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# Eco-innovation in the European Union: Challenges for catching-up economies

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**ABSTRACT**

**Objective:** The objective of the article is to examine the eco-innovation performance of the EU countries measured by the Eco-Innovation Index and identify the key areas for improvement for the EU members with relatively low scores.

**Research Design & Methods:** The research methods include the literature study, the analysis of documents, and the comparative analysis of statistical data collected from the eco-innovation scoreboard database with the use of descriptive statistics, correlation index, and cluster analysis. The comparative analysis covered selected eco-innovation indicators and sub-indicators for nine catching-up economies compared to the leading countries and the EU average.

**Findings:** The results show that despite the fact that almost all economies from the group of catching-up eco-innovators made progress in terms of their overall eco-innovation performance, albeit they were unable to significantly reduce the innovation gap between them, and the leading countries and their classification based on relative results remained unchanged in the recent decade. This suggests that more effort, focused especially on specific thematic areas, is needed for these countries to make bigger progress and to move up to the average eco-innovation performers and even to the leading eco-innovators. The strongest correlation between the value of the Eco-Innovation Index and the value of a given subindex suggests that the main areas for improvement are: total R&D personnel and researchers, eco-innovation-related patents, energy productivity and implementation of sustainable products among SMEs, but all of the areas covered by subsequent subindexes need attention.

**Implications & Recommendations:** Taking into consideration the fact that eco-innovations are important tools for achieving sustainable development goals, the results of the study may provide important guidance for policy-makers in the area of innovation policy and sustainable development, especially in economies classified as 'catching up with eco-innovation.'

**Contribution & Value Added:** By focusing on the eco-innovation gap between the countries leading in this respect and those catching up, we have identified the key areas that require significant improvement, looking from the perspective of countries currently achieving relatively weak results in individual dimensions of eco-innovation and striving to improve their innovation performance.

| | |
|---|---|
| **Article type:** | research article |
| **Keywords:** | eco-innovation; Eco-Innovation Index; the European Union; catching-up eco-innovators; eco-innovation inputs; eco-innovation activities; environmental protection |
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## INTRODUCTION

Innovation is the main and increasing source of growth and development for national and regional economies. A specific type of innovation, which is eco-innovation, currently plays a key role in transforming societies towards sustainable development, combining reduced negative impact on the environment with a positive impact on the economy and society (European Commission, 2011; Piwowar-

Sulej & Podsiadły, 2022). Innovation in general and eco-innovation, in particular, contribute to the achievement of Agenda 2030 Sustainable Development Goals, not only by being one of the three aspects of sustainable development (together with infrastructure and industry) explicitly mentioned the SDG 9, but also through providing scientific and technological solutions to the challenges posed by other SDGs (United Nations, 2015). At the same time, many researchers point to the link between innovation and the competitiveness of economies, arguing that innovations are a way to enhance competitiveness, as they enable enterprises to adapt quickly to the pace of the technological change and to market trends (Ervits, 2020; Wach & Głodowska, 2022; Apostu & Gigauri, 2023), in order to gain a competitive advantage and increase competitiveness (Ciocanel & Pavelescu, 2015; Sułkowski & Stopczyński, 2018; Naglova *et al.*, 2017). Eco-innovation, as one of the leading areas of innovation, is an important path to increasing the competitiveness of economies and ensuring more sustainable development (Chmielewska & Sławiński, 2021; Richterova *et al*., 2021a; Urbaniec, 2015; Doyle & Perez-Alaniz, 2017). Therefore, the issue of eco-innovation has aroused great interest in recent years and is often taken up by researchers and taken into account by politicians in their decision-making processes.

Eco-innovation potential must be addressed at the global, regional, national, and local levels, it is also at the heart of the European Union's policies. In order to properly shape the policy in this area, it is necessary to measure the level of innovation, while taking into account its various determinants. Measuring multiple dimensions of eco-innovation performance of the EU countries using the methodology of Eco-Innovation Index (EII), allows us to better understand its key trends of eco-innovation and main drivers. It helps to build up a better picture of the necessary framework conditions creating eco-innovation. It also reveals the gap between the leading eco-innovators and the countries lagging behind in terms of eco-innovativeness (Al-Ajlani *et al*., 2021), which may be a starting point for the latter to achieve improvement in this area.

The objective of the article is to examine the eco-innovation performance of the EU countries measured by the Eco-Innovation Index and identify the key areas for improvement for the EU member states classified as 'catching up with eco-innovation.'

Taking into account various aspects of eco-innovation activity, we formulated the following research questions:

**RQ1:** What are the latest results of eco-innovation performance in the catching-up EU countries in comparison with the EU average and with the European countries leading in terms of eco-innovation?

**RQ2:** Does the gap between leading and catching-up countries in terms of eco-innovation tend to narrow or increase?

**RQ3:** In what areas of eco-innovation performance have the catching-up countries achieved relative improvement in recent years, and in what areas do they need more effort to make progress?

By attempting to provide answers to the above questions, our study was expected to contribute to the research problem, through focusing on the specific problems of countries with a lower level of eco-innovativeness and revealing the scale of the challenges, but also the opportunities for these countries related to creating conditions for the development of eco-innovations. We believe that the results of the study may provide important guidance for policymakers in the area of innovation policy and sustainable development, especially in economies that strive to improve innovation performance. It should also contribute to a better understanding of the role of innovation, and in particular eco-innovation in ensuring sustainable development, by business and broader society.

## LITERATURE REVIEW

Eco-innovations contribute to mitigating the negative effects of economic growth on the environment, thus playing a crucial role in building a sustainable economy. The concept of eco-innovation addresses a reduction in negative environmental impacts and the more efficient use of resources (Horbach, 2019; Urbaniec, 2018). Eco-innovation can be considered a category of innovation, located at the junction of innovation policy and environmental protection policy, combining innovation and sustainable development (Barbieri *et al*., 2016; Horbach & Reif, 2018; Richterová *et al.,* 2021b; Androniceanu & Sabie, 2022). At the same time, eco-innovation is an integral part of the concept of eco-entrepreneurship, allowing enterprises to generate revenue by solving environmental problems.

One of the first definitions of eco-innovation was proposed by Fussler and James (1996), for whom it is 'new products and processes which provide customer and business value but significantly decrease environmental impacts' (as cited in James, 1997, p. 53). Any such innovation contributes to sustainable development by commercially applying knowledge to engender direct or indirect environmental improvements.

Rennings (2000) broadly defines eco-innovation as '[a]ll 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' (p. 322). According to the author, the distinctive feature of eco-innovation as compared to innovation in general is a concern about the direction and content of progress, in particular concern about whether innovation leads to the mitigation or resolution of an environmental problem (Musaev *et al*., 2023; Tran, 2022).

Andersen (2008) argues that eco-innovations are 'innovations which are able to attract green rents on the market' (p. 5). For Kainrath (2011) eco-innovation is one of the three subconcepts of ecopreneurship, along with eco-opportunities and eco-commitment. An ecopreneurial rent arises from the exploitation of an eco-opportunity, often through creating and implementing eco-innovations. The eco-commited ecopreneur, who first seizes a new opportunity, not only achieves entrepreneurial rents because of the lack of competition, but also alleviates an environmental burden (Dean & McMullen, 2007).

Eco-innovation can also be understood more comprehensively as an entrepreneurial procedure, covering the stage of product design and integrated management throughout its life cycle, which affects pro-ecological modernization of the economy and society by taking into account environmental problems and laws when developing products and the related processes (Kemp & Pearson, 2007; Sobczak, Głuszczuk, & Raszkowski, 2022). Environmental innovation leads to integrated solutions whose aim is to reduce resource and energy inputs while improving the quality of a product or service.

Due to their importance in ensuring sustainable development (Kowalska & Bieniek, 2022), issues related to eco-innovation are of interest to both EU institutions and international organisations. The EU's *Competitiveness and Innovation Framework Programme 2007-2013* (CIP), announced in 2007, defines eco-innovation as 'any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of resources, including energy (European Parliament & Council, 2006, p. 17).

