https://doi.org/10.1038/s44168-024-00104-6

Assessing the sustainability of the European Green Deal and its interlin kages with the SDGs

Phoebe Koundouri[1,2,3,4] ✉, Angelos Alamanos[5], Angelos Plataniotis[2,4,6], Charis Stavridis[7], Konstantinos Perifanos[6,8] & Stathis Devves[1,2,4]

The European Green Deal (EGD) is the growth strategy for Europe, covering multiple domains, and aiming to an equitable, climate neutral European Union by 2050. The UN Agenda 2030, encompassing 17 Sustainable Development Goals (SDGs), establishes the foundation for a global sustainability transition. The integration of the SDGs into the EGD is an overlooked issue in the literature, despite Europe's slow progress to achieve the sustainability targets. We employed a machine-learning text-mining method to evaluate the extent of SDG integration within the 74 EGD policy documents published during 2019–2023. The findings reveal a substantial alignment of EGD policies with SDGs related to clean energy (SDG7), climate action (SDG13), and sustainable consumption and production (SDG12). In contrast, there is a significant underrepresentation in areas related to social issues such as inequalities, poverty, hunger, health, education, gender equality, decent work, and peace, as indicated by lower alignment with SDGs 1, 2, 3, 4, 5, 8, 10, and 16. Temporal trends suggest a marginal increase in the attention given to environmental health (especially water and marine life) and gender equality. Furthermore, we illustrate the alignment of EGD policies with the six essential sustainability transformations proposed by the Sustainable Development Solutions Network (SDSN) in 2019 for the operationalization of the SDGs. The results indicate that besides the prevalence of "Energy Decarbonization and Sustainable Industry", all areas have received attention, except for the "Health, Wellbeing and Demography". The findings call for a more integrated approach to address the complete spectrum of sustainability in a balanced manner.

The European Green Deal (EGD) is the growth plan for a climate-neutral Europe by 2050. It covers a wide range of areas, including climate action, energy, agriculture, industry, infrastructure, environment and biodiversity, transportation, finance and development, and research and innovation[1]. The EGD serves as both an environmental, social, and economic blueprint, covering all sectors through policy areas and initiatives that collectively aim to transform the European Union (EU) into a more sustainable and climate-resilient society while fostering economic growth and social equity.

The United Nations (UN) conceptualize "Sustainability," as the condition of meeting the needs of the present without compromising the ability of future generations to meet their own needs[2], which encompasses an equilibrium between environmental, economic, and social dimensions, ensuring a harmonious relationship between human activities and our planet's ecosystems. Sustainability, in this context, can refer to all efforts trying to ensure the well-being of current and future generations, within the limits of the natural world. This requires integrated and cross-disciplinary knowledge materialized by policy frameworks[3,4].

The UN Agenda 2030, signed by 193 countries, is the global agenda towards the "future we want", focused on the sustainable development at a global scale by 2030[5]. Its 17 Sustainable Development Goals (SDGs) are the plan for building national, continental, and global investment programs for sustainable development. In particular, the SDGs provide a comprehensive

[1]School of Economics and ReSEES Research Laboratory, Athens University of Economics and Business, Athens, Greece. [2]Sustainable Development Unit, ATHENA RC, Athens, Greece. [3]Department of Technology, Management and Economics, Technical University of Denmark, Copenhagen, Denmark. [4]UN SDSN (Global Climate Hub, European Hub, Greek Hub), Athens, Greece. [5]Independent Researcher, Berlin, Germany. [6]National and Kapodistrian University of Athens, Athens, Greece. [7]Aristotle University of Thessaloniki, Thessaloniki, Greece. [8]Codec.ai, London, UK. ✉e-mail: pkoundouri@aueb.gr

universal framework with tangible and measurable indicators (covering multiple sectors with social, economic, and environmental components) that encourages countries to work towards their achievement[6,7]. However, the progress on achieving the SDGs (globally and per country) is still slow, and recent evidence suggests only limited transformative political impact of the SDGs[8].

In an attempt to provide a broader and at the same time a more concise picture of the necessary actions towards sustainability, Sachs et al.[9] presented the Six Transformations as a means to operationalize the SDGs. They practically grouped the 17 goals into six key areas of transformation that societies need to undertake for sustainable development. These are: 1. Education, Gender, and Inequality, recognizing that sustainable development requires a foundation of educated citizens, with equal opportunities for all genders and marginalized groups; 2. Health, Wellbeing, and Demography, addressing demographic changes that can impact societal structures and sustainability outcomes; 3. Energy Decarbonization and Sustainable Industry, calling for a shift to sustainable, renewable energy sources and the decarbonization of industries to mitigate climate change effects and promote economic growth that does not overexploit natural resources; 4. Sustainable Food, Land, Water, and Oceans, aiming to manage natural resources responsibly, and ensure food security, sustainable agriculture, freshwater availability, and marine conservation; 5. Sustainable Cities and Communities, including urban planning, infrastructure, and innovation to support community well-being and environmental health; and 6. Digital Revolution for Sustainable Development, which recognizes the role of technology and digital innovation in accelerating progress towards the SDGs.

Motivated by the ongoing efforts from the EGD, the SDGs, and the research spaces towards sustainability, we explore how the EGD is aligned to the SDG UN Agenda 2030. The aim of this paper is to and quantify how much each SDG and also each of the Six Transformations are supported by the EDG-related policies. By thoroughly assessing the relation of all EGD's central policies and strategies published during 2019–2023 we reveal the major and most overlooked areas of the UN Agenda 2030, in terms of the political attention they have received. A novel machine-learning-based text-mining method (ML), validated and enhanced by a human-based textual analysis is applied to 74 EGD related policy documents. The alignment of the EGD policies with the six necessary transformations for Sustainable Development proposed by Sachs et al.[9] is also quantified to provide policymakers with more insights into the policy areas that should have progressed more, given their presence in EU policy, and others that should be further supported.

Since the introduction of the EGD in December 2019, the European Commission has launched a plethora of policies, regulations, recommendations, and strategy documents to support the actions required by the EU Member States to achieve its goals. The Commission President, Ursula von der Leyen, is committed to integrating the SDGs into European Semester, the EU's budgeting processes[10], while the Annual Growth Strategy outlines that "this economic agenda must transform the Union into a sustainable economy, helping the EU and its Member States to achieve the United Nations Sustainable Development Goals"[11]. Arguably, achieving the sustainability agenda is a difficult and ambitious task. But this statement clearly indicates that although the EGD is focused on climate-neutrality, it is an opportunity to achieve a broader vision, that of sustainable development. This rationale is backed up by research in the field arguing that sustainability goes beyond decarbonization and climate-neutrality, and that all SDG areas are complementary and necessary requirements to achieve each one of them (e.g., we cannot talk about a sustainable world even we use green energy, but we experience wars, inequalities, poverty, etc.)[12–14]. Since all SDGs are interconnected, and a truly sustainable future passes through their complementary achievement[15], the EGD should take the opportunity and evolve EU's development with a holistically sustainable manner.

