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# THE IMPACT OF GREEN BOND FOR ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT: The aim of this article paper is to try to establish whether or not there is a relationship between the issuance of green bonds and the achievement of selected SDG goals. Achieving such a goal required: (1). Defining green bonds - presenting the problem of recognition classification against the backdrop of legal regulations, (2). Determine the scale of green bond issuance and funding directions (3). Assess the impact of green bond issuance on the achievement of selected Sustainable Development Goals (SDGs). In particular, Pearson correlation coefficients, multidimensional scaling and linear ordering results for metric data were used. In the first step, multidimensional scaling is used to visualise objects in two-dimensional space. The study confirmed the link between the SDG goals – goal 7 (7.2.1.) related to energy and the green bond market. It also showed that market size matters for achieving the SDG goals.

KEYWORDS: green bonds, blue bonds, sustainable development, climate finance, SDG targets, multidimensional scaling analysis

## Introduction

A crucial yet often belittled or ignored phenomenon that impacts economic, social, health, and environmental sustainability is climate change. In the face of the COVID-19 pandemic, he devotes a lot of space to the impact of environmental and climatic factors on the economy and humans, showing what needs to be done. The formulated SDG goals are constantly evolving, but problems with their implementation are also indicated. This was especially the case during the COVID-19 period when it was necessary to redefine SDG tasks that occurred in connection with the COVID-19 pandemic, but also new tasks are constantly appearing. Social goals and sustainable development health (especially after COVID-19) are a significant discussion, and climate goals are also analysed from the point of view of their impact on social goals or health. "Linkages between Climate Change, Biodiversity Change, and Human Health" have been demonstrated (Saliba, 2017).

For sustainable development, it becomes important to analyse and compare intensive and extensive growth to argue that certain development trajectories of capturing climate change and its impact on green growth through the use of appropriate financing instruments that stimulate the implementation of climate goals. As indicated, there is a need to strengthen climate action in the implementation of 17 SDGs to tackle climate change and other environmental challenges while increasing investment to ensure the development of society (Eikeset et al., 2018):

a) adding value through certification,
b) technology development to more efficiently utilise resources, and
c) specialisation simultaneously prevents environmental degradation, resource overuse, and pollution. Despite many actions already taken and analyses of their effects, the situation is still difficult, and the degree of implementation of the SDG's objectives is unsatisfactory. It is very often pointed out that the problem is the financing of changes towards sustainability and the implementation of the SDGs (Ferreira et al., 2016; Aspinall et al., 2018). The research review shows that conventional finance and its instruments are inadequate and unsuitable for financing the SDGs as the three-dimensional perspective of sustainable development is not considered, leaving any room for environmental and social issues (Pisano et al., 2012; Fullwiler, 2015).

Actions that are taken in response to climate threats can be summarised in two words: adaptation and mitigation. Mitigation describes the effort to reduce climate change and its consequences, principally through the transition to a low-carbon economy (Ross, 2018). Adaptation, on the other hand, refers to the attempt to create a society that can not only understand but actively act and support the actions of others to eliminate, mitigate and eliminate the deadly consequences of climate change. These activities require funds but also a change in thinking about making a profit, profits at all costs, at the expense of the environment and other people. It requires a change of attitudes, the emergence of new values and acceptance of the ESG risk, and the creation of new instruments conducive to achieving environmental goals (European Commission, 2021). Bonds are an important instrument used to achieve the SDG's goals, especially when it comes to climate change mitigation. Its role in promoting the target of environmental protection is apparent, but little is known about its potential, whereas benefits result from diversification in investment portfolios. Prior studies on political economy point out the significance of the government sector and formulated by public authorities politics in shaping the development of a financial system over time. However, it is indicated that currently the role of the financial sector and private investors in financing climate change is growing (Zhan & Santos-Paulino, 2021) from using green instruments (Sreelekshmi & Biju, 2023).

In the face of the diagnosed climate emergency (Ripple et al., 2020), proposed SDG goals (Agenda 2030) and problems with their financing, there is talk of the need to create new, effective instruments outside the public financial system (Belianska et al., 2022; Ziolo et al., 2022). To be able to interact and interact effectively, it is necessary to below indicated key issues and explain to clarify the following questions:

1. Definition of green bonds.
2. Determination of the size of green bond issuances.
3. Assessment of the significance and scale of green bonds in financing investments aimed at broader environmental protection and achieving selected sustainable development goals.
4. Identify the impact of green bonds on progress towards selected SDG targets in EU countries.

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The aim of this article is to try to establish whether or not there is a relationship between the issuance of green bonds and the achievement of selected SDG goals. In connection with the implementation of the research objective, research procedures were adopted to lead to its achievement, which is illustrated in Figure 1.

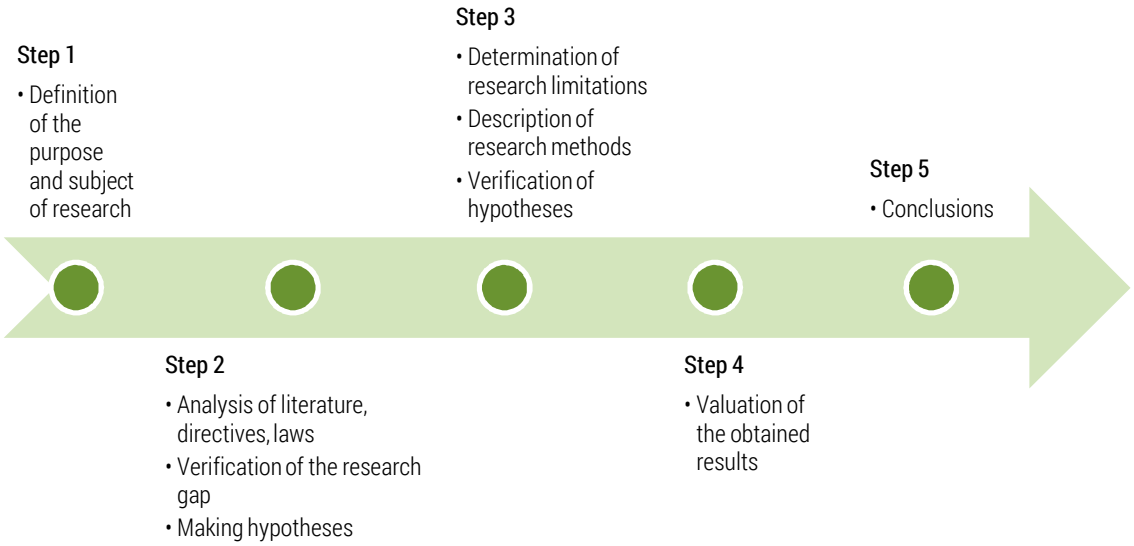


**Figure 1**. Research procedures

## An overview of the literature

The results show various directions of research on green bonds, which mainly focus on their impact on the implementation of the idea of a green economy, as well as on the attitude of investors and financial markets toward them (Figure 2). From the second direction, a new path emerges – research on the impact of non-financial factors, but this direction is relatively new and is still under investigation, which makes the research very attractive. Following the direction of research on the idea of a green economy, two strands can be identified. The first strand is about the essence of green bonds, and the other is related to studies on climate regulation and the role of green bonds in this process.