There are many ways to create innovations, including ecological innovations. The basic types of eco-innovation distinguished in the literature include:

– product innovation: the creation or implementation of new or significantly improved products (goods and services) with the main aim to reduce negative environmental impacts. This goal can be achieved, for example, by minimising material intensity throughout the product life cycle, increasing the possibility of repairing or remanufacturing products, increasing the share of recyclable materials, etc.;

– process innovation: the use of more environmentally friendly production methods, including methods of product delivery. It can lead to the reduction of negative impacts on the environment through, *e.g.,* cutting down the emission of pollutants like greenhouse gases (GHGs) that cause climate change, the reduction of electricity consumption, noise, or the use of materials and raw materials;

– organisational innovation: implementation of new organisational structures, advanced management techniques or new or substantially changed corporate strategic orientations to manage the environmental aspects of processes and products.

– marketing innovation: new marketing activities involving significant changes in product positioning, promotion, distribution, or pricing policy in accordance with the principles of green marketing. The overarching goal in this case is to look for ways to encourage customers to purchase, use, or implement eco-innovations (Sarkar, 2013; Nnaji & Igbuku, 2019).

A broad approach to the eco-innovation concept was proposed by Kemp and Pearson (2007). The authors understand innovation as assimilation or exploitation of a product, production process, service or management or business method that it is novel to the firm or user and argue that eco-innovation includes not only innovation aimed at reducing environmental impacts, but also cases where innovation leads to a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use), without this being an explicit aim. In that sense, general innovations which have positive environmental effects are also counted as eco-innovations. Similarly, according to Sarkar (2013), eco-innovations can be divided into two categories: environmental innovations and non-environmental innovations. In terms of sustainable development, environmental innovations have gained particular importance.

Scarpellini, Valero-Gil, and Portillo-Tarragona (2016) provided an overview of different contributions to the theoretical background of eco-innovations. The researchers assumed that the eco-innovation can be defined taking into account various research perspectives: methodology and measurement, business strategy and firms' setting approach, and innovative projects.

An extended typology of eco-innovation has been proposed by Andersen (2008), which reflects the diverse roles of eco-innovation in 'greening' the market. On this basis, the author distinguishes five types of eco-innovation: (i) add-on eco-innovations; (ii) integrated eco-innovations; (iii) alternative product eco-innovations; (iv) macro-organisational eco-innovations; (v) general-purpose eco-innovations.

Obviously, eco-innovation includes not only the latest technological developments that can make a significant contribution to sustainable development, but also all environmentally friendly ideas and innovations of a non-technological nature (Hazarika & Zhang, 2019; Arranz *et al*., 2020; Zaušková & Rezníčková, 2020).

An organisation characterised by eco-innovation can create and implement innovation, taking into account macro and microenvironment factors and trends and internal organisational determinants (Rodríguez-Rebés, Navío-Marco, & Ibar-Alonso, 2021). Companies can be eco-innovative and pursue sustainable development goals in various ways. They can undertake activities aimed at making profit from pro-environmental activities, such as recycling and waste disposal, contaminated land reclamation, pollution control, water management, environmental consulting services, or organic farming. This is the business model specific to green entrepreneurs who have high environmental awareness and strong eco-commitment and often operate in the sector of environmental protection. They can often exploit eco-opportunities that others don't see or perceive as marginal or uninteresting and this can lead to more radical innovations. However, companies from other sectors can also exploit eco-opportunities by introducing eco-innovations. Thus, whilst striving for better eco-efficiency of goods produced or services offered, they are simultaneously focused on reducing the use of environmental resources or reducing their negative impact on the environment. The activities of this group can also contribute significantly and at the same time profitably to sustainable development goals. This is also the case when the motive for their eco-investment activity is only the pursuit of compliance with the provisions of environmental law or principles, or the desire to minimize costs that may be caused by the deterioration of the company's image, which may be arising from disregarding environmental concerns (Kainrath, 2011).

The improvement of innovation performance of companies leads to increasing of national competitiveness (Ciocanel & Pavelescu, 2015; Świadek *et al.,* 2022) and to ensuring progress towards sustainable development. At a European level, investing in eco-innovation is considered essential to ensure Europe's global leadership in creating a resource-efficient society. The EU's 8th Environment Action Programme represents the determination of the EU to accelerate the green transition and it also includes a framework of 34 'enabling conditions' for achieving the European Green Deal's objectives, with the Eco-Innovation Index (measuring Member States' performance in terms of eco-innovation compared to EU average (EU = 100) and trend) being one of them (European Commission, 2022a, p. 7).

Eco-innovation is considered a powerful instrument to protect the environment with a positive impact on the economy and society and is at the core of various European policies. At the same time, a number of studies reveal a clear divergence in the European Union, in terms of overall innovation performance and eco-innovation performance of its member states (Sobczak, Głuszczuk, & Raszkowski, 2022; Al-Ajlani *et al*., 2021; Ostraszewska & Tylec, 2019). To a great extent, performance factors, like business innovations and business sophistication depend on institutional environment for innovations development, including eco-innovations support within social responsibility programs (Oliinyk *et al.,* 2023). The positive effect of the responsible institutional surrounding can be observed in support of eco-innovations in certain business activities, like social entrepreneurship (Okuneviciute Neverauskiene & Pranskeviciute, 2021) or agriculture with the attempts to mitigate the environmental threats (Piwowar, 2020). Based on the eco-innovation performance of the EU countries measured by the Eco-Innovation Index, the EU member states were divided into three equally sized performance groups: the Eco-Innovation Leaders (the top-9 EU countries), the average eco-innovation performers (the 10th to 18th ranked countries), and the countries catching-up with eco-innovation (the 19th to 27th ranked countries) (European Commission, 2022b). There is a commitment in the European Union towards reducing the persistent innovation gap between the eco-innovation leaders and the countries catching-up with eco-innovation. Unlocking excellence in countries lagging behind can boost competitiveness and increase the rate of economic growth in the entire European Union (Androniceanu & Georgescu, 2023). However, this requires greater involvement both at the level of the EU and individual Member States and the use of special measures. It also requires continuous monitoring of progress on eco-innovation performance as well as improvement of methods for measuring eco-innovativeness and identifying areas requiring improvement, which is an important and current task for researchers dealing with this subject.

## RESEARCH METHODOLOGY

The objective of the study was to examine the eco-innovation performance of the EU countries measured by the Eco-Innovation Index and identify the key areas for improvement for the EU members with a relatively low score.

The quantitative approach was applied to examine the mentioned problem and provide answers to research questions. The analysis was based on statistical data collected from the Eco-innovation Scoreboard and European Innovation Scoreboard databases. The spatial scope of the research covered all EU Member States, although the analysis focused primarily on the category of nine countries 'catching up with eco-innovation,' which include Bulgaria, Croatia, Cyprus, Hungary, Lithuania, Malta, Poland, Romania, and Slovakia. The analysis period covered the period from 2012 (the end of the financial crisis in the EU) to 2021 (the last year of availability of data before the EII structure changes). The addressed gap between the studied groups of countries needs to be observed over a long-term period.

We used descriptive statistics, Pearson correlation coefficient, Euclidean distance, and Ward's agglomerative hierarchical clustering method to achieve the article's goal. Descriptive statistics were applied to characterize the featured groups of EU countries and indicate the existing disparities between them and their intra-group variation. We adopted the division of countries into groups proposed by the European Commission and conducted analysis based on their performance recorded in the European eco-innovation scoreboard 2021. Euclidean distance was used to determine the gap between the EU-27 average score, EU Eco-Innovation Leaders group and the catching-up countries. To track the progress, compare the results of Member States, and classify them according to their achievements in terms of eco-innovation, the value of the summary Eco-Innovation Index and its 16 sub-indicators aggregated in five composite indicators were analysed. The thematic areas include: 1) eco-innovation inputs; 2) eco-innovation activities; 3) eco-innovation outputs; 4) eco-innovation resource efficiency outcomes; 5) eco-innovation socio-economic outcomes (Table 1).

In order to identify factors that can reduce the gap between the eco-innovation performance between the catching-up countries and the rest of the EU, special attention was paid to data on two indicators that are more related to base conditions and efforts (rather than to results) of eco-innovation:

– Eco-innovation inputs that comprise investments (financial or human resources) aiming to trigger eco-innovation activities;

– Eco-innovation activities include indicators to monitor the scope and scale of eco-innovation efforts and activities undertaken by companies.

