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The importance of resource efficiency indicators in assessing eco-innovation in the European Union countries

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Abstract. *The objective of this paper is to examine the range of eco-innovation levels in the area of resource efficiency among the countries that comprise the EU. The resource efficiency output parameters and associated sub-indicators were employed for this goal to be accomplished. The variety of the eco-innovation degree in each member nation of the European Union was analyzed utilizing actual data, and the tendencies for modifications in this heterogeneity were discovered. The evaluation revealed that there continues to be a significant gap between the nation's most and least innovative countries when it comes to the degree of eco-innovation in the variables examined in the member countries of the European Union. According to the data, there is still a significant gap between the nation's most eco-innovative and least eco-inventive nations, with the disparity in eco-innovation levels among the European Union's Member States' indices not decreasing.*

Keywords: eco-innovation, assessing, resource efficiency, indicators, European Union countries.

JEL Classification: O30, O57, Q20, Q50.

1. Introduction

Resource efficiency indicators are considered one of the main pillars of the eco-innovation structure towards achieving national competitiveness, green growth, and sustainability (European Commission, 2022; European Environment Agency, 2023; Horbach, 2016). Therefore, imperative that the European Union's regulations effectively create strategies for this area and evaluate the level of innovation while simultaneously taking into account its variety of resource-efficiency elements. By using the Eco-Innovation Index approach to evaluate several areas of the eco-innovation achievement of the EU countries, the article provides insight into the noteworthy trends in eco-innovation sub-indices in the area of resource efficiency. Considering an essential element of green energy policies and programs and an engine for these modifications, eco-innovation has become particularly important to attaining a sustainable economy (Columbo et al., 2019; Hazarika and Zhang, 2019; Cai and Li, 2018; Terzić, 2022).

The primary objectives of eco-innovation and resource efficiency are to reduce detrimental environmental impacts and create opportunities to improve the long-term sustainability of the natural environment (e.g., reducing pollution and consuming less energy and other resources) (EEA, 2023). One type of innovation that may benefit businesses and consumers alike and have a significant positive impact on the environment is green innovation. An approach, product, organizational change, or advertising strategy that reduces the discharge of hazardous compounds over the duration of their whole life process is referred to as eco-innovation (Díaz-García et al., 2015; Kemp & Foxon, 2007; EC, 2022; UNEP, 2021).

Hence, eco-innovation is an essential part of business competitiveness and directly affects financial gains; however, its scope and implementation are contingent upon several variables, such as the marketplace, rules and laws, consumer responsiveness, and environmental awareness. By reducing energy and production expenditures and minimizing negative environmental consequences, these approaches aim to improve productivity (Nordhaus, 2021; Terzić, 2023; Porter and Van der Linde, 1995). A singular definition of eco-innovation, notwithstanding the many definitions found in the scientific literature, is an innovation that advances the ecological viability of a business by improving environmental quality. Despite the greater focus, there is still little The topic of eco-innovation remains relatively unexplored, despite the rising focus. Furthermore, there is no established approach for estimating the effects of eco-innovation and resource efficiency. However, disparities in the amount and quality of environmental data are found at many levels.

Different conceptual structures, including those unique to European countries, are employed in the literature and actual eco-innovation measurement and analysis. This is vital to keep in mind when talking about eco-innovation at the level of the economic system. This relates to countries' efforts to achieve green growth, as well as their efforts to minimize adverse ecological impacts and maximize the use of renewable resources. To monitor progress toward an environmentally friendly future, eco-innovation needs to be rigorously assessed (UNEP, 2021; EEA, 2023). As a result, methods and criteria for gauging eco-innovation at the levels of the micro and macro have been developed.

The primary goal of the paper is an analysis of the eco-innovation levels in the field of resource efficiency among the countries that constitute the European Union. The methodologies used included a critical analysis of the available research and a review of the synthesis and comparing method based on the Eco-Innovation Score. Using a similar approach, this paper provides an overview of the eco-innovation achievement in the resource efficiency area over the last decade. The paper's framework consists as follows: The initial part covers the paper's introduction. The second part of the paper offers a theoretical background of the academic literature. The study methods and data, along with the theoretical framework for assessing eco-innovation level via resource efficiency indicators, are provided in Section 3. The research's results are presented in the paper's fourth part, which highlights the extent of the European Union countries' progress in eco-innovation. The fifth part presents the conclusions.

