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COMPARATIVE ANALYSIS OF THE ECO-INNOVATION STRUCTURE OF EUROPEAN UNION COUNTRIES IN 2014-2024

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Purpose: The aim of this paper is to analyse and assess the eco-innovation of the European Union Member States in the years 2014-2024, which will allow for determining its level and making comparisons in various aspects.
Design/methodology/approach: The work uses various research methods, such as analysis and criticism of the subject literature, statistical methods, and logical analysis and construction.
Findings: The article presents the results of a comparative analysis of the level of eco-innovation in the European Union Member States over the years 2014-2017. The analysis of the level of eco-innovation in individual countries, based on appropriate indicators, allows for the identification of areas requiring intervention, assessment of the effectiveness of environmental policy and comparison of achievements and the pace of development between countries. The article indicates the leaders of eco-innovation in the group of countries and presents the growth and decline in the most important dimensions. The analyses carried out show that the leaders of eco-innovation in the EU are: Finland, Denmark, Austria, Luxembourg, Sweden, Italy, France, Germany, Netherlands, and the largest increase in the summary eco-innovation index compared to 2014 was recorded in Lithuania, Ireland and Malta (EIS 2024).
Research limitations/implications: In the future, it will be possible to compare the level of eco-innovation of European Union countries with their overall level of innovation, which will allow for a better understanding of the relationship between innovation and actions for sustainable development.
Practical implications: The practical value of the publication is particularly important for public authorities, institutions responsible for shaping environmental policy and decision-makers at national and EU level. It may also be of interest to analysts, researchers and international organizations dealing with sustainable development.
Social implications: The research presented in the article provides knowledge that can contribute to improving the quality of life of European Union citizens by more effectively shaping the environmental policies of EU Member States and supporting sustainable development. By identifying the strengths and weaknesses in the field of eco-innovation in individual countries, the article can support the creation of more precise, fair and effective public strategies.
Originality/value: The article brings new value to the analysis of eco-innovation of EU countries, presenting the level of eco-innovation of EU Member States over the years 2014-2024. Analysis of the level of eco-innovation in individual countries, based on appropriate indicators, allows to identify areas requiring intervention, assess the effectiveness of

environmental policy and compare achievements and the pace of development between countries.
Keywords: innovations, eco-innovation, Eco-Innovation Index and Scoreboard.
Category of the paper: Research paper.

1. Introduction

The concept of eco-innovation emerged in the 1990s as a result of the growing role of innovation in the processes of economic development and the deepening problems related to the degradation of the natural environment. This term, like the concept of innovation itself, is complex and multidimensional. One of the first definitions of eco-innovation was proposed by C. Fussler and P. James in 1996, defining it as products and processes that reduce the negative impact on the environment, while creating added value for both the company and the consumer (Fussler, James, 1996). Contemporary literature contains many definitions of eco-innovation, which often complement each other, emphasizing different aspects of this concept. According to Kemp and Person, eco-innovation is a new production method, resource exploitation, method of providing services, or a management method for an organization, which take into account the environmental aspect throughout the life cycle of a given product or service. They reduce the consumption of raw materials and the emission of pollutants into the environment, and are less harmful to the environment compared to other alternative sources (Kemp, Person, 2008).

Eco-innovation is the process of introducing a new or significantly improved product, process, organizational change or marketing solution, which results in a reduction of raw material consumption and a reduction of harmful substances emissions into the environment throughout the product life cycle (EIO, 2013). Wielewska I. defines eco-innovation as a direction of thinking and action, defining basic development paths, called sustainable development. Such actions carried out in enterprises may be of a corrective or preventive nature (Wielewska, 2013). According to the Oslo Manual, eco-innovation is a new or improved product or process (or their combination) that is significantly different from products or processes made available to potential users (product) or introduced for use (process) and which aims to reduce the negative impact on the environment (OECD, Eurostat, 2018).

The analysis of the concept of eco-innovation shows that its main effect is the reduction of the negative impact on the environment – regardless of whether this action was intentional or a side effect of other processes. In recent years, the approach to eco-innovation has undergone a significant transformation: from reactive actions aimed at reducing pollutant emissions, the emphasis has shifted towards preventive actions focused on the rational use of resources, minimizing energy consumption and preventing waste generation (Sulerz, Rybaczewska-

Błażejowska, 2017; Rybaczewska-Błażejowska, 2019; Rybaczewska-Błażejowska et al. 2022; Czajkowska, Ingaldi, 2022).

In the 1990s, eco-innovation gained importance in the pursuit of a sustainable economy. Therefore, developing indicators and methods for measuring eco-innovation became a significant challenge. Despite the fact that eco-innovation research is still in its early stages of development, several concepts of a methodological approach to this issue have already been developed. Eco-innovation research can be conducted at three levels: macro, meso and micro. Analyses at the macro and meso levels focus on assessing eco-innovation on a national or regional scale. These are general eco-innovation studies. Their aim is to identify factors that support the development of environmental innovations at a systemic level, as well as to compare the effectiveness of individual countries or regions. These studies may include, among others, analysis of public policies, expenditure on research and development, the structure of the economy, support systems for green technologies and the availability of infrastructure that supports sustainable development. A key element of such analyses is the creation of eco-innovation rankings based on aggregated indicators – an example is the summary eco-innovation index, which allows for comparing the level of advancement of ecological innovations between countries (Kumor-Sulerz et al., 2021).

