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Review Paper

OVERVIEW OF INDICATORS FOR ASSESSING ENVIRONMENTAL INNOVATION PERFORMANCE

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Žarko Vranjanac

University of Niš, Innovation Center, Serbia

Abstract. *The European Commission prepared The 2022 European Innovation Scoreboard, which encompasses indicators for assessing innovation performance. The transition to a digital and net-zero economy in the future is generally a key innovation goal for environmental sustainability. This research explores indicators for evaluating innovation performance and their application in the context of environmental protection in both European EU and non-EU countries. The study aims to identify key metrics and assess their effectiveness in measuring innovation within the framework of environmental sustainability. Through a comparative overview, the research seeks to provide insights into how different regions approach innovation in the context of environmental protection.*

Key words: *innovation performance, indicators, environmental sustainability, comparative overview*

1. INTRODUCTION

The New European Innovation Agenda, released in July 2022, marks a pivotal commitment to foster a new wave of technological innovations and start-up's. This visionary agenda places emphasis on entrepreneurial thinking, scientific excellence, the strength of a unified market, and democratic values. Its overarching goal is to enhance access to funding, improve conditions for innovators, facilitate regional networking among innovators, attract and retain talent in Europe, and refine policy-making tools. Complementing this initiative is the European Research and Innovation Framework Programme, Horizon Europe, allocating a substantial budget of 14.3 billion euros for the year 2023 to support projects by researchers and innovators throughout the EU. Furthermore, the Next Generation EU initiative earmarks approximately 44.4 billion euros for research and innovation, focusing on recovery and resilience, particularly in the industrial sector [1]. The updated EU Industrial Strategy

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Corresponding author: Žarko Vranjanac
University of Niš, Innovation Center, Univerzitetski trg 2, 18000 Niš, Serbia
E-mail: zarevranjanac@gmail.com

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proposes new measures to fortify market resilience, reduce dependencies, strengthen Europe's capacity, and preserve strategic values. This concerted effort underscores the EU's commitment to shaping a dynamic and robust innovation landscape [2].

The annual European Innovation Scoreboard (EIS) provides a comparative assessment of the research and innovation performance of EU member states and selected third countries, highlighting the relative strengths and weaknesses of their research and innovation systems. EIS 2022 categorizes activities into four main types: Framework Conditions, Investments, Innovation Activities, and Impacts – across 12 dimensions of innovation (one of the dimensions is environmental sustainability), totalling 32 indicators. Each group comprises an equal number of indicators and carries equal weight in the average performance result, contributing to the overall Summary Innovation Index (SII). Within the EIS, according to the SII methodology, there are four levels of country classification regarding innovation performance, composing the European innovation landscape (Figure 1) [3]:

1. Innovation Leaders (dark green): Countries with innovation performance significantly above the EU average (>125%). This category includes Belgium, Denmark, Finland, the Netherlands, and Sweden.
2. Strong Innovators (light green): Countries with innovation performance above the EU average (100-125%). This category includes Austria, Cyprus, France, Germany, Ireland, and Luxembourg.
3. Moderate Innovators (yellow): Countries with innovation performance below the EU average (70-100%). This category includes the Czech Republic, Estonia, Greece, Italy, Lithuania, Malta, Portugal, Slovenia, and Spain.
4. Emerging Innovators (orange): Countries with innovation performance significantly below the EU average (<70%). This category includes Bulgaria, Croatia, Hungary, Latvia, Poland, Romania, and Slovakia.