2. Theoretical background

Various theoretical stances exist about eco-innovation. There does not exist a single, widely accepted name for eco-innovation in the field of science, and many of the hypotheses presently in possession of varying investigation concepts (Fussler & James, 1996; Díaz-García et al., 2015; Ghisetti et al., 2015; Türkeli and Kemp, 2018; Terzić, 2023). Although the results of eco-innovation are often inconclusive and often rely on scientific methods (sustainable approaches), it tends to be defined by a much larger percentage of variability than conventional creativity. The many causes for eco-innovation identified in academic study and socioeconomic application vary in terms of their volume and quality of knowledge. In general, they are drawn to innovations that increase resource efficiency. Efficiency in the areas of energy and water are indicators of a sustainable economy. According to EEA (2023), water productivity represents the GDP produced by households' utilization of water, while energy efficiency represents the GDP produced by the domestic utilization of energy. The amount of emissions per GDP level is known as the emission efficiency. An indicator of emissions of greenhouse gases in connection to the extent of an operation or manufacturing process is called greenhouse gas (GHG) concentration.

Utilizing factors including energy consumption, the total amount of animals raised for food, industrial output stages, travel lengths, and comparable company data, this measure can be utilized to evaluate pollutants in the air or releases of greenhouse gases (EC, 2022; EEA, 2023). Consequently, it can be said that between 2013 and 2022, there was an overall increase in the eco-innovation index. The expansion can also be attributed, in significant measure, to advancements in the resource-effectiveness output scale, namely in the effectiveness of emissions of greenhouse gasses, or a reduction in emission levels of greenhouse gases produced in terms of GDP. Nonetheless, the most notable progress was noted in the number of eco-innovation literature, that forms a component of the eco-innovation productivity component (EC, 2022). Eco-innovation is an involved procedure, and the potential for general integration on this shared route is obscured by the notable GDP or employment structure disparities throughout EU member states. According to Colombo et al. (2019), eco-innovation needs to be improved to support equitable growth and economic prosperity. Thus far, eco-innovation has predominantly been conceptualized

as eco-efficiency. The term "eco-innovation" has been described further in the last twenty years, referring to "every aspect of the measures including suitable participants (businesses, politicians, institutions, groups, and that; instead, establish innovative ideas, measures, items, or processes, employ or demonstrate one another, and in turn contribute to a reduction of globally pollution requirements or responsibly stated sustainability objectives" (Rennings, 2000; UNEP, 2021; Terzić, 2023).

Eco-innovation includes innovations in products, processes, and marketing strategies along with enhancements in organizational and interpersonal systems. Therefore, eco-innovation does not always have to be a global first or the result of a deliberate business project or strategy. Therefore, it may argued that an idea that surpasses significant potential regarding ecological benefits qualifies as an eco-innovation (e.g., innovations related to products and services, managerial innovations, long-term viability technologies, and advances in technology in green frameworks) (Fussler & James, 1996; Arundel and Kemp, 2009; EEA, 2023).

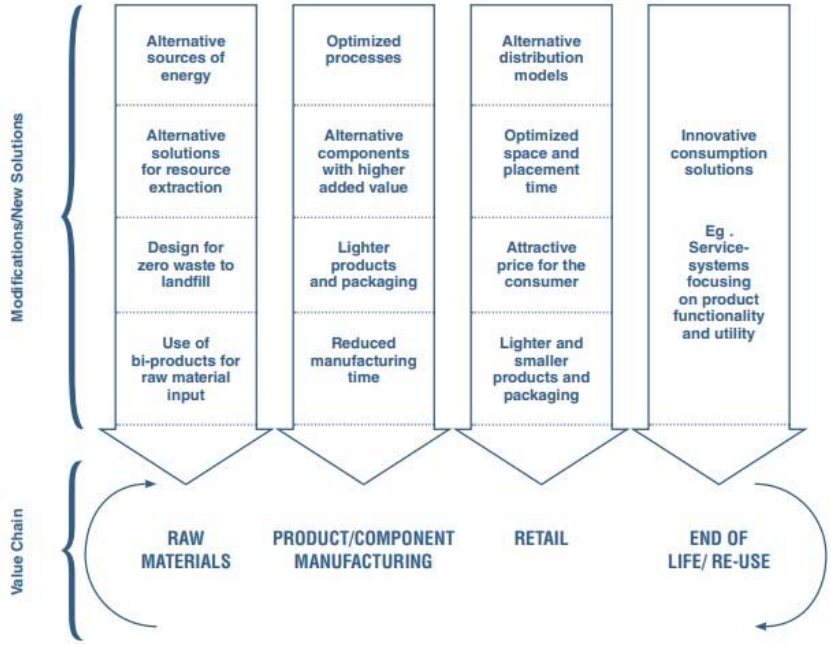
The Eco-Innovation Scoreboard has been implemented using a comparable methodology. According to the European Innovation Observatory (EIO, 2013), eco-innovation is any innovation that genuinely advances the longer-term objective of growth that is environmentally friendly, whether it is through increased efficacy or the careful use of resources to minimize adverse environmental repercussions. This encompasses green technology methods, procedures, and responses, as well as the anticipated and unforeseen environmental implications of novel concepts. The accomplishments of EU nations in eco-innovation are summed up by the Eco-Innovation Index.

