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The Role of Information and Automation in Enhancing the Efficiency of the Functioning of Eco-industrial Parks in Russia

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Abstract — **In modern conditions, there is a need for the formation of an innovative infrastructure for a modern large cities focused on the integration of industries, science and education with the aim of solving existing problems. An important element of this infrastructure is eco-industrial parks. Eco-industrial parks development become a trend in the most of European countries, United States of America, Japan, South Korea and China. These parks implement the principles of circular economy, such as industrial symbiosis, waste recycling, energy saving, etc. Russia is just at the beginning of the process of elaboration of eco-industrial parks development policy. The mission of the eco-industrial parks in Russia is to fulfill the role of a laboratory for advanced researches on improving energy efficiency, resource saving and obtaining synergies through pooling the assets and intellectual capital of residents in the eco-industrial park and sharing the infrastructural subsystems. For the successful operation of eco-industrial parks, combining industrial, research and educational activities, it is necessary to attract and use resources efficiently. First, we are talking about material, financial and labor resources. Equally important is the creation of an advanced information system in the form of constantly functioning monitoring that provides an eco-industrial park with complete, reliable and up-to-date information on modern innovation processes. Also at this point, it is important to use automation and actively involve innovative technologies to enhance the efficiency of the functioning of eco-industrial parks in Russia.**

Keywords —eco-industrial park, efficiency, circular economy, industrial symbiosis, energy efficiency, resource saving, information system, automation

I. INTRODUCTION

At the present, many large cities in the world are developing the innovative infrastructure based on the model of circular economy. This tendency is facilitated by the scarcity of raw materials and energy resources, growing pollution of the environment, expanding areas of landfills and unauthorized dumps [1]. Currently, disposal of hazardous waste is a big problem in Saint-Petersburg, and authorities are looking for solution to create the infrastructure for utilization and neutralization of such kind of waste, and providing additional energy resources for industrial processes at the same time.

The circular economy is aimed at minimizing the resource consumption, increasing the volumes of processed waste, and reducing the areas of landfills and unauthorized dumps. Tokyo city shows the advantages of circular economy implementation by achieving goals of sending to the landfill only about 15% of waste and using other waste as secondary materials and energy resources [2].

The circular economy should be both environmentally friendly and economically efficient. Implementation of the concept of circular economy in Russia will not only reduce the environmental contamination, but also develop the new points of growth in the economy and create new jobs. Eco-industrial parks (EIP) will become the basis for Russia's circular economy. There are about 300 EIP worldwide today, and they will form a network of interregional cooperation in reducing resource consumption, contributing the countries' socio-economic development and minimizing negative impact of waste on human health and the environment [3]. According to experts of the Environmental Industrial Policy Center of the Ministry of Industry and Trade of the Russian Federation and representatives of the Chamber of Commerce, the eco-industrial parks will lead the waste management industry, as well as industries dealing with secondary resource in the Russian Federation [4].

However, the development of the infrastructure of eco-industrial parks requires the concentration of a significant amount of resources, including financial, material, and informational. The joint use of infrastructure and industrial symbiosis form the main effects of creating EIP.

Sharing of informational infrastructure can be implemented in such areas as exchange of experience of using

the best available technologies (BAT) for waste utilization, joint training of employees of residents of the eco-industrial park on issues of resource saving, improving energy efficiency, introducing technological and managerial innovations.

At the same time, the automation of technological processes can contribute a lot to the creation of the most effective infrastructure of eco-industrial parks. The use of WMS (Warehouse Management System) programs to automate the processes of using waste as a resource in the framework of eco-industrial parks will help the EIP residents to act according to a strictly defined algorithm, and to save raw materials, energy and financial resources.

II. Preconditions and Functional Features of Eco-Industrial Parks Development in Russia

Russian law and strategic documents consider eco-industrial parks as an important part of economic growth and the basis of the circular economy. Residents of eco-industrial parks are the functionally related enterprises that will not only process waste, but also produce final products or secondary raw materials, the implementation of which should be the main source of return on investment.

The prerequisites for the active involvement of eco-industrial parks in the process of waste management in the Russian Federation are the following [5]:

- in 2015, the expanded producers' responsibility for final disposal of goods was implemented;
- in 2015, the list of licensed activities in the field of waste management has been expanded (as of September, 2017, about 9,000 licenses were issued and re-issued);
- in 2016, the obligation to confirm the class of hazard for the waste included in the Federal Classification Catalog of Waste (FCCW) was canceled (as of September, 2017, more than 4,000 waste types were included in the FCCW);
- in 2016, the territorial schemes of waste management were implemented at the level of the Constituent Entities of the Russian Federation (as of September, 2017, territorial schemes for 81 Constituent Entities of the Russian Federation were developed and approved)
- in 2017, the list of production and consumption waste with useful components was approved; the incineration or landfill disposal of such kind of waste is prohibited (as of September, 2017, the list includes 182 types of waste in accordance with the FCCW) [6].