**Table 1. The indicators and sub-indicators of the summary Eco-Innovation Index**

| Composite Indicator | Subindicator |
|---|---|
| 1. Eco-innovation inputs | 1.1. Government's environmental and energy R&D appropriations and outlays |
| | 1.2. Total R&D personnel and researchers |
| | 1.3. Total value of green early-stage investments |
| 2. Eco-innovation activities | 2.1. Implementation of resource efficiency actions among SMEs |
| | 2.2. Implementation of sustainable products among SMEs |
| | 2.3. Number of ISO 14001 certificates |
| 3. Eco-innovation outputs | 3.1. Eco-innovation-related patents |
| | 3.2. Eco-innovation-related academic publications |
| | 3.3. Eco-innovation-related media coverage |
| 4. Resource efficiency outcomes | 4.1. Material productivity |
| | 4.2. Water productivity |
| | 4.3. Energy productivity |
| | 4.4. GHG (Greenhouse gases) emissions productivity |
| 5. Socio-economic outcomes | 5.1. Exports of environmental goods and service sector |
| | 5.2. Employment in environmental protection and resource management activities |
| | 5.3. Value added in environmental protection and resource management activities |

Source: European Commission 2022.

The compound average change for each catching-up innovator was calculated for both selected composite indicators. Our benchmarks were: average EU-27 score and the results of the eco-innovation leaders. We also used Ward's hierarchical agglomerative clustering method to identify among all EU-27 groups of countries that are similar in the score of the sub-indices of the Eco-innovation inputs and Eco-innovation activities (Mongi *et al.,* 2019). Applying this method can provide more relevant results and information about dissimilarities and relations between the analysed objects (Kula & Ünlü, 2019). Then the Pearson correlation analysis was applied. This coefficient is known as the best method of measuring the statistical relationship, or association between two variables. We applied the Pearson correlation analysis to examine the direction of the relationship and magnitude of the correlation between certain indicators and sub-indicators of Eco-innovation and Summary Innovation Indexes. It makes it possible to identify the challenges and drivers for national policies in the EU Member States. We have included European Innovation Index and the Eco-Innovation Index, as both indicators are linked in terms of achievement of long-term sustainability and indicate the relative strengths and weaknesses of particular EU countries striving for improvement in their innovation systems.

## RESULTS AND DISCUSSION

Adopting the division of the EU Member States into three equally sized groups (segments) in terms of their green innovation performance, we analysed their intragroup variation and intergroup differentiation according to the value of the Eco-Innovation Index in 2012-2021.

The results of the calculation of descriptive statistics point to the moderate shifts in Eco-Innovation Indexes for both the EU and the selected groups: leader countries, average-performance countries, and catching-up countries. Analysing the changes in values of the mean for the considered groups of countries, the improvement in the situation in eco-innovation can be recorded in the study period. There was no increase in the average value of the EII between 2016 and 2017 in any of the surveyed country groups. The lack of progress in the EII was also noticed in the EU-catching-up countries between 2018 and 2020. The most homogenous group consisted of EU-average performance countries, unlike the most heterogeneous group was EU-catching up countries. However, since 2018 there has

**Table 2. Eco-Innovation Index of EU-27 and by country groups in 2012-2021**

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| **EU-27** | | | | | | | | | | |
| Mean | 0.389 | 0.394 | 0.408 | 0.414 | 0.424 | 0.424 | 0.433 | 0.441 | 0.447 | 0.462 |
| Median | 0.359 | 0.376 | 0.396 | 0.391 | 0.408 | 0.421 | 0.431 | 0.430 | 0.456 | 0.468 |
| Minimum | 0.132 | 0.129 | 0.140 | 0.149 | 0.141 | 0.144 | 0.179 | 0.184 | 0.207 | 0.216 |
| Maximum | 0.639 | 0.649 | 0.695 | 0.686 | 0.697 | 0.674 | 0.673 | 0.709 | 0.701 | 0.734 |
| Lower (First) Quartile | 0.284 | 0.291 | 0.303 | 0.312 | 0.327 | 0.332 | 0.342 | 0.343 | 0.335 | 0.351 |
| Upper (Third) Quartile | 0.473 | 0.474 | 0.483 | 0.482 | 0.496 | 0.496 | 0.497 | 0.519 | 0.535 | 0.546 |
| Range | 0.507 | 0.521 | 0.555 | 0.537 | 0.557 | 0.530 | 0.495 | 0.525 | 0.494 | 0.518 |
| Standard Deviation | 0.135 | 0.139 | 0.143 | 0.138 | 0.137 | 0.136 | 0.131 | 0.134 | 0.136 | 0.135 |
| Coefficient of variation (%) | 34.81 | 35.35 | 34.97 | 33.35 | 32.31 | 32.05 | 30.31 | 30.42 | 30.33 | 29.23 |
| Skewness | 0.454 | 0.445 | 0.530 | 0.451 | 0.302 | 0.316 | 0.337 | 0.389 | 0.186 | 0.128 |
| **EU eco-innovation leaders group** | | | | | | | | | | |
| Mean | 0.544 | 0.555 | 0.573 | 0.569 | 0.576 | 0.575 | 0.580 | 0.593 | 0.598 | 0.611 |
| Median | 0.586 | 0.588 | 0.597 | 0.597 | 0.595 | 0.605 | 0.607 | 0.607 | 0.606 | 0.611 |
| Minimum | 0.416 | 0.445 | 0.457 | 0.450 | 0.464 | 0.456 | 0.462 | 0.472 | 0.509 | 0.535 |
| Maximum | 0.639 | 0.649 | 0.695 | 0.686 | 0.697 | 0.674 | 0.673 | 0.709 | 0.701 | 0.734 |
| Lower (First) Quartile | 0.473 | 0.474 | 0.483 | 0.482 | 0.496 | 0.496 | 0.497 | 0.519 | 0.535 | 0.547 |
| Upper (Third) Quartile | 0.624 | 0.642 | 0.662 | 0.660 | 0.645 | 0.652 | 0.660 | 0.667 | 0.657 | 0.647 |
| Range | 0.223 | 0.204 | 0.238 | 0.237 | 0.233 | 0.217 | 0.211 | 0.237 | 0.193 | 0.199 |
| Standard Deviation | 0.088 | 0.087 | 0.095 | 0.093 | 0.088 | 0.088 | 0.083 | 0.084 | 0.071 | 0.069 |
| Coefficient of variation (%) | 16.14 | 15.65 | 16.55 | 16.31 | 15.26 | 15.36 | 14.30 | 14.20 | 11.93 | 11.30 |
| Skewness | -0.324 | -0.158 | 0.020 | 0.046 | 0.008 | -0.148 | -0.278 | -0.024 | 0.025 | 0.488 |
| **EU average eco-innovation performers group** | | | | | | | | | | |
| Mean | 0.361 | 0.368 | 0.375 | 0.389 | 0.405 | 0.404 | 0.416 | 0.423 | 0.444 | 0.463 |
| Median | 0.359 | 0.376 | 0.396 | 0.391 | 0.408 | 0.421 | 0.431 | 0.430 | 0.456 | 0.468 |
| Minimum | 0.284 | 0.298 | 0.297 | 0.317 | 0.327 | 0.332 | 0.342 | 0.363 | 0.371 | 0.389 |
| Maximum | 0.430 | 0.424 | 0.439 | 0.455 | 0.464 | 0.463 | 0.477 | 0.483 | 0.515 | 0.533 |
| Lower (First) Quartile | 0.339 | 0.341 | 0.340 | 0.355 | 0.382 | 0.353 | 0.389 | 0.398 | 0.413 | 0.439 |
| Upper (Third) Quartile | 0.397 | 0.397 | 0.403 | 0.430 | 0.440 | 0.444 | 0.435 | 0.447 | 0.468 | 0.487 |
| Range | 0.147 | 0.125 | 0.143 | 0.139 | 0.137 | 0.131 | 0.135 | 0.120 | 0.143 | 0.144 |
| Standard Deviation | 0.043 | 0.040 | 0.046 | 0.049 | 0.043 | 0.049 | 0.046 | 0.039 | 0.047 | 0.043 |
| Coefficient of variation (%) | 12.01 | 10.86 | 12.26 | 12.60 | 10.73 | 12.14 | 11.14 | 9.10 | 10.57 | 9.26 |
| Skewness | -0.145 | -0.346 | -0.377 | 0.030 | -0.415 | -0.334 | -0.274 | -0.248 | -0.194 | -0.205 |
| **EU catching-up countries** | | | | | | | | | | |
| Mean | 0.262 | 0.260 | 0.278 | 0.284 | 0.291 | 0.294 | 0.304 | 0.307 | 0.299 | 0.313 |
| Median | 0.282 | 0.259 | 0.298 | 0.296 | 0.298 | 0.299 | 0.315 | 0.330 | 0.300 | 0.305 |
| Minimum | 0.132 | 0.129 | 0.140 | 0.149 | 0.141 | 0.144 | 0.179 | 0.184 | 0.207 | 0.216 |
| Maximum | 0.357 | 0.347 | 0.361 | 0.372 | 0.369 | 0.370 | 0.368 | 0.368 | 0.364 | 0.378 |
| Lower (First) Quartile | 0.237 | 0.246 | 0.236 | 0.255 | 0.258 | 0.259 | 0.277 | 0.271 | 0.281 | 0.288 |
| Upper (Third) Quartile | 0.285 | 0.291 | 0.312 | 0.312 | 0.338 | 0.332 | 0.350 | 0.343 | 0.335 | 0.351 |
| Range | 0.225 | 0.219 | 0.221 | 0.223 | 0.228 | 0.226 | 0.189 | 0.184 | 0.158 | 0.162 |
| Standard Deviation | 0.064 | 0.062 | 0.066 | 0.066 | 0.072 | 0.070 | 0.060 | 0.057 | 0.049 | 0.052 |
| Coefficient of variation (%) | 24.38 | 23.71 | 23.91 | 23.37 | 24.62 | 23.75 | 19.82 | 18.71 | 16.42 | 16.61 |
| Skewness | -0.776 | -1.027 | -1.055 | -0.813 | -1.057 | -1.197 | -1.057 | -1.302 | -0.503 | -0.530 |