The Eco-Innovation Scores ranking may be used to identify the advantages and disadvantages of eco-innovation in each EU country. The Eco-Innovation Scoreboard promotes a holistic view of social, ecological, and economic accomplishments, which complements existing approaches to measuring national innovation (EC, 2022; EIO, 2013). This paper attempts to quantify different aspects of eco-innovation using indicators of resource efficiency outcomes (Horbach et al., 2012; Colombo et al., 2019; Terzić, 2023). Thus, the characteristics that the present study evaluates for European countries are based on the Eco-Innovation Index (EIO, 2013; Jo et al., 2015; Park et al., 2017; EEA, 2023).

The Eco-Innovation Score shows how effectively a country is performing through a variety of eco-innovation elements, making it possible to examine the country's possibilities and drawbacks. The Eco-Innovation Score aims to promote a holistic viewpoint on long-term sustainability in the areas of the economy, society, and environment. Developing a research methodology to measure eco-innovation has been the focus of several scholars (Rennings, 2000; Ekins, 2010; Horbach, 2016; Kiefer et al., 2019; Terzić, 2022; Terzić, 2023). This contributes to the search for new methods of evaluation in the study of economics. Analyzing every link within the eco-innovation and resource efficiency in a product's life cycle includes searching for significant chances for growth and possible revenue streams. After a product expires It gets value as it moves through a life cycle stage or another link in the product chain. Consequently, it's critical to go outside the boundaries of your business's gate and collaborate with other organizations in the value chain to fully realize the promise of eco-innovation. A partnership that is both efficient and prospective in

promoting innovation and environmental sustainability can yield significant mutual advantages in the form of fewer expenses, lower risks, increased productivity, increased revenue, and improved value proposition. Figure 1 presents modifications, new solutions, and benefits from Eco-Innovation along with the value chain.

Figure 1. *Modifications, new solutions, and benefits from Eco-Innovation Resource Efficiency Outcomes along with value chain*



Source: UNEP (2021). The Business Case for Eco-innovation, p. 17.

Improved resilience and increased value can be achieved by finding novel approaches to important environmental, economic, and social issues:

- Improved knowledge-driven benefits, including technological innovations;
- Combined funds from efficiency in operations;
- Distributed costs related to technology support and information sharing; and
- Increased capacity of the company for cooperation and knowledge transfer.

Considering this disparity in the investigation, focusing on eco-innovation and using the techniques used in the Eco-Innovation Score may allow for a comparison of the level of eco-innovation in Europe. The review of the research on theoretical approaches to ascertain and estimate the effects of eco-innovation indicates that, as of right now, there is no accepted measurement or rating methodology. The particular case needs to be suitably tailored because of the intricacy and volume of information involved in the procedures. Conversely, it must ensure that the results of eco-innovation programs are equivalent. The difficulty in measuring the results of eco-innovation is also a result of its correlation with uncertainty. By evaluating eco-innovation at the level of national economies, environmental initiatives may become advanced, and comparative analyses are possible.

The development and implementation of instruments to support green growth particularly depend on eco-innovation prospects (Donis et al., 2021; Arundel & Kemp, 2009; Terzić, 2023). Evaluating eco-innovation also advances our understanding of more general sustainable concerns and raises the consciousness of environmental sustainability. Implementation of eco-innovations faces challenges, as earlier mentioned, primarily due to institutional modifications that include managerial approaches and manufacturing procedures. Furthermore, although there is a great likelihood, there are costs and hazards involved (Porter & Van der Linde, 1995; Cai & Li, 2018; EC, 2023), which reduces the possibility of putting "superior" eco-innovations into practice (Hazarika & Zhang, 2019). Despite a guarantee of profit, labor and capital are required. The Eco-innovation Observatory, or EIO, has been established by the European Commission. The European Innovation Observatory (EIO, 2013) and is a project supported by the European Commission's Directorate-General for Environment. Its goal is to monitor the many forms, intensities, and effects of eco-innovation throughout Europe. Eco-innovation-specific indicators, including:

- The costs (governmental spending on vitality and environmental issues research and development, overall number of investigators, environmentally conscious expenditures of PE/VC funds);
- Activities (businesses incorporating eco-innovations that have an ISO 14001 certification and enhance both energy and material effectiveness);
- The outcomes (inventions, publications, public awareness of eco-innovation).

