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SUSTAINABLE DEVELOPMENT GREEN INDEX: MEASURING PROGRESS TOWARDS SUSTAINABLE DEVELOPMENT GOALS IN THE EUROPEAN UNION

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Abstract. The EU positions itself at the forefront of the global green agenda. Therefore, it is necessary to assess the development of European countries considering the "green" component of this process. Not all currently known indices cover all aspects of sustainable development. The article aims to develop a Sustainable Development Green Index (SDGI), which, on the one hand, would be used as an effective tool for measuring progress in the implementation of sustainable development goals; and, on the other hand, would take into account economic, social, educational, environmental and political aspects. This study's results demonstrate effectiveness of the suggested tool. Practical application of the SDGI may be instrumental for reaching faster movement towards Sustainable Development Goals in the European Union.

Keywords: Sustainable Development Goals; Sustainable Development Green Index

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JEL Classifications: C43, O44, O52, O57, R11, Q20, Q30

1. Introduction

So far, several comprehensive and inclusive indices measuring progress toward more sustainable development have been created. Ryszawska (2013, 2015, 2017) has worked out a Green Economy Index, which includes the following factors: economy (pollution, resource consumption, emissions, waste), society (social inequalities and poverty), natural capital (biodiversity, ecosystems), politics (environmental policies and strategies). Kasztelan (2017a, 2017b, 2018, 2021) used the Organisation for Economic Cooperation and Development methodology. Its Green Growth Indicators include inequality, GDP per capita, low income, air pollution exposure, environmentally

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related innovation and taxation environmentally adjusted multi-factor productivity, CO2 productivity, material productivity. (OECD Green Growth Indicators 2017, 2017).

The analysed indexes aggregate only some aspects of sustainable development, and their framework hasn't been used for testing the relationship with SDGs'. The present article suggests using an original Sustainable Development Green Index (SDGI), which embraces economic, social, educational, environmental and political aspects and demonstrates a strong relationship with some SDGs' progress in the European Union.

2. Review of literature

The industrialisation has caused environmental degradation, climate change, pollution (Mealy et al., 2020; Adamowicz, 2022), biodiversity loss, and uncontrolled resource exploitation (Burck et al., 2018; Zhao et al., 2021; Usman et al., 2022). Negative consequences affect the quality of human life and economic opportunities (Michalak et al., 2020; Purbawati et al., 2023).

In 2015, the United Nations devised seventeen sustainable development goals (SDGs) to counter such negative consequences. SDGs included five critical areas of importance by 2030 – planet, people, peace, partnership, and prosperity (UNDP, 2022). United Nations motivated global economies to incorporate sustainable principles in their industrial processes (Sivageerthi et al., 2022).

SDGs are commonly classified into three groups: economy, society and biosphere (or environment) (Stockholm Resilience Centre, 2016; Paoli et al., 2019; Yu et al., 2022). However, it is necessary to broaden this view because some SDGs have educational (SDG 4, partially – SDG 9) and political (SDG 13, 16-17, partially – SDG 7) dimensions.

The necessity to integrate economic, social, educational, environmental and political factors into the analysis of SDGs predetermined by applying the Quintuple Helix model within the research. The Quintuple Helix model focuses on the transfer of knowledge and public exchange within the ecosystem of the state (Barth, 2011; Arsova et al., 2021; Purbavati et al., 2023). In addition, the innovative Quintuple Helix model explains how the natural environment, knowledge and innovations are interdepended (Carayannis et al., 2012; 2021; Cai, 2022). The Quintuple Helix Model is a complex structure, with all five helices requiring knowledge in natural science, social science, and humanities (Carayannis and Campbell, 2012; Vitola et al., 2021).

Fig. 1 presents the structure of the Quintuple Helix Model, where knowledge moves in a circle from the education system to the economic system, then to the political system, the public, and the natural environment (Grundel et al., 2016). These five helices work as "subsystems" (Ibid).