Source: own study.

been a significant diversity reduction in the presented group of countries. The diversity of the EU-27 was on the average level and also decreased over the study time. Moreover, at least half of the countries in this group had an EII value of 0.282 in 2012, peaking at 0.330 in 2019 and slightly lower at 0.305 in 2021. In comparison, in the case of countries with average performance, at least half of the countries within this group achieved an EII value of 0.359 in 2012 and 0.468 in 2021. For one in four countries classified in the catching-up group, the EII value was at or below 0.237 in 2012 and 0.288 in 2021. In addition, in the analysed group of countries, only 25% achieved an EII value at or above 0.285 in 2012, which increased to 0.351 in 2021. Except for 2014 and 2017-2019, when 6 out of 9 countries recorded EII values above the group average, five countries obtained higher than average group values in the remaining years. A similar direction of asymmetry was recorded for EU-average performance countries (except in 2015) and in 2012-2013 and 2017-2019 for EU leaders (Table 2).

Figure 1 shows that the Eco-innovation Index values of individual countries that are catching up with eco-innovation were characterized by high volatility in the analysed period, with most of them improving their eco-innovation performance. Lithuania, Cyprus, Hungary, and Bulgaria recorded the biggest improvement between 2012 and 2020. The smallest increase was observed in the case of Malta and Slovakia (Figure 1). The only country in this category and the only member of the EU for which a decrease in eco-innovation performance was identified was Romania, whose results have been deteriorating since 2017. Lithuania and Croatia achieved the best results among the countries of this group in recent years, although their EII values were still less than 80% of the EU average.

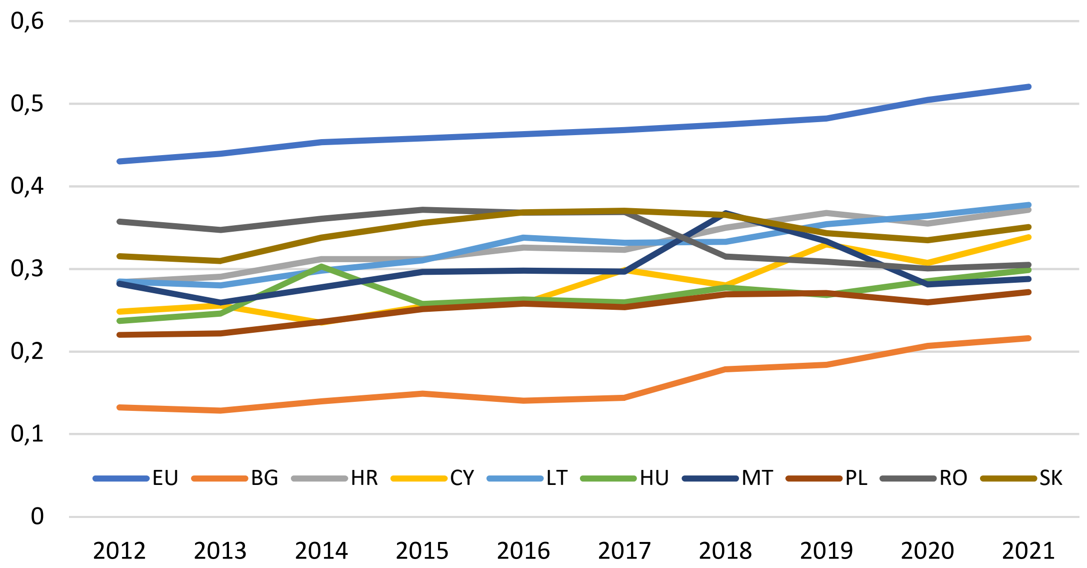



**Figure 1. The value of the Summary Eco-Innovation Index***
**for selected (catching-up) countries and the EU in the years 2012-2021**

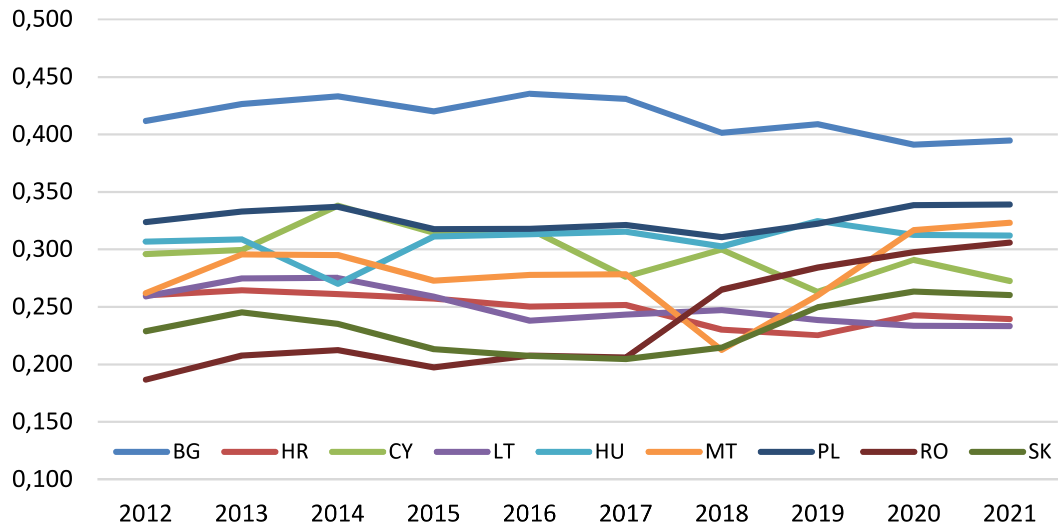
Note: for each year, the Eco-Innovation Index is calculated as the unweighted average of the re-scaled scores for all indicators where all indicators receive the same weight. The maximum re-scaled score is thus equal to 1 and the minimum re-scaled score is equal to 0. For positive and negative outliers, the re-scaled score is equal to 1 or 0, respectively.
Source: own elaboration based on the Eco-Innovation Index Database 2021.

Despite the improvement of the EII index by almost all catching-up countries, they did not manage to significantly reduce the distance to the other selected groups of countries. This proves more action is required to bridge the existing gap between this group and the other EU members. The achieved results correspond to the studies of Ostraszewska and Tylec (2019), Lesáková and Laco (2020), and Sobczak *et al*. (2021).

Figure 2 shows the identified gap between the catching-up countries and the eco-innovation leaders and the distance to the average EU-27 in terms of the Summary Eco-innovation index in 2012-2021.

