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Enhancing University Innovation Through Industrial Symbiosis

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Abstract: In the context of global changes and the transition to a Green Economy, there has been a lack of emphasis in scientific literature to the management of project innovation activities at universities, particularly in collaboration with business and the government. This gap continues despite international experiences that indicate the benefits of industrial symbiosis for regional economic growth, including socioeconomic and environmental issues. The study focuses on the underexplored management of university project innovation activities in collaboration with businesses and the state as the world shifts toward a Green Economy, highlighting the successful use of industrial symbiosis in other countries to boost regional socioeconomic and environmental development. Current engagement channels are insufficient to facilitate the integration of academic ideas into industry throughout the transition to a circular economy. This study intends to establish novel management mechanisms for university innovation activities based on industry symbiosis, as well as optimum collaboration ways for project initiation and implementation. The authors offer successful implementation techniques, such as project formation and realization through partnership with corporations and government bodies, as well as the involvement of bright youngsters. By developing zones of industrial symbiosis and other cooperative ventures, the research hopes to position universities as crucial to building symbiotic chains, eventually boosting university innovation infrastructure efficiency and fostering sustainable regional development.

Keywords: business intelligence, commercialization, Green Economy, higher education, innovation, industrialization, symbiosis

1. Introduction

With the transition of many countries to a circular economy, the application of the concept of industrial symbiosis is becoming increasingly relevant, both by individual organizations and at the level of regions and the country as a whole. In most countries of the world, various measures are taken to stimulate the reduction of environmental load on specific states and on the planet as a whole, and the transition to the circular economy is one of them. In the scientific environment today, one of the most promising concepts of the circular economy is recognized as the concept of industrial symbiosis. Industrial symbiosis is a model of sustainable development of production in the transition to a circular economy, which implies an increase in economic, energy, and environmental efficiency. When considering the issue of environmental pollution by the industrial sector, industrial symbiosis is precisely one of the ways to reduce negative impact [1].

There are several approaches to defining the concept of industrial symbiosis. Let us start with the definition of industrial symbiosis, which is widely spread in the industrial ecological environment and research community [2, 3]: it will be understood as "engaging traditionally divided organizations in a collective approach to competitive advantage involving the physical exchange of materials, energy, water, and by-products" [4, 5]. Later, industrial symbiosis has also been defined as "a business opportunity and a tool for eco-innovation" [6]. Another study presents 6 approaches to the interpretation of industrial symbiosis [7]: (1) a sub-sector of industrial ecology, within the framework of which the mechanisms stimulating cooperation of industrial organizations are formed, taking into account the specifics of the stages of production cycles to form their competitive advantages; (2) a form of implementation of cooperation of industrial enterprises in eco-industrial parks in a closed-cycle economy; (3) a model, within the framework of which the key aspect is the exchange of resources, with production waste becoming resources; (4) an approach, the implementation of which leads to

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synergy between different organizations, stimulating environmental improvement by reducing reduced consumption of natural resources and reducing environmental risks; (5) a tool for implementing the goals of sustainable development and circular economy; (6) an industrial ecosystem.

All the above approaches imply the feasibility of cooperation between different organizations in order to improve environmental, economic, and innovative components. In addition, the concept of industrial symbiosis is often associated with the concept of eco-industrial parks, where there is a place for a community of companies that share various resources to achieve environmental, social, and economic benefits [7]. Given the orientation of most countries of the world to the closed-cycle economy, the issues of applying the concept of industrial symbiosis in the management of project innovation activities of universities are extremely relevant. This topic is poorly covered in the scientific literature, since universities have not been given any role in the construction of industrial symbiosis until recently.

In the context of global changes and the shift to a Green Economy, the study highlights the lack of focus on the administration of university project innovation activities within the framework of collaboration with enterprises and the state. More specifically, in the middle of the shift to a circular economy, the introduction of novel academic discoveries into the industry is made more difficult by the ineffectiveness of the current channels of interaction between businesses, universities, and the government. It is imperative to ask the following questions:

1) What are some successful ways to incorporate the idea of industrial symbiosis into the administration of project innovation activities at universities?
2) What fresh approaches may be created to improve collaboration between academic institutions, corporate entities, and the government to ensure the effective execution of innovation initiatives?
3) How can academic institutions be at the forefront of creating symbiotic networks that support sustainable regional development and ease the shift to a circular economy?

Due to the optimization of interaction processes between different partners, HEIs can achieve better results in their project innovation activities. According to the authors of this article, the introduction of industrial symbiosis principles in the project innovation activity of HEIs will allow to use available resources more efficiently, reduce costs, and improve the quality of the educational process. The study suggests creating new industrial symbiotic management systems for university innovation operations in order to promote productive collaboration between academic institutions, private industry, and government agencies. This strategy seeks to engage young people, improve the integration of innovation into industry, and advance sustainable regional development within the framework of a circular economy.

2. Literature Review

The study also looked at related works to buttress our point in the domain. To begin with, Azevedo et al. [8] offered a methodical way to define and put industrial symbiosis (IS) procedures into practice. Information collecting, content definition, and actual production were the three key processes they delineated. Their research made clear how crucial it is to have theoretical, technological, and strategic backing for IS. The authors offered a thorough set of guidelines for IS implementation by combining data from technical studies, expert consultations, and scientific literature. They emphasized the importance of a collaborative approach engaging several stakeholders in order to optimize both economic and environmental advantages. Stéphane et al. [9] examined the market potential, best practices, and legislative measures required to promote industrial symbiosis in a different related study. In order to promote IS, their study highlights intermediaries, critical technologies, and the significance of regulatory frameworks. They also covered the advantages of IS, including lower costs, less waste, and improved resource efficiency. According to their report, market incentives and robust regulatory support are essential for the effective adoption of IS methods across many businesses.