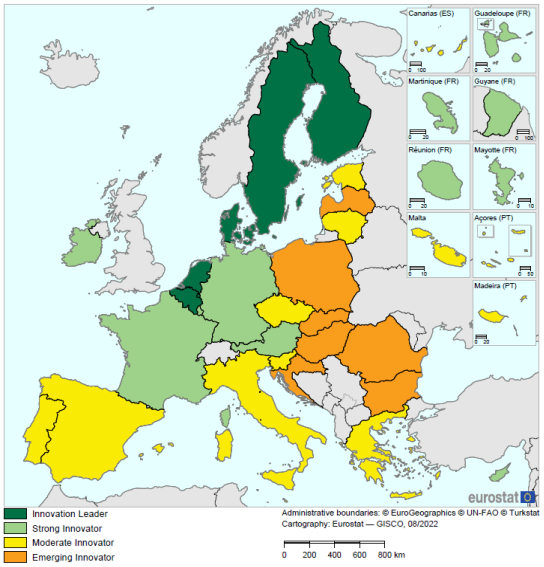

Fig. 1 European innovation landscape
Source: EIS, 2022

On a global scale, Australia, Canada, South Korea, and the United States outperform the EU in terms of innovation. The EU holds an advantage over Brazil, Chile, China, India, Japan, Mexico, and South Africa. Non-EU countries exhibit the following innovation performances: Switzerland is an innovation leader in Europe, while Iceland, Norway, and the UK are strong innovators. Israel falls into the category of moderate innovator, whereas Serbia (SII 61.8%), Bosnia and Herzegovina, Montenegro, North Macedonia, Turkey, and Ukraine are considered emerging innovators [3].

As the world environmental challenges including biodiversity loss, pollution, and the impacts of climate change, the connection between innovation performance and the environmental sustainability, and consequently socio-economic well-being, becomes increasingly crucial. In fact, businesses, public sector entities (public utilities), and researchers are experiencing heightened demands to develop innovations that not only yield environmental benefits but also address broader societal challenges. European Green Deal and the Recovery Plan for Europe, underscore the necessity for the EIS to acknowledge the pivotal role of research and innovation in tackling pressing environmental issues. The following will explore the possibilities of application and existing indicators of innovation performance linked to environmental sustainability.

2. ENVIRONMENTAL INNOVATION

In literature, there is a wide range of different approaches to defining environmental (eco) innovation, which have been analysed within various studies. Systematized definitions of environmental innovation are presented in Table 1 [4].

Table 1 Systematized definitions of environmental innovation

Author	Definition
Kemp and Pearson (2007)	„*eco-innovation as the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives*“
The Community Innovation Survey (2008)	*„a new or significantly improved product (good or service), process, organizational method or marketing method that creates environmental benefits compared to alternatives”*
Reid and Miedzinski (2008)	„*eco-innovation encompasses novel or significantly improved solutions introduced at any stage of the product life-cycle with the aim of improving resource productivity or reducing environmental impact*“
UNEP (2014)	„*the development and application of a business model, shaped by a new business strategy, which incorporates sustainability throughout all business operations based onlife cycle thinking and in cooperation with partners across the value chain*“
UNIDO (2015)	„*products that reduce their overall life-cycle environmental impacts by favouring reparability, disassembly, recyclability and recoverability*“
Sun Park et al (2017)	*„all efforts from relevant actors that introduce, develop, and apply new ideas, behaviours, products and processes and contribute to reducing environmental burdens or ecologically specified sustainability targets“*
EEA (2019)	*„crucial for the transition towards a lowcarbon, resource-efficient and circular economy, but at the same time rebound effects may limit the reduction in environmental pollution”*

Source: Author, based on Cvijanović et al, 2021

The effects of environmental innovation can be examined on different scales, including the organizational (micro) level, industry or regional (meso) level, and the macro level encompassing the national economy or national system [4]. Kemp et al. (2019) identify various types of environmental (eco-)innovation, encompassing process eco-innovation, product eco-innovation, organizational eco-innovation, business model eco-innovation, marketing eco-innovation, social eco-innovation, and systemic eco-innovation [5]. Environmental innovation is commonly linked to favorable outcomes. Nevertheless, caution is warranted, as such innovations may be susceptible to rebound effects, leading to adverse consequences such as impacts on health and increased pollution. The positive gains linked to environmental innovation may be at risk of being surpassed by an increased consumption of natural resources, leading to a net escalation of negative effects at the societal level. This underscores the need for careful consideration when creating, implementing, and measuring such innovations. Considering their positive environmental impact, there is indisputable evidence that their contribution can be crucial for socio-economic progress [6]. The features of environmental innovations highlight several indicators that must be taken into account to capture the comprehensive context.

