere is enveloped in a circle of intense global currents and changes, these currents and changes are almost perfectly balanced; in other words, they are looped. Everything that a living organism has produced, including itself, is consumed by organisms of other species, chain-wise. These processes are cyclical and do not result in the creation of "surplus" matter due to the use of solar energy.

Metabolic (within an organism) and physical (natural circuit of matter) cycles in the biosphere ensure chemical and physical continuity of the environment. The law of equilibrium of cycles may be termed the "principle of cyclical circularity", or "circularity principle". Looped metabolic and physical cycles help to maintain the continuity of chemical and physical properties of the biosphere, which is called sustainability (Mashukova 2016, Skobelev 2020).

Based on various research gaps and research questions the following research objective have been set for the study, objective 1: Analyze the possibility of organizing an industrial system by analogy with the natural system through the creation of eco-industrial parks, objective 2: Develop an algorithm for organizing eco-industrial parks and objective 3: To put the developed algorithm to the test on a real-world problem in one of Russia's regions. The project's major goal is to create a mechanism for putting a circular economy into practice in eco-industrial parks by closing resource cycles. For Russia's sustainable development, improving resource efficiency and decreasing waste disposal at landfills are top priorities.

The paper presents a methodological approach towards the organization of EIP, with five main stages:

Step 1 – Assessment of the current situation in the field of waste and secondary resources management in the region

Step 2 – Collecting the main flows directed to the EIP

Step 3 – Defining the object composition of the EIP and the list of technological solutions

Step 4 – Selection of a land area for EIP location

Step 5 – Defining the EIP performance indicators

This is an aggregative method, but it does not allow for the formulation of a comprehensive concept for the creation of eco-industrial parks. Each level can be detailed in the future based on the unique design conditions of eco-industrial parks.

This principle of natural ecosystems organization is the foundation of the circular economy concept (Tyrganova & Makhashkeeva 2014). Similarly, to a natural ecosystem, the industrial and utility system may be regarded as a spatially defined aggregate of production components (cells), including production sites, facilities, factories, etc., and natural objects, all integrated with material, energy, and information interconnections (Smirnova et al. 2018). Within such a system waste generation is the result of the production processes. Waste management, existing in such systems, requires the collection, transportation, recycling, decontamination, or landfilling (Ayres & Simonis 1994). Material and energy flows are transported between components (objects) of the industrial realm and the environment in municipal/industrial ecosystems, just as they are in natural ecosystems. There is an informal interaction between these objects.

The analogy between natural and municipal/industrial ecosystems can be described as “industrial symbiosis”. Industrial symbiosis, as a part of the new area of the industrial ecology, implies combining of the material and energy flows via local and regional economics. This symbiosis draws the attention of traditionally autonomous industries to collaborate to achieve a competitive advantage in the physical exchange of materials, energy, and water (Fischer-Kowalski 1998). The core elements of the industrial symbiosis are active collaboration and symbiotic opportunities ensured by the geographical proximity of industrial enterprises (Albino et al. 2016).

For optimal implementation, the concept of creating an eco-industrial park should be based on an interdisciplinary approach. Several terminologies and definitions are used by organizations to refer to EIPs and similar related concepts. Fig. 1 presents combinations of commonly used terms relating to EIPs. As per World Bank 2021 International Framework for Eco-Industrial Parks, broadly, EIPs can be defined as, “managed industrial areas that promote cross-industry and community collaboration for common benefits related to economic, social and environmental performance”. The concept of EIP has evolved to address additional and inter-related aspects, including, resource-efficient and cleaner production, climate change, pollution, industrial symbiosis, social standards, shared infrastructure, and management of risks and shared resources at higher echelon, land, and ecosystem services.

In worldwide practice, such interconnections have been evolved into Eco-Industrial Parks (EIP). The generally accepted definition of EIPs is currently based on the wording by Ernest Lowe published in 2001 in the “Eco-Industrial Handbook” prepared with the assistance of the Asian Development Bank - “An Eco-Industrial Park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resources issues including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would have realized if it optimized its individual interests” (Ernest 1995).