However, evidence increasingly shows that the progress towards the achievement of the SDGs is poor[16]. EU still faces several challenges for the achievement of SDGs[17,18]. After the COVID-19 pandemic, the war in Ukraine have further slowed down the successful implementation of several EGD policies and the SDG progress in Europe, on top of other issues such as outsourcing and its considerable environmental footprint[19,20]. So, urgent action is required, and improved understanding of the underlying policy mechanisms is key to implement successful measures[21,22]. Monitoring the impact of the SDGs, along with tracking their progress are expected to be cornerstones for the sustainable development[18,23,24]. Our paper builds towards this direction by assessing the integration of SDGs in the EGD-related policies.

Although researchers have studied the progress of the SDGs in EU[18,25], as well as the impact of the EGD on multiple sectors (e.g.,[26–28]), the interlinkages between the EGD and the SDGs are an overlooked issue. Despite research on specific countries[29] and the exploration of specific SDGs under certain policies, or methodological contributions aiming to improve their monitoring[30], an overview of all SDGs into the EGD policies is missing. The alternative grouping of the SDGs as six broad necessary transformations towards sustainability, as proposed by Sachs et al.[9], still remains unexplored in terms of policy-coverage. The literature has been slow to examine how these domains have been considered into the policy agendas, such as the EGD, and this paper tries to fill this gap, in order to reveal which policy areas, need further support. Having this information is crucial, as it can directly influence future policies and EU Member-States fund planning, to speed up the sustainability transition. Another very important aspect is the addition of the time-dimension. In particular, according to several studies, assessing sustainable development and policy influence over time, towards the 2030 Agenda's objectives is a key research area, that remains under-explored[4,18,23,31]. This paper contributes to this aspect as the integration of SDGs in the EGD-related policies is assessed over time, for the period 2019–2023.

Our assessment combines a machine-learning (ML) language processing approach, with a human-based approach. Artificial Intelligence (AI) and ML have the potential to contribute with various ways to a sustainable development[32]. ML language processing models can identify hidden elements and patterns in complex policy documents[33], and have been used for detecting sustainability-related objectives. Matsui et al.[34] used ML natural language processing modeling for translating semantics, visualizing nexus patterns, and connecting stakeholders using the SDGs. Hajikhani and Suominen[35] have used ML to explore the presence of SDGs in publications and patents. Porciello et al.[36] highlight the advantages of using ML approaches for synthesizing evidence from the literature on SDGs, compared to the quite time-consuming evidence synthesis by human work, in terms of speed and accuracy. There are fewer applications on identifying the SDG policy-related influence, with the exception of Smith et al.[37] who used ML language processing analysis to detect policy and scientific discourse around SDGs, focusing on identifying overlaps in international policies. To our knowledge, an analysis quantifying the presence of SDGs and/or the Six Transformations in EGD has not been performed so far.

This paper contributes to the existing literature by assessing the EGD-SDG alignment, revealing the degree to which SDGs are represented by different EU policy areas. Thus, the results are expected to provide useful insights with respect to the areas that are need to be strengthened. Such insights are of direct interest to researchers and policymakers, as they contribute to an improved understanding of the hidden elements and interconnections among the different policies and SDGs, and outline priorities for action towards more inclusive and sustainable policies. To further enhance our work's policy implications, we reflect on our findings and provide strategic recommendations for addressing the significant issues and current gaps that are likely to arise through the implementation of the ambitious sustainability agenda.

Results

Initial alignment evaluation

The ML model provided the similarity scores representing the probability of a given EGD policy document being relevant to a specific SDG. These scores are presented as percentages, with higher percentages suggesting a stronger

Policy	SDG1-No Poverty	SDG2-Zero Hunger	SDG3-Good Health and Well-being	SDG4-Quality Education	SDG5-Gender Equality	SDG6-Clean Water and Sanitation	SDG7-Affordable and Clean Energy	SDG8-Decent Work and Economic Growth	SDG9-Industry, Innovation, and Infrastructure	SDG10-Reduced Inequality	SDG11-Sustainable Cities and Communities	SDG12-Responsible Consumption and Production	SDG13-Climate Action	SDG14-Life Below Water	SDG15-Life on Land	SDG16-Peace, Justice, and Strong Institutions	SDG17-Partnerships for the Goals
Circular Economy Plan	0,78%	4,60%	1,27%	0,44%	0,33%	0,98%	5,35%	3,14%	2,15%	0,88%	1,95%	23,45%	0,67%	5,60%	0,51%	7,75%	40,15%
EU Energy Integration Strategy	0,02%	0,15%	0,17%	0,06%	0,11%	0,22%	0,07%	0,11%	0,06%	0,02%	0,28%	0,26%	0,11%	0,64%	96,87%	0,14%	0,73%
EU Hydrogen Strategy	0,01%	0,02%	0,01%	0,01%	0,00%	0,08%	99,12%	0,01%	0,03%	0,01%	0,04%	0,33%	0,23%	0,03%	0,03%	0,01%	0,03%
Sustainable Growth Strategy 2021	0,01%	0,09%	0,03%	0,02%	0,01%	0,22%	94,07%	0,02%	0,12%	0,02%	0,08%	2,82%	2,13%	0,13%	0,13%	0,03%	0,08%
EU Biodiversity 2030	2,96%	4,63%	4,82%	3,29%	0,41%	0,85%	11,62%	4,92%	22,86%	6,42%	4,98%	4,15%	1,59%	1,20%	0,47%	5,60%	19,22%
Anti-Deforestation & Soil Health Proposal	0,01%	0,04%	0,05%	0,02%	0,03%	0,06%	0,04%	0,03%	0,01%	0,01%	0,06%	0,08%	0,12%	0,09%	99,25%	0,02%	0,08%
Nature Protection Regulation	0,02%	0,11%	0,21%	0,08%	0,11%	0,35%	0,11%	0,15%	0,03%	0,03%	0,27%	0,26%	0,10%	0,86%	96,25%	0,27%	0,79%
EU Algae Initiative	0,02%	0,22%	0,24%	0,06%	0,08%	0,19%	0,12%	0,04%	0,05%	0,02%	0,05%	1,05%	0,05%	95,11%	2,22%	0,15%	0,32%
Pollinator Protection Deal	0,02%	2,14%	0,10%	0,06%	0,21%	0,61%	0,21%	0,04%	0,07%	0,03%	0,16%	0,19%	0,18%	0,34%	95,38%	0,08%	0,18%
EU Fisheries Energy Transition	0,01%	0,04%	0,06%	0,02%	0,02%	0,04%	0,05%	0,01%	0,01%	0,01%	0,02%	0,11%	0,02%	99,24%	0,11%	0,08%	0,16%
Marine Ecosystems Restoration Plan	0,01%	0,02%	0,06%	0,02%	0,02%	0,03%	0,02%	0,01%	0,01%	0,01%	0,02%	0,11%	0,02%	99,11%	0,30%	0,09%	0,12%
Fisheries Policy Communication	0,01%	0,03%	0,05%	0,02%	0,02%	0,03%	0,02%	0,01%	0,01%	0,01%	0,01%	0,08%	0,01%	99,39%	0,13%	0,04%	0,11%

Fig. 1 | Initial alignment scores of selected EGD Policies with SDGs. Represents the preliminary alignment probabilities of selected EGD policies with the SDGs, visualized through a color gradient from red (low alignment) to green (high alignment).

likelihood of the policy being relevant to the corresponding SDG. Figure 1 provides a representative selection of these policies, showing indicatively four well-known policies with their respective scores. For a comprehensive view of all 74 policies and their SDG - similarity scores, please refer to the Supplementary file (Supplementary Table 2).