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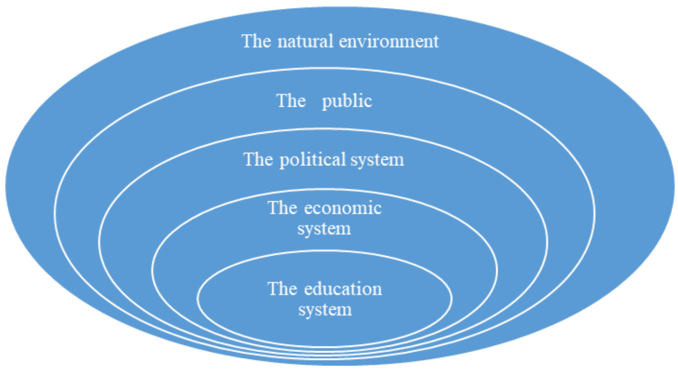

Figure 1. The Model the Quintuple Helix.
Source: The authors' constructions according to Carayannis et al., 2009, 2010, 2011, 2012, 2021

Despite the previous attempts to relate Quintuple Helix Model to sustainable development processes, there is still a gap, in area of how this model could be used for measuring of complex green growth proceeses.

3. Methodology

The authors suggest to look at sustainable development process via lenses of the Quintuple Helix Innovative Model. Here it has to be noted that similar attempts already has been made by e.g. Barcellos-Paula et al. (2021).

Hence, Quintuple Helix Model has been used to make necessary calculations of SDGI. An equal number of indicators (10) were assigned to each of the subsystems (5), 50 indicators in total (see Appendix). All indicators are standardised.

The mean values Sustainable Development Green Index are obtained as arithmetic means of the corresponding indicators. The integrated SDGI was received as the arithmetic mean of the values of five subsystems (Rybalkin, 2022).

3. Results and discussion

The Sustainable Development Green Index (along with its subsystems) has been calculated for the European Union countries (plus the United Kingdom) data collected in 2020. The results of the calculations were analysed and visualised with the help of SPSS software; specifically, cluster analysis was performed. Being a quantitative method of data analysis aimed at discovering groups in data (in the case of the present article – clusters of the EU countries), the value of such research is that it suggests groupings that might form the basis of future hypotheses to be investigated (Landau et al., 2010).

The results of the leading and outsider countries in terms of the Sustainable Development Green Index in 2020 are presented in Fig. 2.

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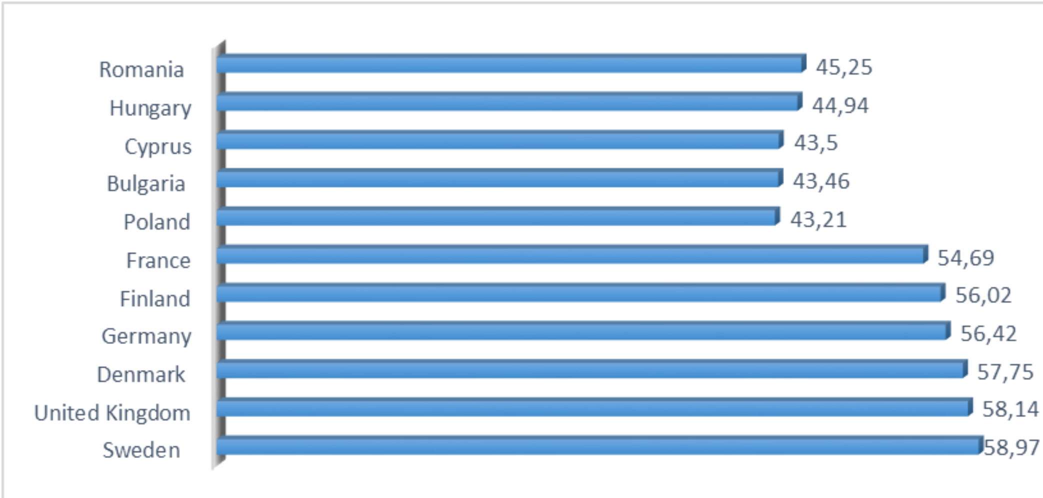

Figure 2. The Sustainable Development Green Index 2020
Source: The authors' calculations in SPSS according to statistical data; were elaborated using mapchart.net.

Cluster analysis allowed to group EU countries into two homogeneous clusters (Figure 2) by their SDGI. The first cluster (Cluster 1) included countries with higher mean values of all five subsystems; a lower level of these mean values characterised other countries (Cluster 2). See Figure 3 below.