In the study period, there were year-to-year changes in the value of the gap between the catching-up countries and the average value for EU-27 countries and eco-innovation leaders. However, it is not easy to state explicitly that the gap was decreasing. Determining the gap with the leading innovators revealed that Bulgaria, Croatia, Cyprus, and Lithuania recorded a slight gap narrowing in 2021 compared to 2012. Croatia and Lithuania were the countries with recognized narrowest gap to eco-innovation leaders among catching-up countries. The five remaining countries recorded the gap increase. The analysis shows that Bulgaria recorded the largest gap. Romania recorded the largest deterioration in the value of

EII throughout the studied period. Poland, Malta, and Hungary also recorded unfavourable changes, indicating a slight increase in the existing gap compared to the EU leader innovators. A modest narrowing of the spread between the catching-up countries as a whole group to the reference group of countries could be found. Only slightly different results were obtained by determining the gap between the EU average and the catching-up countries. Only three countries (Croatia, Cyprus, and Lithuania) recorded that the gap marginally narrowed comparing 2021 with 2012. The remaining six countries (Bulgaria, Hungary, Malta, Poland, Slovakia and Romania) increased their distance to the EU average (Figure 2).



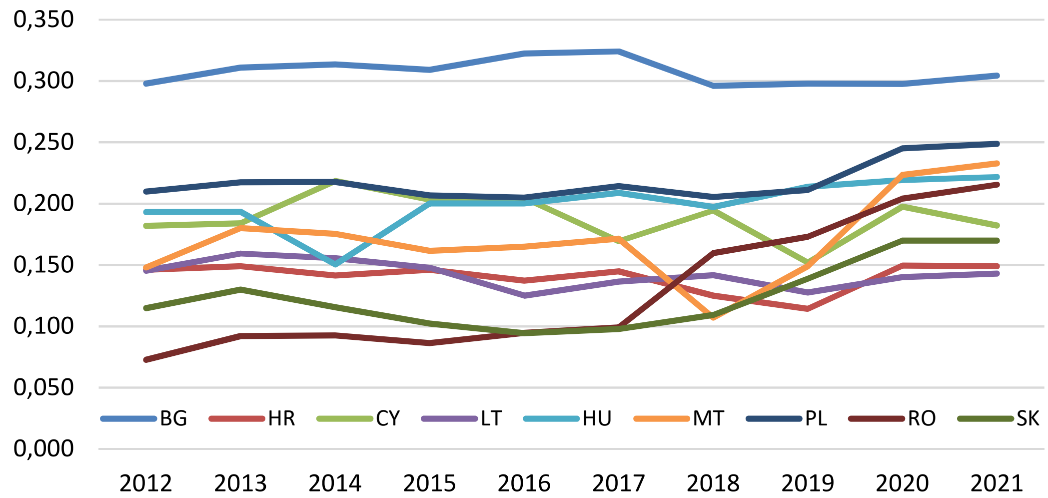




**Figure 2. The gap between the catching-up countries and innovation leaders and average EU-27 in 2012-2021**
Source: own elaboration based on the Eco-Innovation Index 2021 Database.

Taking into account five composite indicators, the analysis revealed that the largest gap between the results of the analysed countries, the EU average and eco-innovation leaders was in the case of Eco-Innovation Inputs. On the other hand, the narrowest gap was recorded between the catching-up countries and the EU-27 and eco-innovation leaders with respect to eco-innovation activities. A relatively small gap was identified between the study group of countries and the EU-27 average value in socio-economic outcomes (Figure 3).

We decided to take a closer look at two out the above-mentioned composite indicators, namely eco-innovation inputs and eco-innovation activities, because in our opinion the dimensions they cover seem to be of key importance for creating favourable conditions for the development of innovation in the long term, which is particularly important for catching-up countries whose environmental protection sectors are not very developed. Their improvement should translate into better results of eco-innovation in the future. Within the composite eco-innovation inputs, the biggest difference between the analysed countries and the EU average was observed in two subindexes: 1.1. Governments environmental and energy R&D appropriations and outlays, 1.2. Total R&D personnel and researchers. The gap between the EU average as well as Eco-Innovation leaders and catching-up innovators significantly increased for the first subindex between 2012 and 2021 (Figure 4). Our results are generally in line with Horbach (2016). The eco-innovations of catching-up economies compared to eco-innovation leaders ('rich' Western European countries) are characterized among others by lower level of R&D input and the dependence on the technology transfer from the higher developed countries.

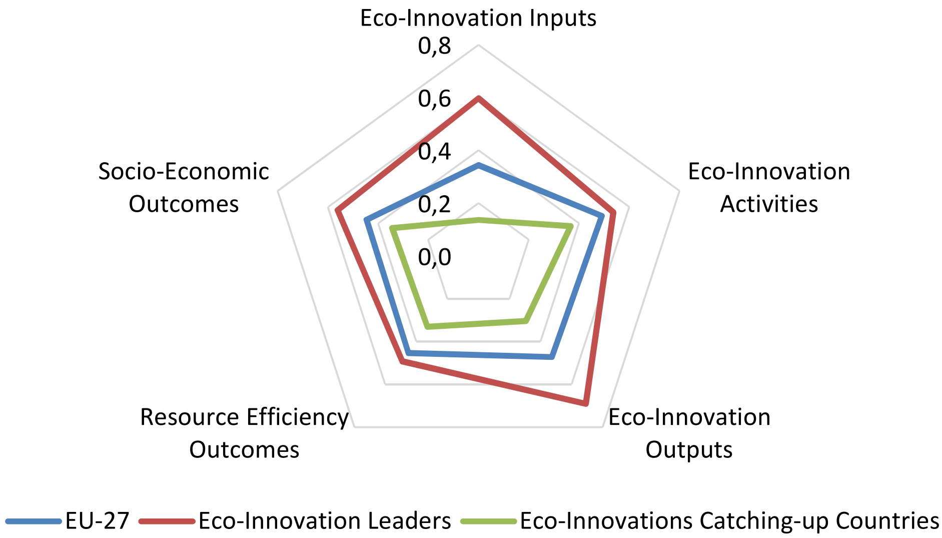



**Figure 3. Composite indicators: A comparison of the EU-27, eco-Innovation leaders and catching-up innovators (based on the average value for the analysed period of 2012-2021)**
Source: own elaboration based on the Eco-Innovation Index 2021 Database.

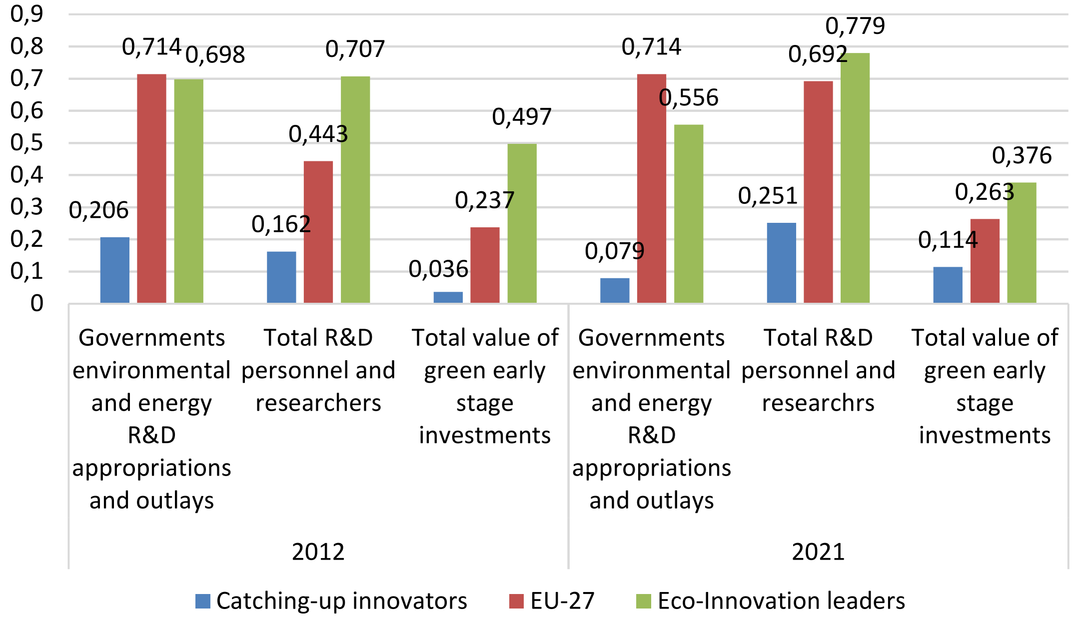



**Figure 4. Eco-innovation performance of the catching-up countries in comparison with the eco-innovation leaders and EU-27 average by eco-innovation inputs sub-indicators in 2012 and 2021 (normalized values)**
Source: own elaboration based on the Eco-Innovation Index 2021 Database.

