Environment, Development and Sustainability (2026) 28:3713–3736
https://doi.org/10.1007/s10668-024-05057-8

The United Nations SDG13 and the EU27 countries performance: A comparative analysis

Marina B. Sena[1] · Leonardo Costa[2] · Alexandra Leitão[2] · Maria C. A. Silva[2]

Received: 19 March 2023 / Accepted: 16 May 2024 / Published online: 14 June 2024

Abstract
This paper evaluates the performance of the European Union 27 (EU-27), its supranational regions, and Member States (MSs) in relation to the Climate Action Sustainable Development Goal (SDG13) of the United Nations 2030 Agenda. The Alkire–Foster method is used to develop the Multidimensional Climate Action Index (MCAI) framework. Regarding individual MSs' overall performance, the results show that Sweden (Northern Europe) performs the best and Croatia (Central and Eastern Europe) the worst. In terms of the average overall performance of individual MSs in the EU-27 and its supranational regions, only Western and Northern Europe have satisfactory scores. Moreover, the performances of the various territories differ by target. This territorial heterogeneity illustrates how the SDG13 targets may require different efforts in each territory. The scores for the MCAI group measure depict an even worse picture. Except for Northern Europe, the proportion of MSs with a satisfactory individual overall composite score (H) is lower than their average overall composite score or intensity (A). The two regions with the lowest H scores (Southern Europe and Central and Eastern Europe) also have the lowest A scores and the lowest average GDP per capita.

Keywords Climate change · SDG13 · EU27 · AF method

✉ Leonardo Costa
lcosta@ucp.pt

Marina B. Sena
marinasena.ms@gmail.com

Alexandra Leitão
apleitao@ucp.pt

Maria C. A. Silva
csilva@ucp.pt

[1] Universidade Católica Portuguesa, Católica Porto Business School, Porto, Portugal

[2] Universidade Católica Portuguesa, Católica Porto Business School, Research Centre in Management and Economics, Porto, Portugal

1 Introduction

The goal of this paper is to assess the performance of the European Union 27 (EU-27), its supranational regions, and individual Member States (MSs) on Sustainable Development Goal 13 (SDG13) and its set of targets.[1] We seek to ascertain where the different EU-27 MSs and groups of MSs stand with regard to SDG13 and its objectives. To reach our goal, the Alkire–Foster (AF) method was applied (Alkire & Foster, 2011) to develop the Multidimensional Climate Action Index (MCAI) framework.

Sustainable development has garnered increasing attention from the United Nations (UN). *The Limits to Growth*, a report from the Club of Rome, initiated the discussion on the physical limits of the planet (Meadows et al., 1972). Subsequently, the Brundtland report, *Our Common Future*, from the UN World Commission on Environment and Development (WCED), presented the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 15). Sustainable development is thus a normative concept of economic growth, implying that it should occur in tandem with social inclusion and environmental protection (Baker, 2016), considering the needs of future generations. This concept was ultimately incorporated into the international political agenda at the Rio-92 Conference.

The 2000 UN Millennium Summit consolidated the discussion on sustainable development with the Millennium Development Goals (MDGs), with environmental sustainability addressed in MDG7 (UN, n.d.a). The Sustainable Development Goals (SDGs) of the UN 2030 Agenda, adopted in 2015, built on the MDGs (Hák et al., 2016) and widened their scope (Biermann et al., 2017). As a result, the SDGs brought the complete legacy of previous discussions, since 1972, in Stockholm, up to 2015, the year in which the UN 2030 Agenda was established by the UN General Assembly in New York (UN, 1972, 2015) and the Paris Agreement was ratified by 187 parties.

According to Richardson et al. (2023), Earth has already surpassed six of the nine planetary boundaries; as such, it has exceeded the "Climate change" boundary. Moreover, these nine planetary boundaries constitute the biophysical boundaries of an interconnected Earth system, where each part of the system affects the others.

Pressure on natural resources has mainly been attributed to economic growth and trade openness (Abid et al., 2023a, b), while Information and Communication Technologies (ICTs), environmental regulations, and energy transition, among others, can help in reducing it (Abid, Ceci, & RazzaAbid et al., 2023a, b). A stable climate requires an atmospheric CO_2 concentration of between 280 ppm and 350 ppm (Lindsey, 2023). However, the safe limit of 350 ppm had already been exceeded by 1992 (360 ppm) and has since increased further, to 400 pm in 2015 and 430 ppm in 2022 (IPCC, 2022a). The latest IPCC assessments corroborated an acceleration in human-induced climate change (IPCC, 2021, 2022a, 2022b) along with a rise in environmental losses.