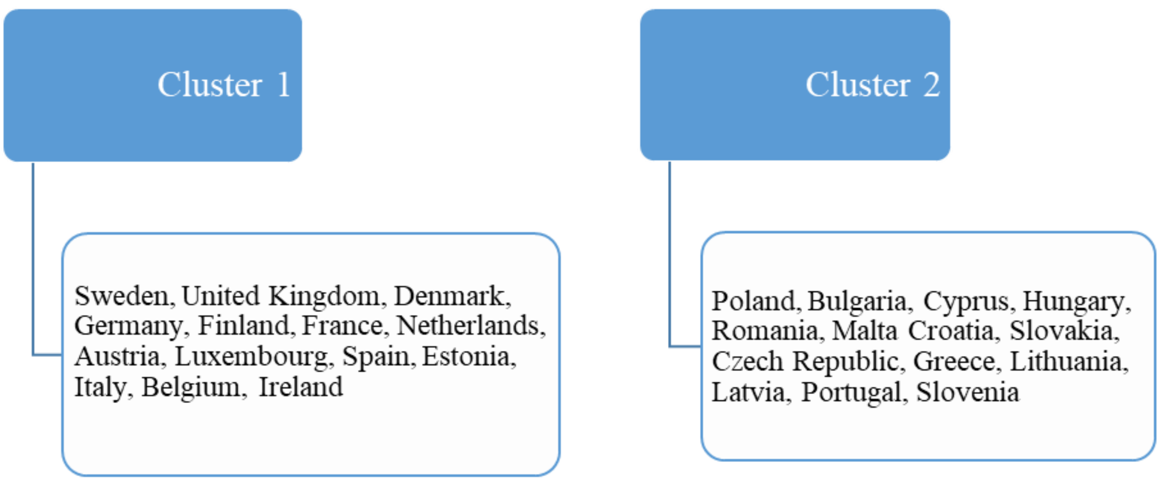

Figure 3. European Union countries are divided into Cluster 1 and Cluster 2 by the Sustainable Development Green Index, 2020
Source: The authors' calculations in SPSS according to statistical data; were elaborated using mapchart.net.

Considering the mean values of the subsystems in the two clusters, it can be concluded that all mean values of subsystems in the Cluster 1 exceed those of subsystems in Cluster 2. Notably, the mean value of the educational subsystem – by 27%, the mean value of the political subsystem – by 18.5%, the mean value of the societal subsystem – by 14.3%, the economic subsystem – by 14.2%, the environmental subsystem – by 11.3% (Figure 4).

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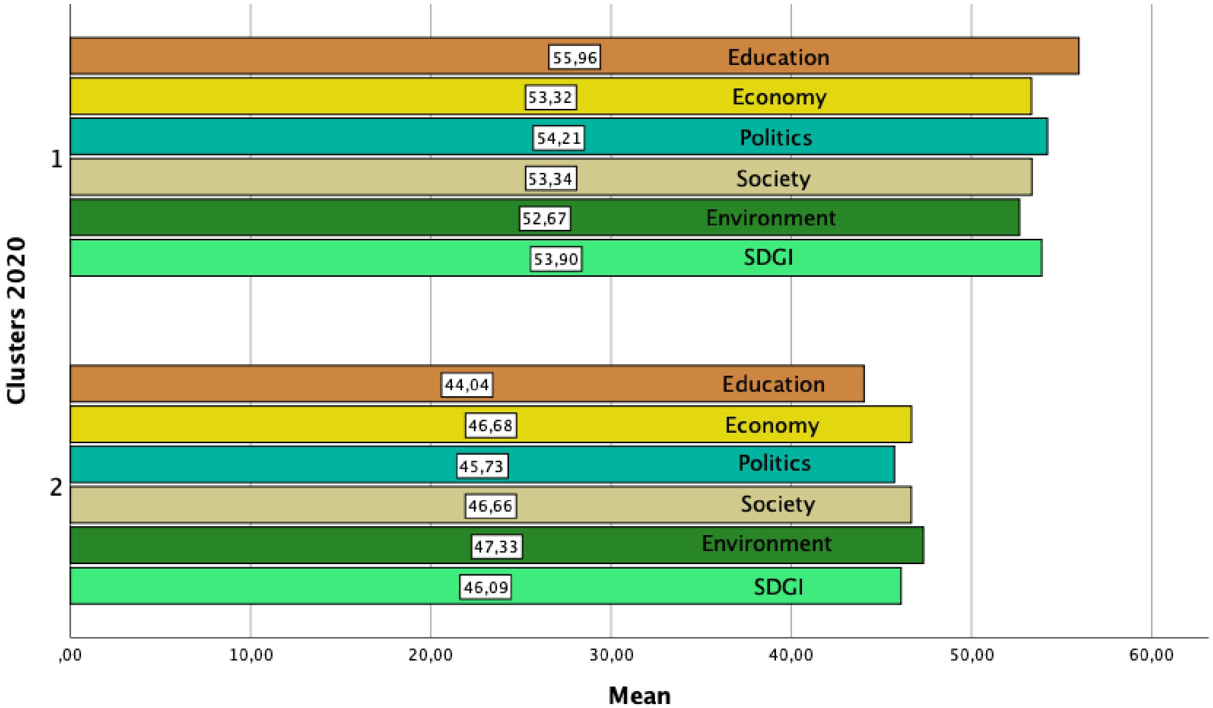