In the literature on the subject, a discussion has been undertaken on the essence that distinguishes green bonds and their general market trends (Więckowska, 2013; Kochetygova & Jauhari, 2014; Flammer, 2021; Fatica et al., 2019; ICMA GBP, 2021; Gilchrist et al., 2021), and barriers for its further development (Clapp, 2014; Doran & Tarner, 2019; Yamahaki, 2022). It started with the European Investment Bank's "climate awareness bond" issued in 2007 (La Société du Grand Paris, 2020) and defining the foundations of the instrument to the inclusion of the "green bond" instrument in internationally significant government documents such as "Strategy for Financing the Transition to a Sustainable Economy" (European Commission, 2021). The discussion, and especially the practice of issuing green bonds, made it possible to indicate the distinguishing feature that is common to "green bonds", which is the specific allocation of funds from the issue and directing them to finance goals related to climate change, biodiversity protection and sustainability. Green bonds are called climate bonds alongside blue bonds (ICMA, 2019). The definition of blue bond is related to the definition of blue economy, and both are similar to the definitions of green economy and green bond. They are more specific and relate to oceans, seas and coastal areas and their biodiversity. The definition proposed by the World Bank says blue bonds are "a debt instrument issued by governments, development banks or others to raise capital from impact investors to finance marine and ocean-based projects that have positive environmental, economic and climate benefits" (World Bank, 2018). The essence of blue bonds is reflected in the definition saying that it is a use-of-proceeds bond that aims to finance sustainable ocean activities (Roth et al., 2019). It is indicated that blue bonds serve the

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implementation of objective 14 of the SDG and serve to finance the use of the sea and its resources for sustainable economic development (Thompson, 2022; Simpson, 2021) and refers to financial support for any economic activity in the maritime sector towards ensuring its sustainability". This approach, evolving in the literature on the subject (March et al., 2023), means that blue bonds must be used for such purposes as to respect ecosystem integrity and biodiversity.

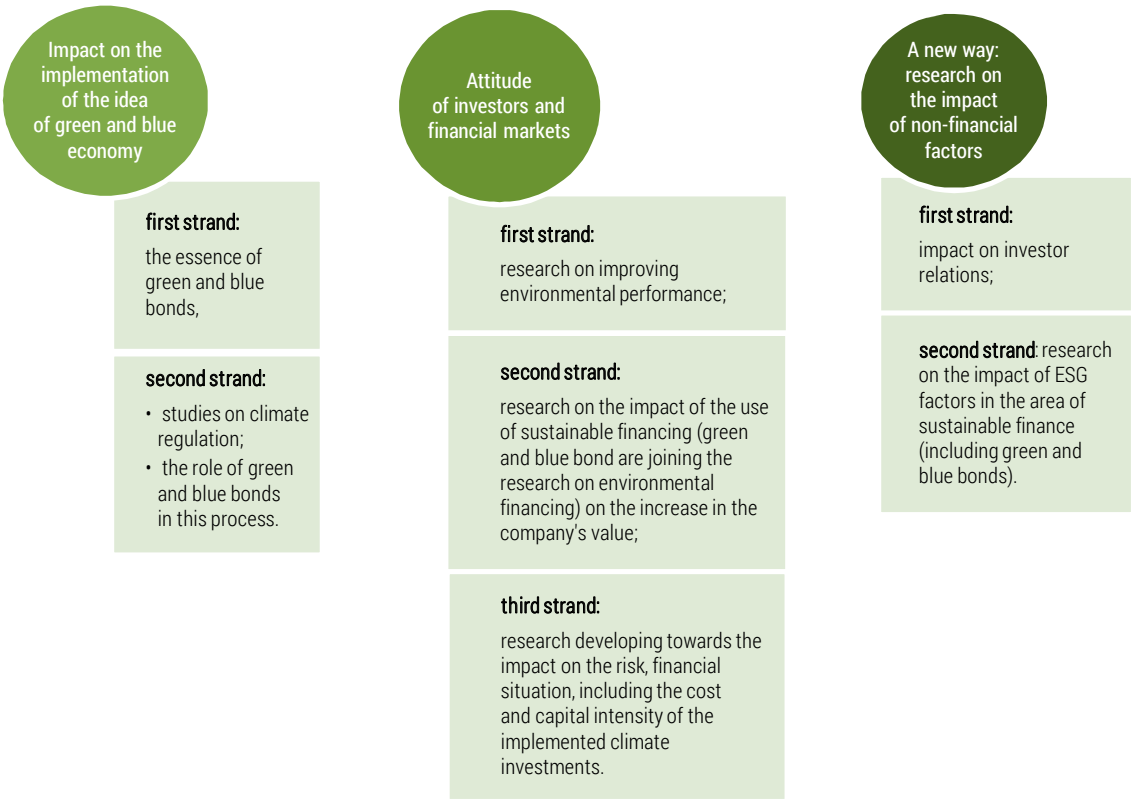


**Figure 2**. The various directions of research on green bonds

As pointed out, the second strand is related to studies on climate regulation and the role of green and blue bonds in this process. In the international context, the factors of the development of the green bond market in terms of financing clean energy are analysed (Kaminker & Stewart, 2012; Ross, 2018), the importance of green bonds for sustainable development (Maltais & Nykvist, 2020), the importance of blue bonds in the development of the blue economy (Tirumala & Tiwari, 2022; Thompson, 2022) and the development of the energy market towards RES (Roth et al., 2019), the importance of blue and green instruments in the circular economy (Bosmans & de Mariz, 2023; March et al., 2023), the importance of green bonds for green (Thompson, 2022; Lipowicz, 2023) and blue development (Tirumala & Tiwari, 2022), the consequences of green bonds for issuers (Gianfrate & Peri, 2019) and investors. Research indicates that green bond issuers have lower $CO_2$ emissions relative to revenue and assets than firms that do not issue green bonds (Schmittmann & Chua, 2021).

The analysis of the literature on the subject shows that there is a tendency to distinguish "green" bonds and "blue" bonds. However, market practice, and especially the existing taxonomy, includes "green" and "blue" bonds in one of five groups and thus does not distinguish "blue" bonds (Chouhan et al., 2024).

The literature identifies key barriers to financing sustainable ocean economy development and proposes different approaches to overcoming them (Sumaila et al., 2021). The importance of using both green bonds in financing innovative climate change is also indicated (Noone et al., 2013). This trend also recognises the role of green bonds as instruments that fit in with the idea of sustainable finance (Libes & Eldridge, 2019) and points to the importance of these instruments in facilitating the "greening" of traditionally brown sectors (Delpla & von Weizsäcker, 2010; Thompson, 2022; March et al., 2023).