In the context of this bleak overall picture, the EU MSs have been at the forefront of efforts to reduce greenhouse gas emissions. Acting jointly, they are committed to the binding obligation of achieving a climate-neutral Europe by 2050 as set out in the European Climate Law (EU, 2021). In addition, some of the EU-27 MSs were among the G20 members

[1] EuroVoc considers the following EU-27 supranational regions: Southern Europe, Western Europe, Northern Europe, and Central and Eastern Europe (EU, 2022a). In this paper, targets are categories or dimensions.

that showed a willingness to increase their mitigation measures in 2021 (Moosmann et al., 2021).

Meanwhile, following the 2015 Paris Agreement, a Global Covenant of Mayors for Climate and Energy was established in 2016, recognizing the importance of cities in global energy consumption (accounting for more than two-thirds) and greenhouse gas emissions (around 70%), as well as the need for action at the local city level (Kona et al., 2021).[2] The relationship between energy consumption and greenhouse gas emissions is well established in the literature, given the continuing high dependence of the world economy on fossil fuel energy sources (Adedoyin et al., 2021).

Several studies have evidenced the overwhelming impacts of climate change. The Stern Review considered various impact channels of climate change, including water distribution, crop yields, food insecurity, and health impacts, among others, and estimated that global warming could lead to losses of between 5.3% and 13.5% of world GDP per capita in 2200 (Stern, 2006). In contrast, the same report estimated an annual cost of around 1% of world GDP for strong action and a substantial reduction of the worst impacts of climate change. More recently, the Swiss Re Institute, from the reinsurance company of the same name, produced a report in April 2021 illustrating the expected GDP losses in 2050 under various temperature rise scenarios (Swiss Re Institute, 2021). Estimates suggested a decline in global GDP of around 10% by 2050 under the current trajectory and assuming the Paris Agreement targets were not met. Thus, any delay in action would not only be dangerous but also very costly.

There is growing evidence that financial markets have started to price in climate risks (Eren et al., 2022). The European Central Bank (ECB) conducted a study on the exposure of individual EU-27 MSs to climate risks. Countries with the greatest climate risk will pay more for access to finance (ECB, 2020).

In its Global Risks Report 2023, the World Economic Forum (WEF) showed that large companies already perceive the severity of environmental risks, in particular the severity of climate change risks (WEF, 2023).

The information cited above demonstrates that academics, different levels of government and/or policy makers, practitioners, and other stakeholders are aware of the risks associated with climate change and the need to act accordingly in terms of mitigation and adaptation. It also illustrates the extent to which indexes or indicators can be relevant tools with which to assess climate change and action by the different stakeholders, by informing appropriate decision-making. However, one should be aware that assessment results may be sensitive to the indexes and indicators used (Tóthová & Heglasová, 2022).

SDG13 – Climate Action – was specifically defined to combat human-activity-induced climate change and its negative impacts (UN, 2021). Campbell et al. (2018) highlighted that SDG13 is broad, and that achieving every objective within its targets would also require the objectives of other associated SDGs to be achieved. SDG13 is thus the focus of our research.

Since the establishment of the UN MDGs in 2000, and, particularly, after the 2015 Paris Agreement on climate change and the adoption of the UN 2030 Agenda and its SDGs, the scientific community has made continuous efforts to assess countries' performance on

[2] The European Commission was also a pioneer in the involvement of cities in the fight against climate change. In 2008, it launched the EU Covenant of Mayors for Climate and Energy initiative, committing participating mayors to reduce greenhouse gas emissions, increase climate resilience, and alleviate energy poverty.

sustainable development. Several studies have contributed to the field, with the creation of composite indexes to assess the performance of territories. Regarding countries, these indexes and their resulting rankings are used to compare performance and also to certify that both national and international actors are achieving certain predetermined goals, such as those of the 2015 Paris Agreement. All of these measures have facilitated the comparison of efforts toward sustainable development and the curbing of climate change, creating greater transparency on the issues and, hopefully, motivating governments to achieve their goals responsibly.

Composite indexes such as the SDG Index, the Climate Change Cooperation Index, the Climate Change Performance Index, and others have been developed in the literature to assess sustainable development and climate action, in particular (see, for instance, Bernauer & Böhmelt, 2013; Burck et al., 2022; Codal et al., 2021; Sachs et al., 2022). However, none of these indexes were developed to specifically assess the UN SDG13 and its five targets. Moreover, although the SDG Index assesses the 17 SDGs, the information for assessing SDG13 focuses solely on CO_2 emissions. We believe that this provides only a limited view of SDG13, as the assessment should include both mitigation and adaptation indicators. These are all important gaps in the literature that this paper aims to fill. Therefore, to the best of our knowledge, the object of analysis in this paper is new (the assessment of SDG13 and its targets) and the method used to address it, namely the AF method, is also novel within the context.[3] Furthermore, and unlike other composite indexes in the literature, the MCAI framework provides a coherent and objective multidimensional and multilevel assessment of SDG13, which is capable of incorporating not only quantitative but also qualitative information, and of dealing robustly with missing values.