Figure 4. Comparison of Cluster 1 and Cluster 2 according to the Sustainable Development Green Index subsystems, 2020
Source: The authors` calculations in SPSS according to statistical data.

The Sustainable Development Green Index elaborated within the present article has helped to divide the EU countries into two homogeneous clusters, find out the main differences in the performance of the green economy in the context of sustainable development between the clusters. It would be helpful to make it less complicated by revealing the most relevant indicators and constructing simplified version of the index which would contained a reduced number of indicators.

The analysis of the multicollinearity of the unified statistical indicators was performed. To that end, the coefficients of determination $R^2 = r^2$ of each of the primary statistical indicators of the analysed set were found (Ajvazyan, 2005). Next, selecting the most informative criteria among the indicators of each Sustainable Development Green Index category was conducted. The most informative set is the one in which the sum of the coefficients of determination of the dependent variable by the explanatory variables is maximum.

I.e., the set of indicators $x^{(jl_1^0)}, x^{(jl_2^0)}, \ldots, x^{(jl_s^0)}$ is considered to be the most informative, if

$$\sum_{l=1}^{m_j} R^2\left(x^{(jl)};\left(x^{(jl_1^0)},\ldots,x^{(jl_s^0)}\right)\right) = \max_{l_1,l_2,\ldots,l_s} \sum_{l=1}^{s_j} R^2\left(x^{(jl)};\left(x^{(jl_1)},\ldots,x^{(jl_s)}\right)\right),$$

where $R^2(y;(x^{(1)},K,x^{(s)}))$ - coefficient of determination of the dependent variable by the explanatory variables $x(1), K, x(s)$.

The quantitative composition of a limited set of indicators is chosen in each specific case based on a combination of theoretical (substantial) considerations and requirements for the minimum allowable values of R^2_{min} of the coefficients of determination.

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After that, it was decided to take three indicators with the most significant sum of the coefficients of determination within each of the subsystems (to ensure equal representation of indicators, just like in the Sustainable Development Green Index itself). The average of their sum constituted the simplified Sustainable Development Green Index (Table 1).

Table 1. Simplified SDGI and its indicators, 2020

Subsystems of the simplified SDGI				
Educational	**Economic**	**Political**	**Societal**	**Environmental**
1. Citations per document	1. Efficiency sectors	1. Enforcement of environmental regulations	1. World Press Freedom Index	1. Environmental Performance Index
2. h-index	2. Growth of innovative companies	2. Environmental performance indicator*	2. Democracy Index	2. Air quality
3, Patents by origin	3. Energy Transition Index	3. Intellectual property protection	3. Incidence of corruption	3. Water resources

* This indicator is a part of the Global Innovation Index and measures environmental performance on a state level; it is not the same as the Environmental Performance Index (environmental subsystem) from the Environmental Performance Index Report (which deals exclusively with the quality of the environment).

Source: the author's calculations in SPSS according to statistical data.

As seen from Table 3, the multicollinearity analysis has allowed us to define the most relevant indicators within each of the subsystems of the Sustainable Development Green Index and construct its simplified version, which consists of 15 instead of 50 indicators.

Now that the simplified version of SDGI has been presented, it is suggested to test empirically its interrelation with indicators connected with some of the Sustainable Development Goals in the European Union by correlation analysis, with a focus on society-related SDGs because of the high demand for such studies (Sianes et al., 2022).