However, other definitions exist, emphasizing specific features and components of an EIP. Below there are some examples of them.

According to Smirnova et al. (2019), the term eco-industrial park is used to define both eco-industrial parks and eco-innovative areas combining residential and industrial activities, such as eco-cities or eco-industrial zones. Eco-innovation parks are designed with the environment in mind (e.g., piloting installations and processes, designing new goods) and actively work with research and development institutions.



Fig. 1: Combinations of terms used internationally in relation to Eco-Industrial Parks (Source: World Bank 2021)

Côté and Cohen-Rosenthal present the following definitions (Côté & Cohen-Rosenthal 1998, Côté & Hall 1995), “An Eco-Industrial Park is a community of businesses aiming at the improvement of their environmental and economic performance through co-operation inefficiently sharing resources including efficient consumption of energy, water, and materials. An EIP is created to improve the economy of its participants while minimizing their environmental impact. Components of this approach involve a new or redefined design of parking infrastructure and installations, prevention of pollution, increasing energy efficiency, and other areas of collaboration between the companies in and EIP. Such form of cooperation may be defined as an industrial ecosystem.”

“An Eco-Industrial Park is an industrial system which conserves natural and economic resources; reduces production, material, energy, insurance, and treatments costs and liabilities; improves operating efficiency, quality, worker health, and public image; and provides opportunities for income generation from use and sale of wasted materials”.

In their publications Chertow (2007), Smirnova et al. (2019), and Côté and Cohen-Rosenthal (1998), the authors claim that the key factor of EIP operation is establishing material and energy flows between businesses both on the local and regional economy levels. The key element of all the above definitions of the concept of “eco-industrial park” is the organization of “closed cycles of materials” between enterprises in EIPs. Such exchanges of material and energy flows are called industrial symbiosis.

As a result, EIPs apply a set of industrial ecology system components, presenting another definition of an EIP as “an industrial unity of businesses aimed at more efficient use of natural resources, also via industrial symbiosis” (Kiseleva et al. 2018).

By physically exchanging materials, energy, water, and by-products, industrial symbiosis encourages industries that operate separately to come together in sharing material and energy flows in areas with essential and technological options, gaining a competitive economic and environmental edge for all participants (Neves et al. 2016). New “unexpected” connections between various facilities operating in different production (among others) industrial areas may appear in EIPs thanks to the geographical proximity of such facilities. For instance, some authors define an EIP as “a set of manufacturing and service businesses located within one site and employing the same infrastructure” (Hein et al. 2016).

EIPs can be developed via two approaches, the first one is based on self-organization of companies into an EIP and the

second one could be based on an analysis of the production processes of the potential EIP participants as well as local/regional material and energy flows, implying a dedicated design of an EIP.

The second approach is more holistic. Owners of business organizations may have an interest in forming (participating in) an EIP as soon as they discover the prospects for maximizing operational efficiency through symbiosis (Alejandro et al. 2018).

Table 1 demonstrates a few examples of eco-industrial parks with the main benefits that have been achieved in their operation.

Designing the organization of an EIP requires methodological approaches and template technical and administrative solutions. Many authors proposed different approaches for this task (Chew et al. 2017, Tiejun 2010, Park & Behera 2014, Leeuwen et al. 2003). Still, the analysis of the solutions proposed by Chew et al. (2017), Tiejun (2010), Park and Behera (2014), and Leeuwen (2003) indicates the need to consider national specifics of economics in the regions where the EIP should be established. This paper attempts to take into account such specific features.

The assessment of material flows that can be directed to the eco-industrial park is the general step of the analyzed approaches to the organization of EIPs and the established methodology. At the same time, in addition to identifying material flows, an important stage in the established technique is determining the location of the eco-industrial park, taking into account the possibilities of the subsequent sale of its products.

MATERIALS AND METHODS

The study is divided into two parts.

The first part describes the developed methodology for organizing eco-industrial parks. The creation of EIPs is a multi-step process that starts with an analysis of the current situation “before the organization of an EIP” to an assessment of its operation. The key steps in the process for organizing Eco-Industrial Parks were formulated after an analysis of socioeconomic factors and environmental indicators in the regions of potential EIP locations. The EIP guide scheme is shown in Fig. 2.