In a similar study, Taddeo et al. [10] used the idea of Innovation Poles (IPs) to specifically investigate the role of networking and innovation in industrial symbiosis. IPs are consortiums supported by the government that attempt to foster innovation among networks of enterprises. Their research examined the ways in which IPs might support IS by promoting cooperation, information sharing, and technical developments. They came to the conclusion that IPs can improve regional economic and environmental sustainability by making a substantial contribution to the creation and adoption of IS practices. In addition, Henriques et al. [11] offered a sector-by-sector examination of the main factors that promote and hinder industrial symbiosis. The study determined that essential criteria for the successful adoption of IS include stakeholder participation, technological preparedness, regulatory backing, and financial incentives. Their analysis also emphasizes how these elements' effects vary depending on the economic sector. The authors sought to address particular issues and advance successful IS practices by providing recommendations that were specifically catered to each sector, ultimately resulting in a more sustainable industrial environment.

Hens et al. [12] looked at the mechanisms of industry-university collaboration in the context of industrial symbiosis in another research. The study highlighted the function of colleges as centers of knowledge that may stimulate industrial innovation and environmentally friendly practices. In their study, successful cooperation tactics were highlighted, such as cooperative research initiatives, technology transfer, and the creation of symbiotic networks. According to their results, these kinds of partnerships can result in notable improvements in environmental performance and resource efficiency, which is advantageous for both business and academics. Finally, Baldassarre et al. [13] explored the incorporation of industrial symbiosis into European policy in their study. They looked into case studies, policy frameworks, and best practices from several European nations. Their research made clear how crucial it is to use legislative tools like tax breaks, subsidies, and requirements from regulators to advance IS. In order to remove obstacles and expand IS projects, they also underlined the necessity of public-private partnerships and cross-sectoral collaboration. The authors contended that the adoption and effect of IS practices in Europe may be greatly increased by a well-coordinated policy approach.

2.1. Analysis of different countries' industrial symbiosis legislation

The analysis of the legislation of foreign countries in the field of industrial symbiosis allows us to identify the best global practices in the implementation of such programs, which can be borrowed by countries that are just forming legislation in the field of closed-loop economy. The structure and content of industrial symbiosis may differ from country to country depending on their legislation, policy, and institutional environment. However, a comparative analysis of industrial symbiosis legislative policies in different countries can help identify effective approaches and mechanisms

that can be applied and adapted in practice by developing countries interested in the transition to a Green Economy.

As part of the literature review conducted by the authors of this research article, the features of legislative policy for the transition to a circular economy were considered on the example of the United States, the European Union, and China (as one of the leaders in this area, according to the authors of the article).

2.2. Peculiarities of the United States (US) legislative policy in the framework of transition to a closed-cycle economy

In the United States, the Resource Conservation and Recovery Act (RCRA) was enacted as early as 1976 to address hazardous waste and non-hazardous solid waste management. This law gave the Environmental Protection Agency (EPA) the authority to control hazardous waste, in particular the generation, transportation, treatment, storage, and disposal of hazardous waste [14].

In 1991, at the U.S. federal level, industrial symbiosis was integrated into the national Green Chemistry Program (Green Chemistry Program) initiated by the Environmental Protection Agency (EPA) to encourage the development of environmentally sound chemistry [14]. This program promotes the development of cost-effective production processes based on green chemistry principles, including the use of renewable energy, the reduction of hazardous chemicals, and the use of technologies that reuse and recycle waste. The program has created several industrial symbioses, such as those between refineries and chemical companies that share waste and resources. The program encourages and supports the development of new technologies, products, and processes that reduce or eliminate the use of hazardous substances in the manufacture and use of chemical products.

The Green Chemistry Program has established a special program called Industrial Ecology and Pollution Prevention (Industrial Symbiosis and Environmental Productivity). It focuses on finding opportunities for cooperation between enterprises, resource sharing, and the use of renewable energy in the chemical industry. The inclusion of industrial symbiosis within the Green Chemistry program has not only reduced environmental impacts but also provided economic benefits to participants, including lower resource costs and increased competitiveness. Also in the U.S., a Sustainable Materials Management Program Strategic Plan 2017 – 2022 has been developed and approved (Sustainable Materials Management Program Strategic Plan 2017 – 2022) [15]. This program has stated three strategic priorities for achieving environmental, economic, and social outcomes: (1) Artificial Environment; (2) Sustainable Food Management; and (3) Sustainable Packaging. Work in each of these areas will contribute to the four main goals of SMM's Sustainable Materials Management program: (1) Reduced recycling, which includes source reduction, reuse, recycling, and prevention; (2) Reduced environmental impacts of materials throughout their life cycle; (3) Increased socioeconomic benefits; and (4) Increased capacity of state and local governments, communities, and key stakeholders to adopt and implement the policies, practices, and incentives of this program [16].

2.3. Peculiarities of the European Union (EU) legislative policy in the framework of transition to a closed-cycle economy

Today, the concept of circular economy is spreading almost everywhere in the EU. For its full-scale implementation, legislation is being improved and comprehensive initiatives are being adopted. Among the most significant instruments aimed at improving the environmental sustainability of products are the Ecodesign and Energy Labeling mechanism, the EU Ecolabel, Green Public Procurement (GPP), and the Extended Producer Responsibility (EPR) scheme.

It should be noted that the European Union has so far adopted about 20 directives relating to various aspects of waste management. Until the early 1970s, legislation on waste management was an internal competence of the EEC Member States. In 1975, in order to harmonize different national practices, the European Council adopted the so-called Waste Framework Directive (the Waste Framework Directive – 75/442/EEC), which established general requirements and basic definitions in this field. In 2006 the Directive was reissued and "codified" (brought to the text canceling the previous versions), and today it is in force in its latest version of 2008 under the designation Directive 2008/98/EC. This regulation governs the collection, treatment, and disposal of waste within the European Union. This directive is successfully applied in 27 countries of the European Union.