The following are some indicators of how eco-innovation is affecting the world:

Environmental (raw substances, water, electricity, and carbon emission efficiencies). The term resource efficiency outcomes (Table 2) describes eco-innovation accomplishments that attempt to save assets like water, electricity, and materials while simultaneously lowering the release of Greenhouse Gas (GHS) emissions.

3. Data and research methodology

The European Eco-Innovation Observatory Scoreboard, the nation's database of the European Commission, and other international and scientific communities are among the data sources that were used to generate the parameters. A comparative analysis and synthesis approach based on the Eco-Innovation Index is employed in the study investigation, in addition to a critical examination of the scientific literature. Table 1 presents components of Eco-innovation resource efficiency outcomes along with indicators and data sources.

Table 1. *Components of the Eco-innovation Resource-efficiency outcomes*

Eco-innovation Resource-efficiency outcomes	Indicators	Data sources
Material productivity	Gross Domestic Product /Domestic Material Consumption	Eco-IS, Eurostat
Water productivity	Gross Domestic Product /Water Footprint	Eco-IS, Eurostat
Energy Productivity	Gross Domestic Product /gross inland energy consumption	Eco-IS, Eurostat
Greenhouse Gas emissions intensity	CO2e/Gross Domestic Product	Eco-IS, Eurostat

Source: Author's summary, founded on Eurostat and the European Eco-Innovation Scoreboard.

The word productivity, which is used often, can refer to any kind of activity. It can be defined as the proportion between the number of resources for input taken in or utilized to the proportion of output generated and marketed throughout the particular and examined timeframe. The different system assets and inputs that are utilized to create the outcome are the only input assets under consideration. Materials, electricity, and knowledge are examples of system components, whereas individuals and capital are examples of resource systems. A progress-focused approach to thought articulated through the organization that encourages any number of enterprises to consistently enhance the effectiveness of an organization's operations is how productivity is defined in the fields of economy and society. Efficiency in the areas of energy and water are indicators of a sustainable economy.

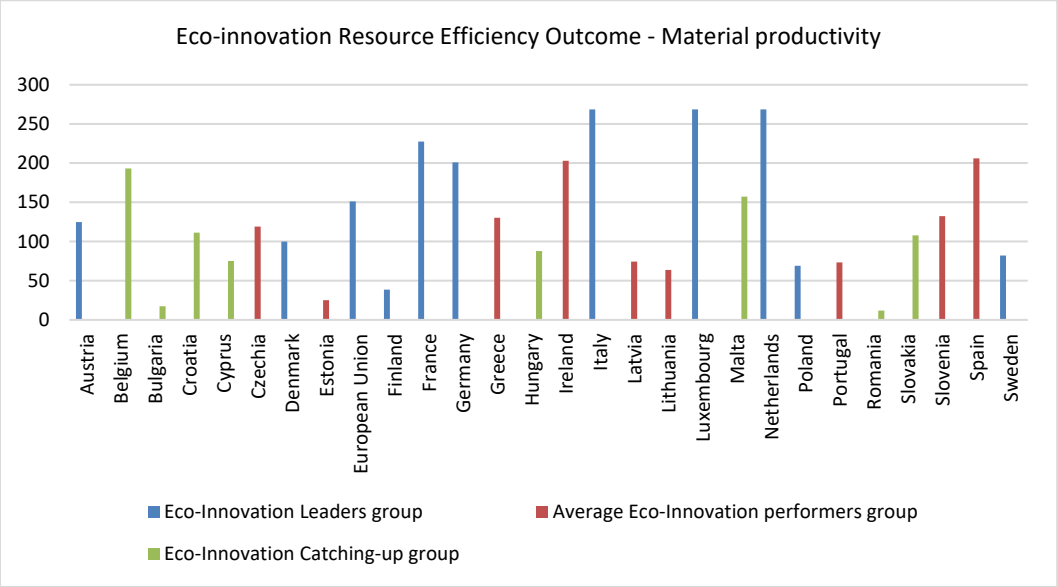
According to EEA (2023), water productivity represents the GDP produced by households' utilization of water, while energy efficiency represents the GDP produced by the domestic utilization of energy. The amount of emissions per GDP level is known as the emission efficiency. An indicator of emissions of greenhouse gases in connection to the extent of an operation or manufacturing process is called the GHG emissions concentration. Utilizing factors including energy consumption, the total amount of animals raised for food, industrial output stages, travel lengths, and comparable company data, this measure can be utilized to evaluate pollutants in the air or releases of greenhouse gases (EC, 2022).