In the second part of the study, the developed approach was applied to create a model of an Eco-Industrial Park in the Voronezh Region, one of the developing regions of the Russian Federation.

The article is based on the analysis of literature sources, official regional data, and case studies of the authors.

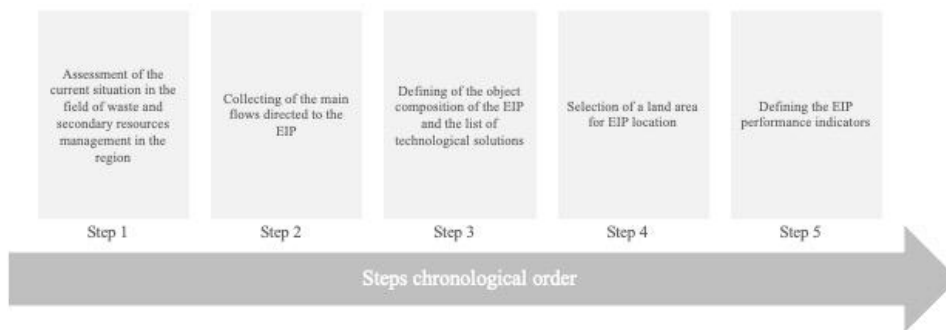


Fig. 2: Schematic Diagram of EIP guide

RESULTS AND DISCUSSION

The EIP Methodology

The entire process is viewed as an algorithm accelerator, allowing for the rapid identification and analysis of relevant

IS opportunities (Fig. 3). Each individual step's methodology, as well as the required inputs and expected outputs, are detailed below.

Step 1 – Assessment of the current situation in the field of waste and secondary resources management in the region

Table 1: Examples of Eco-Industrial Parks implemented on the principles of industrial symbiosis in the world

Country/ Region	Number of enterprises	Network scope (local/ regional/ national)	Supported/ planned / self- organized	Economic benefits	Social benefits (job creation)	Environmental benefits	References
Denmark/ Kalundborg	9	Regional	Self-organized	No data	4614	Waste Prevention (1997): 1 mln.m ³ of sewage sludge 200,000 tons of fly ash and boiler slag 80,000 tons of sludge from gas cleaning 2800 tons of sulfur 300,000 tons - annual reduction of CO ₂ emissions	(Smirnova et al. 2019)
Austria/ Styrian recy- cling network	28	Regional	Self-organized, supported	No data	22943	1 mln tons of by-products collected, 780,000 tons recycled, 200,000 tons thermal recycled. Reached 70% waste recycling rate, reduced 42% of CO ₂ emissions, 25% of energy resources are renewable	(Smirnova et al. 2019)
Finland/ Harjavalta	13	local	self-organized	No data	1000	Waste utilization rate - 81.8%. 351 tons/year of energy waste 181 tons/year of metal waste 124 tons/year of hazardous waste 15 tons/year of paper waste 16 tons/year of MSW	(Cooperation Fostering Industrial Symbiosis Market 2018)
South Korea, Ulsan Mipo, and Onsen Industrial Park	1000	Local	Supported, planned	US\$ 65 million.year ⁻¹ from selling by-prod- ucts and waste for re- cycling purposes. US\$ 78.1 million.year ⁻¹ from energy and ma- terial savings (in 2016)	35	saved 279,761 tons of oil equiva- lent in energy use reduction of 665,712 tons of CO ₂ emissions and 4052 tons of toxic gases during 2005–2016 79,357 tons of water and 40,044 tons of by-products and waste were reused	(World Bank 2021)