These initial results reveal that each policy primarily has impact mainly on one or two SDGs. Figure 1 shows a heatmap visualization of the initial similarity scores between EGD and the SDGs, prior to rescaling for four selected policies. This is an excerpt from the comprehensive list of policies available at the supplementary file (Supplementary Table 2). For instance, EU Energy Integration Strategy has an almost perfect alignment (99.12%) with SDG7 (Affordable and clean energy). Similarly, the EU Hydrogen Strategy also exhibits a substantial link to SDG7, with a score of 94.07%. However, some policies have a more diverse impact. Particularly, Circular Economy Plan contributes significantly to three SDGs: SDG17 (Partnerships for the Goals), SDG12 (Responsible consumption and production), and SDG16 (Peace, justice and strong institutions) with similarity scores of 40.15, 23.45, and 7.75% respectively. The Sustainable Growth Strategy 2021 largely impacts SDG9 (Industry, innovation and infrastructure), SDG17 (Partnerships for the Goals), and SDG7 (Affordable and clean energy), with similarity scores of 22.86, 19.22, and 11.62%, respectively.

Rescaled similarity scores

In order to reveal and highlight the deeper shades of the EGD policy-SDG interplay, we performed a data transformation based on these initial findings. The algorithm allows rescaling the similarity scores of the secondary SDGs, adding up to 100% after omitting the prevailing one with the highest score, provides a more nuanced understanding of the data by de-emphasizing the most dominant connections and focusing more on secondary and tertiary linkages. This enables a more detailed exploration of the policies' impacts across a broader range of SDGs, their ranking, and reveals potential indirect effects and interactions that might have been overshadowed in the initial results. Figure 2 provides a representative selection of the same indicative four well-known policies and their respective final scores. Table S3 of the Supplementary file includes the detailed list with all 74 policies with their SDG - similarity scores.

SDG representation in EGD Policies

These results show that the Circular Economy Plan aligns particularly strongly with SDG12 (Responsible Consumption and Production) at 39.18%, which is reasonable as the plan focuses on sustainability in resource use and waste reduction. The EU Energy Integration Strategy and the EU Hydrogen Strategy have substantial alignment with SDG12 and SDG13

Policy	SDG1-No Poverty	SDG2-Zero Hunger	SDG3-Good Health and Well-being	SDG4-Quality Education	SDG5-Gender Equality	SDG6-Clean Water and Sanitation	SDG7-Affordable and Clean Energy	SDG8-Decent Work and Economic Growth	SDG9-Industry, Innovation, and Infrastructure	SDG10-Reduced Inequality	SDG11-Sustainable Cities and Communities	SDG12-Responsible Consumption and Production	SDG13-Climate Action	SDG14-Life Below Water	SDG15-Life on Land	SDG16-Peace, Justice, and Strong Institutions	SDG17-Partnerships for the Goals
Circular Economy Plan	1,30%	7,69%	2,12%	0,74%	0,55%	1,64%	8,94%	5,24%	3,58%	1,48%	3,26%	39,18%	1,12%	9,36%	0,86%	12,94%	100,00%
EU Energy Integration Strategy	0,63%	2,36%	0,93%	0,92%	0,47%	8,79%	100,00%	1,53%	3,74%	1,00%	4,63%	37,04%	26,51%	3,15%	3,52%	1,65%	3,11%
EU Hydrogen Strategy	0,16%	1,46%	0,59%	0,33%	0,18%	3,69%	100,00%	0,32%	1,97%	0,28%	1,31%	47,62%	35,87%	2,13%	2,11%	0,57%	1,41%
Sustainable Growth Strategy 2021	3,84%	6,01%	6,24%	4,26%	0,53%	1,10%	15,07%	6,38%	100,00%	8,33%	6,46%	5,38%	2,06%	1,55%	0,61%	7,26%	24,92%
EU Biodiversity 2030	0,68%	4,76%	5,28%	1,86%	3,36%	6,91%	2,35%	3,41%	1,95%	0,65%	8,94%	8,21%	3,38%	20,60%	100,00%	4,46%	23,21%
Anti-Deforestation & Soil Health Proposal	1,11%	5,14%	6,59%	2,62%	4,23%	7,54%	5,74%	4,17%	1,41%	1,75%	7,62%	10,22%	16,33%	11,79%	100,00%	2,98%	10,77%
Nature Protection Regulation	0,65%	3,01%	5,69%	2,09%	2,93%	9,34%	2,81%	3,94%	0,75%	0,85%	7,27%	7,00%	2,54%	23,06%	100,00%	7,14%	20,94%
EU Algae Initiative	0,38%	4,49%	4,99%	1,19%	1,54%	3,80%	2,56%	0,81%	1,06%	0,50%	1,05%	21,57%	1,03%	100,00%	45,42%	3,03%	6,58%
Pollinator Protection Deal	0,33%	46,43%	2,21%	1,35%	4,46%	13,16%	4,55%	0,88%	1,57%	0,70%	3,37%	4,13%	3,94%	7,41%	100,00%	1,71%	3,81%
EU Fisheries Energy Transition	1,52%	5,18%	7,29%	2,49%	2,95%	5,36%	6,11%	1,72%	1,91%	1,57%	2,07%	14,21%	2,23%	100,00%	14,56%	10,37%	20,47%
Marine Ecosystems Restoration Plan	1,02%	2,68%	6,90%	2,62%	2,61%	3,73%	2,12%	1,36%	1,51%	1,43%	1,84%	12,15%	2,55%	100,00%	34,16%	9,87%	13,46%
Fisheries Policy Communication	1,84%	4,94%	7,74%	3,47%	3,66%	5,45%	2,80%	2,03%	2,28%	2,10%	2,29%	12,47%	2,28%	100,00%	21,93%	6,80%	17,92%

Fig. 2 | Detailed alignment scores of EGD Policies with SDGs. Provides a detailed view of the alignment scores between selected EGD policies and the SDGs, using the same color gradient for visualization, as in Fig. 1.

(Climate action), reflecting the focus on integrating energy systems and addressing climate change. The Sustainable Growth Strategy 2021 shows significant alignment with SDG17 (Partnerships for the Goals), suggesting an emphasis on collaborative efforts to drive sustainable growth. The relations reported in Fig. 1 are expected, given the nature of the policies examined, indicating their association to a certain SDG, but the analysis allowed us to quantify the similarity scores for each SDG. The results of Fig. 2, however, were not so obvious from the beginning, indicating the value of the ML approach with respect to a deeper interpretability of the results, spanning across more than one main SDG target.

The results summary for all the 74 EGD policies are depicted in Fig. 3. Notably, SDG7 (Affordable and Clean Energy), SDG12 (Responsible Consumption and Production), SDG13 (Climate Action) and SDG17 (Partnerships for the Goals) emerge as the most prominent in terms of their alignment with EGD policies.