In the European Union, industrial symbiosis is widely applied in various countries, including Finland, Denmark, Germany, Italy, and others. The EU industrial symbiosis is being developed within the framework of the Europe 2020 strategy, which aims at sustainable economic and environmental development. The Europe 2020 strategy is a long-term program that was adopted by the European Union in 2010 and aims to support sustainable economic growth and job creation in EU member states [17]. As part of this strategy, a dedicated Innovation Union program has been identified, which includes various activities to support environmentally sustainable industrial development. Industrial symbiosis is one of the key topics addressed under the Innovation Union program. In particular, the program has developed and implemented tools and methods to promote industrial symbiosis, such as waste exchange databases, networks, and platforms for communication between companies, as well as methodologies for assessing the environmental performance of project implementation [17]. Also, as part of the Europe 2020 strategy, an Eco-Innovation program has been created that funds projects to develop industrial symbiosis and other environmental technologies.

2.4. Peculiarities of China's legislative policy in the framework of transition to a closed-cycle economy

China is currently the only country in the world that is implementing industrial symbiosis initiatives at the national level on a large scale and at a rapid pace [18]. China has developed various standards that emphasize the economic efficiency of industrial symbiosis. In 2008, the country adopted the Law on Promotion of Closed Loop Economy. It was amended in 2018. The latest revision came into effect on October 26, 2018. This law contains provisions requiring organizations to develop cyclical economy plans, improve energy efficiency, reduce emissions, and optimize resource use. It also provides various support measures, including financial incentives and tax breaks for companies that actively implement the cyclical economy. The law also establishes public procurement requirements, encouraging the purchase of goods and services that comply with the principles of the circular economy. This encourages the development of a circular economy and promotes more efficient use of resources and reduction of waste.

In 2013, China formulated and adopted the Action Plan for the Development Strategy of Circular Economy (Action Plan for the Development of Circular Economy). Some of the key measures

proposed in the Action Plan for the Development of Circular Economy are summarized below:

1) Improving energy and resource efficiency.
2) Development of environmentally friendly and sustainable industrial parks. Creating environmental parks and areas where businesses can cooperate and share resources to reduce waste and improve resource utilization.
3) Encouraging green investment and developing the circular economy market.
4) Improving the waste management and recycling system.
5) Promoting environmental education and consciousness. Educational programs, campaigns, and initiatives to raise awareness and understanding of the circular economy among residents, businesses, and the public [19].

The Chinese government plans to complete the energy transition by 2060, for which China has already developed and put into practice 36 symbiotic chains (the highest figure in the world, which includes 171 green industrial parks) [20].

Consequently, the constant transformation of legislative norms and initiatives in the field of circular economy and industrial symbiosis in different countries of the world testifies to the importance of transition to circular economy for achieving such environmental effects as reducing the consumption of natural materials and energy, reducing emissions and waste, as well as increasing the energy, social, and economic efficiency of the participants of symbiotic interactions. Different measures of state regulation in the field of circular economy are related partly to the specificity of approaches of different states in the field of industry, education, innovation, and international activities, etc. Let us consider some examples of the implementation of the concept of industrial symbiosis in different countries of the world with the participation of universities.

3. Methodology

3.1. Research design

This study develops and assesses new mechanisms for managing university project innovation activities based on industrial symbiosis through the use of a mixed-methodologies approach that combines quantitative and qualitative research methods. To identify best practices, facilitators, challenges, and gaps in the field, a thorough study of the literature on industrial symbiosis, university-industry cooperation, and innovation management was conducted. In order to extract important insights and useful techniques, comprehensive case studies of successful industrial symbiosis efforts in universities across the world were also taken into account.

In order to obtain primary data on current collaboration practices, obstacles, and opportunities, surveys and semi-structured interviews with stakeholders from universities, businesses, and government agencies were used. The survey data were then statistically analyzed in order to identify trends and important factors influencing successful project innovation activities. In order to fully comprehend the viewpoints of the stakeholders, a qualitative analysis of the interview data was also taken into account.

3.2. Project innovation activity of universities based on the concept of industrial symbiosis: Case study

Project innovation activity of higher education institution based on the concept of industrial symbiosis may include the implementation of various projects, usually implemented with the support of government programs and initiatives. Among the widely known programs to support projects in the field of closed-loop economy are the following programs: Interreg [21], Horizon, as well as cross-border cooperation programs, etc.,

Let us consider some specific examples of projects implemented by universities in different countries:

1) SYMBIOTIC project (University of Zagreb, Croatia): In this project, the university cooperates with enterprises from different regions to stimulate industrial symbiosis. The project includes developing a training program, conducting research, and creating innovative tools to support symbiosis between enterprises.
2) SYMBIOSIS+ project (Helsinki University of Technology, Finland): This project aims to develop innovative methods and tools to support industrial symbiosis in the Helsinki region. The university conducts research, training, and exchange of experience between enterprises to create sustainable and effective symbiotic relationships.
3) SYNERGY project (University of Manchester, UK): In this project, the university collaborates with different enterprises to assess and develop the potential of industrial symbiosis. The project includes research, development of tools, and organization of networking platforms for sharing experience and knowledge [22].
4) SYMBIOCITY project (University of Alto, Finland): in this project, the university works with municipalities and businesses to develop sustainable and innovative urban systems based on industrial symbiosis. The project includes research, training, and development of practical solutions for the implementation of symbiotic relationships in urban environments.
5) SYMBIO-TECH project (Uppsala University, Sweden): in this project, the university cooperates with technology companies to develop and implement new technologies and innovations in the field of industrial symbiosis. The project includes research, pilot projects, and exchange of experience to create sustainable and efficient symbiotic solutions.
6) SYMBIOMAT project (University of Katowice, Poland): within the framework of this project the university cooperates with industrial enterprises to develop and implement innovative materials and products based on industrial symbiosis. The project includes research, development of new technologies, and practical testing to create a sustainable and environmentally responsible industry.
7) CIRCLES project (Technical University of Delft (TUDelft) in the Netherlands). This project was developed to promote industrial symbiosis in the South Holland region. It brings together the Technical University of Delft, businesses in the region, and public authorities to collaborate and develop sustainable solutions. The main goal of the project is to create a closed-loop system where one company's waste becomes a resource for others, thus reducing the negative environmental impact and creating new opportunities for the region's economy [4].
8) INSET project, implemented with the financial support of the Horizon Europe program. The aim of the project is to stimulate industrial symbiosis and the transition to cyclicality and sustainability in the European business structure. The project is funded by the Horizon Europe program, which is an important research and innovation program of the European Union. The INSET project may involve various actions and activities, including research and development of innovative technologies and methods, pilot projects, and exchange of experience between participants. The project may also include the development of tools to assess the potential for industrial symbiosis, training activities, and

platforms for collaboration and knowledge exchange. The financial support from the Horizon Europe program allows the INSET project to successfully realize its objectives and promote industrial symbiosis and sustainability in the European business environment. This is an excellent example of how funding programs at EU level can support innovative projects and initiatives in the field of industrial symbiosis.