The paper proceeds as follows. After this introductory section, Sect. 2 considers the previous literature on composite indexes for sustainable development and climate change. This is followed by Sect. 3, which describes the method and the data. The results and discussion are presented in Sect. 4. Section 5 concludes the paper.

2 Literature review

The literature review is organized thematically and, within each theme, chronologically. Taking into account our objective of assessing SDG13 and its targets in the EU-27, its supranational regions, and its MSs, the indexes covered are on sustainable development, climate change mitigation, and climate change adaptation and assessing countries' corresponding performance.

2.1 Sustainable development indexes

The Sustainable Society Index (SSI), computed since 2006 for a wide range of countries, was one of the first indexes calculated to assess countries' sustainable development performance. It reflects the triple-bottom-line approach to sustainability of the Brundtland report, incorporating 21 partial indicators sorted into seven categories and three well-being dimensions: human, environmental, and economic (van de Kerk et al., 2014). However, it has no

[3] The method is in line with the UN's use of the Multidimensional Poverty Index (MPI) to inform SDG1 – No Poverty (UNDP & OPHI, 2019).

overall sustainability score, with the composite indexes limited to each of the three dimensions of well-being.

The SDG Index assesses the overall performance score of the 193 UN MSs regarding the 17 SDGs, since 2015. Detailed information is provided on the individual SDGs for each country, based on more than 100 partial indicators. Priorities for further action are identified and there is information on whether countries are on- or off-track to achieve the goals in each target by 2030, based on the latest trend data (Sachs et al., 2022).

Similar analyses to the SDG Index have been conducted for different scopes and territories. For instance, Luomi et al. (2019) performed this type of analysis for the Arab region, and ICS & SDSN (2021) for Brazilian cities. Tóthová and Heglasová (2022) used the SDG Index to assess environmental sustainability alone (including only goals 6, 7, 12, 13, 14, 15) in the EU-27 countries and compare it with two other methods. Hametner and Kostetckaia (2020), using time series data, proposed measures to assess progress toward the 2030 Agenda's SDGs. Guo et al. (2022), using Big Earth data, presented a comprehensive analysis of several SDGs in China, including SDG13.

To adjust the UN Human Development Index for ecological impact, Hickel (2020) proposed the Sustainable Development Index (SDI), considering consumption-based CO_2 emissions and material footprint (two key indicators of the ecological impact of human activity).

2.2 Climate change mitigation indexes

Several indexes have been introduced that focus solely on climate change mitigation. The Cooperation Index on Climate Change (CI) (Baettig et al., 2008), the Climate Change Cooperation Index (C3-I) (Bernauer & Böhmelt, 2013), and the Climate Change Performance Index (CCPI) (Burck & Bals, 2011; Burck et al., 2022) are the most well-known. The CI arose from the UN Framework Convention on Climate Change (UNFCCC) and the implementation of the 1997 Kyoto Protocol (Baettig et al., 2008). This composite index is based on five partial indicators: two that measure whether and how fast countries have committed to the two international treaties; and three (reporting, finance, and emissions) that assess whether and how effectively measures have been implemented in line with those treaties. The CI resulting from aggregation is a measure of countries' cooperative behavior toward the international climate agenda. Baettig et al. (2008) assessed 198 countries, using cross-sectional average data for the period 1990–2005.

Bernauer and Böhmelt (2013) relied on CI as a foundation for C3-I but considered the data in a panel format. C3-I provides information on 172 countries for the period 1996–2008, allowing for a systematic global comparison of countries' climate policies.