The prominence of SDGs 7, 12, and 13 in the alignment with EGD policies could be attributed to several factors. The EGD inherently emphasizes climate-neutrality, clean energy, and climate action, directly correlating with the themes of SDG7, SDG12, and SDG13. These areas were identified as urgent priorities within the EU's strategic goals. Additionally, the high score of SDG17 indicates that partnerships are considered vital for a continent-wide initiative like the EGD, as achieving sustainability goals requires cooperation between member states, private sector actors, and international bodies.

These targets are followed by other important SDGs, namely SDG 9 (Industry, Innovation & Infrastructure), SDG11 (Sustainable Cities and Communities), SDG14 (Life Below Water), and SDG15 (Life on Land). These rankings underscore the emphasis on biodiversity and sustainable urban and industrial development within the EGD.

The SDGs that appear to have received 'medium' attention in the EGD context include SDG2 (Zero Hunger), SDG3 (Good Health and Well-being), SDG6 (Clean Water and Sanitation), SDG8 (Decent Work and Economic Growth), and SDG16 (Peace, Justice, and Strong Institutions). This indicates a moderate emphasis on crucial aspects of social welfare and environmental health.

The less represented SDGs in the EGD policies include SDG1 (No Poverty), SDG4 (Quality education), SDG5 (Gender equality), and SDG10 (Reduced inequalities). These SDGs showing the least alignment with EGD initiatives, might be due to their more multidimensional nature involving complex social factors that are harder to address directly through environmental policy frameworks. While environmental policies can be more sector-specific, social goals require cross-sectoral efforts that integrate various policy domains, which may be less developed within the current scope of the EGD. Another explanation might be a stronger political will for immediate decarbonization and renewable energy action, compared to the more systemic and long-term societal changes needed for a more sustainable world across all domains.

These results from Fig. 3 showing the degree of the representation of each SDG in the EGD, are also summarized in Table 1.

Examining the attention that each SDG received over time by comparing the percentage shares of the similarity scores (Fig. 3), it is obvious that in 2019 only SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action) were mobilized by the EGD, signaling the significance and prioritization of these two areas in the EU's sustainability agenda. Nevertheless, from 2020 onwards, the policy contributions become more diversified

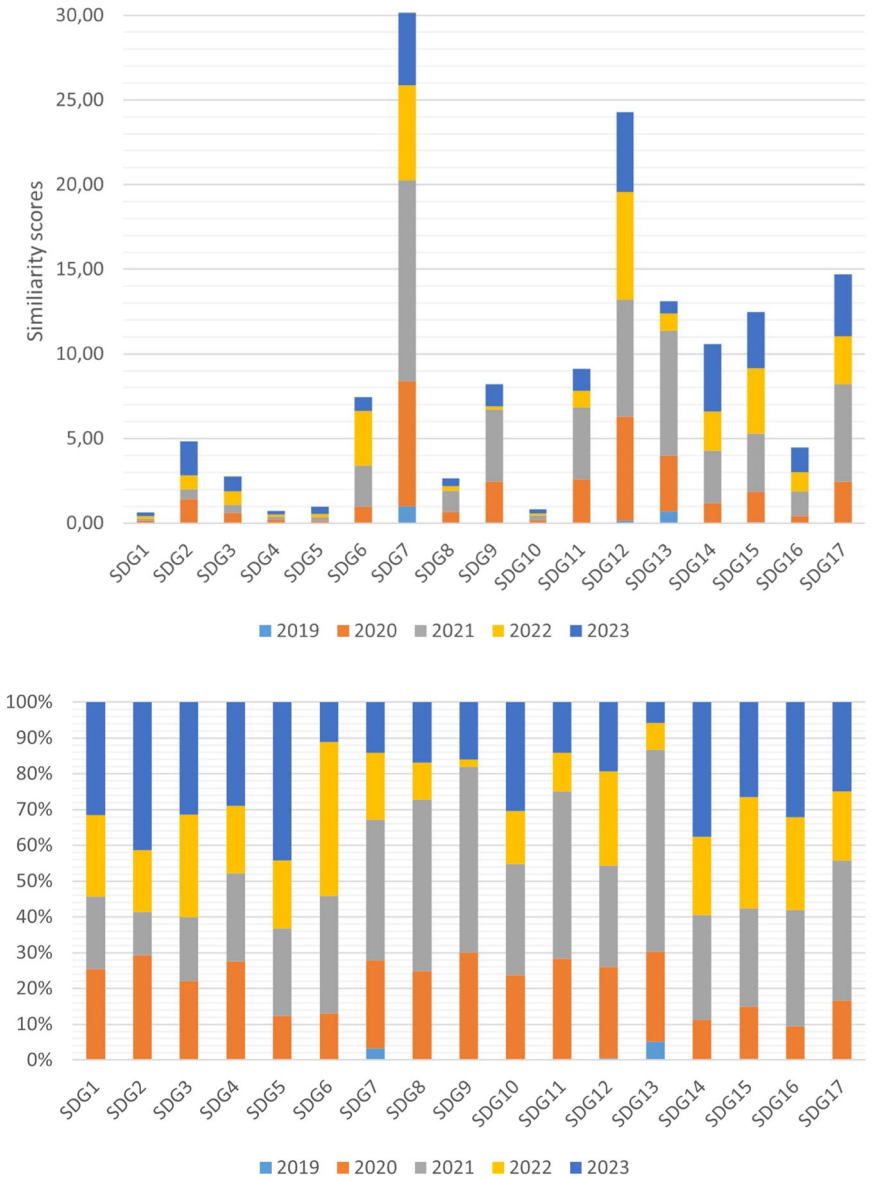

Fig. 3 | Overview of EGD Policy Contributions to SDGs Over Time. Displays the evolution of EGD policies' contributions to SDGs from 2019 to 2023, using similarity scores and percentage shares.

across different SDGs, indicating an expansion of the EGD's policy scope. SDG9 (Industry, Innovation & Infrastructure) had the comparatively larger 'attention' increase in 2020 (around 30%). This trend for SDG9 continued in 2021, along with SDG8 (Decent Work and Economic Growth), SDG13 (Climate Action), and SDG11 (Sustainable Cities and Communities) (all spanning from around 45–55%). A significant increase in the alignment of EGD policies with SDG6 (Clean Water and Sanitation) was observed in 2022, more than any other SDG (around 45%), suggesting a strengthened focus on environmental health. However, this was the case only for 2022 (e.g., SDG6's share in 2023 is around 10%). Some generally 'overlooked' SDGs have received the most attention in 2023. In particular, SDG5's (Gender Equality) alignment with EGD policies peaks in 2023 (43%). Same applied for SDG2 (No Hunger) (41%), and SDG14 (Life Below Water) (38%), which received their highest attention in 2023.

These results of Fig. 3 showing the evolution of the representation of each SDG in the EGD over time, are presented in Table 2 below.