9) Green Power Park project in Sweden. The project, based at Lund University, has created a platform that brings together local entrepreneurs, academic institutions, and municipalities to utilize renewable energy sources and reduce carbon dioxide emissions. The project also involves local universities that are developing new technologies in the field of renewable energy.
10) Sustainable Industrial Park project in the Netherlands. The project created a park at the Technical University of Eindhoven that brings together companies from different industries to create an economically efficient and environmentally sustainable infrastructure. The project also involves local universities that are engaged in research in the field of sustainable development.
11) The Waste Technology Cluster project was implemented in the UK as part of the National Industrial Biomass Technology Cluster program. Within the framework of the project several partner organizations, including universities, cooperated in the field of waste management. The cluster was based on the principles of industrial symbiosis and brought together different competencies to create more efficient and environmentally friendly methods of waste management.
12) The Ecological Industrial Park is a joint project between a Chinese university and a company in China. The Ecological Park is based on the principles of industrial symbiosis and is a joint venture between several companies that have joined together to create a more efficient green industrial zone.
13) The Eco-Industrial Park project was implemented in Malaysia as part of a program to create green manufacturing zones. The project was based on the principles of industrial symbiosis and brought together several partner organizations, including a university, to create a more efficient and environmentally friendly industrial zone.
14) The project "Baltic Industrial Symbiosis", BIS is one of the most promising examples of cooperation between partners from different organizations (universities, business, and professional organizations) in the field of industrial symbiosis. The aim of the project is to support and promote industrial symbiosis in the Baltic Sea Region by establishing an exchange of experience between experts and practitioners from different organizations. The project was led by the Symbiosis Center in Denmark and supported by the European Regional Development Fund through the Interreg Baltic Sea Region program. Linköping University (Sweden) was one of the key participants of the project, providing training to partners in the field of industrial symbiosis. More than half of the BIS project participants are food industry enterprises, as the problem of organic waste utilization and reuse has become a topical issue. Agro-industrial enterprises, such as fertilizer, feed, and meat producers, also took part in the project. The BIS project consists of several stages, including promotion of enterprise development, establishment of a partner network, research and development, and development of a roadmap for industrial symbiosis.

There are many other successful examples of universities' participation in the implementation of industrial symbiosis projects. The study of existing projects in the field of industrial symbiosis, implemented by universities together with partners, allows us to assess the prospects of such cooperation. The above-mentioned examples are evidence of the fact that universities are becoming more and more active participants of consortia in the implementation of projects related to industrial symbiosis around the world. However, it should be noted that within the framework of the above-mentioned projects the individual methods and mechanisms of cooperation within the framework of building symbiotic chains are being tested, various opportunities are being considered from the point of view of introducing the technologies that the university has at its disposal into symbiotic chains. The issues of modernization of the management processes of project innovation activity of universities regarding the application of the industrial symbiosis concept remain outside the scope.

In addition, universities in the framework of the projects are considered exclusively as organizations with promising developments and advanced knowledge in various subject areas. The approach of considering HEIs as a potential driver of industrial symbiosis development has not been investigated by scientists at all before. Consequently, industrial symbiosis is an important area of research, and many universities are actively working in this area, but the issue of initiating projects in the field of industrial symbiosis under the leadership of universities, is studied very poorly to date. And one of the forms of creating symbiotic interactions based on universities can be the concept of industrial symbiosis zones.

3.3. Industrial symbiosis zones: Essence and prospects

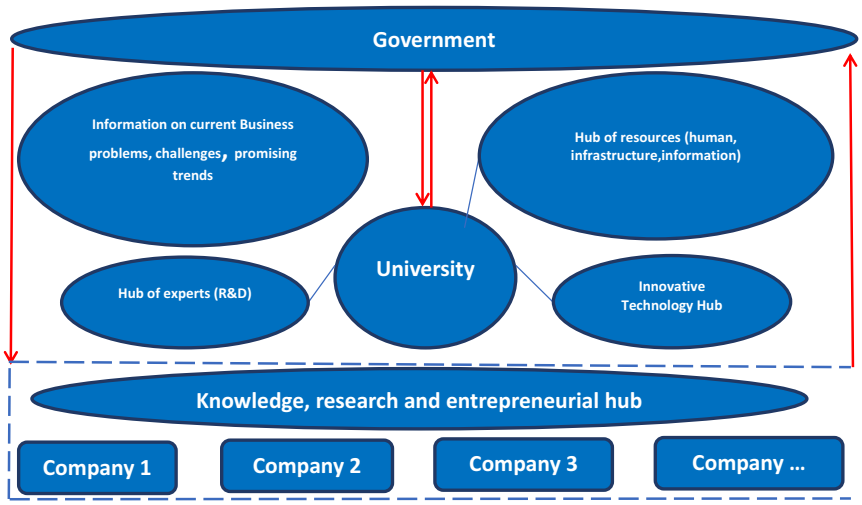
Industrial symbiosis zones, special economic zones, eco-industrial parks include various models of economic development based on cooperation between enterprises and organizations of different industries to optimize the use of resources and increase the efficiency of production.

Industrial symbiosis zones represent cooperation of organizations (universities, enterprises, authorities, etc.,) in a certain territory, built on the principle of industrial symbiosis. This increases production efficiency, reduces resource costs, and creates new opportunities for innovation. Within industrial symbiosis zones, special attention is paid to environmental analysis and control to minimize the negative impact on the natural environment.

