

Industrial Symbiosis as a Way to Solve Environmental Problems in Regions (on the Example of the Russian Black Sea Area)

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Abstract. The study examines potential opportunities for the implementation of the concept of industrial symbiosis as a component of the circular economy in the regions of the Russian Black Sea region. The logic of solving this objective reflects the transition from a theoretical analysis of concepts and key components of industrial symbiosis to a comprehensive consideration of the industrial specialization of the territory under consideration and the regions forming it. The analysis made it possible to conclude that there are potentially significant opportunities for the implementation of industrial symbiosis between industrial enterprises in the Russian Black Sea region.

1 Introduction

Currently, one of the fastest-growing regions of Russia with a high concentration of global geopolitical interests is the Black Sea region [1]. Professor A.G. Druzhinin refers to 42 municipalities in the Black Sea region, representing specific urban areas and municipal districts [2], and considers the Russian Black Sea region as a set of individual subjects of the Russian Federation. This approach is taken as the basis for this study. Industry is actively developing in the regions of the Russian Black Sea region, which leads to an increase in the technogenic pressure and anthropogenic transformation of the biosphere [3], and consequently, the deterioration of the ecological situation in industrial areas.

Modern economic challenges (globalization, Industry 4.0, as well as the crisis of the resource-oriented model of development) require the modernization of industry [4]. One of the key directions of this modernization is to increase the responsibility of industrial enterprises for environmental damage. Focusing on the environmental aspects of industrial development is associated with the dissemination and fixation on practical implementation of the concept of sustainable development, which is based on a balance between solving socio-economic problems and preserving the environment [5,6,7,18].

In 2015, Russia adopted the Resolution "Transforming Our World: the 2030 Agenda for Sustainable Development", containing 17 UN Sustainable Development Goals. The twelfth goal of sustainable development is "Responsible consumption and production", one of the

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approaches to its implementation being the transition from a linear economy to a closed-loop economy (circular economy). A circular economy is an economy in which all material and commodity flows, after use, are re-incorporated into production cycles as raw materials for new goods and services [8].

The transition to a circular economy makes a significant contribution to the creation of a sustainable economy through more efficient use of resources and the transition to low-carbon energy sources [9]. The concept of industrial symbiosis is one of the ways to "close" the production cycle. Since there are different definitions of industrial symbiosis [10], this paper will use the definition of Marian Ruth Chertow, a leading researcher in this field, according to which this term refers to a business model in which two or more organizations cooperate in the process of making business decisions and share common resources [11]. At the practical level, industrial symbiosis is a promising approach that increases environmental sustainability and, at the same time, contributes to the achievement of economic benefits [12].

Taking into account the above provisions and arguments, this study is aimed at studying the possibilities of organizing symbiotic interactions between industrial enterprises in the Russian Black Sea region.

2 Materials and Methods

To determine the general patterns in the regional specialization of the territories of the south of Russia, which could potentially be attributed to the Black Sea due to their proximity to the sea, data from the Atlas of Economic Specialization of the Regions of Russia of the Higher School of Economics were used [13]. After analyzing the regional profiles, it was decided to include the following subjects within the framework of this study in the Black Sea region: Rostov Region, Krasnodar Territory, the Republic of Crimea, and the federal city of Sevastopol. The key characteristic when choosing regions was the presence in the regional profile of the subject of a large number of branches of specialization of national and local significance. Despite the fact that only one branch of national and local significance is currently developed in the city of Sevastopol, it was decided to attribute this territory to the Black Sea because of its location in the coastal zone and close economic ties with the rest of the Crimean Peninsula.