4. Research results

The 27 European Union Member States: Sweden, Spain, Slovenia, Slovakia, Romania, Portugal, Poland, the Netherlands, Malta, Luxembourg, Lithuania, Latvia, Italy, Ireland, Hungary, Greece, Germany, France, Finland, Estonia, Denmark, Czechia, Cyprus, Croatia, Bulgaria, Belgium, and Austria were the countries in which the paper's investigation was conducted. Each member nation's data collection encompasses the years 2021–2022, as well as the expansion of the eco-innovation era from 2013–2022. Utilizing a range of criteria from the Eco-Innovation Index for 2021-2022, Figure 2 shows the eco-innovation resource outcome – material productivity of the EU countries. Policymakers must consider these factors when selecting appropriate strategies and tools for eco-innovation policies, as all EU member states face comparable limitations to eco-innovation. The Eco-Innovation Leaders in the EU according to the material productivity for the year 2021-2022 period are Luxembourg, Netherlands, Italy, France, Germany, Austria, Sweden, Denmark, Poland, and Finland.

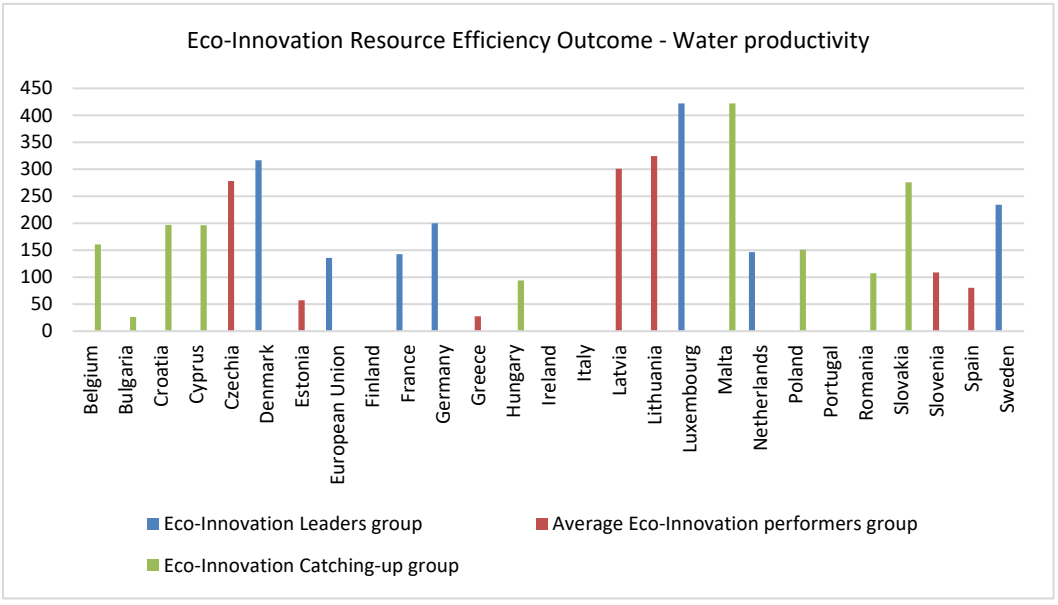
The Eco-Innovation Leaders in the EU according to the material productivity for the year 2021-2022 period are Luxembourg, Netherlands, Italy, France, Germany, Austria, Sweden, Denmark, Poland, and Finland. The eco-innovation performance of the most Eco-Innovation Leaders group is under the EU-27 average score, as shown in Figure 2. EU Member States in the category of catching up with eco-innovation include Belgium, Malta, Slovakia, Croatia, Cyprus, Bulgaria, and Romania. Ireland and Spain are the best-positioned EU nations in the average Eco-innovation performers group. According to material productivity, Romania represents the lowest-positioned country. Figure 3 presents the eco-innovation resource outcome – water productivity of the EU nations.