3. INDICATORS OF ENVIRONMENTAL INNOVATION PERFORMANCE

The categorization of world-countries in relation to their innovation and eco-innovation status relied on three comprehensive indicators: SII, the Global Cleantech Innovation Index (GCII) and the Eco-Innovation Index [7]. GCII, developed by United Nations Industrial Development Organization (UNIDO), investigates the countries with the highest potential to foster the emergence of entrepreneurial CleanTech start-ups that will bring clean technology innovations to the market in the next decade. Historically, the focus of this assessment has been on 40 countries. The Eco-Innovation Index, devised by the Eco-Innovation Observatory (EIO), represents an initiative funded by the European Commission's Directorate-General for the Environment [4]. Kemp et al. (2019) suggest a streamlined causal chain for eco-innovation impact. These factors fall into three groups: 1) Framework conditions and capacity for environmental innovations are shaped by; 2) investments on one side and 3) environmental innovation activities on the other, both capable of generating environmental (innovation) impacts [5]. OECD and Eurostat indicators of environmental innovation are successfully and most frequently utilized for measuring innovations in numerous studies, such as those related to the circular economy [6,8,9]. In order to make a selection and obtain the most accurate representation, EIS initially utilizes a large number of contextual indicators from relevant institutions such as Eurostat, the European Environment Agency (EEA), and others. These indicators serve as justification and support for the final set of innovative dimensions. For example, in the field of climate change and the circular economy, the following indicators are used: Circular material use rate, Greenhouse gas emissions intensity of energy consumption, and Eco-Innovation Index [7]. Within the EIS 2022, the twelfth dimension of innovativeness is environmental sustainability (within Impacts), captures improvements to reducing the negative impact on the environment including three indicators (the explanation of indicators is provided in Table 2) [10]:

1. Resource productivity
2. Air emissions by fine particulates PM2.5 in Industry
3. Development of environment-related technologies

Table 2 Explanation of EIS 2022 environmental sustainability indicators

Indicator	Explanation	Source
Resource productivity	The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy. Resource productivity is expressed by the amount of GDP generated per unit of direct material consumed, i.e. GDP/DMC in euros per kg.	Eurostat: Resource productivity [env_ac_rp] Most recent year: 2020
Air emissions by fine particulates PM2.5 in Industry	Air pollution can originate either from human activities (anthropogenic) or natural sources. It has the potential to adversely affect both human health and the environment. Particulate matter (PM), nitrogen dioxide, and ground-level ozone are identified as pollutants that pose significant health risks. Prolonged and high exposures to these pollutants may contribute to various health issues, including cardiovascular and respiratory diseases, as well as an elevated risk of cancer. This indicator measures the average concentration levels of fine particulate matter (PM2.5), which consists of particles with a diameter of 2.5 micrometers or less, representing the exposure of the population. The European Union has established an annual limit of 25 μg/m³ for fine particulate matter in Directive 2008/50/EC on ambient air quality and cleaner air. Additionally, the World Health Organization (WHO) has set a more stringent, though non-binding, guideline value stating that annual mean concentrations should not exceed 10 μg/m³ to safeguard human health.PM2.5 is acknowledged by the WHO as the pollutant with the most significant impact on human health. Air emissions by fine particulate matter (PM2.5) in the Manufacturing sector in Tonnes.	Eurostat, Air emissions accounts [env_ac_ainah_r2] Most recent year: 2019
Development of environment-related technologies	The percentage of domestic inventions across all technologies that are specifically related to the environment is calculated to determine the number of environment-related inventions. Indicators for technology development are created by assessing inventive activities through patent data in various environmental technological domains, such as environmental management, water-related adaptation, and climate change mitigation technologies (ENVTECH27). The counts considered in this analysis include only higher-value inventions, defined by a patent family size of two or more. The data utilized for this analysis are sourced from the Patents: Technology development dataset within the OECD Environment Database. Number of environment-related inventions.	OECD Green Growth database Most recent year: 2019