The next important stage of the study was the identification of the most developed industries in the regions of the Black Sea area. To do this, the data of the Rosstat of the Russian Federation for 2021 [14] were analyzed in terms of the volume of shipped goods of own production at actual prices for four industries in the regions of the Russian Federation. After that, the analysis of the structure of the volume of shipped products for each of the four categories was carried out. The data obtained were ranked, and for each region of the Black Sea area, five types of industrial activities were identified that brought in the largest share of income. After that, a map of the regions of the Russian Black Sea area was compiled, reflecting the key areas of industry in each region. The indices of industrial production in the Black Sea regions were also analyzed in historical context, which allowed us to draw conclusions concerning the pace of development of the industry in the Black Sea regions.

In order to study the main components of the concept of industrial symbiosis, bibliometric analysis was used. To do this, the metadata of the 2000 most relevant articles was found and downloaded in the international Scopus database at the request of "industrial AND symbiosis". In total, the collected metadata contained 10,794 keywords. Only those words or phrases that were used in 15 or more works were selected from them. There were 241 such keywords, and 10 words were excluded from them, which did not reflect the specifics of articles about industrial symbiosis. Based on the selected data in the

VOSviewer software, a network map was built. Based on the results, general conclusions were drawn.

3 Results and Discussion

3.1 Components of industrial symbiosis

The concept of "industrial symbiosis" has several definitions. In order to determine what exactly different scientists refer to as the concept of industrial symbiosis, a network map was built based on keywords from articles indexed by Scopus (Fig. 1).

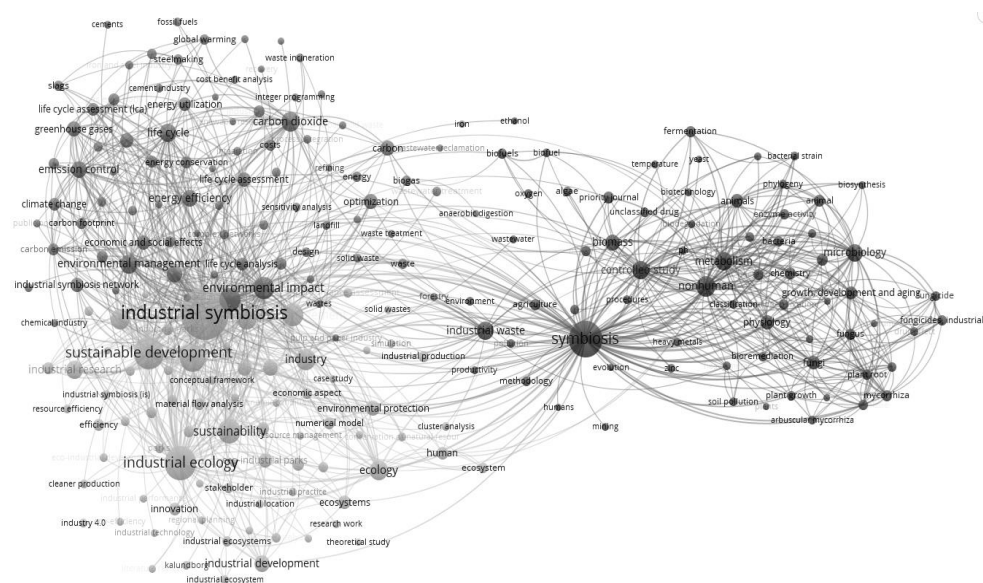


Fig. 1. Network map of the distribution of keywords for the query "industrial AND symbiosis" to the main clusters.

As can be seen from the graphical representation of the network map, all keywords can be divided into three clusters:

- 1) The first cluster (dark gray) includes keywords that characterize various ways of symbiosis, with an emphasis on specific industrial waste that can be used as raw materials.
- 2) The second cluster (gray) represents keywords that are associated with the negative consequences of industrial activity and those indicators that allow us to assess the scale of these consequences.
- 3) The third cluster (light gray) combines keywords on the subject of modern approaches and theoretical concepts aimed at reducing the negative externalities of industrial production.

There is a close relationship between the second and third clusters, while the third cluster is more isolated. This situation is due to the fact that many researchers in research devoted to the study of the negative impacts of industrial enterprises offer certain approaches to reduce such a negative impact.