Four of nine countries in the analysed group (Malta, Poland, Romania, and Slovakia) recorded a deterioration in the level of eco-innovation inputs in 2012-2021. The most undesirable changes were experienced in Romania where eco-innovation and transparency of the administrative process were visibly affected (Androniceanu, 2021). The largest improvement of this indicator occurred in the case of Cyprus. With the exception of Croatia and Hungary, for which positive changes were recorded for governments' environmental and energy R&D appropriations and outlays, a negative growth rate was seen for the rest of the countries in the study group that allocated public funds to environmental R&D. In terms of the total personnel and researchers there was a particularly positive rate of changes. Almost all the analysed countries (with exceptional of Malta and Lithuania) reported improvement in this area, *i.e.* an increase in research staff and personnel. The positive growth rate of the research personnel and researchers, as well as the value of green early investments, were achievements of almost the entire group of catching-up countries. In the case of investment, a negative rate of change was recorded for Slovakia. For the remaining countries (Bulgaria, Cyprus, and Malta), it was not possible to determine the direction of developments in this area. Comparing the differences between the catching-up group of countries and eco-innovation leaders, it could be noted that the negative changes were more turbulent and positive ones – with a higher dynamic – occurred in the study group of countries. Moreover, they did not move in the same direction in both country groups, *e.g.* early green-stage investments. The catching-up countries were characterized by a highly positive direction of change, while the eco-innovation leader countries recorded negative growth in this area. The reasons for these different patterns can be found in the different stages of market development, with more mature environmental markets in the leading countries (Table 3).

**Table 3. Compound annual change in the eco-innovation inputs indicator in the catching-up countries in 2012-2021 (in%)***

| Country | EU | $EU_{EIL}$ | BG | HR | CY | LT | HU | MT | PL | RO | SK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CAC_{EIIn}$ | 1.39 | -1.18 | 5.26 | 6.78 | 21.46 | 1.59 | 7.35 | -1.78 | -3.26 | -10.03 | -2.01 |
| $CAC_{1.1}$ | 0.00 | -2.51 | - | 41.42 | - | -7.41 | 8.01 | - | -5.63 | -14.28 | -7.41 |
| $CAC_{1.2}$ | 3.46 | 1.08 | 9.61 | 5.65 | 21.46 | -0.40 | 6.81 | -1.78 | 13.67 | 2.51 | 1.01 |
| $CAC_{1.3}$ | 1.15 | -3.06 | - | 8.55 | - | 12.33 | 8.24 | - | 14.00 | 0.29 | -0.07 |

Note: $CAC_{11}$ – the sub-indices were on 0 levels for the whole research period for countries BG, CY, MT. The calculation for HR was based on data from three consecutive years; $CAC_{13}$ – the value of sub-indices for BG, CY, MT sub-indices were on 0 levels for the whole research period. The calculations for RO and SK were based on data from two consecutive years.
Source: own elaboration based on the Eco-Innovation Index 2021 Database.

Ward's hierarchical clustering method was applied to compare the level of components and similarities of the eco-innovation inputs indicator across countries. We focus only on the results obtained by the catching-up innovators. The analysed countries belonged to three clusters in 2012 and 2021. In 2012, the countries with the lowest levels of sub-indexes formed a separate cluster (Malta, Croatia, Cyprus, and Bulgaria). Poland and Romania achieved relatively similar results to Italy, Slovenia, and the Czech Republic (classified as average-performance countries). This group was characterized by a relatively high level of the governments environmental and energy R&D appropriations and outlays and low levels of the other two measures (total R&D personnel and researchers and total value of green early-stage investments). Lithuania, Slovakia and Hungary, formed a cluster together with the Netherlands and Austria (both countries are Eco-Innovation leaders). These countries were distinguished by an average level of the governments environmental and energy R&D appropriations and outlays and total R&D personnel and researchers and slightly lower total value of green early-stage investments. In 2021, there was a deterioration in the level of governments environmental and energy R&D appropriations and outlays and improvements in performance for total R&D personnel and researchers and total value of green early-stage investments, so seven of nine catching-up countries formed one cluster. Still, their achievements were the weakest with respect to these indicators. Hungary only created a cluster with countries classified as eco-innovation average innovators (Portugal, Italy, and the Czech Republic) and leaders (Spain). In these countries, the level of environmental and energy R&D appropriations and outlays and total R&D personnel and researchers remained at the average values compared to other EU-27 members. The green early-stage investment measure remained at a relatively low level in this group of countries. Similarly to Hungary, Lithuania formed a two-entity group with Estonia only. Both countries achieved relatively high value in the green early-stage investment but average level of total R&D personnel. Weaknesses for countries included a very low level of the governments' environmental and energy R&D appropriations and outlays (Table 4).

**Table 4. Segmentation of the EU countries by eco-innovation inputs in 2012 and 2021**

| 2012 | 2021 |
|---|---|
| Cluster 1: {EE, SE, FR, ES, DE} | Cluster 1: {**SK,** LV, **RO**, **MT**, **CY, PL**, **HR**, **BG**} |
| Cluster 2: {LU, FI, DK} | Cluster 2: {EL, SI, FR, DE, SE, FI, NL, DK} |
| Cluster 3: {**MT**,**HR**, **CY**, **BG**} | Cluster 3: {**HU**, ES, PT, IT, CZ} |
| Cluster 4: {**RO**, **PL**, SI, IT, CZ} | Cluster 4: {**LT**, EE} |
| Cluster 5:{NL PT, **LT**, **SK**, LV, **HU**, EL,IE, AT, BE} | Cluster 5: {LU, IE, AT, BE] |

Source: own elaboration based on the Eco-Innovation Index 2021 Database.

Subsequently, the analysis of the EU eco-innovation performance with respect to the second composite indicator of eco-innovation activities was carried out. The value of the implementation of resource efficiency actions among SMEs and the implementation of sustainable products among SMEs decreased in 2021 compared to 2012. The catching-up countries stood out in terms of the number of received ISO 14001 certificates on the environmental management system. Their results were better than the EU-27 average and eco-innovation leaders in this regard (Figure 5).

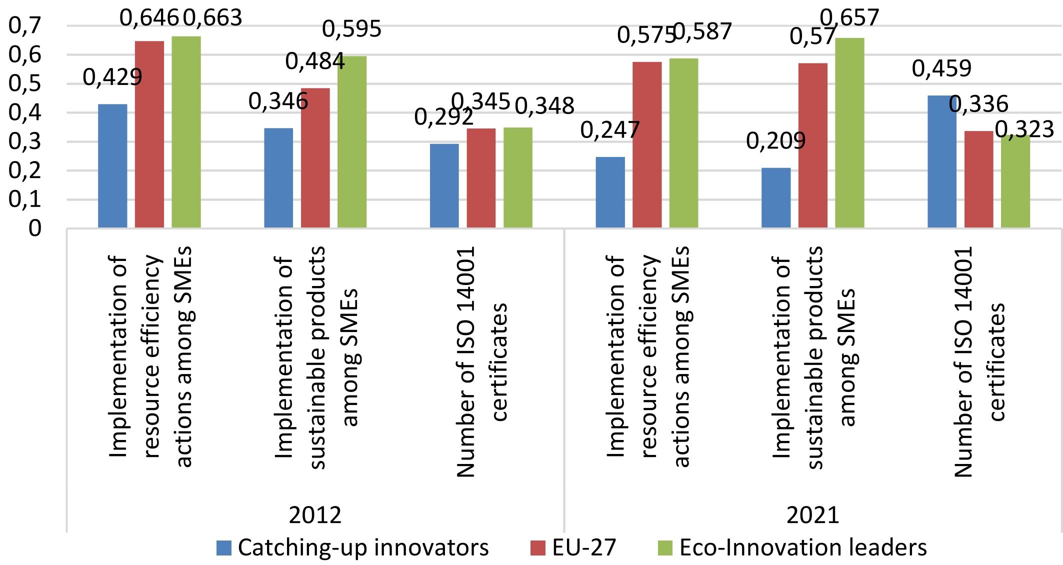



**Figure 5. Eco-innovation performance of the catching-up countries in comparison with the eco-innovation leaders and EU-27 average by eco-innovation activities sub-indicators in 2012 and 2021 (normalized values)**
Source: own elaboration based on the Eco-Innovation Index 2021 Database.