Eco-innovation research at the micro level focuses on the activities of individual enterprises. Their aim is to assess the ability of companies to implement environmental innovations, analyze innovation strategies and identify internal processes supporting the development of new pro-ecological products, services and technologies. Such research allows for the diagnosis of the state of innovation of the enterprise and the identification of key factors influencing its innovation potential (Kaczmarska, 2015; Kumor-Sulerz, Michta, 2022).

Each level of research presents the issue of eco-innovation from a different perspective, based on different indicators and measurement methods. Modern analyses increasingly integrate data from the macro, meso and micro levels, which allows for a more complete and multidimensional picture of innovation processes taking place in the economy.

The aim of this work is to analyze and assess the eco-innovation of the European Union Member States in the years 2014–2024, which allows for determining its level and making comparisons in various aspects. The work uses various research methods, such as analysis and criticism of the subject literature, statistical methods, and logical analysis and construction. Due to the high variability of eco-innovation of countries and the multitude of factors influencing this process, its analysis is extremely important. Eco-innovation research can take into account various aspects. The article presents an original analysis of eco-innovation of countries, in which the Author selected the key, in his opinion, assessment parameters.

The following research hypothesis was adopted in the article: There is an upward trend in the European Union countries in terms of eco-innovation over the years 2014-2024.

2. Materials and methods. Eco-IS research methodology

The most important general studies on eco-innovation include, among others, the Eco-Innovation Index and Scoreboard (Eco-IS), Measuring Eco-Innovation (MEI) and the Community Innovation Survey (CIS). These are tools used to assess the level of eco-innovation at the macro level – both national and regional – and to observe trends and changes occurring in this area. In contrast, detailed studies focus on the level of enterprises (micro) and are most often based on original approaches of researchers specializing in the subject of eco-innovation.

The Eco-Innovation Index and Scoreboard (Eco-IS) is a methodology developed in 2010 by the Eco-Innovation Observatory (EIO), created as a supplement to existing tools for examining economic innovation. Eco-innovation is measured using 12 indicators, grouped into 5 key categories, which allow for a comprehensive assessment of the level of eco-innovation (Table 1).

Table 1.
Eco-IS 2024 Indicators

Eco-IS 2024 indicators				
Eco-innovation inputs - include financial, human and institutional resources allocated to the development of eco-innovations.	**Eco-innovation activities -** refer to the implementation of innovations in processes, products and organizational models.	**Eco-innovation outputs -** concern the direct effects of innovative activities, such as new technologies or products.	**Resource efficiency outcomes -** assess the impact of eco-innovations on savings and rational use of natural resources.	**Socio-economic outcomes -** measure the impact of eco-innovation on the economy, including job creation and improved competitiveness.
Governments environmental and energy R&D appropriations and outlays. Total R&D personnel and researchers.	Number of ISO 14001 certificates.	Eco-innovation related patents. Eco-innovation related academic publications.	Material productivity Water productivity (GDP/total fresh water abstraction) Energy productivity GHG productivity.	Exports of environmental goods and service sector. Employment in environmental protection and resource management activities. Value added in environmental protection and resource management activities.

Source: Own study based on (European Commission, 2024).

3. Results and discussions

The Eco-IS 2024 study uses 12 indicators presented in Table 1. Based on the aggregated indicator – the Eco-Innovation Index (EII), which is calculated as an unweighted arithmetic average of partial indicators and then compared with the average value for the entire European Union, an eco-innovation ranking of EU member states is created. This classification allows for assigning individual countries to one of three categories: eco-innovation leaders, Average EI Performers and countries catching up with EI (Table 2).

Eco-innovation leaders group – these are countries that achieve the highest level of eco-innovation in the EU. They are characterized by the highest results of the EII index. These countries are distinguished by advanced pro-ecological solutions, effective policies supporting environmental innovations, as well as a high level of investment in the development of environmentally friendly technologies. They are usually also characterized by strong cooperation between the public, private and scientific sectors, as well as ecological awareness of society, which favors the implementation of eco-innovations on a large scale. Average EI Performers group – these are countries that achieve results in the range of 90-125% of the average indicator for the EU. These countries are characterized by an average level of implementation of eco-innovations. In many cases, they lack a coherent strategy that would combine the efforts of the public and private sectors, but they have the development potential and the ability to enter the group of leaders with appropriate support and investments. They may be less developed in terms of technology and research compared to innovation leaders, but they still show some progress in this area. Eco-innovation Catching- up group – these are countries that are below the EU average in terms of eco-innovation. Their SII is below 90% of the EU average. These countries often struggle with insufficient financing for pro-ecological activities, limited institutional support and a lower level of ecological awareness. According to the results of the Eco-IS 2024 study, the leaders of eco-innovation in the EU are: Finland, Denmark, Austria, Luxembourg, Sweden, Italy, France, Germany, Netherlands (Figure 1). The remaining countries are assigned to groups according to Table 2 (European Commission, 2024).