The Strategy for development of the industry for waste utilization and neutralization by 2030 defines eco-industrial parks as a complex of objects united by interdependent energy and material flows, including buildings and facilities, technological and laboratory equipment involved in the process of waste utilization and neutralization, and ensuring the sustainability of production on their basis of industrial products and the implementation of scientific, research and (or) educational activities [4].

The main functional features of eco-industrial parks are presented in Figure 1.

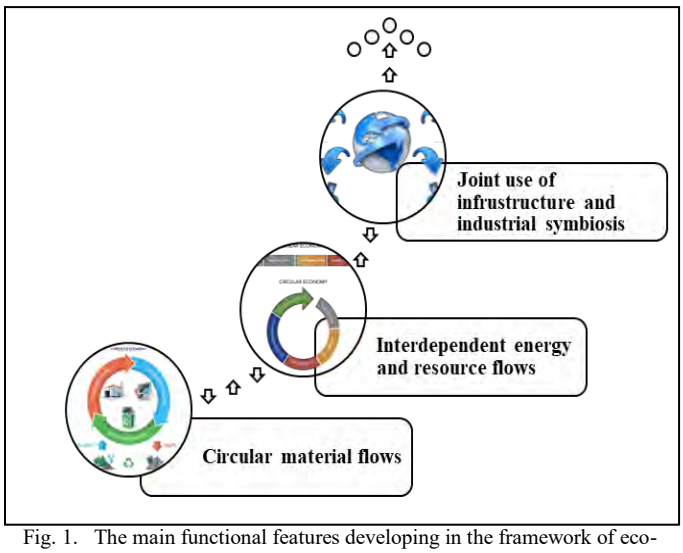

Fig. 1. The main functional features developing in the framework of eco-industrial parks in Russia

The main functional features developing in the framework of eco-industrial parks in Russia include the exchange of resources between residents and sharing the infrastructure. There are three main types of interaction between the residents of EIP:

- interaction in the process of involvement of waste or by-products generated in the production process of one resident in the technological processes of the others;
- interaction in the process of decreasing the energy consumption and increasing energy efficiency of production process, including partial or complete replacement of primary energy resources with secondary ones;
- interaction in the process of joint use of infrastructure (administrative, communal, logistical, informational).

III. Informational Support for the Implementation of Circular Economy Principles in the Framework of Eco-Industrial Parks

The joint use of the informational infrastructure of the eco-industrial park should be aimed at raising the awareness of the EIP residents of the possibilities of resource saving and improving the energy efficiency of production processes. At the initial stage, it is possible to organize the joint use of the informational infrastructure in such areas as exchange of experience in using the best available technologies (BAT) for involving secondary resources in production processes, joint training of staff of EIP residents on resource saving, energy efficiency, and technological and managerial innovations.

In the subsequent stages, it is necessary to proceed to the formation of circular economy corporate culture based on the principles of "3R" (Reduce, Reuse, Recycle) in the framework of eco-industrial parks. The "Reduce" principle means the need for EIP to restrict and restrain the use of raw materials, because their availability are very limited. The "Reuse" principle means the need for EIP to develop the technologies chains allowing the replacement of raw materials with waste or by-products. The "Recycle" principle means the need for EIP to implement the mechanisms for circular using of

resources. To act according to these principles more effectively, the EIP residents should share the knowledge through the communications, participate in the joint training programs, etc. (Fig. 2).

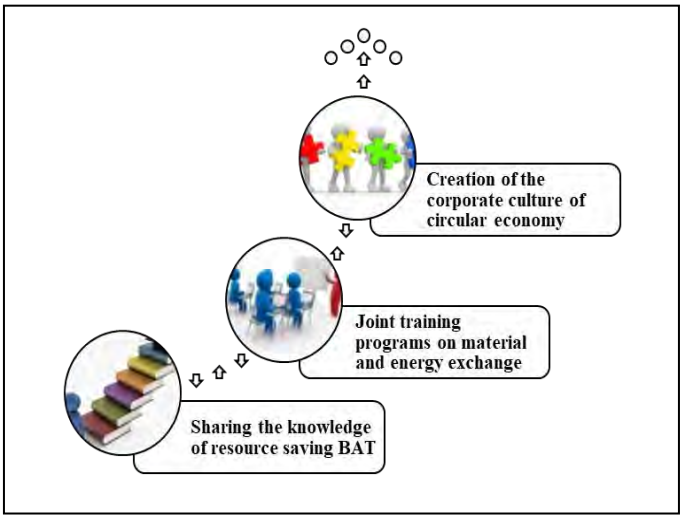

Fig. 2. The main elements of the informational support for the implementation of circular economy principles in the framework of eco-industrial parks

It is advisable to create information support for the activities of residents of the eco-industrial park. The first level of such support implies bringing to all residents the basic concept of forming a circular economy within the eco-industrial park. The concept should include guarantees for ensuring a quality environment for activities in the park, principles for saving resources, reducing environmental pressures and increasing energy efficiency.