It is important to note that the SDGs that were traditionally central in EGD policy, received their comparably less attention over the past two years (2022–23), such as SDG7 and SDG13. The declines in the alignment of EGD policy with SDG7 from 2021 to 2023 indicates potential shifts in policy focus that may necessitate strategic adjustments to sustain progress. The SDGs that have overall received less attention, having consistently low similarity scores, exhibit similar distribution of percentage shares across the years, suggesting that there was not any trend of shift in priority for addressing these gaps.

Human textual analysis validation

The human textual analysis was performed as a complementary process for the validation of the ML text-mining results. A comprehensive review of all 74 policy documents was undertaken to ensure the accuracy and plausibility of the ML findings. The outcome confirmed the validity of the ML approach's results, in terms of the prevalence of SDGs 7, 13, and 9, as well as the gaps with respect to the SDGs 5, 10, 4, 1, 2, 3, 6, and 16. It is noteworthy that SDG3 (Health and Well-being) received little attention, even during the peak of the COVID-19 pandemic. Similarly, another continuously overlooked area is the SDG16 (Peace, Justice, and Strong Institutions) with increasing and ongoing wars since 2022.

Six transformations analysis

As mentioned earlier, the same analysis was conducted to illustrate the relations of the EGD policies with the broader sustainability concept in terms of the Six Transformations. The results are summarized in Fig. 4.

Table 1 | SDG representation in EGD Policies Ranked

Ranking	SDGs	Comment
1. Highly represented	SDG7	Affordable and Clean Energy
	SDG12	Responsible Consumption Production
	SDG13	Climate action
	SDG17	Partnerships for the Goals
2. Medium representation	SDG9	Industry, Innovation, and Infrastructure
	SDG11	Sustainable Cities and Communities
	SDG14	Life Below Water
	SDG15	Life on Land
3. Low representation	SDG2	Zero Hunger
	SDG3	Good Health and Well-being
	SDG6	Clean Water and Sanitation
	SDG8	Decent Work and Economic Growth
	SDG16	Peace, Justice, and Strong Institutions
4. Very low representation	SDG1	No Poverty
	SDG4	Quality Education
	SDG5	Gender Equality
	SDG10	Reduced Inequalities

Categorizes SDGs based on their representation within EGD policies into four levels: Highly represented, Medium representation, Low representation, and Very low. representation.

Table 2 | Comparative SDG alignment with EGD Policies

Year	Main SDG themes 'trending' in EGD policies
2019	SDG7 (Affordable and Clean Energy) and SDG13 (Climate Action)
2020	SDG9 (Industry, Innovation & Infrastructure)
2021	SDG9 (Industry, Innovation & Infrastructure); SDG8 (Decent Work and Economic Growth); SDG13 (Climate Action); SDG11 (Sustainable Cities and Communities)
2022	SDG6 (Clean Water and Sanitation)
2023	SDG5 (Gender Equality); SDG2 (No Hunger); SDG14 (Life Below Water)

Ranks SDG groups by their alignment with EGD policies, highlighting the relative emphasis of different SDGs in the policy framework.

In line with the results presented above, the main focus areas have been: no.3 Energy Decarbonization and Sustainable Industry, no.4 Sustainable Food, Land, Water, and Oceans, and no.6 Digital Revolution for Sustainable Development. A medium attention is observed in the areas no.5 Sustainable Cities and Communities, and no.1 Education, Gender, and Inequality, while the less represented area is still no.2 Health, Wellbeing and Demography. According to Fig. 4, the annual distribution of policy influence of the Six Transformations has been consistent over the years, with the most areas receiving their highest attention in 2021.

Discussion

In this paper we explored whether and how the SDGs, and the Six Transformations, fit inside the EGD's policies, by combining ML and human text-mining approaches. By identifying policy areas that are most and least represented in terms of their sustainability themes we can provide to policymakers a tangible set of SDGs/ areas that need to be strengthened in terms of policies and investments, respectively.

The main findings suggest that EGD policies are heavily focused on specific areas so far, such as decarbonization and clean energy, and growth (production-consumption). Consistently overlooked areas pertain to social sustainability components, namely tackling inequalities, poverty, hunger, improving health and well-being, education, and achieving peace, justice, and decent work.

These findings are more evident in the detailed analysis considering the SDGs, where the specific areas can be assessed, compared to the more high-level, "aggregated" view of the Six Transformations. For instance, the relatively high scores of the Six Transformations' areas such as no.1 Education, Gender, and Inequality and no.4 Sustainable Food, Land, Water, and Oceans, are not representative of all the sub-areas included. From the more detailed analysis presented by assessing the SDGs-related policies, it is clear that all the social-related SDGs and certain environmental ones (e.g., clean water) are in principle overlooked. In general, as noted by Di Lucia et al.[38], "decision-makers prioritize methods that are simple and flexible to apply and able to provide directly actionable and understandable results. They are less concerned with the accuracy, precision, completeness or quantitative nature of the knowledge". However, in the context of multi-dimensional and complex policies, we demonstrate the crucial need to examine the detailed progress across specific areas (as e.g., reflected by the SDGs) for more efficient and targeted policy improvements.

The EGD is inherently focused on climate-neutrality, so decarbonization and clean energy without significant production losses are expected to be its core. However, this is not necessarily sustainable, as previous research has pointed out[39], neither efficient, since it cannot address persisting social issues[40]. As Fankhauser et al.[41] explain, the climate neutrality concepts have emerged from physical climate science, but cannot be operationalized through social, political and economic systems, if broader sustainable development objectives such as equitable net-zero transition, socio-ecological sustainability and the pursuit of broad economic opportunities, are missing. This concern is being increasingly expressed, by questioning the justice of climate politics[42,43], and their social legitimacy[44]. Considering the policy areas that have received less attention within the EGD policies, it would be naïve to assume that they were reasonably underrepresented because their progress is satisfactory. On 24 February 2022 the ongoing war in Ukraine begun, with multiple sustainability impacts[45]. Nevertheless, "Peace, Justice, and Strong Institutions" (SDG16), "No Poverty" (SDG1), "Zero-Hunger" (SDG2), and "Good Health and Well-being" (SDG3) continue to be overlooked and have represented missed opportunities, even by the Recovery and Resilience Fund. However, such social aspects of the SDGs are necessary for reducing inequalities and contribute to a truly sustainable future. We believe that future EU policies should have a special funding focus on these areas.

Besides economically efficient climate-neutrality, EGD is and should be regarded as an opportunity for the achievement of a broader sustainability vision, which cannot be achieved only by focusing on specific SDGs. A world with wars, recessions and inequality cannot be considered to be sustainable, even if it is climate-neutral and the industry maintains high productivity rates. Sustainability emanates from all areas, as outlined in the SDGs, and these should be regarded as complementary policy actions, that should be reflected in the future policies. Future EU policies should distribute the necessary funds to multiple, cross-SDG objectives, particularly focusing on social and environmental aspects, that will facilitate the achievement of the current EGD's targets.