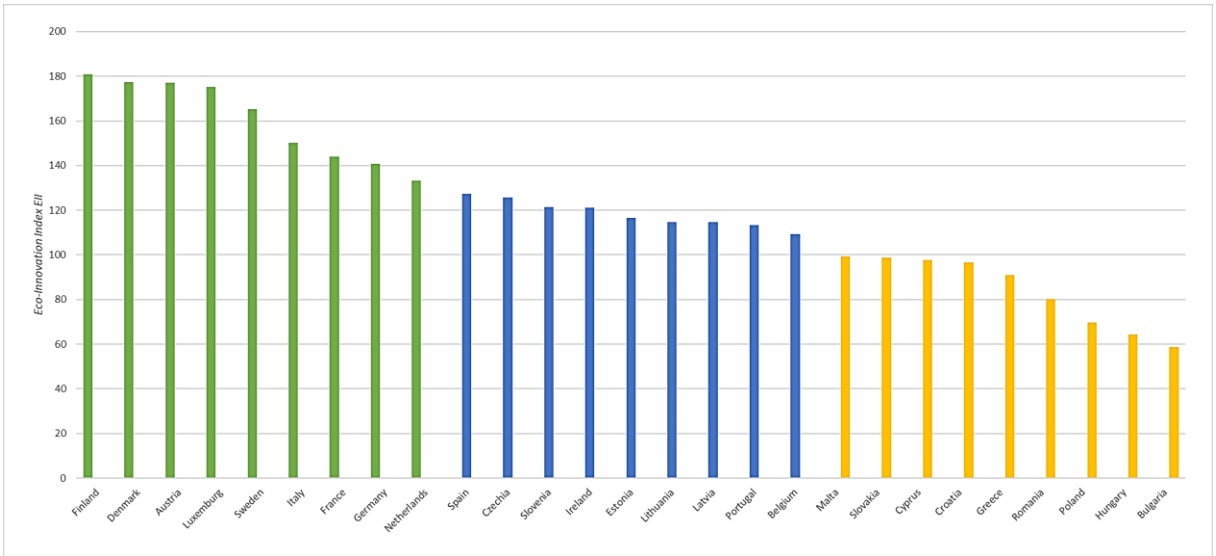

Figure 1. Eco-innovation of EU countries in the EIS 2024 study.

Source: own study based on (European Commission, 2024).

Table 2.
Eco-IS 2024 results

Group	States
Eco-innovation leaders Summary eco-innovation index above 125% of the EU average	Finland, Denmark, Austria, Luxembourg, Sweden, Italy, France, Germany, Netherlands
Average EI Performers Summary eco-innovation index in the range of 90-125% of the average indicator for the EU	Spain, Czechia, Slovenia, Ireland, Estonia, Lithuania, Latvia, Portugal, Belgium
Catching up eco-innovators Summary eco-innovation index below 90% of the EU average	Malta, Slovakia, Cyprus, Croatia, Greece, Romania, Poland, Hungary, Bulgaria

Source: (European Commission, 2024).

Finland maintained its position as the leader in the field of eco-innovation among the European Union countries both in the years 2014-2018 and in the period 2020-2024. In 2019, the leader was Sweden, which currently ranks 5th in the ranking. The largest increase compared to 2014 was recorded in Lithuania, Ireland and Malta. Only in Romania, a decrease in the EII index was noted (Figure 2). The largest increase compared to 2014 was recorded in Lithuania, Ireland and Malta. Only in Romania, a decrease in the EII index was noted. Therefore, countries with a lower level of eco-innovation record larger increases in the summary eco-innovation index than countries that are in the group of eco-innovation leaders.