Five out of nine catching-up innovators experienced a significant improvement with respect to the indicator of Eco-Innovation Activities compared to the score achieved by the EU-27. The rate of change was relatively high, from min. 1.03% in the case of Poland to the max. 4.00% for Croatia. The efforts in the implementation of resource efficiency in Croatian economy were also presented in the study by Harc (2019). On the other hand, performance deterioration in the second dimension of the Eco-Innovation Index occurred for four countries. The largest decreases in the compound annual growth rate were recorded for Romania (-11,2%) and Lithuania (approximately -6%). Malta and Slovakia also recorded negative growth in this indicator. Only Cyprus and Croatia recorded a positive growth rate for the implementation of resource efficiency actions among SMEs. Poland and Hungary experienced a positive growth rate for the second sub-index regarding the implementation of sustainable products among SMEs. In contrast the strengths of all catching-up countries, with the exception of Romania, was a relatively high score in terms of the number of ISO 14001 certificates. Very similar conclusions about the direction of change in narrowing the gap can be drawn for Malta, Poland, Cyprus, Croatia, Bulgaria, Slovakia, Hungary, and Lithuania (Table 5).

**Table 5. Compound annual change of the eco-innovation activities composite indicator in 2012-2021 (in%)**

| Country | EU | $EU_{EIL}$ | BG | HR | CY | LT | HU | MT | PL | RO | SK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $CAC_{EIA}$ | 0.04 | 0.00 | 2.94 | 4.00 | 1.37 | -6.00 | 1.18 | -4.37 | 1.03 | -11.18 | -3.09 |
| $CAC_{2.1.}$ | -1.29 | -1.35 | -14.45 | 0.93 | 8.52 | -5.31 | -4.45 | -2.78 | -1.83 | -26.02 | -9.09 |
| $CAC_{2.2.}$ | 1.83 | 1.11 | -3.32 | -1.17 | -12.52 | -14.77 | 2.48 | -10.13 | 1.14 | -19.72 | -6.08 |
| $CAC_{2.3}$ | -0.29 | -0.80 | 10.91 | 15.77 | 20.37 | 2.43 | 4.94 | 52.07 | 22.44 | -5.21 | 5.75 |

Source: own elaboration based on the Eco-Innovation Index 2021 Database.

As in the case of the composite eco-innovation inputs indicator, the analysis of the sub-indices for catching-up countries carried out using Ward's clustering method enabled the identification of similarities in terms of the achieved results. The catching-up countries were assigned to four of the five distinguished bundles. Hungary, Lithuania, Romania, Cyprus, and Bulgaria formed the largest group with three average-performance countries (Italy, Estonia, and Slovenia). The value of all sub-indexes: implementation of resource efficiency actions among SMEs, implementation of sustainable products among SMEs, and the number of certificates of ISO 14001 on environmental management systems were at the average level for all these countries. The performance in terms of eco-innovation activities put these countries on par with the selected leader innovators, such as Greece, Luxembourg, and Germany. In 2012, Slovakia was in the cluster with four countries ranked as eco-innovation leaders with respect to this indicator. Malta was assigned to a cluster with France (one of the leader countries) and Portugal and Belgium (average-performance countries). The affiliation of countries to the distinguished clusters in 2021 was significantly different compared to 2012. The catching-up countries belonged to three out of the five clusters. Romania, Lithuania, Cyprus, and Bulgaria formed a group together with Estonia (ranked to average-performance country). The results achieved by Slovakia, Hungary, and Croatia were relatively close to the objects classified as average-performance countries (Finland, Slovenia, and Italy). Moreover, Poland and Malta also formed a cluster with an average eco-innovation performance (Latvia and Greece) (Table 6).

**Table 6. Segmentation of the EU countries by eco-innovation activities in 2012 and 2021**

| 2012 | 2021 |
|---|---|
| Cluster 1: {ES, SE, CZ} | Cluster 1: {EE, **RO**, **LT**, **CY**, **BG**} |
| Cluster 2: {**HU**, **LT**, **RO**, IT, EE, SI, **CY**, **BG**} | Cluster 2: {PT, AT, FR, SE, ES, IE, CZ} |
| Cluster 3: {LV, **HR**, **PL**, EL, LU, DE} | Cluster 3: {**SK**, **HU**, FI, SI, IT, **HR**} |
| Cluster 4: {**SK**, NL, IE, FI, AT, DK} | Cluster 4: {**PL**, **MT**, LV, EL} |
| Cluster 5: {PT, FR, BE, **MT**} | Cluster 5: {LU, DK, NL, DE, BE} |

Source: own elaboration based on the Eco-Innovation Index 2021 Database.

The conducted analysis occurred in two dimensions of the eco-innovation index and revealed considerable variation among the Catching up economies. Croatia achieved the best results of all countries in the catching-up innovators in both dimensions and its gap between each group of countries was decreased. Nevertheless, all catching-up countries should focus more on activities and undertakings directed to narrow the existing gap not only on the general level, but on regulations and activities enabled the implementation of the tools and support the development of eco-innovativeness. Moreover, identifying determinants of eco-innovation can help policy-makers to develop and implement instruments which are effective and efficient in mitigating the existing gap between the leaders and catching-up countries (del Rio, Penasco, & Romero-Jordan, 2016).

The strongest correlation between the Eco-innovation Index value and the value of a given subindex was observed in the case of total R&D personnel and researchers, eco-innovation-related patents, energy productivity. This could indicate that these are the key areas for improvement for the catching-up countries, as they are more related to eco-innovation performance than others, thus requiring special attention. However, policies at EU-level and national level should also take into account other areas of eco-innovation where progress is required. Especially those related to ensuring appropriate conditions for the development of eco-innovation (composite indicators 1 and 2 with their sub-indicators). Other dimensions of eco-innovation, related to the results of innovative activity, are also crucial, because they directly determine getting economic, ecological, and social benefits from eco-innovation, and thus contribute to the increase in the competitiveness of enterprises and national economies. They can also contribute to the achievement of sustainable development goals. The improvement in those dimensions of eco-innovation, which are related to ensuring appropriate conditions for its further development, seems to be of particular importance (composite indicators 1 and 2 with their sub-indicators). Other dimensions of eco-innovation, related to the results of innovative activity, are also very important, because they directly determine the achievement of benefits from eco-innovation, of an economic, social and ecological nature, and thus contribute to the increase in the competitiveness of enterprises and national economies and to achieve the goals of sustainable development (Martin & McNeill, 2013). However, without ensuring proper input conditions for achieving progress in the field of eco-innovation, good outcomes are difficult or even impossible to obtain. For each of the catching-up countries, the most urgent actions should be identified and further research should discover the sources of existing limitations of their eco-innovation.