To determine if there is an interrelation between the Sustainable Development Green Index and SDG 3, 'Good health and well-being', SDG 4 ', Quality education', SDG 9 'Industry, innovation and infrastructure' correlation analysis were performed. The 'Smoking Prevalence' indicator reflects progress towards Sustainable Development Goal 3 (Eurostat, 2022a). For Sustainable Development Goal 4 – the indicator 'Share of individuals having at least basic digital skills' (Eurostat, 2022b). Finally, for Sustainable Development Goal 9, the indicator of the market share of plug-in electric vehicles in the EU countries in 2020 (European Automobile Manufacturers Association (ACEA, 2021) was analysed.

The results upon analysing the relationship between progress towards the abovementioned SDGs and SDGI and its subsystems were as follows (Table 2). They are also compared to the correlation with GDP per capita in the EU countries.

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Table 2. Correlation analysis between SDGI and some SDGs' progress in the EU

		tion	onomy	tics	ety	ment	fied	GDP
Smoking prevalence (SDG 3 'Good health and well-being)	Pearson Correlation	,654**	,793**	,684**	,796**	,660**	,766**	,528**
Digital skills (SDG 4 'Quality education)	Pearson Correlation	,752**	,767**	,830**	,814**	,816**	,850**	,547**
ECV registration growth (SDG 9 'Industry, innovation and infrastructure)	Pearson Correlation	,793**	,835**	,738**	,797**	,730**	,835**	,522**
Average Pearson Correlation		,733	,798	,751	,802	,735	,817	0,532

**. Correlation is significant at the 0.01 level (2-tailed)
Source: The authors' calculations in SPSS according to statistical data.

As can be seen from the table, the correlation between the indicators corresponding to SDGs 3, 4, 9 and the simplified version of the Sustainable Development Green Index was significant and can be characterised as very strong according to Quinnipiac University's interpretation (as quoted from Akoglu, 2018).

Also, it can be observed that all analysed SDGs interrelated with the simplified SDGI are more robust than with such conventional metrics as GDP per capita, which covers only the economy.

These findings substantiate the statement that Sustainable Development Green Index is more suitable for measuring progress towards SDGs in Europe than conventional metrics, since it is more consistent with sustainable development and considers all subsystems: educational, economic, political, societal and environmental.

It can also be seen that the correlation coefficients of various subsystems of simplified SDGI are different (Fig. 5):

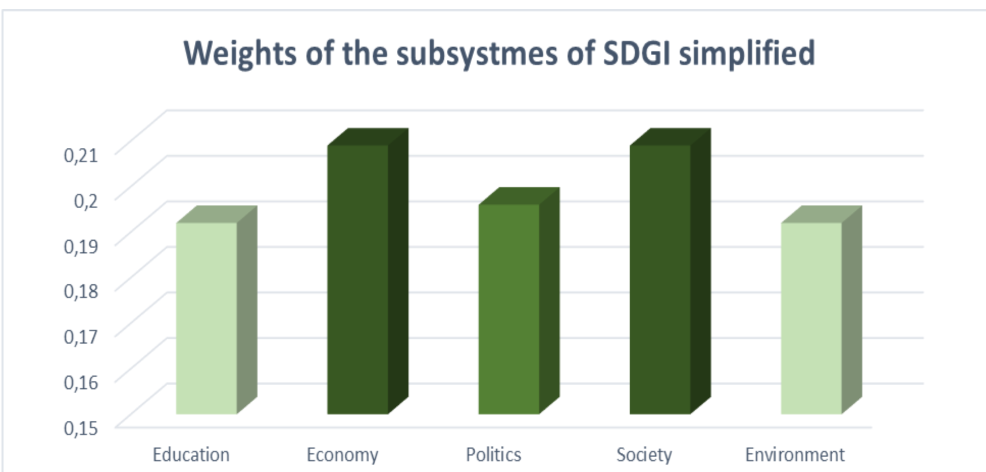

Figure 5. SDG-weighted subsystems of SDGI simplified
Source: The authors' calculations according to statistical data

As the Figure 5 shows, in an SDG-weighted simplified version of the Sustainable Development Green Index, the subsystems have the following weights: education and environment – 0,192, politics – 0,196, economy and society – 0,209.

4. Conclusions

The article revealed strong interrelations between the simplified version of the Sustainable Development Green Index and SDGs 3, 4, and 9 progress in the European Union.

The correlation was higher than with GDP per capita. It makes the newly elaborated SDGI more relevant to measuring progress towards SDGs than conventional metrics. The created SDGI considers all subsystems of the phenomenon: educational, economic, political, societal and environmental, and thus more consistent with the context of sustainable development.