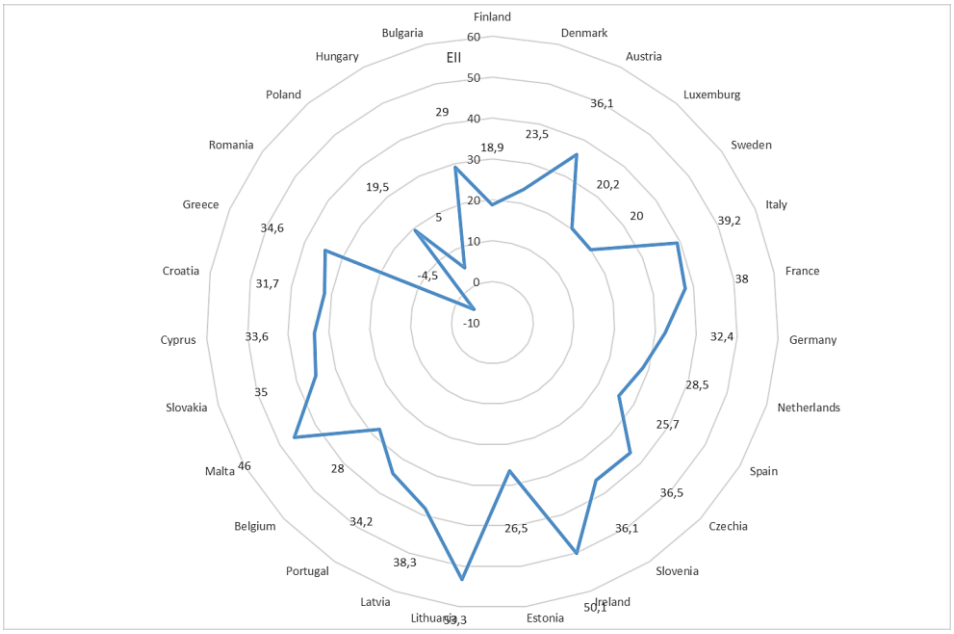

Figure 2. Growth of the EU countries' summary eco-innovation index in the Eco-IS study over the years 2014-2024.

Source: own study based on (European Commission, 2014-2024).

The analysis of eco-innovation in the European Union countries in the years 2014-2024 indicates a general upward trend in the value of the summary eco-innovation index (EII) for the entire EU (Figure 3) (European Commission, 2024). The only exception was 2017, when a decrease in the average EII value was noted at the EU level. The decrease in this indicator occurred in nine Member States, with the greatest regression observed in Romania, Denmark, Estonia and Bulgaria. However, in recent years, a slight upward trend has been noted, which can be attributed, among others, to the actions of enterprises aimed at reducing production costs, tightening legal regulations in the field of environmental protection, access to external financing of eco-innovation projects, as well as the growing importance of ecological products and processes as a source of competitive advantage.

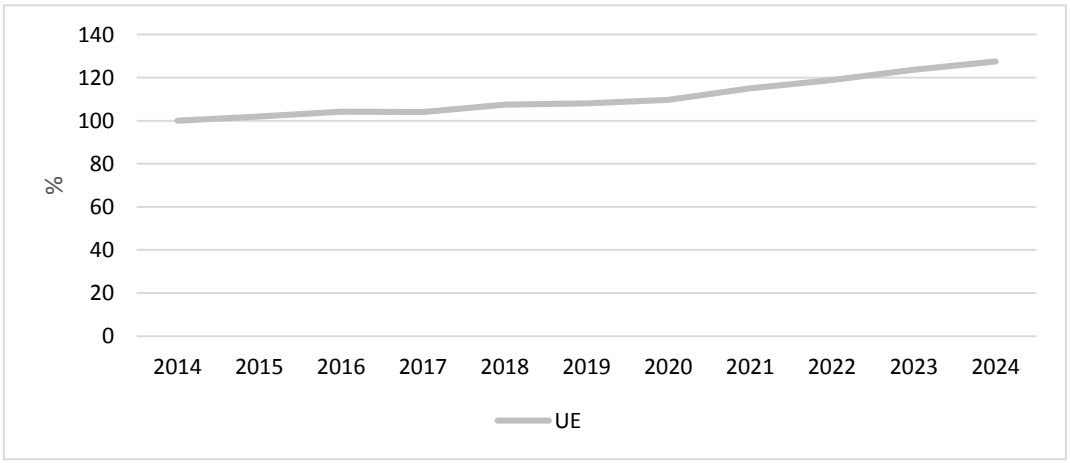

Figure 3. EU eco-innovation in the Eco-IS 2014–Eco-IS 2024 studies.

Source: own study based on (European Commission, 2014-2024).

In the Eco-IS 2024 study, compared to the previous year, there was an increase in the summary eco-innovation index in 22 Member States. The largest increases were recorded in Italy, Lithuania and the Netherlands, while a decrease was recorded in Estonia and Sweden (Figure 4).

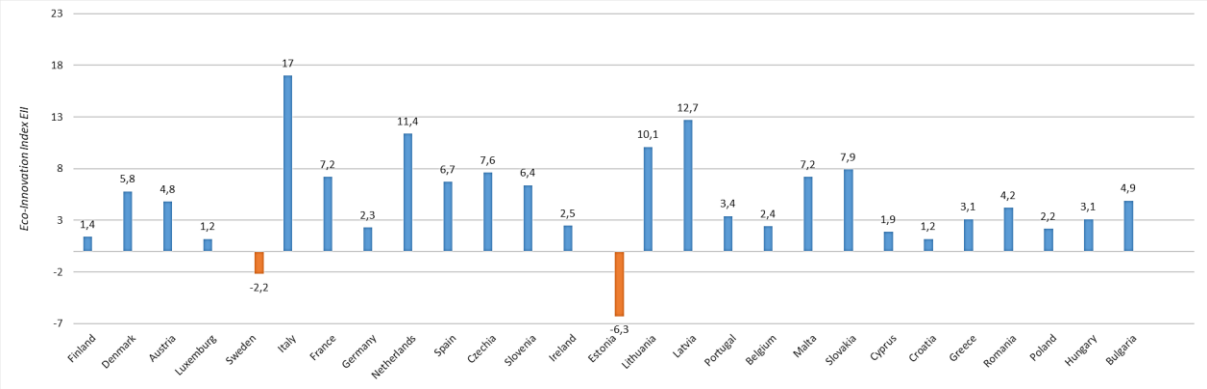

Figure 4. Dynamics of changes in the level of eco-innovation of EU countries in the Eco-IS 2023–Eco-IS 2024 studies.