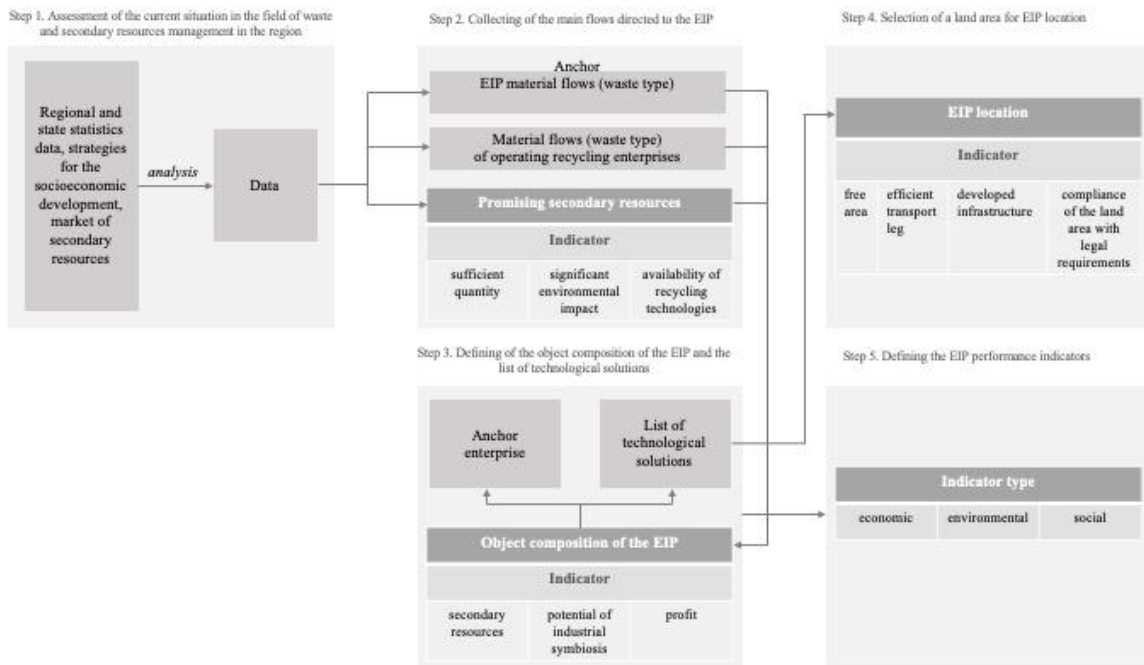


Fig. 3: EIP organization methodology

Input data analysis is the cornerstone of creating an EIP in a given region. This stage envisages evaluation of all available data on waste management in the region and its bordering regions; regional and national statistical accounts; data from environmental reference guides and databases; strategies for aerial and socioeconomic development; strategies for the development of certain industries; and marketing research reports on secondary resources markets.

These activities provide information on the following:

- amount of municipal solid waste (MSW) and industrial waste generated in the region;
- presence of the facilities for treatment, recycling, and landfilling of waste, if any, and the rate of capacity utilized;
- number of prospective sites for collecting, recycling, and decontamination and their location;
- Options for the development of industrial symbiosis;
- Opportunities for the interregional collaboration;
- Problems in waste management in bordering regions.

This set of data is the baseline for the next step.

Step 2 –Collecting the main flows directed to the EIP

At this stage, the analysis focuses on raw material flows of the potential EIP, including MSW, industrial waste, and prospective secondary resources to be probably generated

during EIP operations including waste sorting and waste recycling.

The criteria for the selection of prospective secondary resources include their sufficient weight or volume; significant environmental impact; and the availability of recycling technologies.

The design of an EIP project requires drawing a plan to combine enough physical resources to enable reaching target rates of recycling and producing a strategy for collecting such resources.

A prospective increase in estimated capacity due to a possible increase in future waste flows resulting from interregional interaction or the elimination of objects of accumulated environmental damage, among other causes, must be considered in addition to the forecast average level of material flows towards a planned EIP.

Step 3 – Defining the object composition of the EIP and the list of technological solutions

Following the creation of the EIP’s list of material resources, one must then create a list of technological solutions for the treatment, recycling, and decontamination of industrial and municipal waste/secondary resources to use in the manufacturing process. The analysis and marketing for the output based on secondary resources must be the following step.

Selection of technologies requires envisaging the interconnectivity of technologies for the realization of symbiotic industrial connections between industrial facilities.