It also underlines the fact that a market-centric approach seems to be entirely one-sided, overestimating the influence of economic prosperity on sustainable development.

That SDGI provides a better-balanced and multidimensional view of this phenomenon, considering all related factors.

Sustainable Development Green Index proposed within the present study offers academia, society, business and governments a tool to measure a country's performance in terms of sustainable development and progress towards some of the SDGs. The suggested tool can be helpful for different stakeholders. The study opens up new research opportunities regarding the further applicability of the index towards sustainable development issues in EU countries and globally.

Analysing the interrelation between the SDGI and other SDGs by performing correlation analysis will still need to be the purpose of subsequent research.

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Appendix

Indicators used for subsystems of Sustainable Development Green Index with the justification of their use:

<u>Educational subsystem</u>
S_1_1 Research institutions prominence 0–100 (best) (World Economic Forum, 2019a) –
SDG 4; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_1_2 Scientific publications score (World Economic Forum, 2019a) – SDG 9; justified at Ryszawska, 2015; Kasztelan, 2021; Barcellos-Paula et al., 2021;
S_1_3 Gross expenditure on R&D, % of GDP (World Intellectual Property Organization, 2020) – SDG 9; justified at Ryszawska, 2015; Kasztelan, 2021; NETGreen, 2015; Barcellos-Paula et al., 2021;
S_1_4 Total number of documents in Scopus, Environmental science, cumulative, 1996-2019 (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015; Barcellos-Paula et al., 2021;
S_1_5 Citable documents, 1996 – 2019 (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015;
S_1_6 Citations (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015; Barcellos-Paula et al., 2021;
S_1_7 Self-citations (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015;
S_1_8 Citations per document (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015;
S_1_9 h-index (SJR – SCImago, 2021) – SDG 9; justified at NETGreen, 2015; Barcellos-Paula et al., 2021;
S_1_10 Patents by origin / bn PPP$ GDP (World Intellectual Property Organization, 2020)*** – SDG 9; justified at Kasztelan, 2021; Barcellos-Paula et al., 2021.

<u>Economic subsystem</u>
S_2_1 GDP per unit of energy use (World Intellectual Property Organization, 2020) – SDG 7, 12; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_2_2 ISO 14001 environmental certificates per bn PPP$ GDP (World Intellectual Property Organization, 2020) – SDG 12; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_2_3 Resource efficiency index (Solability, 2020)*** – SDG 12; justified at NETGreen, 2015; Ryszawska, 2015; Dual Citizen, 2018; Kasztelan, 2021;
S_2_4 Greenhouse gas emissions score (Climate Change Performance Index, 2021) – SDG 13; justified at NETGreen, 2015; Ryszawska, 2015; Vertakova, Plotnikov, 2017; Dual Citizen, 2018; Kasztelan, 2021;
S_2_5 Share of renewable energy in gross final energy consumption by sector, % (Eurostat, 2019) –
SDG 7; justified at Ryszawska, 2015; Dual Citizen, 2018; Kasztelan, 2021;
S_2_6 The global sustainable competitiveness index (2020)*** – SDG 9; justified at Kasztelan, 2021;

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S_2_7 Circular material use rate, % of material input for domestic use (Eurostat, 2019)*** –
SDG 12; justified at Kasztelan, 2021;
S_2_8 Efficiency sectors (World Economic Forum, 2019a) – SDG 9; justified at NETGreen, 2015;
S_2_9 Growth of innovative companies 1–7 (best) (World Economic Forum, 2019a) –
SDG 9; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_2_10 Energy transition index (Energy transition index by World Economic Forum, 2020)*** – SDG 7; justified at NETGreen, 2015.