Special Economic Zones (SEZ) is a part of the territory, which has certain privileges and a special regime for conducting business activities. However, SEZs do not always take into account the possibility of using waste from one enterprise as resources for others. There is a mixed opinion about the effectiveness of SEZs, as they are primarily focused on the socioeconomic development of the region, attracting investment and creating new jobs.

Eco-industrial parks are industrial parks where businesses cooperate with each other and with the local community in an attempt to reduce waste and pollution, allocate resources (such as materials, water, energy, natural resources, etc.,) efficiently, and promote sustainable development to increase economic benefits and improve environmental quality [23]. There is also a definition in which an eco-industrial park is a community of manufacturing and service enterprises located together in a common area, whose members are committed to improving environmental, economic, and social performance through collaboration in addressing environmental and resource challenges. The key difference between eco-industrial parks and industrial parks is that eco-industrial parks may include, in addition to enterprises,

Figure 1
Peculiarities of interaction between cooperation of higher education institutions with enterprises and the state



universities, research institutes, authorities, and professional associations.

In eco-industrial parks, cooperation takes place exclusively between resident enterprises of these industrial parks. Thus, industrial symbiosis zones, special economic zones, and eco-industrial parks represent different models of economic development, which are based on cooperation, and optimization of resource use. At the same time, it is important to consider the impact on the environment and take measures to protect it. According to the authors of the article, the formation of ZPZs can be an alternative to the existing SEZs and eco-industrial parks. Since EIPs are territories where cooperation between enterprises, universities, research institutes, and public infrastructure objects is carried out on the basis of the principles of industrial symbiosis, it will optimize the use of resources, increase the efficiency of production, and stimulate the introduction of innovative developments of universities in the real sector of the economy [24].

The development of the concept of industrial symbiosis zones was conditioned by a number of disadvantages of the existing special economic zones, which cannot fully ensure the economic development of the country and regions. The problems of special economic zones are geographical location (remoteness from megacities), imperfect legislation, lack of cooperation between enterprises of different industries, and different terms of functioning of the zones. Unlike special economic zones, industrial symbiosis zones do not have geographical limitations. Instead, industrial symbiosis zones emphasize the development of sustainable links and interaction between enterprises and market players. Exports become a secondary issue. In addition, the SEZ model does not apply the principles of circular economy and environmental management.

Analyzing the peculiarities of SEZs and eco-industrial parks, it becomes obvious that universities are not considered as the main source of innovative developments. The introduction of the concept of an IPZ represents a potential alternative to the existing SEZs and eco-industrial parks.

The authors of the article propose to consider HEIs as information, analytical, research, and innovation centers that possess advanced knowledge and technologies in various fields through cooperation with other HEIs and research institutes (Figure 1). HEIs are also engaged in analyzing, conducting, and studying foresight studies and accumulating information on the needs of various markets through cooperation with industrial partners. Leading universities include in some engineering education programs lectures on the principles of circular economy and even open separate educational programs related to recycling and industrial symbiosis.

According to the authors of the article, universities can become a key element in the development of such cooperation between organizations, being a driving force of research and design activities in various fields (information technology, energy, nanotechnology and new materials, food and biotechnology, etc.,). They can stimulate technology transfer to different regions of the country and ensure sustainable development of the region. Figure 1 below shows the peculiarities of interaction between cooperation of higher education institutions with enterprises and the state.

State support programs could encourage universities to initiate promising infrastructure projects in the field of industrial symbiosis, where cooperation with industrial partners would allow testing university research and development in a real industrial environment. Thus, projects for the development of industrial symbiosis zones should be aimed at intensifying the interaction between universities, enterprises, and the state in order to effectively use the potential of universities in the development of the economy, while ensuring sustainable development of the regions. In this regard, let us further consider in more detail the expediency of improving the mechanisms of management of project innovation activity of universities in the conditions of application of the industrial symbiosis concept.

4. Results and Discussion

When considering the issues of management of project innovation activity of universities, it should be noted that the very concept of project innovation activity is poorly researched in scientific literature. Under the project innovation activity of HEIs, we will understand the activity that:

1) is aimed at identification, initiation, evaluation (expertise), supervision (support), support, promotion, and commercialization of innovation projects of all types;
2) should be supervised by a separate structural subdivision of the HEI, which can be both within the framework of the innovation infrastructure of the HEI and outside it;

3) is aimed at comprehensive support of the target audience both inside the HEI (the so-called internal loop), which includes teaching staff, administrative and managerial staff, students of different levels of training (undergraduate, graduate, specialist students), postgraduates, and for the external target audience (external loop), including the state (authorities, regional administrations, profile committees), business, graduates, entrants, professional organizations (associations, clusters, etc.,), society.