Figure 2. *Eco-innovation resource efficiency outcome – material productivity in the EU countries for 2021-2022*



Source: Derived from the author using the data from the European Eco-Innovation Scoreboard 2021-2022.

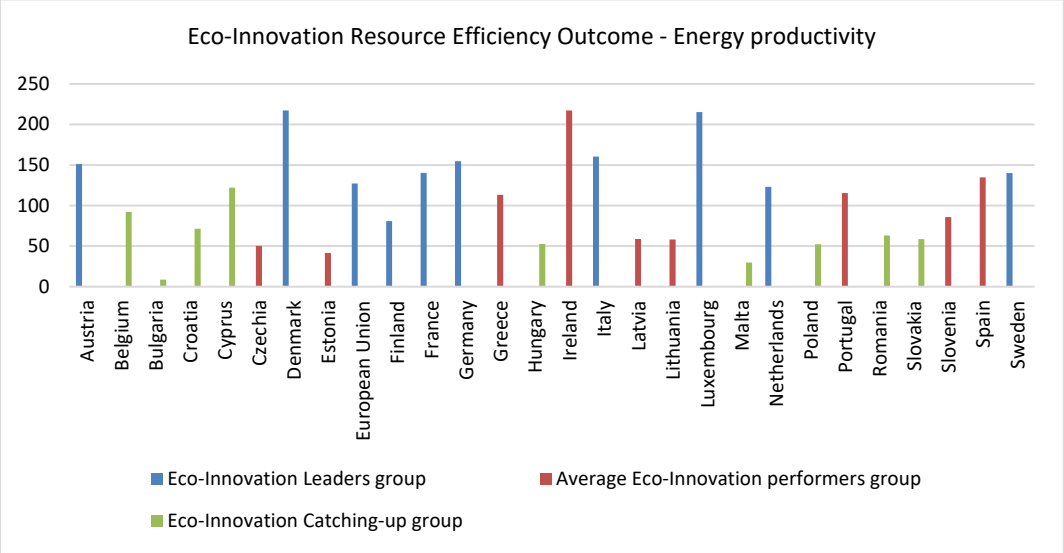
Figure 3. *Eco-Innovation resource efficiency outcome - water productivity in the EU countries for 2021-2022*



Source: Derived from the author using the data from the European Eco-Innovation Scoreboard 2021-2022.

The Eco-Innovation Leader in the EU according to the water productivity for the year 2021-2022 period is Luxembourg. Malta is the best-scored EU nation by water productivity in the Eco-innovation Catching-up group while Bulgaria is the lowest-scored country. In the average Eco-Innovation performer's group, Lithuania and Latvia are the best-positioned countries. Greece, Italy, and Ireland are the lowest-scored positioned EU economies according to water productivity. The indicator is useful for assessing various countries, but it is not a suitable substitution to gauge the advancement of water efficiency because, in nations with resilient GDP growth, the production of value-added will contribute to water productivity, covering up the total quantity of water utilized. Figure 4 shows the Eco-innovation resource efficiency outcome - energy productivity in the EU countries for 2021-2022.

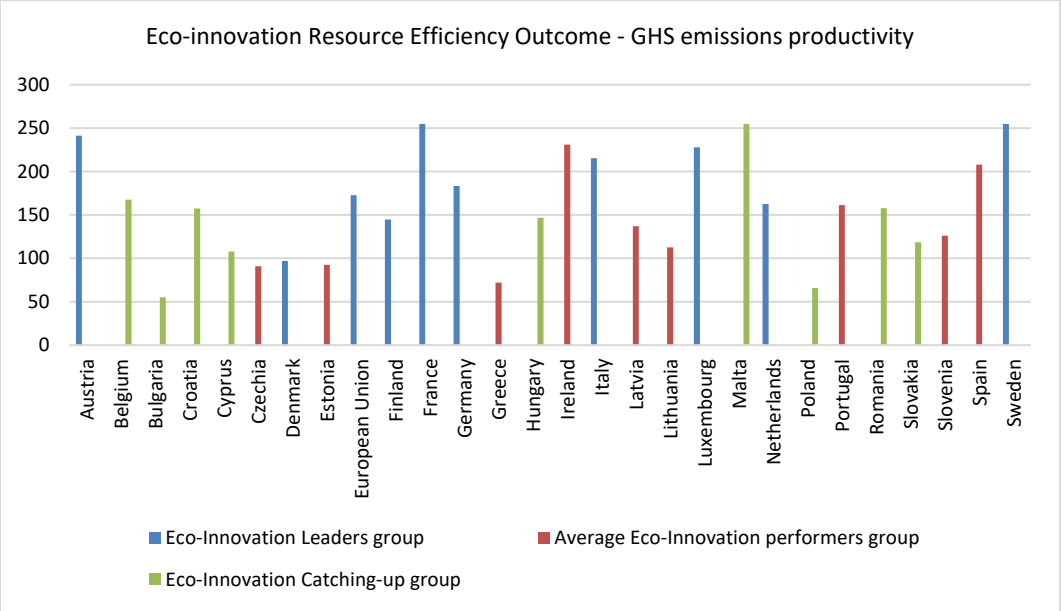
Figure 4. *Eco-innovation resource efficiency outcome - energy productivity in the EU countries for 2021-2022*