Source: own study based on (European Commission, 2023-2024).

In the Eco-IS ranking for 2024, Poland was ranked low, falling into the group of countries catching up in terms of eco-innovation. Figure 5 and Figure 6 illustrate the detailed values of Poland's eco-innovation indicators in individual categories against the EU averages.

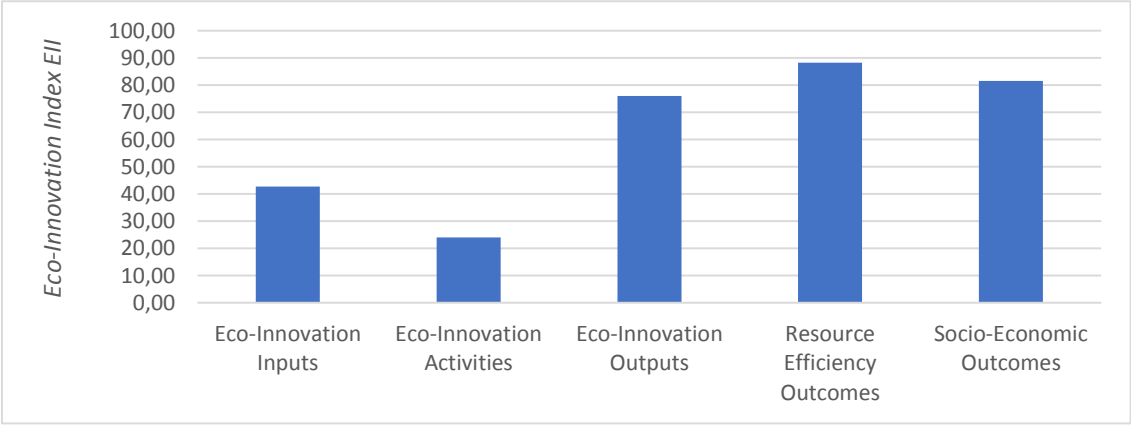

Figure 5. Poland's eco-innovation in the Eco-IS 2024 study for individual categories.

Source: own study based on (European Commission, 2023-2024).

The analysis of individual indicators shows that for eight indicators Poland recorded an increase compared to 2014. Four indicators showed a deterioration in results compared to the 2014 level, i.e. Governments environmental and energy R&D appropriations outlays, Exports of environmental goods and service sector, Eco-innovation related patents and Value added in environmental protection and resource management activities (Figure 6).

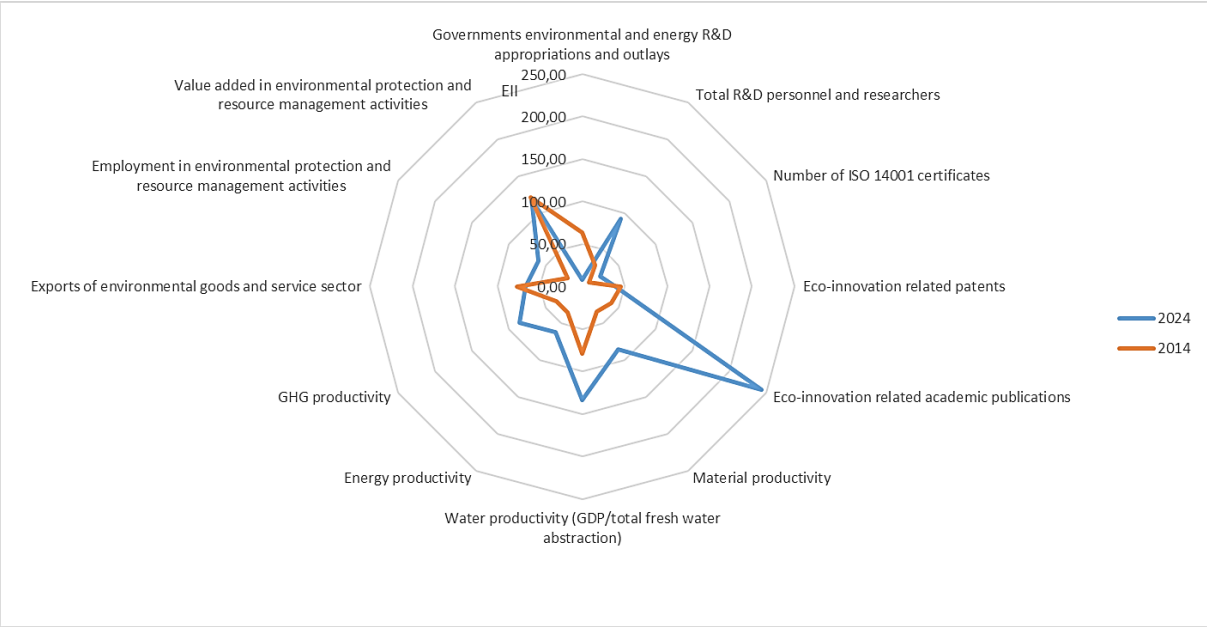

Figure 6. Poland's eco-innovation indicators in Eco-IS 2014 and Eco-IS 2024 studies.