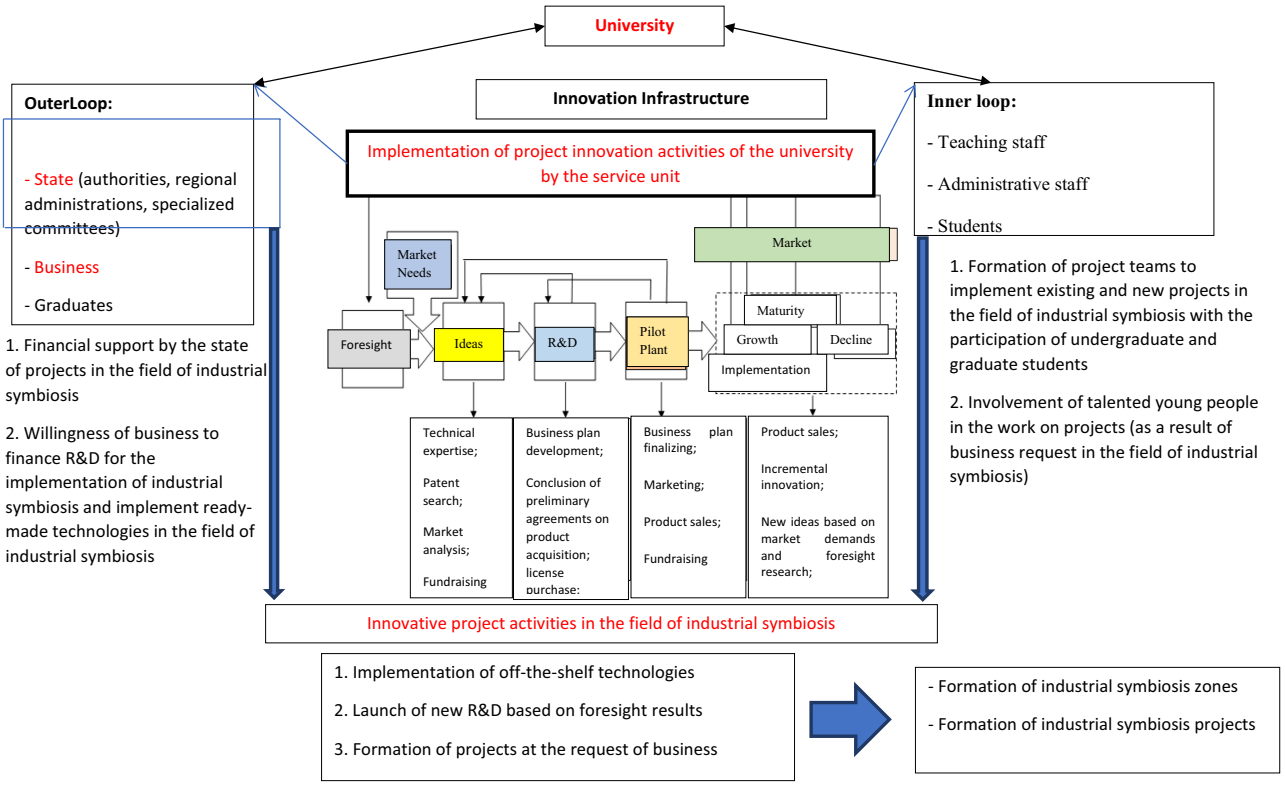
This definition is rarely used in scientific literature and is a symbiosis of the concepts of "project activity" and "innovation activity". On the one hand, project activity is realized in any sphere (scientific, educational, innovative, international, etc.,), i.e., innovation activity can be a part of project activity. At the same time, the innovation approach can also be applied in various spheres, including project activity. Consequently, the project innovation activity implies the activity of organizing complex support of projects at all stages of the life cycle (from the formation of ideas to the implementation of final products/ services on the market). To supervise this activity, it is necessary to have a separate structural unit in the university within the established innovation infrastructure or outside it. It can be a project office, a technology transfer center, or a center for project activities and commercialization, etc. Figure 2 below summarizes the project innovation activity of higher education institution based on the concept of industrial symbiosis.

The authors of this scientific article propose to consider the possibility of modernizing the management of project innovation prospective university research and development, which begins with the activities of the university based on the concept of industrial symbiosis (Figure 2). The center of the scheme represents the process of initiation, implementation, and commercialization of foresight research and identification of market demands in certain technologies. It is obvious that knowledge of business needs and understanding of the development trends of this or that industry reduces the risk of creating projects with low market potential.

According to the authors of the article, the process of project innovation activity, starting from the stage of idea to the stage of bringing an innovative product/service to the market, should be supervised by a separate subdivision, which usually functions within the innovation infrastructure of the university. Among the tasks of such a service unit are technical expertise, patent search, market analysis, search and attraction of financing, development of a business plan, negotiations with potential customers and preparation of letters of interest and cooperation, assistance in the creation of a small innovative enterprise, contracting for custom research, assistance in the preparation of project applications for competitions and grants, assistance in staffing the project team, etc. In case the university does not have a foresight center, the tasks of conducting foresight research also fall on the above-mentioned subdivision. The university's service unit can work both with projects that are created by individual authors or research teams within the university and with external projects.

In addition, it is also advisable for such a specialized subdivision of a higher education institution to initiate complex infrastructure projects that would take into account the interests of several categories of potential participants at once: other organizations (universities, research institutes, non-profit specialized organizations), enterprises, authorities (committees, regional administrations, etc.,), and society. Projects to create industrial symbiosis chains (for example, the creation of industrial symbiosis zones) are precisely aimed at improving not only economic, energy but also environmental and

Figure 2
Management of project innovation activity of higher education institution based on the concept of industrial symbiosis



social efficiency of both individual organizations and entire regions. As key generators of innovative technologies and advanced knowledge in various fields, universities are aware of both the tasks and problems of business and the state priorities in the field of science and technology policy. Higher education institutions, being a forge of personnel, attract talented young people to work on promising innovative projects during the educational process. Service units of universities, responsible for project innovation activities within the application of the concept of industrial symbiosis, can form project teams to implement existing and new projects in the field of industrial symbiosis with the participation of undergraduate and graduate students. In addition, these units need to solve the problem of involving talented young people in the work on projects in the field of industrial symbiosis, received from the business.

At the same time, not all enterprises are positively inclined to cooperate with universities in the field of project innovation activities. Therefore, the role of state support for cooperation between science and business cannot be underestimated. The authors of the article believe that both financial support of the state for projects in the field of industrial symbiosis and the readiness of business to finance R&D for the implementation of symbiotic interactions and implement ready-made technologies in the field of industrial symbiosis in their business processes are necessary.

The research presents a number of important conclusions about the management of university project innovation activities based on the idea of industrial symbiosis. Firstly, the data suggests that universities are essential in promoting innovation by means of symbiotic relationships with industry and government. Eighty-five percent of university respondents think that working with industry partners improves their research outputs and applications in the real world. These conclusions are corroborated by case studies from universities such as MIT and Stanford, which have effectively incorporated industrial symbiosis into their innovation strategies, leading to increased technological innovations and sustainability initiatives. The absence of efficient channels for coordination and communication between government agencies, businesses, and academic institutions has been noted as a significant obstacle. Stakeholder interviews reveal that 70% of industry partners believe the present frameworks for collaboration are insufficient, which causes delays and inefficiencies in the execution of projects. The data also shows that legislative backing and financial incentives are essential facilitators of industrial symbiosis success. In comparison to universities without such backing, those who obtained funding from the government or tax incentives for symbiotic initiatives reported a 40% greater success rate in project outputs.