Source: Derived from the author using the data from the European Eco-Innovation Scoreboard 2021-2022.

The Eco-Innovation Leaders in the EU according to the energy productivity for the observed period are Denmark and Luxembourg. In the average Eco-Innovation performer's group, Ireland is the best-scored EU country. Greece, Italy, and Ireland are the lowest-scored positioned EU economies according to water productivity. Cyprus is the best-scored EU nation by energy productivity in the Eco-innovation Catching-up group while Bulgaria is the lowest-scored nation. There are various policy problems associated with the shift to a resource-efficient economy, as the European Commission points out. Promoting eco-innovation, enhancing energy efficiency, and raising the percentage of recyclable material should be the main priorities. Decreasing energy use at every stage of the energy supply chain, from production to ultimate consumption, is another way to move toward an increasingly resource-efficient economy. Figure 5 presents the Eco-innovation resource efficiency outcome – GHS emissions productivity in the EU countries for the analyzed period.

Figure 5. *Eco-innovation resource efficiency outcome GHS emissions productivity in the EU countries for 2021-2022*



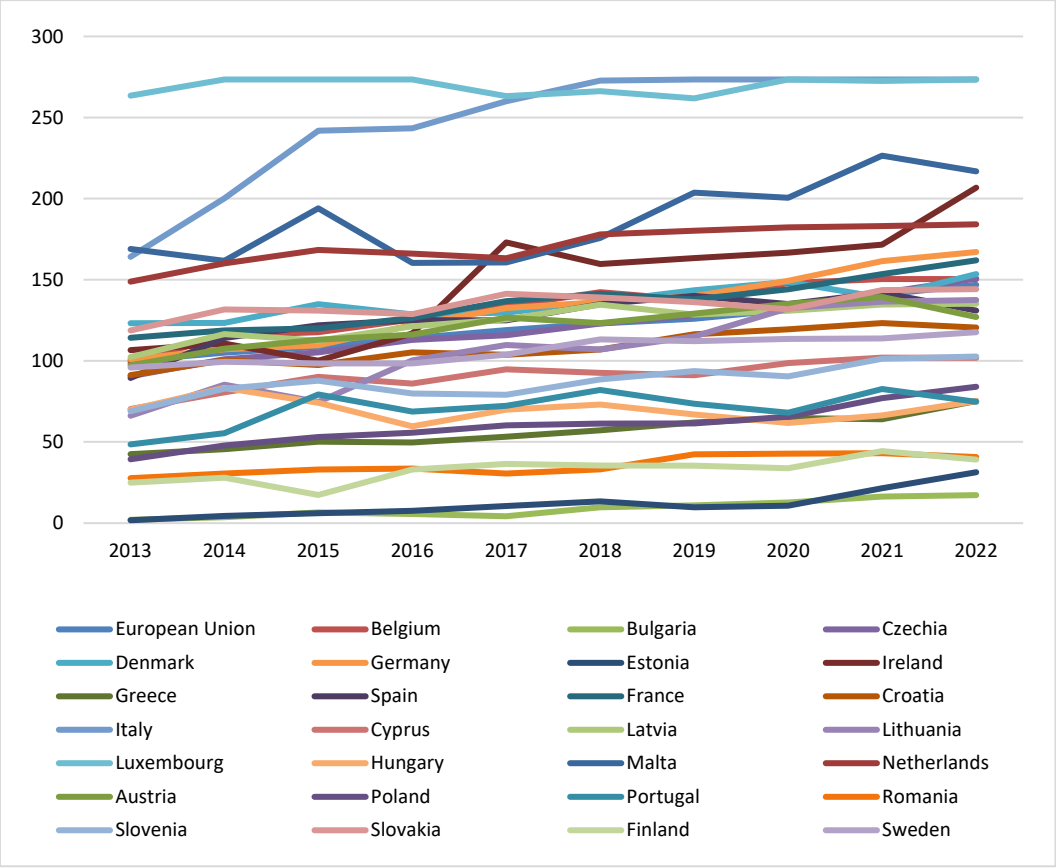
Source: Derived from the author using the data from the European Eco-Innovation Scoreboard 2021-2022.