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To sum up, the ongoing discussion on the role and meaning of green bonds and their formalisation in the form of a definition leads to an unequivocal conclusion that international organisations such as the World Bank or major financial intermediaries acting as issue agents (e.g. Deloitte, KPMG, ICMA) agree on the essence of these instruments and associate their role in contributing to the change of the economy towards a circular economy, greening the economy, moving away from the brown economy and ensuring biodiversity. Moreover, such bodies as the EU Commission, pointing out in one of the most important environmental documents, i.e. the European Green Deal, emphasises that it should be made easier for investors and enterprises to determine which investments are environmentally sustainable and to ensure that they are credible, which is why uniform approach (European Commission, 2021; ICMA GBP, 2021). This goal is achieved through the introduction of a taxonomy, more transparent labelling of retail investment products and the development of a European standard for green bonds, which would facilitate making environmentally sustainable investments in the most convenient way. The presented position will, in the future, direct and develop the research of the discussed trend towards the importance of taxonomy and will contribute to the ordering and classification of activities towards climate and circular economy.

The second direction is the attitude of investors and financial markets toward green bonds. Here, you can also point to some strands of research development and evolution. It should be pointed out: research on improving environmental performance, research on the impact of the use of sustainable financing (green and blue bonds are joining the research on environmental financing) on the increase in the company's value, research developing towards the impact on the risk, financial situation, including the cost and capital intensity of the implemented climate investments.

The literature review shows that green bonds are effective in improving environmental performance, but only when they are certified by third parties (Yeow & Ng, 2021). Additionally, green bonds offer distinct advantages to the issuers and shareholders (Nguyen et al., 2021). Research shows that green bond issuance resulted in a positive market reaction and raised the company's value (Kuchin et al., 2019). Tang and Zhang (2020) and Flammer (2021) confirmed the positive effects of green bond issuance on the performance of issuance firms' stock prices and the impact on saw improvements in short-run firm value, institutional ownership, and stock liquidity.

The impact of external certification was also studied, and the consequences of an underdeveloped green bond market, where weak governance still dominates, were pointed out. Moreover, the negative effect is that corporations tend to take advantage of green finance's growing popularity, causing the greenwashing problem as a problem of externalities occurrences (Yeow & Ng, 2021).

Another strand is research aimed at understanding the impact of green bonds on risk and the financial situation of the entities issuing them, including the cost and capital intensity of the implemented climate investments. Related to this strand is the study of investors' motives from the point of view of choosing green or blue bonds. The use of green bonds confirms the company's environmental commitment and its focus on the implementation of projects that are environmentally friendly and counteract climate change (Pimonenko et al., 2020; Flammer, 2021).

The use of green instruments, such as green bonds, in the financing of projects contributing to climate risk mitigation affects the overall assessment of the risk associated with the project itself (Antoniuk & Leirvik, 2021). Exposure to climate risk restricts access to finance in general (Ginglinger & Moreau, 2021). Higher exposure to such risk leads to higher costs of debt (Kling et al., 2021), lower credit ratings, and higher yield spreads (Seltzer et al., 2021) because such entities are perceived as more likely to default (Capasso et al., 2020). Green bonds widen the choice for investors who are socially responsible since they can invest in a project and not in the company itself (Shishlov et al., 2016). In addition, these instruments might have an uncompensated advantage for investors since they offer higher returns with lower volatility (Antoniuk & Leirvik, 2021). Feb et al. (2018) investigated the effects of the liquidity premium on the green bond yield spreads, and Chiesa and Barua (2018) examined the factors affecting green bond issuance and pricing.

More and more space in the literature is devoted to research on non-financial factors and their role in sustainability. Therefore, taking into account the issues of including communication related to corporate responsibility and sustainability (especially the discussion on ESG, reporting, and taxonomy), we can talk about " the new way", which focuses research on the impact of non-financial factors on the green and blue bonds market (see Figure 2). Research on investor relations and their reactions was conducted by Wong and Zhang (2022). They showed that the reputation of entities is considered

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a valuable intangible asset by investors, and adverse ESG disclosure via media has a significant and negative impact on firm valuation.

Research shows that the use of decent ESG practices not only increases the propensity for green bond issuance by entities but also helps them issue more green bonds (Wang et al., , 2022; Chen et al., 2023), which means easier access to capital financing for climate change. It should also be noted that studies on the impact on financial results, including ESG factors, were developed. The research identified the negative effect of financial performance in issuing green bonds when combining the effect of ESG performance (Wang et al., 2022; Wong & Zhang, 2022). The research also showed that brand reputation alone may not be sufficient to help firms successfully issue green and blue bonds and that they may need superior corporate social responsibility performance in the form of high ESG scores to unlock the full potential of their brand reputation (Cheng et al., 2023).

Only a few papers have been concerned with the assessment of the impact of green bonds on the achievement of SDG's goals. The climate and the social themes are intertwined and, directly or indirectly, affect the implementation of the SDGs. The literature indicates that Climate Action (SDG13) is linked to other SDGs, including Food Production (SDG2), Health (SDG3), Water (SDG6), Energy (SDG7), Building & Transport (SDG9), City Infrastructure (SDG11), Sea (SDG14) and Agriculture (SDG15), and the achieved level of climate action affects the achievement of other SDGs (Ahmed et al., 2023). Green bond issuance is also assessed in the context of climate change and regional impacts (Delpla & von Weizsäcker, 2010; Thompson, 2022; March et al., 2023; Samuwai & Wiese, 2022; Bernabé Argandoña et al., 2022; ESCAP, 2023). Consequently, green bonds are considered as a bridge to the SDGs in a sense that climate mitigation and adaptation are integral to successful implementation of the SDGs while respecting the ESG risk (ICMA, 2018, 2019a, 2019b, 2019c).

There is no general discussion and research on the impact of green bonds on the achievement of the indicated SDG goals. However, no less interesting is the analysis of the degree of achievement of these goals and how their implementation is progressing in individual countries. The discussion shows only specific goals and bonds as a source of financing. There is no comprehensive approach to assess whether green bond financing is an important source for achieving the SDG goals, which countries use green bonds as a priority to finance the SDG goals, and where it is a marginal instrument. Such research would allow for a better focus of activities for the development of the green bond markets.

## Research methods

In order to answer the research questions (b, c and d) posed in the introduction, it is necessary to analyse the evolution of selected SDG indicators that, according to the authors, are most dependent on the type of funding analysed. The selection of these indicators was based on an analysis of trends in the use of green bonds, as well as statistical data presenting the volume and target areas of green bond issuance in European Union countries (the United States of America and China were also presented as the largest green bond issuers, but were not included in the dependency analyses due to data gaps). These indicators were identified in the framework under Goals 7 (Ensure access to affordable, reliable, sustainable and modern energy for all), 8 (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all), 9 (Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation), 12 (Ensure sustainable consumption and production patterns) and 13 (Take urgent action to combat climate change and its impacts) and are presented in Table 1[1].