Technologies for treatment, recycling, and decontamination of industrial and municipal waste/secondary resources shall meet the following requirements:

- waste generated within the EIP operations process shall be safe or present minimal risks to the environment and human health;
- most of the waste shall be returned to the production cycle or must be securely disposed of as environmentally safe objects;
- the amount of landfilled waste must be minimized.

Step 4 – Selection of a land area for EIP location

The composition of the prospective EIP objects defines the requirements for the land area to locate the EIP. Its selection is a standalone task that also needs a multifactor approach.

The main criteria for the *selection of a land area for EIP* include:

- available area;
- effective transportation leg, from the source of waste generation through the waste storage places to the recycling and utilization facilities;
- suitable infrastructure (water supply and removal, energy and thermal power supply, good surface transport network);
- the land area's compliance with the current regulations and demands.

Other meaningful factors are the potential for the development of neighboring urban and rural communities, their functional zoning and development pattern, utility and transport infrastructures, rational management of natural resources, and environmental protection. It's essential to consider the efficient material sources while deciding where to locate EIPs. As a result, it is vital to select places with the maximum concentration of material flow sources, as well as factors affecting the region's development, such as physiographic, socioeconomic, transportation, and logistical.

EIPs' infrastructure is built in accordance with legislation governing industrial and technological infrastructure, operational profiles, and material and energy inputs.

The design of EIPs and implementation plans for innovative solutions shall account for reliability, ease of use, and the operational and maintenance efficiency of infrastructural facilities, as well as their reorganization and reconstruction,

to ensure sustainable cost efficiency and the opportunity for technical upgrades.

There is the option to use economically and technically viable decentralized facilities.

In the design of an EIP, the transport and utility infrastructure shall ensure the following:

- possibility for the cooperation between utility facilities such as water supply and wastewater disposal, power and heating and gas supply, communications, etc.;
- interaction between industry facilities;
- transport links between urban and rural communities;
- separation of cargo and passenger traffic, the building of parking areas and networks of walkways and bicycle lanes;
- rational organization of pedestrian and automobile traffic towards workplaces, minimization of distances from operation support infrastructure.

Step 5 –Defining the EIP performance indicators

At this stage, we apply specially designed performance indicators to assess the efficiency of the EIP project in three main aspects, environmental, economic, and social.

As the key part of the circular economy, an EIP primarily aims at creating closed-loop supply chains to maximize the return of waste and secondary resources to new production. This approach enables efficient preservation and augmentation of natural resources and streamlining production processes, increasing resource and energy efficiency, which helps to scale down environmental problems and improve the region's economic efficiency and sustainability. Symbiotic connections between EIP participants allow addressing a number of diverse tasks as follows:

- reducing landfill areas;
- reducing emissions, dumping, and generation of waste;
- reducing energy and material costs;
- increasing resource and energy efficiency;
- returning secondary material resources to the production cycle and reducing consumption of natural resources;
- strengthening climate resilience by reducing greenhouse gas emissions from landfills;
- boosting capex efficiency while reducing operating costs;
- creating new jobs;
- raising the quality of life, also by improving environmental and economic conditions;
- supporting the region's transition to the development in the circular economy model.

Below are the results of the evaluation of the described methodology applied to the organization of an EIP in the Voronezh Region of the Russian Federation.

Case Study

Voronezh Region, located in the Central European part of Russia, has an area of 52,216 sq.km, with a population of 2.4 million. The region comprises eight administration clusters: Voronezhsky, Liskinsky, Rossoshansky, Bogucharsky, Paninsky, Buturlinovskiy, Borisoglebsky, and Kalacheevskiy. The climate is continental. Economically, the region focuses on agriculture, industrial manufacturing, and construction. The main sources of waste generation are manufacturing facilities, MSW and food production, animal farms, and agricultural farms. Combined, they account for 4/5 of the region's total industrial output. Leaders by waste generation in Voronezh Region are animal farms, sugar factories, and vegetable processors (The Strategy of Socio-Economic Development of the Voronezh Region 2018).