Source: Author, based on EIS 2022

Figure 2 depicts the innovation performance of EU Member States in 2022 concerning indicators related to environmental sustainability. The shaded columns represent the performance of Member States in 2022, utilizing the latest available data for the indicators in this dimension, compared to the performance of the EU in 2015. The horizontal hyphens indicate the performance in 2021, using the subsequent most recent data for the indicators in this dimension, relative to the EU performance in 2015. The grey columns illustrate the performance in 2015 relative to that of the EU in the same year [3].

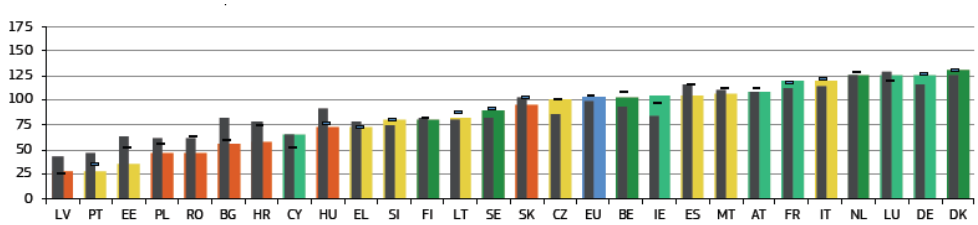

Fig. 2 Environmental sustainability innovation performance in EU countries in 2022 Source: EIS, 2022

The group of the top 5 best-performing countries consists of two Innovation Leaders, namely Denmark-DK (the overall best-performing Member State) and the Netherlands-NL, along with two Strong Innovators, Germany-DE and Luxembourg-LU, and one Moderate Innovator, Italy-IT. Notably, two Innovation Leaders, Finland-FI and Sweden-SE, exhibit performance levels below the EU average. Among the Strong Innovators, five surpass the EU average, while Cyprus-CY falls below it. Among the Moderate Innovators, three perform above the EU average, whereas six perform below it. All Emerging Innovators perform below the EU average, with Slovakia-SK being the closest to the EU average. Between 2015 and 2022, the performance has shown an increase for 12 Member States, with the highest rate observed in Ireland-IE (20.0%-points) and Czechia-CZ (15.2%-points). On the contrary, performance declined for 15 Member States, notably in Estonia-ES (29.4%-points), Bulgaria-BG (26.6%-points), and Croatia-HR (20.5%-points). The overall EU average experienced an increase of 2.6%-points. Comparing to 2021, performance increased for 11 Member States, particularly in Cyprus (13.6%-points). Conversely, 16 Member States witnessed a decline in performance, with the most significant drops seen in Estonia (17.4%-points), Romania-RO (14.8%-points), and Croatia (14.6%-points). The EU average saw a decrease of 1.4%-points [3,4,10].

Benchmarking environmental innovation performance with non-EU countries is challenging due to the unavailability of data, variations in data quality, and inconsistency, resulting in a different landscape in different countries outside the EU. Nevertheless, some data has managed to crystallize as standard, given that within the EIS 2022, innovation profiles for 1216 countries are considered using the same methodology but with limitations in terms of availability, scope, and data quality. Switzerland (CH) emerges as the top-performing country in Europe, surpassing all EU Member States. Notably, Switzerland achieves the highest performance in the Resource Productivity indicator (193.7% relative to EU in 2022). The Environmental Sustainability dimension in Switzerland is 123.3%, while Air Emissions by Fine Particulate Matter is 127.6%, both relative to the EU in 2022. The United Kingdom is designated as a Strong Innovator, showcasing the highest

level of performance in Resource Productivity, matching the value of CH. Several countries classified as Emerging Innovators exhibit the highest performance in at least one environmental sustainability indicator. For instance, Albania and Bosnia and Herzegovina (both, 190.8% relative to EU in 2022) excel in the indicator of Environment-Related Technologies.