1 United Nations. (2024). Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. https://unstats.un.org/sdgs/indicators/Global-Indicator-Framework-after-2024-refinement-English.pdf

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Table 1. Selected SDG indicators in targets 7, 8, 9, 12 and 13[2]

| Target | Indicator |
|---|---|
| 7.2.1 | *Renewable energy share in the total final energy consumption (%)* |
| 7.b.1 | *Installed renewable energy-generating capacity in developing and developed countries (in watts per capita)* |
| 8.4.2 or 12.2.2 | *Domestic material consumption, domestic material consumption per capita, and domestic material consumption per GDP (Domestic material consumption per capita (tonnes), Domestic material consumption per unit of GDP (kilograms per constant 2015 United States dollars)* |
| 9.4.1 | *$CO_2$ emission per unit of value added (Carbon dioxide emissions per unit of manufacturing value added (kilogrammes of $CO_2$ per constant 2015 United States dollars, Carbon dioxide emissions per unit of GDP PPP (kilogrammes of $CO_2$ per constant 2017 United States dollars))* |
| 12.a.1 | *Installed renewable electricity-generating capacity (watts per capita)* |
| 13.2.2 | *Total greenhouse gas emissions without LULUCF for Annex I Parties (Mt $CO_2$ equivalent)* |

Sources: authors' own calculation based United Nations (2024).

Data on green bonds and progress towards the selected SDG targets were then collated, and their relationship was established using Pearson correlation coefficients (with statistical significance determined using the Pearson product correlation coefficient test). To illustrate the ranking of the analysed countries in terms of the level of achievement of the indicated SDG indicators, a synthetic measure was calculated using a multidimensional scaling method, and the relationship of the calculated measure with the volume of green bond issuance was then determined.

Data on the volume and sectors of green bond financing were taken from the Climate Bonds Interactive Data Platform, the first sustainable debt data tool of its kind (Climate Bonds, n.d.), data on SDG indicators were taken from the Sustainable Development Goal Indicators website (United Nations, n.d.). The analysis was conducted for the period 2014-2023.

As mentioned above, a multidimensional scaling method was used to analyse the level of achievement of selected SDG targets by EU countries (as a directly unobservable phenomenon) by linearly ordering and grouping a set of objects (countries) described by variables measured on a quotient scale.

Initially, 16 variables from the Sustainable Development Goal Indicators website for 2014 and 2022 were used, describing the indicated SDG target indicators, supplemented by two variables representing environmental expenditure (*Share of environmental expenditure in GDP in % and National expenditure on environmental protection – total economy in million euros per 1,000 inhabitants*).

The data were statistically analysed to reduce the number of variables to 9. Finally, countries were ranked and grouped based on the results of multidimensional scaling. Multidimensional scaling is a two-step (hybrid) test procedure for visualising linear ordering results for metric data. In the first step, multidimensional scaling is used to visualise objects in two-dimensional space. In the second step, a linear ordering of objects is performed based on the Euclidean distance from the development pattern. The hybrid method uses the concept of isoquant and developmental path (the shortest path between a developmental pattern and an anti-pattern)[3]. The research procedure was carried out in the following steps:

1. Identification of a complex phenomenon that is not directly measurable (level of achievement of selected country SDG indicators based on selected SDG indicators).
2. Definition of a set of objects (countries) and a set of diagnostic variables describing the phenomenon analysed.
3. Present the data in the form of a matrix. $X = [xij]_{n \times m}$.
4. Identify a pattern (upper pole) and an anti-pattern (lower pole) from the diagnostic variables.
5. Normalise the values of the variables and create a matrix $Z = [zij]_{n \times m}$.

2 An analysis of Objectives 7.a.1, 9.1.2 and 13.a.1 was also considered, but for the former data are only available for China, for the latter data are not available at all or only for selected countries for passenger and freight transport and for the latter data are not available at all.

3 More about this method: Walesiak (2017), Walesiak and Dehnel (2019).

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6. Choice of distance measure for metric data (urban, Euclidean, Chebyshev, Euclidean square, GDM1) and construction of distance matrix $\delta = [\delta_{ik}(Z)]_{n\times n}$, i, k = 1,..., n.
7. Multidimensional scaling: f : δik (Z ) → dik (V ) for all pairs (i, k), where f denotes the mapping of distances from the m-dimensional space δik (Z ) into the corresponding distance dik (V) in a q-dimensional space q < m.
8. Create a data matrix in two-dimensional space: $V = [vij]_{n\times k}$ , (q = 2).
9. Arrangement of objects based on the value of an aggregate measure based on the Euclidean distance from the benchmark object:

$$d_i = 1 - \sqrt{\sum_{j=1}^{2}\left(v_{ij} - v_{+j}\right)^2} \Big/ \sqrt{\sum_{j=1}^{2}\left(v_{+j} - v_{-j}\right)^2} \quad (1)$$

where:
vij – is the j-th coordinate for the i-th object in two-dimensional space,
v+j (v-j ) – is the j-th coordinate for the pattern (anti-pattern) object in two-dimensional space.

In this way, the calculated aggregate measures for 2022[4], representing countries in terms of the level of achievement of selected SDG indicators, were juxtaposed with the volume of green bonds issued between 2014 and 2022 to determine the relationship between them. The Pearson correlation measure was used for this purpose.

## Results of the research

Interest in green bond issuance increased significantly over the period. Their level in 2023 is almost USD 725 billion, compared to less than USD 39 billion in 2014. Between 2014 and 2023, the global volume of green bonds amounted to USD 2795.8 billion. European countries issued the most green bonds, while African countries issued the least. Looking at individual countries, the largest volumes of this type of debt instrument were issued in China, the United States, Germany, France and the Netherlands (together accounting for almost 60% of the total green bond volume). The volume of green bond issuance in EU countries and, for comparison, in the US and China is shown in Table 2.