Within the framework of this study, it is important to analyze the changes in the context of scientists' perception of the term "industrial symbiosis" over time. The analysis showed that in early studies, scientists were mainly focused on what industrial waste could be considered secondary raw materials and what theoretical approaches could be used for this.

After 2018, the greatest interest of scientists was mainly caused by what environmental, economic, and social effects arise during the implementation of industrial production, as well as methods of measuring them.

3.2 Structure of industrial production of the Russian Black Sea regions

Despite the similarity of the natural landscape, the selected regions of the Russian Black Sea area have differences in the number of mineral deposits, the area of the territory, and the development of infrastructure. This fact served as an incentive to study the similarities and differences between these regions in terms of the volume of shipped goods from their own production (Fig. 2).

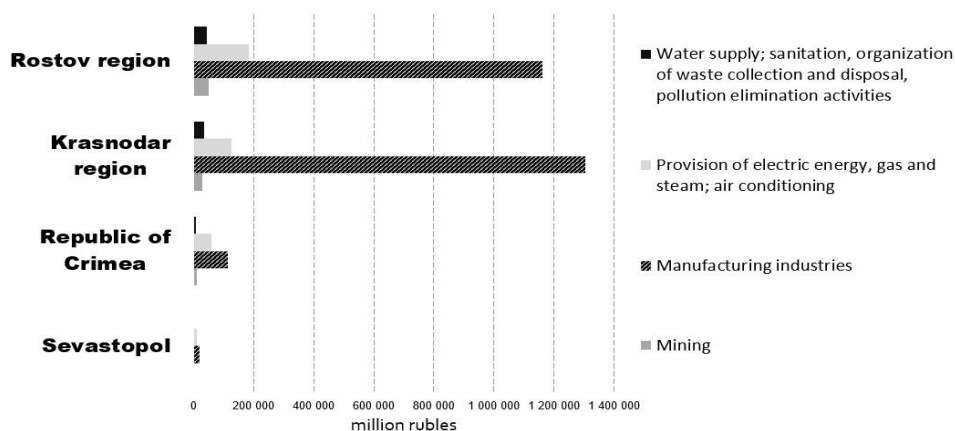


Fig. 2. Structure of the volume of shipped goods of own production, works and services performed by own forces by types of economic activity for 2021 by regions of the Russian Black Sea region (at actual prices; million rubles).

In the city of Sevastopol, due to its territorial location and small area, mining, water supply, and waste disposal services are practically represented by a small number of enterprises. Therefore, in order to ensure the confidentiality of primary statistical data in accordance with the Federal Law of November 29, 2007, the Federal State Statistics Service does not publish these data and, therefore, they are not reflected on the diagram. According to the diagram, it can be seen the similarity in the distribution of income by type of industry. Thus, all regions are characterized by high development of manufacturing industries; in second place are enterprises engaged in power supply and air conditioning. There are also minor differences. For example, in the Republic of Crimea and the Rostov region, the volume of production in the field of mining is higher than in the field of water supply, and in the Krasnodar Territory, the opposite situation is observed.

To assess the possibility of implementing the concept of industrial symbiosis in the territory under consideration, an analysis of the most developed industries in each region by volume of production was carried out (Fig. 3).

The most developed industry in the Black Sea regions is the food industry. Also, a significant share of the volume of production in each region was occupied by the electric power industry, although its size varied depending on the specific subject of the Russian Federation. In all regions except the Rostov region, the production of non-metallic mineral products is in the top 5 in terms of production. A similar situation concerns the production of machinery and equipment, developed to a lesser extent in the Krasnodar Territory. The Rostov region and the Krasnodar Territory are characterized by a high degree of development in the production of rubber and plastic products, as well as metallurgy. The

specialization of the Black Sea regions has a lot in common; only eight industries are the most developed in the four regions.