Methods

In our attempt to reveal the sustainability components of the EGD policies, a mapping of those policies from 2019–2023 was performed. These sustainability components were found in: (a) the SDGs, as they represent a holistic sustainability measure; (b) the Six Transformations proposed by Sachs et al.[9], as they can provide the policymakers with something broader (or conceptually more high-level) than the many SDGs. By assessing both the SDGs and the Six Transformations, we provide a thorough and holistic evaluation capturing all elements of the different policy documents, aiming

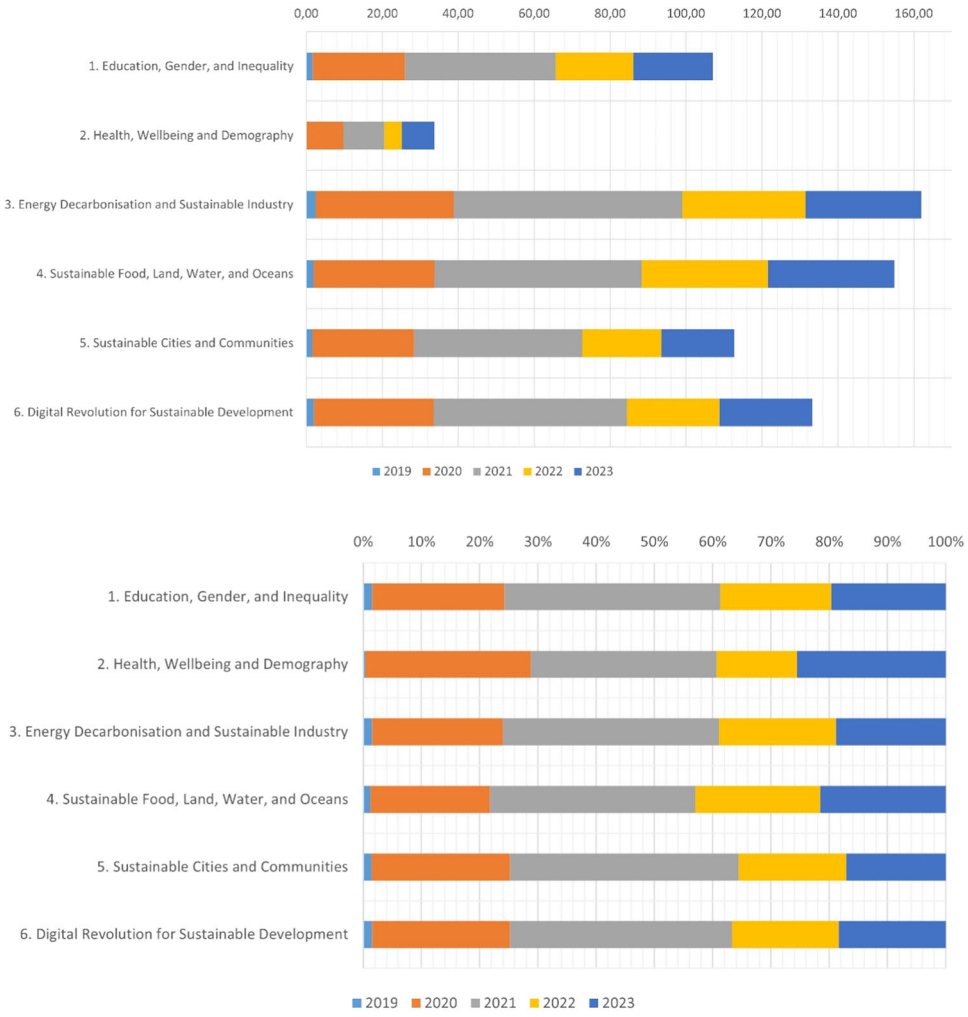

Fig. 4 | Impact of six transformations on EGD Policies' Evolution. Illustrates the impact of the Six Transformations on EGD policies from 2019 to 2023, showing changes in similarity scores and percentage shares. More details on the data processing and extensive results can be found in the Supplementary file (Supplementary Tables 4, 5, 6, Supplementary Fig. 1).

to identify overlooked areas in sustainability terms. These will be key areas of focus for further policy support and orienting the necessary funds to enhance their sustainability angle.

Policy documents selection

The sample of policies selected included all policy and strategy documents derived from the EGD, spanning from its inception in December 2019 to the latest policies up to November 2023, ensuring an up-to-date dataset. This allowed us to assess the progress of each policy area by year (Table 3). The full list of policies along with a short description for each one and their detailed list of references, according to the EUR-Lex[46] are available in the Supplementary File (Supplementary Table 1).

Detecting connections with text-mining

To present an integrated mapping of the policies of Table 3 and their joint implementation with the 17 SDGs and the Six Transformations, a methodology based on Machine Learning (ML) text-mining was applied, and in specifically, on Deep Learning (DL) techniques. DL refers to extensive neural networks with many layers (deep) that "allow computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction"[47]. Simply put, machines learn from experience by representations that are expressed in terms of other, more straightforward representations, and this is particularly useful for text-mining[48]. The model chosen for the analysis was BERT, a pre-trained transformer-based model. BERT stands for "Bidirectional Encoder Representations from Transformers" and was first introduced by Google Research in 2018[49]. The BERT model is pretrained using a combination of the Toronto Book Corpus and Wikipedia, totaling around 2.5 billion words. The "bert-base-uncased" variant, with 12 layers, 768 hidden dimensions, 12 heads, and 110 million parameters, was chosen for this study. BERT's architecture focuses on learning deep bidirectional representations from text, considering context from both sides. The 'base' version contains 12 transformer layers, each outputting a 768-dimensional hidden state, and is trained on lowercase text (uncased). This model is widely used in NLP tasks like question answering and sentiment analysis. BERT was fine-tuned by employing the OSDG Community Dataset, incorporating targets and indicators for each goal[50]. For goals lacking text, relevant expressions from policies were used. The dataset is curated by over 1400 citizen scientists from over 140 countries, labeling sentences related to each SDG[51]. More information about the model's specifications can be found in the Supplementary file.

The dataset used in this paper was formed after text excerpts of paragraphs deriving from public documents, such as reports, policies, and publication abstracts. Furthermore, some documents originate from UN-related sources e.g.,[52], and SDG Library[53]. The dataset includes over 42,000 labeled document excerpts and it contains the referred SDG, the number of volunteers participating in the OSDG's classification process that classified the connection to the SDG as negative, the number of volunteers that classified the connection to the

Table 3 | Analysis of EGD policy publication frequency by year

Year	Number of Policy documents
2019	1
2020	16
2021	27
2022	15
2023	15
Total	74

This table shows the annual count of European Green Deal (EGD) policies published between 2019 and 2023.

SDG as positive and the agreement score based on Eq. 1:

$$\text{agreement} = \frac{\left|labels_{positive} - labels_{negative}\right|}{labels_{positive} + labels_{negative}} \quad (1)$$

The data used were pre-selected using the following criteria:

1. $labels_{positive} > labels_{negative}$, as we needed only to use data related to an SDG,
2. agreement > 0.6, as we needed to be sure that the volunteers agreed to the labeling.

For fine-tuning BERT, we incorporated additional descriptions and indicators for each of the 17 SDGs, as sourced from sdg-tracker.org[54], since it was not included in the OSDG-CD. To ensure the credibility of the labeled text-excerpts, the dataset was further refined by applying criteria like a positive labeling agreement above 0.6, ensuring consensus among the volunteers in the dataset. In total, 35,001 text excerpts were used to train the model.