The second level of information support forms a narrower direction in the spheres of waste utilization, rational use of material and energy resources. In particular, methodological documents of this level prescribe the principles of reducing waste generation, providing the opportunity for safe disposal, and reducing the energy intensity of production processes.

The third level of informational support includes documents regulating involvement of EIP residents in the circular resource flows in the framework of eco-industrial parks.

Information on the basic concept of forming a circular economy within the eco-industrial park should be placed both on the official website of the EIP and on the website of the administration of the region of EIP location. In the framework of cooperation with eco-industrial parks, regional authorities can act as initiators and the main consumers of EIP by-products, as well as provide information support for EIP activities.

The projects of industrial intellectual clusters (IIC) developed in Japan at the beginning of the 21st century and implemented jointly with the administrations of the Japanese prefectures pursue the same goals as the eco-industrial parks. These projects influenced the success of Japanese approach to stimulate the formation of circular economy in the country. At the same time, 4 out of 17 ICC projects are directly related to recycling and efficient use of resources, and promote the introduction of innovations in the field of environmentally friendly technologies [7].

Information support plays an enormous role in the increasing of ICC , as well as EIP functioning efficiency. This support includes monitoring of changes in the awareness of the "3R" principles not only among EIP residents, but also among the residents of the territory of EIP location.

IV. AUTOMATION OF MATERIAL FLOW CIRCULATION IN THE FRAMEWORK OF ECO-INDUSTRIAL PARKS

At the present, it is important for the Russian Federation not only to pay attention to the development of eco-industrial parks, but also to optimization of allocation of the resources during their functioning. Further increasing of the productivity of EIP residents without the involvement of additional labor, can be implemented through automation of existing and newly created production processes.

Within the framework of the interactions of EIP residents, two main steps to the formation of automated EIP material flows circulation system can be distinguished (Fig. 3):

- automation of the process of joint use of warehouse logistical infrastructure;
- automation of the process of involvement of waste or by-products generated in the production process of one resident in the technological processes of the others.

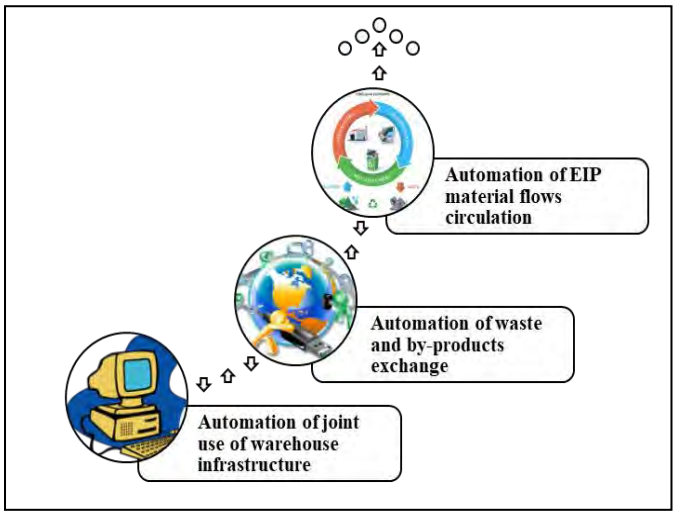

Fig. 3. The main steps to the automation of material flows circulation in the framework of eco-industrial parks

Automation processes are widely developed all over the world, and one of the world leaders in automation is South Korea. According to the latest data, there are 476 robots per 1000 workers at Korean industrial enterprises. Despite the current low level of automation of industrial processes in the Russian Federation, there are some Russian companies involved in the development of automation technologies. Since 2008, these companies showing a growing trend in the share of Russian Warehouse Management Systems (WMS) automation market. Currently, the usage of WMS automation

programs are concentrated on trading and logistics warehouses [8]. At the same time, some of these programs can be successfully incorporated in the process of EIP functioning.

The example of successful using of automation technologies on the Russian market represents “Technopark of Industrial Automation” located in the city of Omsk. The main activities of this industrial park are aimed at the development of automation systems in order to increase the level of productivity, efficiency and safety in the field of oil production and refining [9].