**Table 2.** Green bond volumes in selected countries from 2014 to 2023 (in USD billion)

| Country | Value of green bonds (USD billion) | Value of green bonds per 100 000 inhabitants (USD billion) | Share of global emissions (%) |
|---|---|---|---|
| Austria | 29.70 | 0.3308 | 1.06 |
| Belgium | 30.00 | 0.2582 | 1.07 |
| Bulgaria | 0.00 | 0.0000 | 0.00 |
| Croatia | 0.00 | 0.0000 | 0.00 |
| Cyprus | 0.60 | 0.0663 | 0.02 |
| Czechia | 0.30 | 0.0029 | 0.01 |
| Denmark | 40.50 | 0.6896 | 1.45 |
| Estonia | 0.20 | 0.0150 | 0.01 |
| Finland | 24.40 | 0.4398 | 0.87 |
| France | 228.70 | 0.3484 | 8.18 |
| Germany | 287.10 | 0.3449 | 10.27 |
| Greece | 2.90 | 0.0277 | 0.10 |

4 For most of the SDG indicators, the latest available data is presented for 2022.

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| Country | Value of green bonds (USD billion) | Value of green bonds per 100 000 inhabitants (USD billion) | Share of global emissions (%) |
|---|---|---|---|
| Hungary | 7.00 | 0.0722 | 0.25 |
| Ireland | 26.00 | 0.5138 | 0.93 |
| Italy | 91.30 | 0.1547 | 3.27 |
| Latvia | 0.50 | 0.0267 | 0.02 |
| Lithuania | 0.90 | 0.0321 | 0.03 |
| Luxembourg | 16.70 | 2.5535 | 0.60 |
| Malta | 0.00 | 0.0000 | 0.00 |
| Netherlands | 137.90 | 0.7839 | 4.93 |
| Poland | 14.40 | 0.0382 | 0.52 |
| Portugal | 12.10 | 0.1169 | 0.43 |
| Romania | 1.20 | 0.0063 | 0.04 |
| Slovakia | 1.10 | 0.0202 | 0.04 |
| Slovenia | 0.60 | 0.0285 | 0.02 |
| Spain | 84.40 | 0.1779 | 3.02 |
| Sweden | 84.20 | 0.8056 | 3.01 |
| United Kingdom of Great Britain and Northern Ireland | 101.40 | 0.1513 | 3.63 |
| United States of America | 454.40 | 0.1363 | 16.25 |
| China | 371.90 | 0.0263 | 13.30 |
| Total | 2795.80 | | 100 |

Sources: authors' work based on Climate Bonds (n.d.).

In the early years of the analysis, development banks were the main issuers of green bonds, but over time the issuers of this type of instrument have been mainly financial corporations and non-financial corporations (each responsible for issuing 30% of the total volume of green bonds in 2023). Local governments and government-backed entities are also among the issuers, but they do not represent a very significant share of the market. The former accounted for 3% of issuance and the latter for 17.4% over the entire period analysed.

Funds from the sources analysed were mainly used to finance projects in the energy (USD 965 billion – 34% of the total), construction (USD 707 billion – 25% of the total) and transport (USD 522 billion – 18% of the total) sectors. To a much lesser extent in the water (7% of the total) and waste (4% of the total) sectors. The trends in the use of green bonds by year of analysis are shown in Figure 3.

Regarding the analysis of the level of the selected SDG indicators, it should be noted that they improved in most EU countries between 2014 and 2022. Examples of countries with unfavourable trends in this respect are Romania and Hungary, where there was a decrease in the share of renewable energy in total final energy consumption (%). In the case of Romania, there is also an increase in domestic material consumption per capita (tonnes) (8.4.2 = 12.2.2) and in Hungary, an increase in total greenhouse gas emissions without LULUCF for Annex I Parties (Mt $CO_2$ equivalent) (13.2.2). Unfavourable changes in the analysed SDG indicators can also be observed in other countries, such as Bulgaria, Lithuania or Slovakia. A summary of the key measures describing the indicators chosen for further analysis is presented in Table 3.

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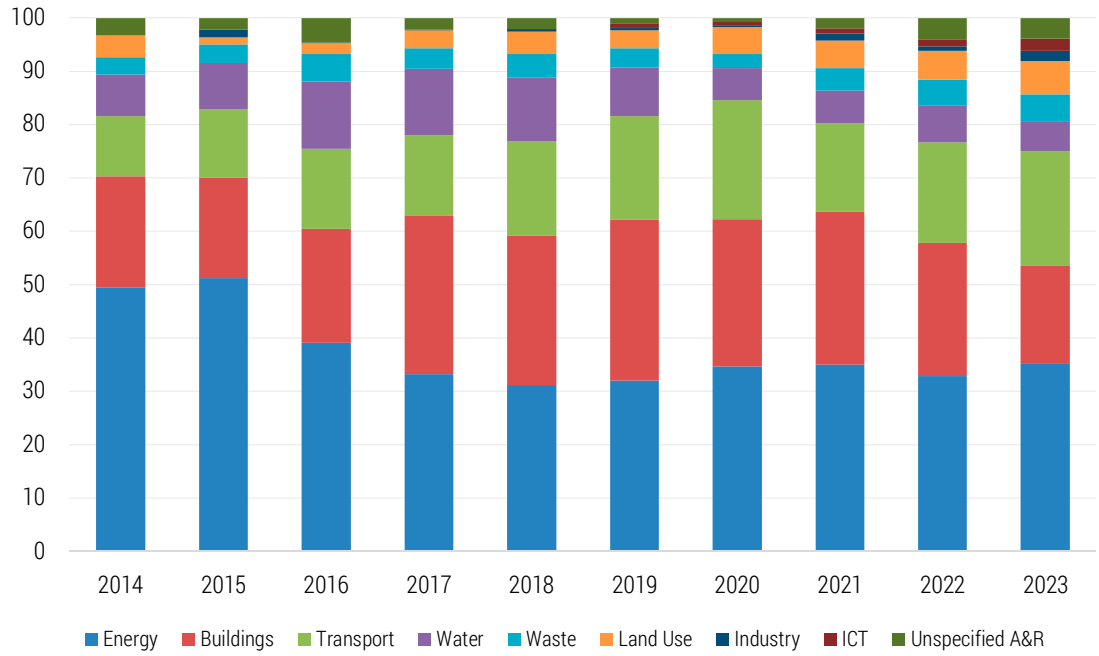


**Figure 3.** How to use Green Bonds

Sources: authors' work based on Climate Bonds (n.d.).

**Table 3.** Characteristics of diagnostic variables

| Diagnostic variables | Arithmetic mean | | Median | | Standard deviation | | Coefficient of variation | |
|---|---|---|---|---|---|---|---|---|
| | 2014 | 2022 | 2014 | 2022 | 2014 | 2022 | 2014 | 2022 |
| *Renewable energy share in the total final energy consumption (%) – $x_1$* | 20.52 | 24.86 | 17.13 | 20.38 | 11.71 | 12.49 | 57.06 | 50.25 |
| *Installed renewable energy-generating capacity in developing and developed countries (in watts per capita) – $x_2$* | 720.12 | 1174.24 | 560.68 | 1011.68 | 563.17 | 748.86 | 78.20 | 63.77 |
| *Domestic material consumption per capita (tonnes) – $x_3$* | 16.35 | 18.21 | 14.84 | 16.00 | 6.82 | 7.82 | 41.73 | 42.94 |
| *Domestic material consumption per unit of GDP (kilograms per constant 2015 United States dollars) – $x_4$* | 0.80 | 0.73 | 0.64 | 0.61 | 0.59 | 0.59 | 73.71 | 80.42 |
| *Carbon dioxide emissions per unit of manufacturing value added (kilogrammes of $CO_2$ per constant 2015 United States dollars) – $x_5$* | 0.25 | 0.21 | 0.22 | 0.19 | 0.16 | 0.13 | 62.61 | 65.21 |
| *Carbon dioxide emissions per unit of GDP PPP (kilogrammes of $CO_2$ per constant 2017 United States dollars) – $x_6$* | 0.17 | 0.13 | 0.15 | 0.12 | 0.07 | 0.04 | 40.63 | 33.33 |
| *Total greenhouse gas emissions without LULUCF for Annex I Parties (Mt $CO_2$ equivalent) – $x_7$* | 139.72 | 128.76 | 58.99 | 56.36 | 196.21 | 175.12 | 140.43 | 136.01 |
| *Share of environmental expenditure in GDP in % – $x_8$* | 1.91 | 2.02 | 1.90 | 2.00 | 0.58 | 0.63 | 30.18 | 31.25 |
| *National expenditure on environmental protection – total economy in million euros per 1,000 inhabitants – $x_9$* | 0.56 | 0.65 | 0.48 | 0.59 | 0.33 | 0.38 | 59.79 | 58.76 |