The model was developed in Python, using PyTorch and Scikit-Learn[55]. 80% of the text excerpts were used as training data and 20% as testing data. As an optimizer, the Adam Optimizer method was employed, while the optimization criterion was the Cross-Entropy Loss[56]. The model was trained for 10 epochs with a learning rate of 10^{-5}, resulting in an accuracy score of 0.85. Considering that the training data used for each SDG are not of the same size and the fact that a text excerpt is most probably linked to more than one SDG, the accuracy score is acceptable.

In other words, the algorithm effectively answers the question 'how probable is the X policy document to be related to the Y SDG'. Therefore, the algorithm's score provides a numerical estimation (similarity score) of the probability that a given policy document is relevant to a specific SDG. Then, the algorithm allows a second-level evaluation, by examining only the rest of the SDGs (except the prevailing one(s) with the highest similarity scores), to identify the less obvious relations, as well.

Human textual analysis

The ML approach enabled us to assess the policy documents thoroughly and fast, revealing connections and linkages between EGD policies and the Six Transformations with SDGs. The advantage of this approach is that many of these connections and patterns are not always evident by the human-eye, in a consistent way when reading the documents (especially for our case where the subject was to 74 policy documents). Although the ML approach was found to be very insightful, offering efficiency and speed at processing large volumes of text and identifying 'hidden' relationships within the data that may not be immediately apparent to human readers, ML models can sometimes lack the nuanced understanding that comes from human interpretation. In our effort to validate this ML approach and provide robust results, we complemented it with the human manual reading of the policy documents. We leveraged the expertize of individuals familiar with the sustainability policy landscape to interpret results and assess their plausibility. The human textual analysis involved 18 experts on sustainability science, across 5 countries, including the author team, that read manually the policy documents, identifying phrases that were semantically linked to the objectives of one or more SDGs. This served as a validation to the ML approach. This is a complementarily process to the ML text-mining, which could confirm the relations or reveal further links. Unlike algorithms, humans have an intrinsic ability to detect nuanced semantic connections between policies and SDGs, thereby providing a more in-depth and thoughtful interpretation.

Mapping EGD policies to the six transformations

The same analysis was also carried out for the Six Transformations as described by Sachs et al.[9], to illuminate the broader links of various policies on these six core areas required to achieve the 17 SDGs. These include: (1) Education, Gender, and Inequality; (2) Health, Wellbeing, and Demography; (3) Energy Decarbonization and Sustainable Industry; (4) Sustainable Food, Land, Water, and Oceans; (5) Sustainable Cities and Communities; (6) Digital Revolution for Sustainable Development. Their complex interaction highlights the need for comprehensive, cross-sectoral efforts in the policy-making process.

This complementary analysis aims to provide policymakers with insights into how existing EGD policies contribute to these transformative areas and to highlight where additional focus might be required. Initially, based on the estimates by Sachs et al.[9], the SDG contributions (the average influence each SDG) on the Six Transformations were estimated. We then multiplied these average contributions by the similarity scores of EGD policies to SDGs obtained from the ML approach, to formulate a matrix indicating the degree to which each policy contributes to the Six Transformations. By summing the results from step two across each year (2019–2023), we conducted a temporal analysis to detect trends and shifts in the EGD's influence on the Six Transformations over time.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

All data are available in the manuscript and the Supplementary Material.

Code availability

The code is available at this link: https://github.com/kperi/17_SGDs.

Received: 10 September 2023; Accepted: 19 February 2024;
Published online: 13 March 2024

References

1. European Commission (2019), The European Green Deal, COM (2019) 640 final, 11 December. https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.
2. Brundtland, G. H. Our common future—Call for action. *Environ. Conserv.* **14**, 291–294 (1987).
3. Alamanos, A. *Public Policy to Support Environmental Sustainability and Circular Economy: Efforts towards integrated approaches. 2nd Symposium on Circular Economy and Sustainability. 14-16 July, 2021*. (Alexandroupolis, Greece, 2021).
4. Alamanos, A. & Linnane, S. Estimating SDG Indicators in Data-Scarce Areas: The Transition to the Use of New Technologies and Multidisciplinary Studies. Earth, 2(3). https://doi.org/10.3390/earth2030037 (2021).
5. United Nations, The 17 goals, Available online: https://sdgs.un.org/goals (2015).
6. De Neve, J. E. & Sachs, J. D. The SDGs and human well-being: a global analysis of synergies, trade-offs, and regional differences. *Sci. Rep.* **10**, 15113 (2020).
7. Wang, X. et al. Cross-national perspectives on Using Sustainable Development Goals (SDGs) indicators for monitoring sustainable