Source: own study based on (European Commission, 2014-2024).

Compared to 2023, Poland recorded growth. Four indicators showed a deterioration in results compared to the 2014 level, i.e. Governments environmental and energy R&D appropriations outlays, Exports of environmental goods and service sector, Eco-innovation related patents and Value added in environmental protection and resource management activities (Figure 7).

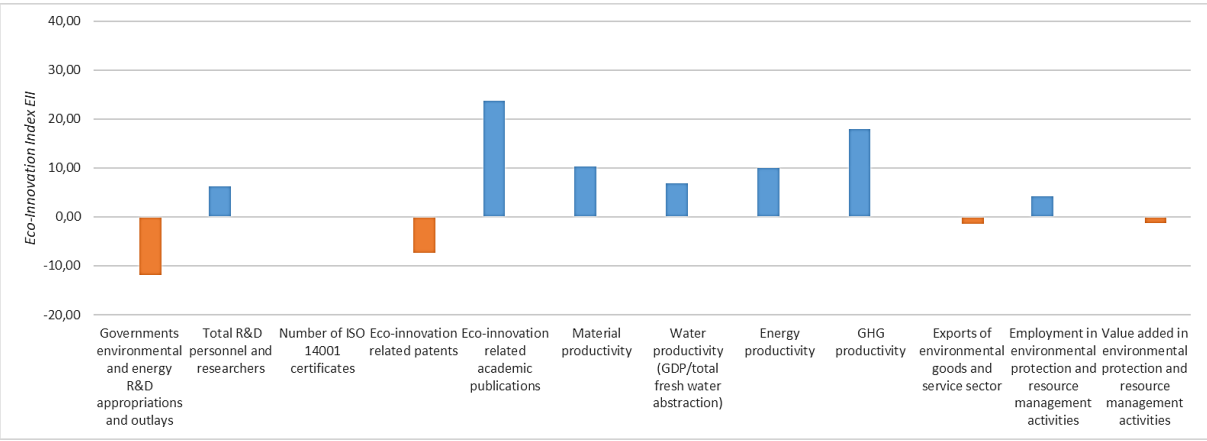

Figure 7. Dynamics of changes in Poland's eco-innovation indicators in the EIS 2023 and EIS 2024 studies.

Source: own study based on (European Commission, 2023-2024).

The level of eco-innovation in Poland remains significantly lower than in countries in the group of eco-innovation leaders. Poland achieved results lower than the EU average in all analysed indicators. Figure 8 shows Poland's eco-innovation indicators compared to Finland - the leader of the Eko-IS 2024 ranking.