Source: authors' work based on Eurostat (n.d.) and United Nations (n.d.).

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The value of the Pearson correlation coefficient between the adopted diagnostic variables and the volume of green bonds issued between 2014 and 2022 is shown in Table 4.

**Table 4**. Correlation coefficient between green bond size and selected diagnostic variables

| $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ |
|---|---|---|---|---|---|---|---|---|
| 0.604226 | -0.10333 | 0.210994* | 0.030872* | 0.092181 | 0.413224 | -0.04209 | 0.14712 | 0.489713 |

* No statistical significance.

Source: authors' work based on Eurostat (n.d.) and United Nations (n.d.).

When analysing the magnitudes of the Pearson correlation coefficients, it should be noted that in the case of 7 variables, it is possible to speak of the existence of coexistence between the volume of green bond issuance and between them (with the exception of variables $x_3$ and $x_4$). However, given the strength of the coefficient calculated, only 3 of them should be noted, namely:

- share of renewable energy in total final energy consumption (%) – $x_1$,
- carbon dioxide emissions per unit of GDP PPP (kilograms of $CO_2$ per constant 2017 US dollars) – $x_6$,
- national expenditure on environmental protection – total economy in millions of euros per 1,000 inhabitants – $x_9$.

However, when the analyses are deepened, and a linear regression analysis of a variable is used, where the explanatory variable is the size of green bonds and the indicated diagnostic variables $x_1$, $x_6$ and $x_9$, only in the case of the share of renewable energy in total final energy consumption (%) is the regression model statistically significant. Therefore, only in this case can it be said that there is a relationship between the variables. In this case, the coefficient of determination $R^2$ is 0.362, which means that only slightly more than 36% of the variable Green Bonds (converted into million euros per 100 000 inhabitants) – GB explains the share of renewable energy in total final energy consumption (%). This variable is, therefore, also significantly influenced by other determinants. The results of the regression analysis allowed the formulation of the explanatory function Renewable energy share in total final energy consumption (%) – RES described by the formula:

$$RES = 3.05 + 4.44\ GB \tag{2}$$

In search of a relationship between the level of achievement of the selected SDG targets and the volume of green bond issuance, an additional ranking of EU countries in terms of the achievement of the indicators of the selected SDG targets in 2014 and 2022 was performed using the multidimensional scaling method described. The results of this analysis are shown in Figures 4 and 5.

Finally, the results of the 2022 country ranking were compared with the volume of green bonds issued per 100,000 inhabitants between 2014 and 2022 (Figure 6).

As can be seen in Figure 6, countries with higher levels of green bond issuance are closer to the benchmark, i.e. the best object created for the study – characterised by the most favourable indicators for the selected SDG targets. At the opposite extreme are the countries with the lowest issuance, with the exception of Luxembourg, which clearly has the highest green bond issuance per 100,000 inhabitants and yet ranks about halfway between the benchmark and the anti-benchmark. Significantly, the Pearson correlation coefficient between the variables analysed reached a fairly high level (0.7), indicating that a co-occurrence can be observed between them, i.e. an increase in green bond emissions leads a country to move closer to the calculated benchmark in the method used to rank the objects (countries).

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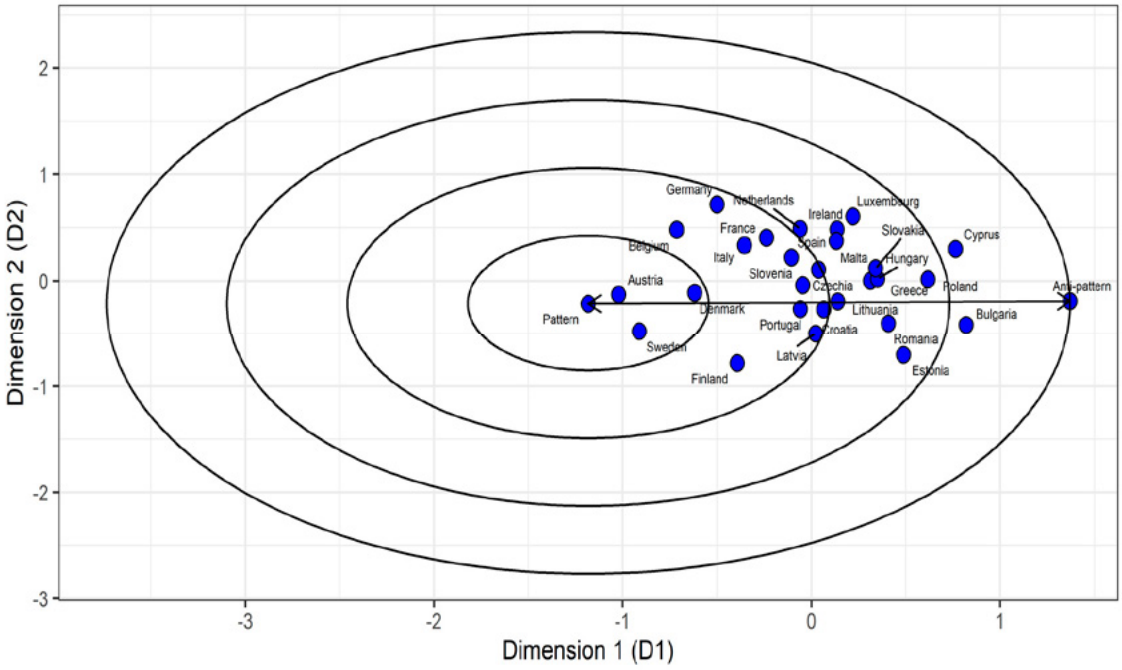


**Figure 4.** Distance from the patern/anti-patern object in 2014

Source: authors' work based on Eurostat (n.d.) and United Nations (n.d.).