development: a database and analysis. *Chin. Geogr. Sci.* **31**, 600–610 (2021).
8. Biermann, F. et al. Scientific evidence on the political impact of the sustainable development goals. *Nat. Sustain.* **5**, 795–800 (2022).
9. Sachs, J. D. et al. Six transformations to achieve the sustainable development goals. *Nat. Sustain*. **2**, 805–814, https://www.nature.com/articles/s41893-019-0352-9 (2019).
10. von der Leyen, U. A Union that strives for more - My agenda for Europe, POLITICAL GUIDELINES FOR THE NEXT EUROPEAN COMMISSION 2019-2024, available at: https://ec.europa.eu/info/sites/default/files/political-guidelines-next-commission_en_0.pdf, 2019.
11. European Commission, Annual Sustainable Growth Strategy 2021 COM(2020) 575, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0575&qid=1642319648572 (2020).
12. Nunes, A. R., Lee, K. & O'Riordan, T. The importance of an integrating framework for achieving the sustainable development goals: the example of health and well-being. *BMJ Glob. Health* **1**, e000068 (2016).
13. Messerli, P. et al. Expansion of sustainability science needed for the SDGs. *Nat. Sustain.* **2**, 10 (2019).
14. Breuer, A., Janetschek, H. & Malerba, D. Translating Sustainable Development Goal (SDG) Interdependencies into Policy Advice. *Sustainability* **11**, 7 (2019).
15. Nature Sustainability. A truly sustainable future. *Nat. Sustain.* **5**, 281 (2022).
16. Leal Filho, W. et al. Heading towards an unsustainable world: Some of the implications of not achieving the SDGs. *Discov. Sustain.* **1**, 2 (2020).
17. Kloke-Lesch, A. Why is the EU Failing to Champion the SDGs? *Horizons: J. Int.Relations Sustain. Dev.* **12**, 144–159 (2018).
18. Hametner, M. & Kostetckaia, M. Frontrunners and laggards: how fast are the EU member states progressing towards the sustainable development goals? *Ecol. Econ.* **177**, 106775 (2020).
19. Wood, R. et al. Growth in environmental footprints and environmental impacts embodied in trade: resource efficiency indicators from EXIOBASE3. *J. Indus. Ecol.* **22**, 553–564 (2018).
20. Cabernard, L., Pfister, S., Oberschelp, C. & Hellweg, S. Growing environmental footprint of plastics driven by coal combustion. *Nat. Sustain.* **5**, 2 (2022).
21. Siddi, M. The European Green Deal: Assesing its current state and future implementation. UPI REPORT, 114. Available at: https://iris.unica.it/handle/11584/313484 (2020).
22. Dzebo, A. The European Green Deal and the war in Ukraine: addressing crises in the short and long term. Available at: https://policycommons.net/artifacts/2653328/the-european-green-deal-and-the-war-in-ukraine/3676224/ (2022).
23. Biggeri, M., Clark, D. A., Ferrannini, A. & Mauro, V. Tracking the SDGs in an 'integrated' manner: a proposal for a new index to capture synergies and trade-offs between and within goals. *World Dev.* **122**, 628–647 (2019).
24. Maurice, J. Measuring progress towards the SDGs—A new vital science. *Lancet* **388**, 1455–1458 (2016).
25. Kostetckaia, M. & Hametner, M. How Sustainable Development Goals interlinkages influence European Union countries' progress towards the 2030 Agenda. *Sustain. Dev.* **30**, 916–926 (2022).
26. Von Homeyer, I., Oberthür, S., & Dupont, C. Implementing the European Green Deal during the evolving energy crisis. JCMS-JOURNAL OF COMMON MARKET STUDIES. https://doi.org/10.1111/jcms.13397 (2022).
27. Pietzcker, R. C., Osorio, S. & Rodrigues, R. Tightening EU ETS targets in line with the European Green Deal: impacts on the decarbonization of the EU power sector. *Appl. Energy* **293**, 116914 (2021).
28. Leonard, M., Pisani-Ferry, J., Shapiro, J., Tagliapietra, S., & Wolff, G. B. The geopolitics of the European green deal (No. 04/2021). Bruegel Policy Contribution. http://hdl.handle.net/10419/237660 (2021).
29. Shevchenko, H., Petrushenko, M., Burkynskyi, B. & Khumarova, N. SDGs and the ability to manage change within the European green deal: The case of Ukraine. *Problems Perspect Manag.* **19**, 53 (2021).
30. Borchardt, S., Barbero Vignola, G., Buscaglia, D., Maroni, M. and Marelli, L. Mapping EU Policies with the 2030 Agenda and SDGs, EUR 31347 EN, Publications Office of the European Union, Luxembourg, https://doi.org/10.2760/87754 (2022).
31. Xu, Z. et al. Assessing progress towards sustainable development over space and time. *Nature* **577**, 7788 (2020).
32. Vinuesa, R. et al. The role of artificial intelligence in achieving the Sustainable Development Goals. *Nat. Commun.* **11**, 1 (2020).
33. Goldberg, Y. *Neural Network Methods for Natural Language Processing* (Springer Nature, 2022).
34. Matsui, T. et al. A natural language processing model for supporting sustainable development goals: Translating semantics, visualizing nexus, and connecting stakeholders. *Sustain. Sci.* **17**, 969–985 (2022).
35. Hajikhani, A., & Suominen, A. The interrelation of sustainable development goals in publications and patents: a machine learning approach. https://trepo.tuni.fi/handle/10024/133267 (2021).
36. Porciello, J., Ivanina, M., Islam, M., Einarson, S. & Hirsh, H. Accelerating evidence-informed decision-making for the Sustainable Development Goals using machine learning. *Nat. Machine Intelligence* **2**, 10 (2020).
37. Smith, T. B., Vacca, R., Mantegazza, L. & Capua, I. Natural language processing and network analysis provide novel insights on policy and scientific discourse around Sustainable Development Goals. *Sci. Rep.* **11**, 1 (2021).
38. Di Lucia, L., Slade, R. & Khan, J. Decision-making fitness of methods to understand sustainable development goal interactions. *Nat. Sustain.* **5**, 2 (2022).
39. Hafner, M. & Raimondi, P. P. Priorities and challenges of the EU energy transition: From the European Green Package to the new Green Deal. *Rus. J. Econ.* **6**, 4 (2020).
40. Papadis, E. & Tsatsaronis, G. Challenges in the decarbonization of the energy sector. *Energy* **205**, 118025 (2020).
41. Fankhauser, S. et al. The meaning of net zero and how to get it right. *Nat. Clim. Change* **12**, 1 (2022).
42. Armstrong, C. & McLaren, D. Which Net Zero? Climate Justice and Net Zero Emissions. *Ethics Int. Affairs* **36**, 505–526 (2022).
43. Khosla, R., Lezaun, J., McGivern, A. & Omukuti, J. Can 'Net Zero' still be an instrument of climate justice? *Environ. Res. Lett.* **18**, 061001 (2023).
44. O'Beirne, P. et al. The UK net-zero target: Insights into procedural justice for greenhouse gas removal. *Environ. Sci. Policy* **112**, 264–274 (2020).
45. Nature Sustainability. Urgent action is needed to restore the water sector in Ukraine.*Nat. Sustain.* **6**, 491–492 (2023).
46. EUR-Lex. Homepage. Retrieved March 1, 2024, from https://eur-lex.europa.eu/homepage.html (2024).
47. LeCun, Y., Bengio, Y. & Hinton, G. Deep Learning. *Nature* **521**, 436–444 (2015).
48. Goodfellow, I., Bengio, Y., & Courville, A. *Deep learning* (MIT press, 2016).
49. Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. Bert: Pre-training of deep bidirectional transformers for language understanding. arXiv preprint arXiv:1810.04805 (2018).
50. OSDG, UNDP IICPSD SDG AI Lab, & PPMI. OSDG Community Dataset (OSDG-CD) (2021.09) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.5550238 (2021).

51. Pukelis, L., Puig, N. B., Skrynik, M., & Stanciauskas, V. OSDG -- Open-Source Approach to Classify Text Data by UN Sustainable Development Goals (SDGs). ArXiv.org. https://arxiv.org/abs/2005.14569 (2020).
52. SDG Pathfinder. SDG Pathfinder - Homepage. Retrieved from https://sdg-pathfinder.org/ (2023).
53. United Nations. Sustainable Development. Retrieved from https://sdgs.un.org/publications (2022).
54. Ritchie, R., Mispy, O-O. "Measuring progress towards the Sustainable Development Goals." SDG-Tracker.org, website https://sdg-tracker.org/ (2018).
55. PyTorch. PyTorch. Retrieved December 7, 2023, from https://pytorch.org/ (2023).
56. Kingma, D., & Lei Ba, J. ADAM: A METHOD FOR STOCHASTIC OPTIMIZATION. https://arxiv.org/pdf/1412.6980.pdf (2017).

Acknowledgement

The authors acknowledge funding from the European Research Council (ERC) under the ERC Synergy Grant Water-Futures (grant agreement 951424).

Author contributions

Conceptualization, P.K., A.A., A.P.; methodology, C.S., K.P., A.P., A.A., S.D.; data analysis and validation, C.S., K.P., A.P., S.D.; writing—original draft preparation, P.K., A.P.; writing—review and editing, A.P, A.A., P.K., C.S.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s44168-024-00104-6.

Correspondence and requests for materials should be addressed to Phoebe Koundouri.