Step 1 – Assessment of the current situation in the field of waste and secondary resources management in the Voronezh Region

The amount of MSW generation

According to the waste inventory register of the Voronezh Region, the Voronezhsky inter-municipal cluster generates the greatest amount of waste, standing at 755.5 thousand tons (66% of the total in Voronezh Region), due to a significant concentration of population in the Voronezh agglomeration and a higher level of industrial and business activity. In each of the other seven inter-municipal clusters of the Voronezh Region, the amounts of annually disposed of MSW are meaningfully lower (Voronezh waste management system 2016).

Waste disposal facilities

There are 30 facilities on the list of waste disposal sites in the Voronezh Region. Over 80% (24 facilities) are landfills. 17 of them deal with MSW and seven deal with industrial waste. Six facilities are dumpsites.

The majority of MSW landfills in the Voronezh Region are located in the Voronezhsky inter-municipal cluster. The capacity of landfills (filled with wastes) in the Voronezh Region ranges from 14% up to 115 %.

MSW treatment facilities

The sites for MSW treatment in the Voronezh Region are waste sorting facilities, five are in operation and are located in the Voronezhsky cluster (Novosumansky and Semilukinsky Districts), Borisoglebsky cluster (Povorinsky District), and Rossoshansky cluster (Rossoshansky District) (Voronezh Waste Management System 2016).

Waste recycling facilities

These are concentrated mainly in the Voronezhsky cluster, in the City of Voronezh, and recycle all fractions of MSW.

Interregional co-operation

To assess the options for interregional collaboration in the operation of an EIP, we analyzed waste management systems in neighboring regions. Voronezh Region borders the Lipetsk, Tambov, Volgograd, Belgorod, Kursk, Rostov, and Saratov Regions. This analysis helped to define prospective districts from which waste (secondary resources) flows could be directed to the Voronezh EIP. Selection criteria included geographical proximity to the Voronezh Region and the absence of facilities for treatment, recycling, decontamination, and landfilling of MSW. The authors advise directing MSW flows from Terbunsky, Khlevensky, and Umansky Districts of Lipetsk Region as well as from Rovensky District of Belgorod Region (Belgorod Waste Management System 2016, Lipetsk Waste Management System 2019).

Industries and industrial waste

The industrial sector of the Voronezh Region is dominated by agriculture (The Strategy of Socioeconomic Development of the Voronezh Region 2018). As of 2018, the breakdown of industrial waste by volume in the Voronezh Region was as follows:

- food production – 3,810.23 thousand tons;
- animal farms waste – 2,852 thousand tons;
- mineral fertilizer production – 287.33 thousand tons.

Voronezh Region has no facilities for demercuration. Being a major logistical hub, Voronezh is the main producer of mercury-containing waste, while also accumulating the residue of such type delivered from other municipalities. It handles redirection of waste for decontamination outside of the region: to Moscow and the Regions of Moscow, Kursk, Ryazan, and Ulyanovsk.

The results of the analysis of the current situation in waste management in the Voronezh Region and bordering regions are presented in Table 2.

The Voronezhsky cluster is the primary source of MSW in the Voronezh Region. In Semilukinsky Municipal District, there are three garbage disposal sites, facilities for recycling all MSW fractions, and a waste sorting facility with a used capacity of 440 thousand tons.year⁻¹ (Voronezh Waste Management System 2016). The MSW sorting plant has a design capacity of 900 thousand tons.year⁻¹.

Step 2 –Collecting the main flows directed to the EIP

We believe that recycling potential secondary resources

such as scrap paper, plastic trash, and scrap glass have the most potential.

The establishment of a chain of interactions from waste generation to the manufacturing of products from waste and secondary resources is an example of how the methodological approach to the formation of material flows can be used to the EIP. (see Table 3).

Agriculture has the highest industrial load in Voronezh Region. Organic waste, manure, and food producers' waste could be generated by producers of meat, sugar, oils, fats, canned vegetables, and fruits, etc.