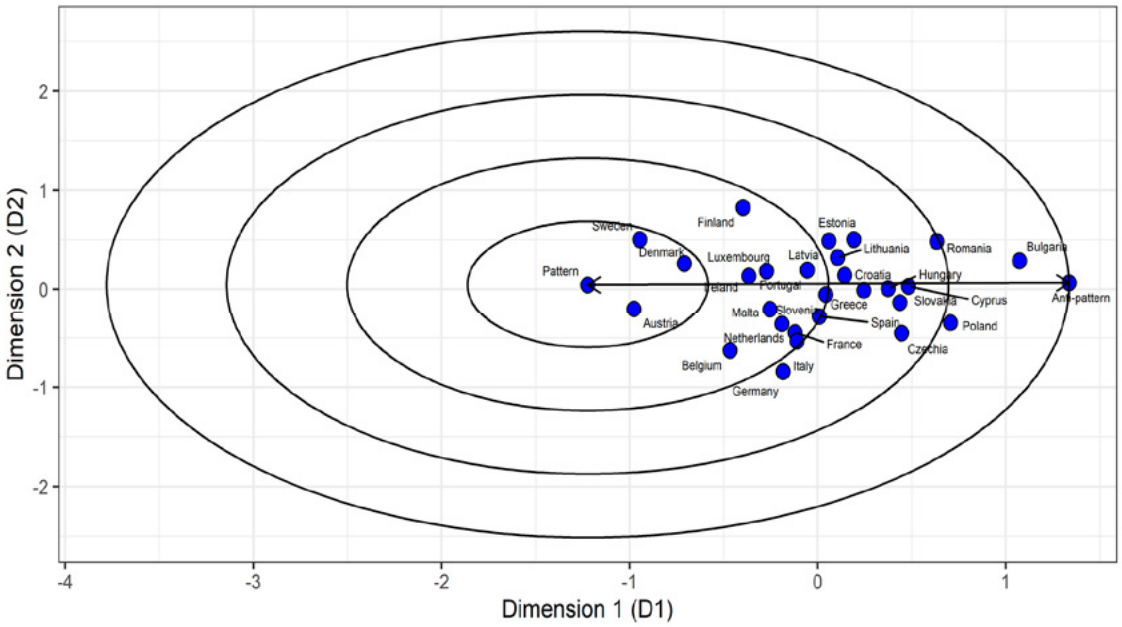


**Figure 5.** Distance from the patern/anti-patern object in 2022

Source: authors' work based on Eurostat (n.d.) and United Nations (n.d.).

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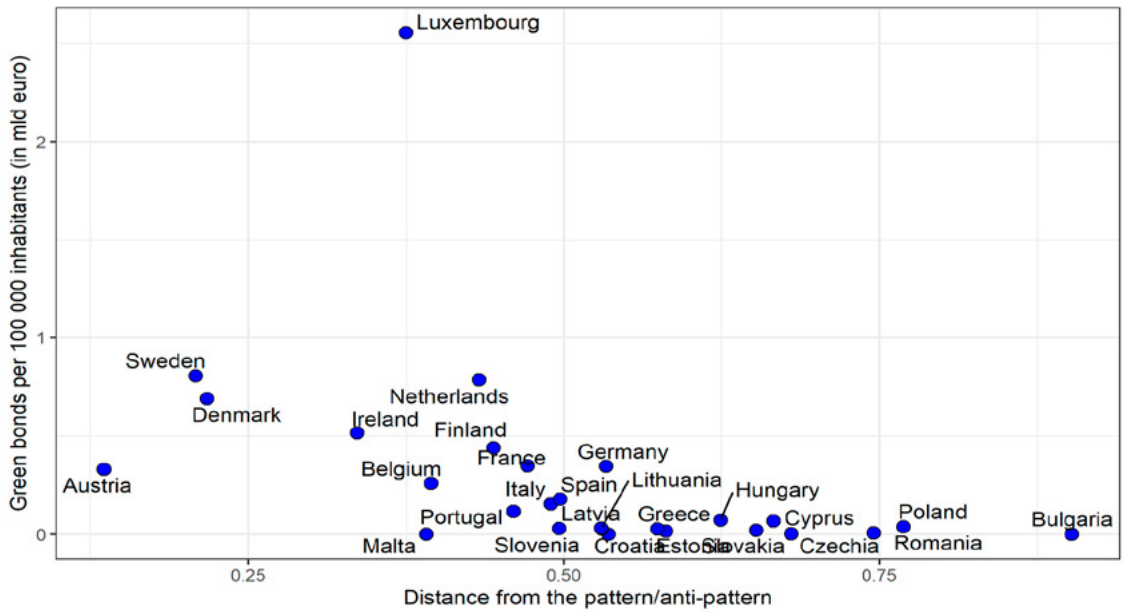


**Figure 6.** Distance from the pattern/anti-pattern object and green bonds

Source: authors' work based on Eurostat (n.d.) and United Nations (n.d.).

## Discussion/Limitation and future research

Global and EU green bond markets are showing annual growth and strong interest. The pace of growth is uneven. While data from the Climate Bonds Initiative shows that between 2014 and 2020, the value of issuance increased by an average of 50% per year, after 2020, a decline in the share of green bonds in total bond issuance is visible (Chouhan et al., 2024). To achieve the goals set out in the Paris Agreement and the European Green Deal, the market for high-quality green bonds must grow faster.

As shown in the literature, for sustainable development, it becomes important to analyse and compare intensive and extensive growth to argue that certain development trajectories of capturing climate change and its impact on green growth require assessment but also change (Eikeset et al., 2018). Our study allows for an assessment in the context of the change indicated by Chouhan et al. (2024), Delpla and von Weizsäcker (2010), Thompson (2022) and March et al. (2023).

An important factor influencing our results was regulatory changes on the market, which, on the one hand, changed the approach to classifying instruments towards taxonomy, but on the other hand, an important factor in recognising emissions is their certification by third parties, which is discussed by Yeow and Ng (2021). Regulatory changes caused the need for adjustment but also greater investor awareness, which affected the volume of emissions (recognition of emissions as green). Thus, the previously unrecognised problem of classifying emissions as "green" affected the degree of implementation of SDG goals. This problem also concerns the unambiguity of the classification of the instruments themselves. As we indicated, green and blue bonds are distinguished (World Bank, 2018); however, their current classification based on taxonomy makes it difficult to select blue bonds, and they are recognised in different classification positions, as indicated by Chouhan et al. (2024). Thus it should be demonstrated that it is difficult to capture the implementation of SDG goals using green and blue bond issues. While examining the degree of implementation of SDG goals, we encountered another limitation, which is the data describing SDG goals. Variables can be used to describe several SDG goals, which distorts the measurement. In our study, we selected only unambiguous data, which we grouped in Table 1.