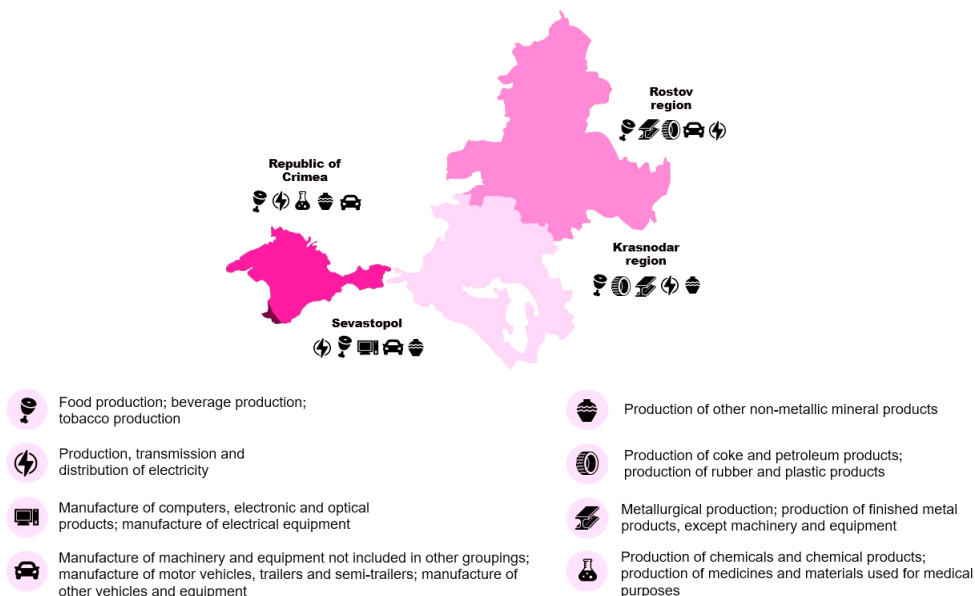


Fig. 3. TOP 5 industries in terms of the volume of shipped goods of their own production, works and services performed by their own forces by types of economic activity in the regions of the Russian Black Sea area for 2021.

An industrial symbiosis is possible between many of these industries. For example, waste from the production of machinery and equipment could be used as raw materials in metallurgy. In addition, it is possible to carry out symbiotic interactions between enterprises in the same industry. For example, a number of companies could be engaged in the production of goods and recycled rubber and plastic products. Due to the specifics of the geographical location of the Black Sea regions, there are opportunities for organizing water logistics transportation between the regions, which can reduce the delivery time of secondary raw materials.

4 Conclusion

Industrial symbiosis, as part of the circular economy, is a global megatrend [15]. It is aimed at strengthening the cyclical nature of resources and increasing their sustainability. The implementation of industrial symbiosis in the industrial territories of the Russian Federation can contribute to the improvement of the environmental situation by reducing the use of water, electricity consumption, and the share of buried or incinerated production waste.

Despite the fact that the regions of the Russian Black Sea area are characterized by similar patterns of industrial development and have a small territorial distance from each other, the organization of industrial symbiosis in the territories of the Black Sea region is quite a difficult task. This is due to the fact that it is difficult for companies to independently assess whether they have the conditions for inclusion in the industrial symbiosis since there are no official methods adopted at the state level yet. Scientists name the following factors as possible factors for assessing the degree of symbiotic readiness: the possibility of exchanging by-products of activities; the availability of production information about other companies; the availability of infrastructure to ensure symbiotic

partnership, etc. [16] To implement industrial symbiosis in the Black Sea region, it is important to identify not only the potential of symbiotic interaction in the region but also the potential of individual enterprises.

Despite the complexity of implementing the concept of industrial symbiosis for companies that are forced to reorganize their supply chains, the introduction of this approach can have a beneficial effect on the environmental situation in industrial territories and improve sustainability indicators [17].

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