In addition, it has been demonstrated that including gifted young people in project innovation activities fosters creativity and infuses new views. Higher levels of creativity and satisfaction among all stakeholders were reported by universities that actively involved students in their symbiosis initiatives. The study emphasizes the necessity of strong foundations for efficient academic, business, and government collaboration. To overcome obstacles and realize the full potential of industrial symbiosis in promoting sustainable innovation, it promotes improved communication, monetary incentives, and active youth engagement.

5. Conclusion and Future Works

In the modern world, the problem of effective waste utilization is becoming more and more urgent. To solve this problem, we can offer the following solutions:

1) Stimulate the formation of partnerships between industry and universities where research in the field of ecology and sustainable development is conducted. This will allow companies to get access to up-to-date scientific data and technologies.
2) Create joint research projects in which faculty, graduate students, undergraduates, university students, and industry employees work together to develop new technologies in the field of closed-loop economics and new ways of producing products from recycled materials.
3) Provide financial support for such projects from the government and investors. This will help to attract talented scientists, graduate students, and postgraduates from universities and specialists from industry, as well as to attract the necessary resources for research.
4) Organize the exchange of knowledge and experience between industry, universities, and authorities. Through special events such as seminars, conferences, and round tables, representatives of the above organizations will be able to discuss mechanisms for implementing and introducing modern university technologies in the field of circular economy, as well as form consortia to create industrial symbiosis zones [25].
5) Support successful projects that will lead to a significant reduction in the environmental impact of industrial companies on the environment. If such projects are successful, their results can be implemented in other regions and industries. The implementation of projects to form industrial symbiosis will contribute to improving the environment in the regions and increasing the economic efficiency of industry. Thanks to cooperation with universities, companies will be able to use new high-tech solutions that will also contribute to their energy efficiency.

The management of project innovation activities of higher education institutions based on the concept of industrial symbiosis is an important aspect of the development of cooperation between higher education institutions, industrial enterprises, and authorities. The application of the industrial symbiosis concept can contribute to the efficient use of resources and the creation of innovative projects in the field of sustainable development.

It should be noted that universities should not only be actively involved in the processes of creating industrial symbioses but also become drivers of the formation of consortia with the participation of industrial enterprises, authorities, specialized organizations and offer innovative solutions and business models to stimulate the country's transition to a circular economy. Of course, the role of universities in the process of initiating industrial symbioses is ambiguous, as the world experience shows that enterprises, with the participation of the state, mostly independently build symbiotic chains. At the same time, universities undeservedly get the role of an intermediary that unites various parties – industrial enterprises, government agencies, and scientific institutions. Higher education institutions themselves are often outside the framework of large infrastructure projects.

The study also revealed that the management of project innovation activities of HEI based on the concept of industrial symbiosis requires a systematic approach. This comprehensive approach implies not only the analysis of the university's potential and its resources but also the development of a strategy of interaction with partners, action plans for commercialization of own developments, selection of the most suitable investors, and integration of existing and new projects into the innovation ecosystem in the conditions of transition to a circular economy. In general, the application of the concept of industrial symbiosis in the management of project innovation activities of the university can contribute to the creation of sustainable and effective projects that can promote the development of the regional economy and solve the problems of sustainable development. This requires the

active involvement of all stakeholders, the development of cooperation, and exchange of experience, as well as the application of modern methods of project and innovation management.

The study may have several drawbacks. Firstly, the sample size was limited and might not accurately reflect the wide range of academic institutions, businesses, and governmental organizations engaged in industrial symbiosis, despite being stratified. Furthermore, the utilization of self-reported data obtained from surveys and interviews may include biases that might possibly compromise the validity of the results. Furthermore, the research may have missed new developments and creative approaches in the quickly developing field of industrial symbiosis due to its emphasis on current frameworks and procedures.

To improve the generalizability of the results, it is advised that future studies increase the sample size and involve a wider range of institutions and stakeholders. Further understanding of the long-term effects of industrial symbiosis on university innovation activities may be obtained through longitudinal research. Additionally, investigating how digital technologies, data analytics, and machine learning algorithms support industrial symbiosis may provide insightful viewpoints on enhancing productivity and efficacy in collaborative frameworks.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data generated or analyzed during this study are included in this published article.

Author Contribution Statement

Daria Y. Mironova: Conceptualization, Methodology, Formal analysis, Writing – original draft, Project administration. **Evgeniya A. Pashkova:** Validation, Visualization. **Alexander G. Budrin:** Methodology, Writing – review & editing. **Igor V. Baranov:** Methodology, Data curation, Writing – review & editing. **Vijayakumar Varadarajan:** Methodology, Formal analysis, Supervision. **Stephen Afrifa:** Investigation, Project administration.

References

[1] Dong, L., Liang, H., Zhang, L., Liu, Z., Gao, Z., & Hu, M. (2017). Highlighting regional eco-industrial development: Life cycle benefits of an urban industrial symbiosis and implications in China. *Ecological Modelling*, *361*, 164–176. https://doi.org/10.1016/j.ecolmodel.2017.07.032

[2] Albino, V., Garavelli, A. C., & Romano, V. A. (2013). A classification of industrial symbiosis networks: A focus on materials and energy recovery. In *Advances in Production Management Systems. Competitive Manufacturing for Innovative Products and Services: IFIP WG 5.7 International Conference,* 216–223. https://doi.org/10.1007/978-3-642-40352-1_28

[3] Alix, T., & Vallespir, B. (2013). Service delivery process based on service composition mechanisms. In V. Prabhu, M. Taisch, & D. Kiritsis (Eds.), *Advances in production management systems. Sustainable production and service supply chains. APMS 2013. IFIP advances in information and communication technology*, *415*. Springer. https://doi.org/10.1007/978-3-642-41263-9_28

[4] Chertow, M. R. (2000). Industrial symbiosis: Literature and taxonomy. *Annual Review of Environment and Resources*, *25*, 313–337. https://doi.org/10.1146/annurev.energy.25.1.313