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Our study, against the background of the literature, shows which specific SDG goals are correlated with the issuance of green bonds. Our study extends the existing findings of March et al. (2023) to state that green bonds must be used for such purposes as to respect ecosystem integrity and biodiversity in terms of: the impact on the share of renewable energy in total final energy consumption (variable – $x_1$), carbon dioxide emissions per unit of GDP PPP (variable – $x_6$) and on national expenditure on environmental protection – total economy (variable – $x_9$). The importance of links between energy transition and green instruments was pointed out by Ross (2018), and our study not only confirmed his earlier findings but also demonstrated the link between the SDG target – goal 7 (7.2.1.) related to energy and the green bond market.

The impact of green bonds on the implementation of SDG goals is significant. Further in-depth analysis showed that only in the case of the share of renewable energy in total final energy consumption did the statistically significant relationship occur and there is a relationship between the variables (green bond issuance and the degree of SDG target implementation). In seeking an answer to the question of whether countries with higher levels of green bond emissions are closer to the most favourable indicators for the selected SDG targets? Our study showed that an increase in green bond emissions leads a country to move closer to the calculated benchmark, i.e. to the most favourable indicators for the selected SDG targets.

Our study revealed limitations and difficulties related to the data. The first limitation is the uniformity of the data treatment for bonds. As the literature shows, terminology related to the EU taxonomy has been unified, which has had an impact on financial markets, especially the bond market and the treatment of financial instruments. This limitation affects the lack of data on "bule" bonds but also the classification of "green" bonds in one of the five categories, which are officially indicated in the practice of instruments financing the transformation towards sustainability (ICMA, 2019; ICMA GBP, 2021; Chouhan et al., 2024).

The second limitation and difficulty related to the data is the data describing the SDG goals. The data analysis shows changing indicators for the SDG goals. Data for the indicators are not always included in the analysed period, new indicators can be found, or those that have existed for several years show the information "no data". It should also be noted that the selection of indicators is difficult due to the fact that indicators describing a particular SDG goal are used to characterise another SDG goal. We excluded such a set of indicators from our research. In addition, the data presented for some countries are estimates and are not available for all years.

Importantly, the limitation of our results is also due to the fact that other determinants, not just green bond issuance, also affect the achievement of SDG goals. The Scandinavian countries, which stand out from the other countries analysed, have long pursued policies that favour environmental protection and the adoption of renewable energy sources. These are countries where societies are highly aware of the importance of the SDG goals. A similar conclusion applies to the so-called old EU members. Of the countries and members that joined the EU in 2004, only Lithuania and Slovenia stand out, which consistently lead the transformation towards sustainability and implement the SDG goals pattern. The countries that need to make the most effort and make the most changes are Bulgaria, Poland, Romania and the Czech Republic. It is difficult to clearly indicate the reasons for such a significant departure from the pattern, but political conditions and other determinants influencing the implementation of SDG goals are undoubtedly important. The problem of capturing the factors determining the implementation of SDG goals (in particular, group 7 goals) is addressed in the literature in various contexts, thus indicating a number of factors (Bose et al., 2024), of which non-financial ones are also analysed. However, the main conclusion from the literature review is that financial factors are important, and our study confirms this relationship.

## Conclusions

Green bond volume had an impact on the implementation of SDG goals but contributed more to the transformation towards sustainability. Due to the limitations and difficulties related to the data, the study should be repeated to see which goals, apart from the "energy transformation", are associated with the volume of "green" bonds. Thus, the authors express the hope that the existing recognition of the bond market related to the transformation towards sustainability and the implementation

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of SDG goals will already be shaped, and it will be possible to obtain objective and statistically significant data. It should be noted that there is still enormous untapped potential for the bond market when it is only a few to a dozen percent of the global debt market, and in the primary markets, supply and demand imbalances persist in the scope of financing SDG goals. It should also be pointed out that there is a methodological problem regarding the accuracy of the recognition of "green" bond issues. Therefore, issuers are advised to be more ambitious and embrace greater rigour in their planning and disclosure of green bond issues.

For the literature on the subject, it is important to clearly link the SDG goal regarding financing the energy transformation on the "green" bond market. Our research confirmed this fact but also showed that the leaders of the changes towards the implementation of SDG goals finance themselves on the green bond emissions market. Our study, therefore, confirms the belief that the development of the green bond emissions market is conducive to the implementation of SDG goals.

Issuers, including those operating in hard-to-abate sectors, can leverage the opportunity to connect their investment tasks to their sustainability objectives, beginning with a robust transition plan and linking investments with ESG. This approach can lend credibility. Green bonds offer guidance to support issuers in the development of credible transition plans, which can significantly contribute to greater implementation of SDG goals.

The green bond market thrives with labels such as financing the SDG goals towards transition, gaining momentum, and adding to the diversity of the investible opportunity set and investors. It should be pointed out that understanding the relationship between the size (volume of green bonds issued per 100,000 inhabitants) and the implementation of SDG goals allows for influencing the choices of potential investors. Our study confirms the relationship between the volume of green bonds and goal 7 of SDG. Thus, it can be indicated that the social involvement of investors contributed to changes towards energy transformation. Thus, our study had social significance, as it showed the desired changes in investor attitudes.

We believe that research into the impact on the degree of SDG implementation will continue. We also see the need to undertake research on the impact of green bonds and ESG factors (as important factors for transformation) on the degree of SDG implementation.

### The contribution of the authors

Conceptualization, B.Z.F. and D.W.; literature review, B.Z.F.; methodology, D.W.; formal analysis, B.Z.F. and D.W.; writing, B.Z.F. and D.W.; conclusions and discussion, B.Z.F. and D.W.

The authors have read and agreed to the published version of the manuscript.

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# WPŁYW ZIELONYCH OBLIGACJI NA OSIĄGNIĘCIE CELÓW ZRÓWNOWAŻONEGO ROZWOJU

STRESZCZENIE: Celem artykułu jest próba ustalenia istnienia bądź nie zależności pomiędzy emisją zielonych obligacji a osiąganiem wybranych celów SDG. Realizacja tak sformułowanego celu wymagała: (1). zdefiniowania zielonych obligacji – przedstawienia problemu ujęcia, klasyfikacji na tle regulacji prawnych, (2). określenia wielkości emisji zielonych obligacji oraz kierunków finansowania, (3). oceny wpływu emisji zielonych obligacji na osiąganie wybranych celów zrównoważonego rozwoju (SDG). W szczególności wykorzystano współczynniki korelacji Pearsona, skalowanie wielowymiarowe i wyniki uporządkowania liniowego dla danych metrycznych. W pierwszym kroku skalowanie wielowymiarowe jest wykorzystywane do wizualizacji obiektów w przestrzeni dwuwymiarowej. Badanie potwierdziło związek między celem SDG – celem 7 (7.2.1.) odnoszącym się do energii a wielkością emisji zielonych obligacji. Wykazano również, że wielkość rynku ma znaczenie dla osiągnięcia celów SDG.

SŁOWA KLUCZOWE: zielone obligacje, niebieskie obligacje, zrównoważony rozwój, finansowanie działań klimatycznych, cele SDG, analiza skalowania wielowymiarowego

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