Finally, the CCPI (Burck & Bals, 2011; Burck et al., 2022) assesses countries' performance based on 14 partial indicators grouped into four categories with previously established weights. The categories are greenhouse gas emissions (40%), renewable energy (20%), energy use (20%), and climate policy (20%) (Burck et al., 2022).[4] The CCPI has been published annually since 2005, with increasing coverage of countries over time, and

[4] Most indicators are quantitative. Qualitative indicators on the latest developments in the implementation of a country's national climate policy and its international climate diplomacy are based on a survey of national experts.

currently includes the 60 countries (including the EU-27 MSs) responsible for over 90% of global greenhouse gas (GHG) emissions.[5]

The CCPI has been extended in the literature. Epule et al. (2021b) introduced the African Climate Change Performance Index (ACCPI). As opposed to the original CCPI, which included only four African countries,[6] the ACCPI provides an assessment of the performance of climate change policy across the entire African continent, both nationally and regionally. It follows a methodological approach similar to that provided by the CCPI but differs in terms of the four categories assumed, the weights considered, and the data collection. Unlike the CCPI, the ACCPI does not include energy use, and it includes a perception of corruption category. Furthermore, it does not work with national expert surveys, and it employs online data repositories. It utilizes cross-sectional average data for the period 2016–2020 and will be updated every five years.

Other studies have also relied on the CCPI. Puertas and Marti (2021) found that geographical and economic proximity between countries does not result in homogeneous performance patterns in combating climate change. They also found evidence of a link between active climate policy actions and achievements, such as an increase in the use of renewable energy resulting in a reduction in greenhouse gas emissions.

However, the assessment of countries' performance in tackling climate change mitigation is not limited to these indexes. Codal et al. (2021) used a multidimensional perspective (financial, emissions, policy, and legislative, non-governmental organizations) and a balanced scorecard approach to assess the efforts of G20 countries regarding climate change.

Boehm et al.'s (2022) Climate Action Tracker (CAT) provided an overview of global progress toward limiting global warming to 1.5 ºC. Projections of current trends were compared with desirable trajectories needed to reach near-term (2030) and long-term (2050) targets. The final performance of countries according to each partial indicator was classified into categories of progress: on-track, off-track, well off-track, wrong direction, and insufficient data. Partial indicators referred to sectors with relevant contributions to GHG emissions: power, buildings, industry, transport, forest and land, food and agriculture, and technological carbon removal. All measurements were made based on historical data from the last 10 years and used the 2015 Paris Agreement as a reference point. The authors also calculated each country's overall ranking by combining all rankings. Their results showed that, to date, no country had met the goals of the 2015 Paris Agreement.

2.3 Climate change adaptation indexes

While the above indexes on climate change focus on mitigation, adaptation to climate change is also a focus of interest in the literature. Epule et al. (2021a) introduced a readiness index for climate change adaptation in Africa – the ClimAdaptCap Index. It weighted into a single index a climate score (based on temperature and precipitation) and an adaptive capacity score (proxied by literacy and poverty rates). Regional averages were calculated over the period 1991–2016 and for each of the five African regions.

[5] CCPI was last revised in 2017, to adapt to the 2015 Paris Agreement.

[6] Algeria, Egypt, Morocco, and South Africa.

Fu et al. (2021) developed the Index for Climate Change Adaptation in China (ICCAC), to evaluate the overall progress on climate change adaptation in China during the period 2010–2018.

2.4 The gaps filled by the MCAI framework

Table 1 provides a summary of the main indexes described above

We conclude this section by noting that the extant literature contains several composite indexes to assess sustainable development, the UN SDGs, and climate action to tackle climate change. However, none of the above-mentioned composite indexes are counting indexes, most do not consider both quantitative and qualitative information, none provide an explicit way to deal with missing values, and none have their focus on SDG13 and its targets (addressing, simultaneously, climate change mitigation and adaptation). As we demonstrate in the following section, the MCAI framework fills all these gaps.

3 Method and data

SDG13 comprises the following five targets (Project Everyone, 2022):

13.1 "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries" (Resilience);
13.2 "Integrate climate change measures into national policies, strategies and planning" (Action);
13.3 "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (Education);
13.A "Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible" (Commitment A); and.
13.B "Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities" (Commitment B).

To measure and monitor the performance of a country against each target, partial indicators are needed to demonstrate the effectiveness of this performance in relation to the established benchmarks (McCarthy et al., 2012). The same applies to the average performance of MSs.

The UN 2030 Agenda includes several partial indicators per SDG13 target; sometimes, however, it includes only one partial indicator.[7] In this paper, we are as thorough as possible in the definition of partial indicators per target, depending on the available information. For instance, regarding target 13.2 (Action), we move beyond the existence or not of long-term strategies and total GHG emissions (partial indicators included in the UN 2030 Agenda)

[7] To apply the AF method it is recommended to have at least two partial indicators per dimension.