When it comes to Serbia's innovation profile, with environmental sustainability performance standing at 27%, Serbia is unequivocally categorized as an Emerging Innovator. Relative weaknesses are observed in the Air Emissions by Fine Particulate Matter indicator, with a value of 0.0%, marking the lowest score in this dimension and alarmingly the lowest value across all 32 indicators in all 12 innovation dimensions. Additionally, the Resource Productivity indicator records an extremely low value of 3.1% relative to the EU in 2022. Based on the Environment-related technologies indicator, with a value of 91.6% relative to the EU in 2022 (Moderate Innovator).

4. CONCLUSION

The European Innovation Scoreboard serves as a comprehensive tool, evaluating the research and innovation performance of EU member states and selected third countries. With 32 indicators spanning four main activity types, EIS offers a nuanced perspective on the strengths and weaknesses of innovation systems. The classification of countries into four innovation performance levels creates a clear European innovation landscape.

Within the environmental sustainability dimension, EIS 2022 introduces three key indicators: Resource Productivity, Air Emissions by Fine Particulates PM2.5 in Industry, and Development of Environment-Related Technologies. The top-performing countries showcase diverse profiles, with Innovation Leaders (Denmark, Netherlands), Strong Innovators (Germany and Luxembourg) and one Moderate Innovator pack (Italy) leading the. Analyzing the trend between 2015 and 2022 reveals noteworthy shifts in performance among Member States. Ireland and Czechia stand out with substantial improvements, while Estonia, Bulgaria, and Croatia face significant declines.

The benchmarking of environmental innovation with non-EU countries poses challenges, yet standardized data for 1216 countries highlights disparities and opportunities. Switzerland emerges as the overall best-performing country in Europe, particularly excelling in Resource Productivity. The United Kingdom mirrors this strength as a Strong Innovator. Notably, Emerging Innovators like Albania and Bosnia and Herzegovina demonstrate excellence in specific environmental sustainability indicators.

Serbia, identified as an Emerging Innovator, exhibits promise in environmental sustainability but grapples with challenges, notably registering the lowest value in the Air Emissions by Fine Particulate Matter indicator. This underscores the need for improvement and increased investment, particularly in addressing low-performing indicators. The current structure of the study provides a comprehensive overview and lays the foundation for a more in-depth exploration of innovative indicators and their significance. This exploration is crucial for advancing overall environmental sustainability and elevating Serbia's country profile.

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PREGLED POKAZATELJA ZA PROCENU INOVACIONIH PERFORMANSI ŽIVOTNE SREDINE

Pokazatelji za procenu inovacionih performansi sadržani su u okviru Evropskog pregleda inovacija za 2022. godinu, pripremljenog od strane Evropske Komisije. Tranzicija ka digitalnoj i neto nultoj ekonomiji u budućnosti, generalno predstavlja ključni inovacioni cilj za održivost životne sredine. Ovo istraživanje istražuje pokazatelje za evaluaciju inovacionih performansi i njihovu primenu u kontekstu zaštite životne sredine kako u EU, tako i u evropskim državama koje nisu članice EU. Cilj studije je identifikacija ključnih indikatora i procena njihove efikasnosti u merenju inovacionih performansi u okviru održivosti životne sredine. Komparativni prikaz, ima za cilj pružanje uvida u to kako različite države pristupaju inovacijama u kontekstu zaštite životne sredine.

Ključne reči: *inovacione performanse, indikatori, održivost životne sredine, komparativni prikaz*