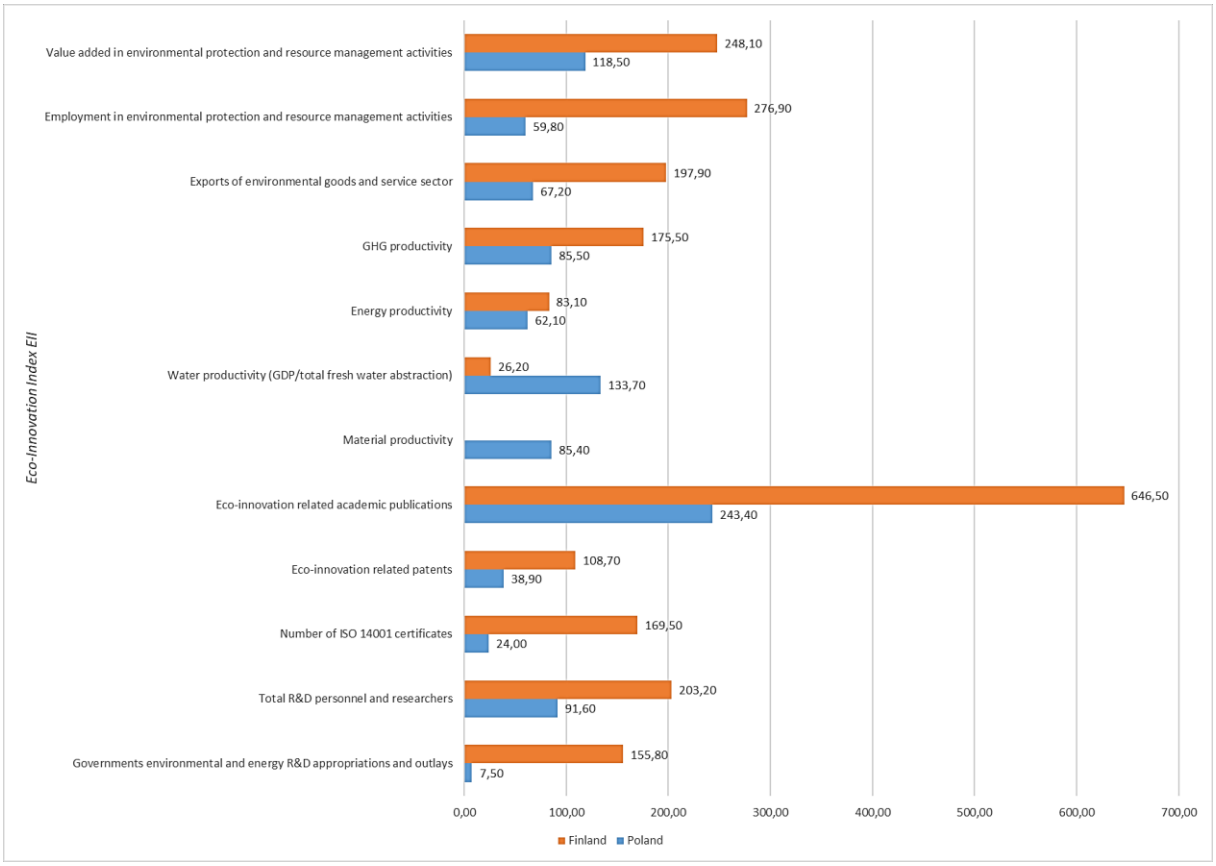

Figure 8. Eco-innovation indicator values for Poland and Finland in the EIS 2024 study.
Source: own study based on (European Commission, 2024).

Although some countries did not make it to the top of the Eco-IS 2024 ranking, they nevertheless achieved high results in selected eco-innovation indicators. For example, the Czech Republic took first place in the European Union in terms of Number of ISO 14001 certificates, while Estonia and Luxembourg became the leader in the category of Employment in environmental protection and resource management activities (Figure 9 and Figure 10) (European Commission, 2024).

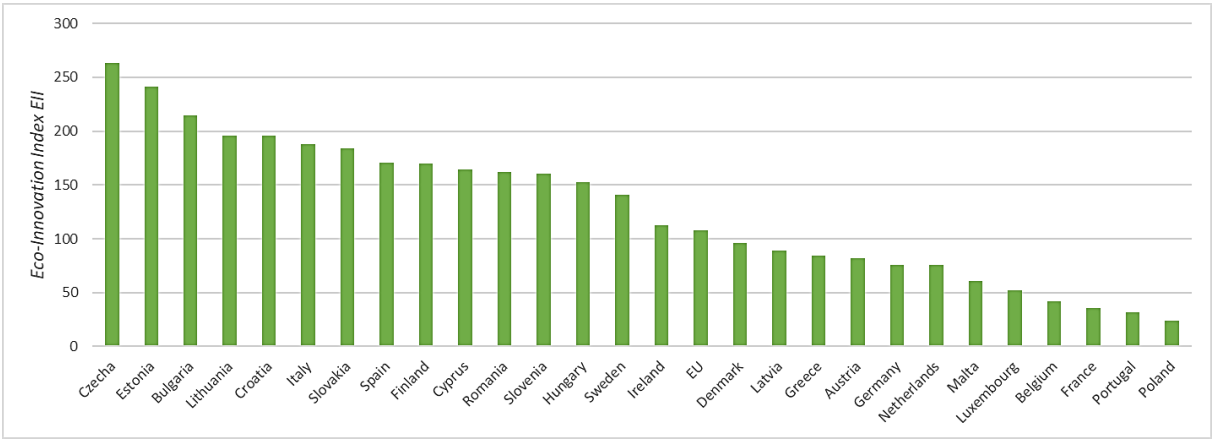

Figure 9. Values of the number of ISO 14001 certificates indicator in the Eco-IS 2024 study.
Source: own study based on (European Commission, 2024).