Step 3 – Defining the object composition of the EIP and the list of technological solutions

The agricultural sector defines the base for the prospective EIP. We advise building a complex for composting organic waste that would act as the anchor facility of the EIP. Produced compost shall be used for reclamation (remediation) of full landfills and unauthorized dumps. In the future, the complex may be converted to generate energy for the construction of other facilities within the EIP. Based on the analysis in steps one to three, we propose locating two sites

of the Voronezh EIP in the Semiluksky and Rossoshansky districts. The proposed composition of the EIP by the example of Semiluksky District is presented in Fig. 4.

Step 4 – Selection of a land area for EIP location

The assessment based on our methodological approach resulted in the selection of two sites for the creation of the EIP:

- in Semiluksky District, with the area of 30.88 hectares and the developed infrastructure in the distance of 1.7 km from the MSW sorting plant;
- in Rossoshansky District, with an area of 4.6 hectares and the developed infrastructure in the distance of 3 km from the MSW sorting plant.

Step 5 – Defining the EIP performance indicators

The evaluation of the efficacy of the EIP activities was facilitated by the identification of three areas and the development of specific and quantitative performance indicators for each of them (Table 4).

The cornerstone of industrial symbiosis, according to leading Russian and worldwide specialists in the circular economy, is established by the combination of resource exchange between companies, recycling of secondary resour-

Table 2: The results of data analysis.

Waste generation	Voronezh cluster 755.5 thousand tons (65% of the total education in the Voronezh Region)
Waste disposal facilities, percentage of filling	Only 30, of which 14 are 115% filled
Current MSW recycling facilities	Recycling companies of all MSW fractions (Voronezh cluster)
Planned waste recycling facilities	8
MSW processing facilities	7 waste sorting facilities
Interregional interaction	Belgorod region (Rivne district) Lipetsk region (Terbunsky, Khlevensky, and Umansky districts)
Industrial waste	Waste from food production, farm animal waste, garden waste, mercury lamps, used oils

Table 3: Chains of relationships from waste generation to the final consumer of products.

Material flow (waste type)	Waste recycling company	Secondary resources	Recycled products	Potential consumers of secondary resources
Plastic waste	Voronezh-Polymer LLC LLC Polymer-Chernozemye LLC "Contact" LLC "Management Company Region-Resource" Voronezhvtorma LLC	Crusher, agglomerate, granules, flex	Polyethylene film, garbage bags, polyethylene granules, LDPE film, plastic packaging	Producers of PET bottles and other plastic packaging, bristles for cleaning equipment, building materials
Paper waste	Eco Liner LLC LLC "Kharti" LLC "Kivo Market" LLC "KartonChernozemye"	Pressed sorted waste paper, cellulose wool	Sanitary and hygienic products, corrugated board, cardboard	Producers of cardboard, sanitary products
Scrap glass	"Branch of LLC RASCO" Voronezh glass container plant" LLC "Sferastek"	Sorted scrap glass Processed containers	Foam glass, fiberglass, glass crystal materials, road marking materials Reusable packaging	Producers of glass containers, building materials Producers of drinks, food