Specialists of the industrial park are working on testing and development of industrial automation systems. One of the key features of the industrial park in Omsk is creation of material flows circulation systems for industrial enterprises.

Table 1 presents the most recent Russian WMS automation programs, which can be used for the automation of the process of joint use of warehouse logistical infrastructure with expansion to the automation of the process of involvement of waste or by-products generated in the production process of one resident in the technological processes of the others in the framework of eco-industrial parks.

TABLE I. RUSSIAN WMS WITH POSSIBILITIES OF THE IMPLEMENTATION IN THE FRAMEWORK OF EIP

WMS name	**WMS Characteristics**		
	Area of use	***Accomplishing tasks***	***Functions***
1C: Logistic	Warehouses up to 4000 square meters	Automation of loading/unloading processes, registration of products characteristics (amount, weight, class, etc.), terms of transportation (distance, time)	Placing products in ABC-order, analyzing transportation information, developing transportation schedules
Expert Logistic	Enterprises of oil and gas industry, electronics and microelectronics	Automation of loading/unloading processes	Analyzing transportation information, developing transportation schedules, 3D models
Solvo	Industrial enterprises, transportation companies	Automation of loading, unloading, transportation processes	Analyzing transportation information, developing transportation schedules, graphic models

[a.] Completed by authors based on [10], [11]

At the present, industrial enterprises in Russia are facing the challenges of organizing proper waste handling. Circular economy considers waste as a resource or by-product. So, WMS automation programs developed for trading industry could be upgraded with features allow them to manage the waste as a resource.

The waste management system in the framework of the eco-industrial park must comply with the norms of the Federal Law No. 89-FZ "On Production and Consumption Waste", according to which the waste handling process should guarantee:

- zero or minimal negative impact of waste on the environment;
- minimal risk of deterioration of the sanitary and epidemiological situation at the territory;
- preservation of potential for using waste as a resource;
- convenience of the inventory (primary accounting) of waste and control of waste flows.

In the conditions of this study, the WMS automation program “1C: Logistics” was applied to ensure the safe and effective process of involvement of waste or by-products generated in the production process of one EIP resident in the technological processes of the others. This system allows to automate the management of waste flows in the territory of the eco-industrial park due to:

- development of an optimal route of circulation of each type of waste, ensuring maximum use of material and energy resources;
- creation a schedule for the circulation of waste through the territory of the eco-industrial park;
- in case of need, organization of temporary storage of waste, their distribution on the territory of the warehouse area in ABC-order.

After the creation of the application for WMS and the selection of the optimal route, it is possible for EIP residents to obtain the following data:

- route of waste movement through the territory of the eco-industrial park;
- the procedure for waste collecting, loading and unloading;
- time of waste generation and usage.

Automation of waste circulation processes is an extremely important part of the functioning of modern eco-industrial parks. Timely introduction of new technological innovations influence the success of their development.

V. RATIONALE FOR INCREASING THE EFFECTS FOR THE EIP RESIDENTS THROUGH THE INFORMATION SUPPORT AND AUTOMATION OF WASTE CIRCULATION

Due to information support and automation of waste circulation in the framework of eco-industrial parks, the magnitude of potential effects for EIP residents in the following areas may be increased trough optimization of:

- operational costs due to increased energy efficiency and efficient use of resources by organizing waste circulation inside the EIP and beyond;
- payments for negative impact on the environment due to reduction of waste generation volumes (transfer to other companies for disposal) and reduction of discharges and emissions from enterprises (closed systems);
- costs of the infrastructural services provided in the EIP (for example, environmental education seminars, emergency management, and networking services, etc.).

VI. CONCLUSIONS

As mentioned above, one of the most important tasks for Russia and other countries is the gradual transition to a circular economy that provides the maximum use of secondary resources [12]. Eco-industrial parks serve as the basis for the circular economy. Their functioning is highly effective due to the concentration of financial, material and informational resources. It aimed at the exchange of resources between residents and sharing the infrastructure.

Effects can be gained during the interaction between the EIP residents in the process of involvement of waste or by-products generated in the production process of one resident in the technological processes of the others. Automation of waste circulation in the framework of eco-industrial parks using WMS programs will help to increase these effects.

The use of the information infrastructure of eco-industrial parks starting with the exchange of experience of using of BAT for involving secondary resources in production processes, joint training of staff of EIP residents on resource saving, energy efficiency, and technological and managerial innovations, and continuing with the creation of corporate culture based on "3R" principle.

The effects of using information support and automation of eco-industrial parks reflects in such areas like income from waste exchange, reduction of payments for waste disposal, as well as obtaining savings through energy efficiency.

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