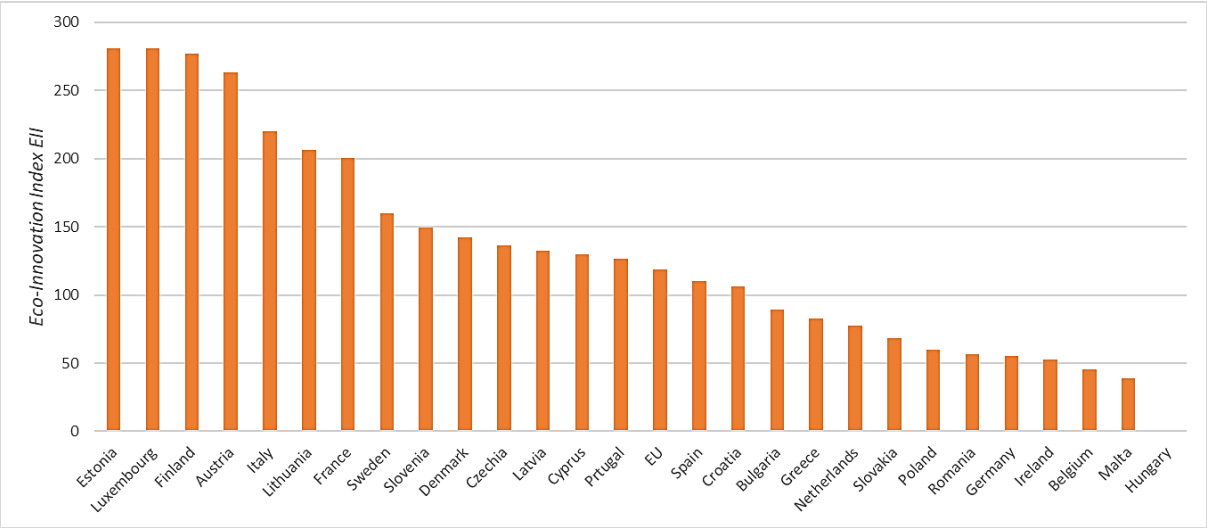

Figure 10. Values of the employment indicator in environmental protection and resource management activities in the Eco-IS 2024 study.

Source: own study based on (European Commission, 2024).

4. Conclusion

The Eco-innovation can be analyzed at three levels: macro, meso and micro. The presented analyses show that the leaders of eco-innovation in the EU are Finland, Denmark, Austria, Luxembourg, Sweden, Italy, France, Germany, and the Netherlands. Over the last 10 years, Finland has been the leader of eco-innovation in the European Union nine times. Only in 2019 did Sweden overtake Finland, taking first place in the ranking.

Analysis of the level of eco-innovation in the European Union countries in the years 2014-2024 reveals a general upward trend in the value of the summary eco-innovation index (EII) on a EU scale. The research hypothesis was confirmed: There is an upward trend in the European Union countries in terms of eco-innovation over the years 2014-2024. The most dynamic increase in the EII indicator compared to 2014 was observed in Lithuania, Ireland and Malta. The exception was 2017, when a decrease in the average EII level was observed in nine member states – the strongest regression was observed in Romania, Denmark, Estonia and Bulgaria. In the following years, however, a gradual improvement was visible, which may be the result of, among others, the actions of companies aimed at reducing production costs, tightening environmental regulations, increased access to external financing for eco-innovation purposes, as well as the growing importance of ecological solutions as a factor building a competitive advantage.

Available research shows that Poland is doing very poorly in terms of eco-innovation compared to other European Union countries. For 10 years, it has consistently been in the group of catching up eco-innovators. This group also includes countries such as Malta, Slovakia,

Cyprus, Croatia, Greece, Romania, Hungary, and Bulgaria. Therefore, the key challenge is to identify the reasons for such a low level of development in this area. The use of policy instruments – for example green subsidies or tax breaks for R&D – can explain the different performances achieved by Member States. Countries that rank among the top countries, such as Finland, Denmark and Austria, have more developed public support systems that effectively stimulate innovation and ecological transformation, while others struggle with budget constraints, weak institutional coordination or lower efficiency of policy implementation, such as Bulgaria. Green subsidies can support investments in renewable energy sources, energy efficiency or sustainable transport, accelerating the transformation towards a low-carbon economy. Tax breaks for R&D can in turn stimulate the private sector to develop new technologies and products, which helps to increase competitiveness and create jobs. The different performances may also be due to different economic structures, levels of technological development and administrative capacities. Countries with strong institutions, stable legal frameworks and a high innovation culture are usually better prepared to use public policy instruments effectively, which translates into better results in areas such as energy transformation, digitalisation and sustainable development. Poland's low position is primarily due to the general deficit of innovation in the economy. The Polish economy is characterized by high energy intensity, a low share of energy from renewable sources, and inefficient resource management, which is manifested, among others, in the low level of recycling and reuse of materials (Rybaczewska-Błażejowska, Mastenak-Janus, 2018; Kumor-Sulerz, Dziedzic-Jagocka, 2023). Despite these challenges, the country has significant potential for improvement, resulting from the growing involvement in climate action, access to financial resources from EU funds, and increasingly stronger integration with the green technology market. The analysis of eco-innovation of countries allows not only to identify their strengths and weaknesses, but also to indicate potential directions of development. In order to reduce disparities between Member States and increase the effectiveness of the implementation of EU climate policy, it is necessary to take actions supporting the transformation in a more sustainable way. One of the priorities should be to increase financing for sectors with a high potential for emission reduction – which could significantly accelerate the transformation in the most emission-intensive areas of the economy. At the same time, it is worth expanding the scope of tax relief for small and medium-sized enterprises involved in the development of green technologies to stimulate innovation and increase their participation in the energy transformation process. It would also be important to introduce a common regulatory framework and create mechanisms supporting the exchange of experiences and proven solutions between Member States. In the case of regions with a lower level of economic development, it would be important to use equalisation tools – such as special funds supporting their adaptation to new challenges. In addition, it is necessary to strengthen administrative capacities in countries that have difficulties with effective management of public funds, which would allow for more effective implementation of policies and fuller use of available funds.

Effective implementation of these strategies can lead to improved competitiveness and increased economic efficiency.

In the future, it will be possible to compare the level of eco-innovation of European Union countries with their overall level of innovation, which will allow for a better understanding of the relationship between innovation and actions for sustainable development.

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