**Table 7. The value of Pearson's correlation coefficient (r) between the EII indicators and the summary innovation indexes (EII, SII), 2012 and 2021**

| Subindicator | EII | | SII | |
|---|---|---|---|---|
| | 2012 | 2021 | 2012 | 2021 |
| 1.1. Governments environmental and energy R&D appropriations and outlays (% of GDP) | 0.637*** | 0.564*** | 0.464** | 0.398** |
| **1.2. Total R&D personnel and researchers (% of total employment)** | 0.879*** | 0.842*** | 0.859*** | 0.801*** |
| 1.3. Total value of green early-stage investments (USD/capita) | 0.786*** | 0.564*** | 0.724*** | 0.612*** |
| 2.1. Implementation of resource efficiency actions among SMEs (Score) | 0.431** | 0.531*** | 0.272 | 0.482** |
| 2.2. Implementation of sustainable products among SMEs (% of surveyed firms) | 0.464** | 0.685*** | 0.493*** | 0.469** |
| 2.3. Number of ISO 14001 certificates (per mln population) | 0.212 | -0.183 | -0.041 | -0.195 |
| **3.1. Eco-innovation-related patents (per mln population)** | 0.810*** | 0.783*** | 0.823*** | 0.771*** |
| 3.2. Eco-innovation-related academic publications (per mln population) | 0.676*** | 0.543*** | 0.676*** | 0.470** |
| 3.3. Eco-innovation-related media coverage (per mln population) | 0.623*** | 0.657*** | 0.659*** | 0.537*** |
| 4.1. Material productivity (GDP/Domestic Material Consumption) | 0.296 | 0.441** | 0.431** | 0.430** |
| 4.2. Water productivity (GDP/total freshwater abstraction) | 0.194 | -0.005 | 0.134 | 0.024 |
| **4.3. Energy productivity (GDP/gross inland energy consumption)** | 0.627*** | 0.745*** | 0.630*** | 0.603*** |
| 4.4. GHG (Greenhouse gases) emissions productivity (CO2e/GDP) | 0.495*** | 0.560*** | 0.434** | 0.376* |
| 5.1. Exports of environmental goods and service sector (% of total exports) | 0.699*** | 0.562*** | 0.284 | 0.260 |
| 5.2. Employment in environmental protection and resource management activities (% of the workforce) | 0.566*** | 0.520*** | 0.276 | 0.318 |
| 5.3. Value added in environmental protection and resource management activities (% of GDP) | 0.052 | 0.450** | -0.233 | 0.249 |
| Summary Eco-Innovation Index | 1 | 1 | 0.780*** | 0.794*** |

Note: statistical significance: *** p<0.01; ** p<0.05; *p<0.1

Source: own elaboration based on the Eco-Innovation Index 2021 and European Innovation Index 2021 Database.

There was also a strong positive relationship between the Eco-Innovation Index and the Summary Innovation Index (SII), which is the main measurement tool for the research of innovation performance of EU Member States and their innovation systems. In the case of EII sub-indicators, the highest positive correlation was recorded for: total R&D personnel and researchers, eco-innovation-related patents, the total value of green early-stage investments, and energy productivity. It is not surprising that countries that achieve good results in terms of overall innovation, measured by the SII, are also among the top countries in terms of eco-innovation, measured by EII. On the other hand, those that lag behind in overall innovation perform relatively poorly also in terms of eco-innovation. Therefore, it appears that the development of eco-innovation calls for a more integrated policy framework, including a combination of environmental, technology, innovation, and development policies and specific measures that can be implemented to promote innovation in general, and eco-innovation in particular and mitigate the barriers to innovation, considering different barriers and eco-innovation types (Del Río, Carrillo-Hermosilla, & Konnola, 2010). The eco-innovation interrelation with the other innovation was also confirmed by Arranz *et al*. (2020). The authors also highlighted the dual nature of eco-innovation as a performance and as innovation capabilities.

Figure 6 shows the strong correlation between both summary indexes, also indicating distribution of the countries based of the value of EIS and EII.

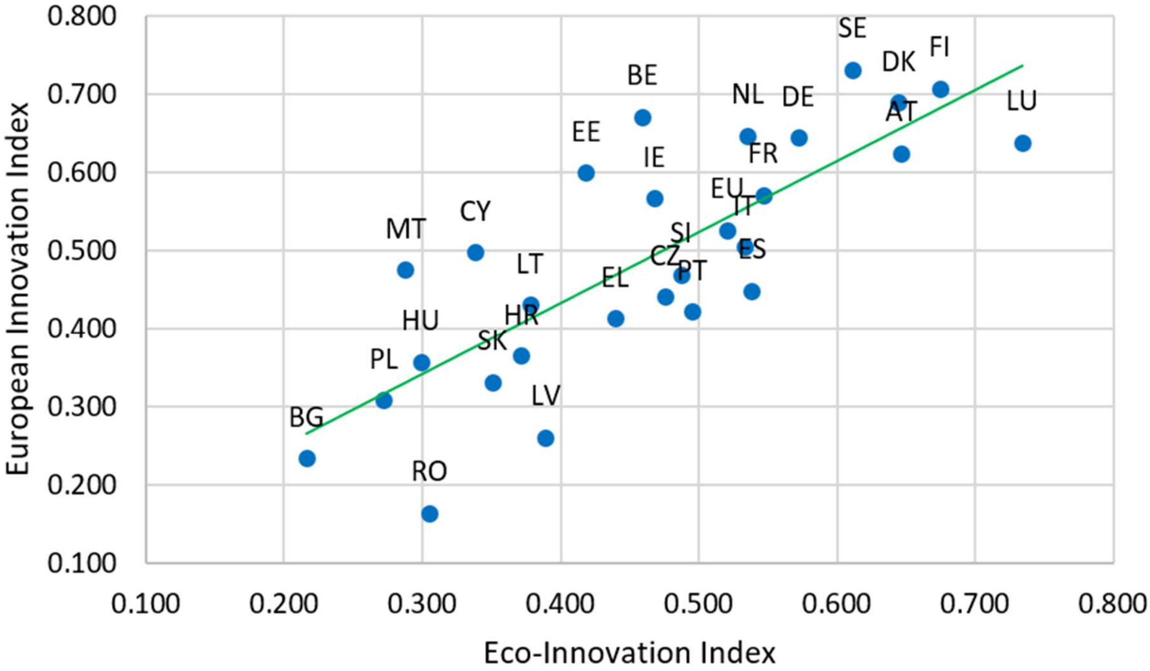



**Figure 6. Comparison of the Eco-Innovation Index and the European Innovation Scoreboard by EU country (average value, 2021; normalised scores)**
Source: own elaboration based on the Eco-Innovation Index 2021 and the European Innovation Index 2021 Database.

## CONCLUSIONS

Eco-innovation helps the EU countries optimize their growth potential while addressing our common challenges such as climate change, resource scarcity, and declining biodiversity, thus contributing to the achievement of sustainable development goals. Eco-innovation is at the heart of various European Union's and national policies, but member countries' performance varies significantly in this regard. The study based on the Eco-Innovation Index methodology revealed that the group of countries with relatively poor innovation scores, catching up with eco-innovation, failed to significantly reduce the innovation gap to the leading countries and to get closer to the EU average, even if they made progress in several dimensions of eco-innovativeness.

This shows only partial effectiveness of pro-innovation policies in these countries and indicates the need to take action to close the innovation gap, which would allow these countries to improve their competitive position and increase the effectiveness of the implementation of sustainable development goals and tasks. The study helped to identify areas in which improvement may allow for faster progress and upgrade to a higher category of the average eco-innovation performers and even to the leading eco-innovators. It showed that, taking into account five composite indicators, the largest gap between the results of the analysed countries, the EU average and eco-innovation leaders was in eco-innovation inputs. Investment in R&D appears to be the key area for improvements for the catching-up eco-innovators. In two of the sub-indicators of eco-innovation inputs: governments environmental and energy R&D appropriations and outlays, total R&D personnel, the biggest distance to the leaders was recorded. A stronger commitment from national governments to eco-innovation in the countries catching up with eco-innovation, is an important factor in ensuring that the positive trend in the EII index is continued in future. Moreover, the existence of strong pro-environmentally oriented SMEs can contribute to better eco-innovation performance in future. Other key drivers include eco-innovation-related patents, energy productivity and implementation of sustainable products among SMEs, which are strongly correlated with the summary EII index. However, policymakers for sustainable development should ensure that all dimensions of eco-entrepreneurship are integrated into the pursuit of the SDGs. There is a strong positive relationship between the Eco-Innovation Index and the Summary Innovation Index (SII), which indicates that eco-innovation is related to the overall innovativeness of the economy and requires the provision of conditions conducive to the development of innovation.

The limitations of our study lie mainly in its narrow scope. Using the EII index methodology, we focused exclusively on the areas of eco-innovation covered by this indicator and we conducted detailed analyses only for eco-innovation inputs and eco-innovation activities. Further research should be carried out to identify the sources of the existing barriers to eco-innovation as well as drivers of implementing a pro-environmental strategy in SMEs from an entrepreneur's perspective. Taking into consideration the fact, that eco-innovations are important instruments for achieving sustainable development goals, the results of the study may provide important guidance for policy-makers in the area of innovation policy and sustainable development, especially in economies classified as catching-up with eco-innovation. The study should also contribute to a better understanding of the role of innovation, and in particular eco-innovation in ensuring sustainable development, by business and broader society.

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