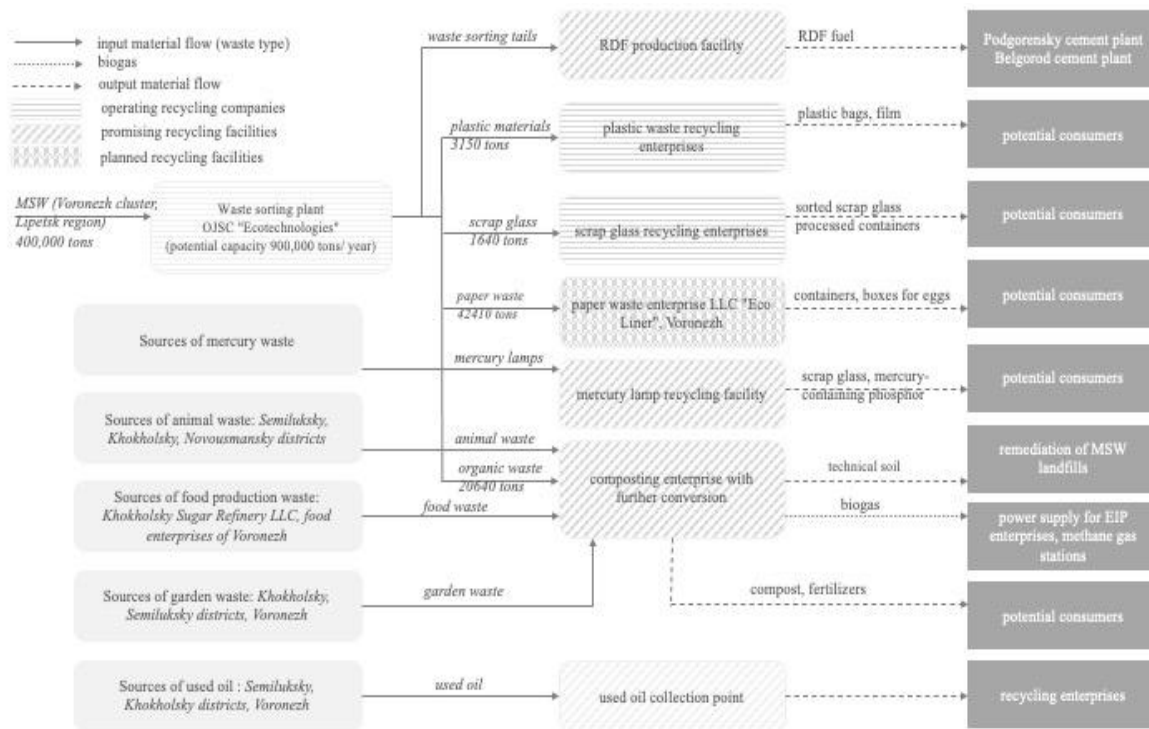


Fig. 4: Model of the object composition of the EIP in the Semiluksky district

es, involvement of many enterprises, and manufacture of competitive goods. The proposed methodological approach reflects this viewpoint.

The findings of the work on the EIP model’s organization have been approved, and the Voronezh Region Administration is considering them further. The

approach is planned for possible replication in other regions.

Thus, using the Voronezh Region of Russia as an example, the five stages of EIP organization proposed in the study make it possible to close waste streams to recycling firms operating and developed within the eco-industrial park.

Table 4: Assessment of compliance with the criteria for sustainable development of performance indicators of the EIP

Indicator type	Indicator
Economic	Increasing share of secondary resources usage in production
	Increasing investments in waste recycling and recovery and use of secondary resources
	Decreasing fees for the negative impact of waste disposal
	Decreasing operating costs
Environmental	Reducing landfill disposal
	Increasing waste recycling rate
	Decreasing emission of greenhouse gases
	Increasing the secondary resources recovery rate
	Increasing volume of production using waste and secondary resources
	Improving resource and energy efficiency
	Increasing number of facilities implementing the best technologies available
Social	Increasing public satisfaction with the quality of the environment
	Increasing the number of jobs involved in waste recycling and using secondary resources

This is in line with the primary goals of establishing an eco-industrial park: improving resource efficiency and reducing landfill waste disposal.

CONCLUSION

The authors presented a methodological approach based on classification and algorithmization of operations that must be followed to create an Eco-Industrial Park. In steps One and Two, initial data is processed to evaluate and calculate material flows to the prospective EIP. In step 3, the data collected and processed is used for designing the project composition of the EIP and choosing the required technological solutions. Step four sets the requirements for the land area and infrastructure for the EIP. In the final step, five performance indicators of the EIP are defined. This approach aims at delivering a comprehensive solution to the problem of waste management and reuse of secondary resources in regional economics. Implementing this technology to construct an EIP in the Voronezh Region could help to streamline trash flows and raise recycling rates by increasing capacity, all while lowering the negative environmental impact of waste landfilling. Implementing the circular economy in the appropriate region is one of the EIP's core ideas.

This paper gives a general outline of the methodology for the Eco-Industrial Parks organization. The authors continue refining the approaches to develop more detailed operations at each step and produce template technological solutions for EIPs.

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