[5] Neves, A., Godina, R., Azevedo, S. G., & Matias, J. C. O. (2020). A comprehensive review of industrial symbiosis. *Journal of Cleaner Production*, *247*, 119113. https://doi.org/10.1016/j.jclepro.2019.119113

[6] Lombardi, D. R., & Laybourn, P. (2012). Redefining industrial symbiosis: Crossing academic–practitioner boundaries. *Journal of Industrial Ecology*, *16*(1), 28–37. https://doi.org/10.1111/j.1530-9290.2011.00444.x

[7] Huang, B., Yong, G., Zhao, J., Domenech, T., Liu, Z., Chiu, S. F., . . . , & Yao, Y. (2019). Review of the development of China's Eco-industrial park standard system. *Resources, Conservation and Recycling*, *140*, 137–144. https://doi.org/10.1016/j.resconrec.2018.09.013

[8] Azevedo, J., Henriques, J., Estrela, M., Dias, R., Vladimirova, D., Miller, K., & Iten, M. (2021). Guidelines for industrial symbiosis—A systematic approach for content definition and practical recommendations for implementation. *Circular Economy and Sustainability*, *1*(2), 507–523. https://doi.org/10.1007/s43615-021-00006-3

[9] Stéphane, O., Jean-Baptiste, Q., Charles-Xavier, S., Gwenaël, L. M., Mouad, M., & Alexandre, B. (2019). A cross-sectorial synergies identification methodology for industrial symbiosis. In *Sustainable Design and Manufacturing 2019: Proceedings of the 6th International Conference on Sustainable Design and Manufacturing,* 229–240. https://doi.org/10.1007/978-981-13-9271-9_21

[10] Taddeo, R., Simboli, A., Ioppolo, G., & Morgante, A. (2017). Industrial symbiosis, networking and innovation: The potential role of innovation poles. *Sustainability*, *9*(2), 169. https://doi.org/10.3390/su9020169

[11] Henriques, J., Ferrão, P., Castro, R., & Azevedo, J. (2021). Industrial symbiosis: A sectoral analysis on enablers and barriers. *Sustainability*, *13*(4), 1723. https://doi.org/10.3390/su13041723

[12] Hens, L., Cabello-Eras, J. J., Sagastume-Gutiérez, A., Garcia-Lorenzo, D., Cogollos-Martinez, J. B., & Vandecasteele, C. (2017). University–industry interaction on cleaner production. The case of the Cleaner Production Center at the University of Cienfuegos in Cuba, a country in transition. *Journal of Cleaner Production*, *142*, 63–68. https://doi.org/10.1016/j.jclepro.2015.10.105

[13] Baldassarre, B., Schepers, M., Bocken, N., Cuppen, E., Korevaar, G., & Calabretta, G. (2019). Industrial symbiosis: Towards a design process for eco-industrial clusters by integrating circular economy and industrial ecology perspectives. *Journal of Cleaner Production*, *216*, 446–460. https://doi.org/10.1016/j.jclepro.2019.01.091

[14] Benvenuto, M. A. (2019). *Green chemical Processing*. Germany: De Gruyter.

[15] United States Environmental Protection Agency. (n.d.). *EPA sustainable materials management program strategic plan for fiscal years 2017–2022*. Retrieved from: https://19janua

ry2017snapshot.epa.gov/smm/epa-sustainable-materials-management-program-strategic-plan-fiscal-years-2017-2022_.html

[16] Preobrazhensky, B. G., Tolstykh, T. O., & Shmeleva, N. V. (2020). Promyšlennyj simbioz kak instrument cirkuljarnoj èkonomiki [Industrial symbiosis as a tool for circular economy]. *Region: Sistemy, èkonomika, upravlenie*, *45*(1), 37–48. https://doi.org/10.22394/1997-4469-2020-51-4-37-48

[17] European Union. (2006). Opinion of the Committee of the Regions on the Communication from the Commission to the Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Healthier, safer, more confident citizens: A health and consumer protection strategy proposal for a decision of the European Parliament and of the Council establishing a programme of community action in the field of health and consumer protection 2007–2013. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52005AR0149

[18] Hong, H., & Gasparatos, A. (2020). Eco-industrial parks in China: Key institutional aspects, sustainability impacts, and implementation challenges. *Journal of Cleaner Production*, *274*, 122853. https://doi.org/10.1016/j.jclepro.2020.122853

[19] Bobylev, S. N., & Solovyeva, S. V. (2020). Cirkuljarnaja èkonomika i ee indikatory dlja Rossii [Circular economy and its indicators for Russia]. *The World of New Economy*, *14*(2), 63–72. https://doi.org/10.26794/2220-6469-2020-14-2-63-72

[20] Utkina, E. E. (2020). Analysis and classification of methods for assessing industrial-symbiotic interactions. *Bulletin of the Plekhanov Russian University of Economics*, *17*(5), 26–41.

[21] Interreg Europe. (2023). Retrieved from: https://www.interregeurope.eu/green4heat

[22] Domenech, T., Doranova, A., & Smith, M. (2018). *Cooperation fostering industrial symbiosis: Market potential, good practice and policy actions: Final report*. European Union. https://doi.org/10.2873/346873

[23] Hein, A. M., Jankovic, M., Farel, R., & Yannou, B. (2015). A conceptual framework for eco-industrial parks. In *Proceedings of the ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. https://doi.org/10.1115/DETC2015-46322

[24] Sinenko, O., & Mayburov, I. A. (2018). Regulation of environmental aspects in special economic zones. In *Proceedings of the 6th International Conference Innovation Management, Entrepreneurship and Sustainability*, 978–988.

[25] Mironova, D. Y., Pashkova, E. A., Baranov, I. V., Budrin, A. G., Varadarajan, V., & Afrifa, S. (2024). Project innovative activity in the higher education system of the Russian Federation. *Higher Education in Russia*, *33*(6), 104–123. https://doi.org/10.31992/0869-3617-2024-33-6-104-123

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