As shown in Figure 5 Eco-innovation leading economies according to GHS emissions productivity are Sweden, France, Luxembourg, Italy, and Austria. Malta achieved the best score by GHS emissions productivity in the Eco-Innovation Cathing-up group. In the Average Eco-innovation performer's group, Ireland and Spain are the best-scored EU countries by GHS emissions productivity. Enhancing our understanding of the advancement of Europe requires analyzing the evolution of the Eco-Innovation Index during the last decade through the context of European countries. To identify the sectors that still require financing and attention, it is also critical to demonstrate how the eco-innovation indicators have evolved. The following graph 5 illustrates how the overall Eco-Innovation Index Resource Efficiency outcomes for each EU member state have changed over the past decade, between 2013 to 2022.

Luxembourg, Italy, and Malta are the leading EU countries according to Resource Efficiency outcomes for 2013-2022. The Netherlands has improved its eco-innovation performance as compared to 2013 among EU countries in this category. The ten-year trend in the member state scores that are catching up with eco-innovation resource efficiency outcomes is constantly shifting for most of the EU countries, as Figure 6 illustrates. Over the studied time, Bulgaria is the EU member state with the worst achieved resource efficiency outcomes. The extensive use of natural resources has been the driving force behind Europe's economic progress during the past decade. Nonetheless, it now faces several difficulties in promoting expansion while making sure that it is both economically and environmentally sustainable. Sustainability concerns include reduction of materials,

consumption of energy, scarce resources such as water, land constraints, and disposal of waste. The long-term prosperity and general well-being of the European Union are closely associated with the quality of its environment. In the future, the need for resource-efficient and green energy alternatives globally will generate employment and economic growth.

Figure 6. *Trend of the Eco-Innovation Index Resource Efficiency outcomes in the EU countries for 2013-2022*



Source: Derived from the author based on the European Eco-Innovation Scoreboard 2013-2022.

5. Conclusions

The research results showed that in terms of the level of eco-innovation according to the parameters assessed in the EU countries, there is still a considerable difference between the most and least inventive nations. Eco-innovations are innovative strategies for achieving green growth via ecologically conscious businesses that make the most feasible use of natural resources that are already accessible without jeopardizing the sustainability of the planet. Rigorous requirements have been set by the European Union for reducing the detrimental impacts associated with climate transformation. The EU aims to reduce its

greenhouse gas emissions and achieve carbon neutrality. Stakeholders, companies, and governments should all be dedicated to accomplishing these goals and flexible enough to make necessary changes. To be competitive in renewable energy technologies and to achieve carbon neutrality, Europe must adopt eco-innovative policies. Every innovation that moves closer to the goal is considered an eco-innovative activity. After considering the aforementioned, it can be said that the variable of resource efficiency impacts, along with its sub-indicators, have helped achieve the goal of analyzing the differences in the degree of eco-innovation between EU Member States regarding resource effectiveness. The variance in the eco-innovation levels across the EU Member States is not reducing, and as a result, there currently continues to be a significant difference between the highest and lowest innovative economies, according to an examination of the disparity in eco-innovation levels of EU Member states from 2013 to 2022.

The study's findings emphasize how critical it is to advance eco-innovation in EU nations to promote sustainable and environmental consciousness. Utilizing the eco-innovation index including resource efficiency indicators, which are derived from appropriate and objective data, is essential for comparing the achievements of national innovation programs. This could be a crucial component and foundational source that offers quantitative data to understand the level of national eco-innovation in the EU member states. The stakeholders may find useful implications from sorting the index according to subsections when determining how best to encourage eco-innovation in the pursuit of sustainable growth and resource efficiency. Although they offer EU member states nation-specific values that show how successful each country is at the national level on recently highlighted environmental concerns, eco-innovation resource-efficient outcomes are essential components.

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