Political subsystem
S_3_1 Stringency of environmental regulations, index (World Economic Forum, 2019b) – SDG 13, 16; justified at NETGreen, 2015; Kasztelan, 2021;
S_3_2 Enforcement of environmental regulations, index (World Economic Forum, 2019b) – SDG 13, 16; justified at NETGreen, 2015; Kasztelan, 2021;
S_3_3 Environment-related treaties in force count (out of 29 possible) (World Economic Forum, 2019a) – SDG 17; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_3_4 Climate policy index – covers both national and international climate policy performance (Climate change performance index, 2021)*** – SDG 16, 17; justified at Kasztelan, 2021;
S_3_5 Climate Change Performance Index (Climate change performance index, 2021) – SDG 13; justified at NETGreen, 2015; Kasztelan, 2021;
S_3_6 Environmental performance, index (Wendling et al., 2020) – SDG 13; justified at NETGreen, 2015; Kasztelan, 2021;
S_3_7 Environmental tax revenues, % of GDP (Eurostat, 2018) – SDG 13, 16; justified at the Table 1.3; NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
S_3_8 Intellectual property protection 1–7 (best) (World Economic Forum, 2019a) – SDG 9, 16; justified at Ryszawska, 2015; Kasztelan, 2021;
S_3_9 Population covered by the Covenant of Mayors for Climate & Energy signatories – percentage of total population (Eurostat, 2019, for the UK – 2018)*** – SDG 17;
S_3_10 Renewable energy regulation 0–100 (best) (World Economic Forum, 2019a) – SDG 7, 16; justified at Ryszawska, 2015; Kasztelan, 2021.

Societal subsystem
S_4_1 Attitude of European citizens towards the environment, % of population who consider environmental issues to be important (Eurobarometer, 2017)*** – SDG 13; justified at NETGreen, 2015;
S_4_2 World Press Freedom Index (Reporters without borders, 2020)* – SDG 16; justified at
Brundtland, 1987; NETGreen, 2015;
S_4_3 Democracy index (Economist Intelligence Unit, 2020) – SDG 16; justified at
Brundtland, 1987; NETGreen, 2015;
S_4_4 Civil liberties (Economist Intelligence Unit, 2020)*** – SDG 3, 16; justified at Brundtland, 1987; NETGreen, 2015;
S_4_5 Social Capital Index (Solability, 2020)*** – SDG 3; justified at Kasztelan, 2021; NETGreen, 2015; Barcellos-Paula et al., 2021;
S_4_6 Incidence of corruption, scores 0-100 (best) (World Economic Forum, 2019a) – SDG 16; justified at United Nations, 2022; NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021; Barcellos-Paula et al., 2021;
S_4_7 Internet users, % of adult population (World Economic Forum, 2019a) – SDG 3; justified at Ryszawska, 2015; Kasztelan, 2021;
S_4_8 People at risk of poverty or social exclusion (Eurostat, 2019, except for Ireland, Italy,
the UK – 2018)*** – SDG 1, 10; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021;
Barcellos-Paula et al., 2021;
S_4_9 Share of busses and trains in total passenger transport, % of total inland passenger-km (Eurostat, 2018)*** – SDG 11 'Sustainable cities and communities'; justified at NETGreen, 2015;
S_4_10 Females employed with advanced degrees, % (World Intellectual Property Organization, 2020)*** – SDG 5; justified at NETGreen, 2015; Kasztelan, 2021; Barcellos-Paula et al., 2021.

Environmental subsystem
S_5_1 Environmental performance index (Wendling et al., 2020)*** – SDG 13; justified at NETGreen, 2015;
S_5_2 Air quality (Wendling et al., 2020)*** – SDG 15; justified at NETGreen, 2015;
S_5_3 Water resources (Environmental performance index report, 2020)*** – SDG 6; justified at NETGreen, 2015; Dual Citizen, 2018; Kasztelan, 2021;
S_5_4 Biodiversity and habitat (Wendling et al., 2020)*** – SDG 14, 15; justified at NETGreen, 2015; Kasztelan, 2021;
S_5_5 Forest cover change, % (World Economic Forum, 2019b)* – SDG 15; justified at NETGreen, 2015;
S_5_6 Wastewater treatment, % of total (World Economic Forum, 2019b) – SDG 6, 12; justified at NETGreen, 2015;
S_5_7 Total protected areas, % of territory (World Economic Forum, 2019b) – SDG 15; justified at Organisation for Economic Co-operation and Development (OECD), 2011; NETGreen, 2015; Kasztelan, 2021;
S_5_8 Natural capital (Solability, 2020)*** – SDG 14, 15; justified at Kasztelan, 2021;

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S_5_9 Ecological sustainability, index (World Intellectual Property Organization, 2020) – SDG 13; justified at NETGreen, 2015; Kasztelan, 2021;
S_5_10 Agriculture (Wendling et al., 2020)*** – SDG 2 'Zero hunger'; justified at NETGreen, 2015; Ryszawska, 2015; Kasztelan, 2021.

***** destimulant (inverse relationship with sustainable development and green economy).