Table 1 Main indexes for sustainable development and climate assessment

Authors	Name of the Index	Assessment Goal	Scope	Extensions
Sustainable development				
van de Kerk et al. (2014)	Sustainable Society Index (SSI)	Sustainable development	A wide range of countries, since 2006	N.a.
Sachs et al. (2022)	Sustainable Development Goals Index (SDG Index)	Overall performance regarding the 17 SDGs	93 UN Member States, since 2015	Luomi et al. (2019); ICS & SDSN (2021); Tóthová & Heglasová (2022); Hametner and Kostetckaia (2020); Guo et al. (2022);
Hickel (2020)	Sustainable Development Index (SDI)	Correcting the UN Human Development Index for ecological impact	N.a.	N.a.
Climate change mitigation				
Baettig et al. (2008)	Cooperation Index on Climate Change (CI)	Climate change mitigation	198 countries, 1990–2005, cross-sectional average data	N.a.
Bernauer and Böhmelt (2013)	Climate Change Cooperation Index (C3-I)	Climate change mitigation	172 countries, 1996–2008, panel data	N.a.
Burck and Bals (2011); Burck et al. (2022)	Climate Change Performance Index (CCPI)	Climate change mitigation	Currently for 60 countries, since 2005	Epule et al. (2021b); Puertas and Marti (2021)
Codal et al. (2021)	N.a.	Climate efforts	G20 countries	N.a.
Boehm et al. (2022)	Climate Action Tracker (CAT)	Progress toward limiting global warming to 1.5ºC	N.a.	N.a.
Climate change adaptation				
Epule et al. (2021a)	ClimAdaptCap Index	Climate change adaptation	5 key African regions, cross-sectional 1991–2016 average data	N.a.
Fu et al. (2021)	Index for Climate Change Adaptation in China (ICCAC)	Overall progress on climate change adaptation	China, 2010–2018	N.a.

Source Own work

and explore partial indicators that have characterized the European climate policy on GHG emissions reduction since the Kyoto Protocol, such as renewable energy promotion, energy efficiency, or the carbon market. Regarding target 13.3 (Education), we seek indicators that reflect greater education and awareness about climate change, at both the individual and institutional levels.

We consider loss, mitigation, and adaptation partial indicators, which show, respectively, vulnerability, how human-induced climate change is being tackled, and how the effects of climate change are being addressed. We closely follow the AF method (Alkire & Foster, 2011; Alkire et al., 2018; Alkire & Santos, 2010a,b) – a counting dual cut-off method created to measure multidimensional poverty, but also used for other purposes (e.g., Pereira et al., 2018) – to develop an MCAI framework capable of assessing the performance of the EU-27, its supranational regions, and MSs regarding SDG13. The method implies the following seven steps:[8]

Step 1 – Establish the dimensions and partial indicators per dimension In the MCAI case, the dimensions correspond to the SDG13 targets. We assume four targets since we have merged 13.A and 13.B into a single target that we refer to as 13.4 (Commitment), which considers more than one partial indicator.[9] A total of 14 partial indicators were considered, covering all SDG13 targets;

Step 2 – Dichotomize partial indicators Knowing the critical cut-off values for all partial indicators, original scales are converted to 1, when the partial indicator is above the critical cut-off level, and 0 otherwise. In the MCAI case, these critical cut-off values can be specific policy objectives, if they exist, or the average performance of the EU-27 MSs, otherwise;

Step 3 – Fill in missing values Set missing values equal to the second set of critical cut-off values in Step 5, so as not to alter the performance assessment decisions in Step 6. In the MCAI case, these critical cut-off values are set equal to 0.5, which is also the best guess when no information is available;

Step 4 – Select the relative weights of dimensions and partial indicators The sum of the weights of all dimensions or partial indicators should add up to 1. In the MCAI case, equal weights are chosen for all targets and the partial indicators within each target;

Step 5 – Compute individual composite scores These are weighted averages of the corresponding partial indicators, to be compared with the second set of critical cut-off values. In the MCAI case, these critical cut-off values, per target and overall, are set equal to 0.5 and correspond to the proportion of weighted achievements an MS needs to exceed for its performance to be satisfactory, whether in a certain target or overall. That is, the second set of critical cut-off values enables us to identify the extent to which the MS should perform satisfactorily in order to be considered satisfactory in a certain target or overall;

Step 6 – Compute the average performance of a group of individuals Based on the individual scores, compute the average performance of a group of individuals, contrasting the average score for each partial and composite (target and overall) indicator with the corresponding critical cut-off values. In the MCAI case, individuals are the MSs and groups of individuals or MSs correspond to supranational territories. The territories considered are the

[8] We opted to expose the AF method in general and immediately explain how it materializes in the MCAI case.

[9] Both targets (13.A & 13.B) relate to the support that should be given to least developed economies by the developed economies.

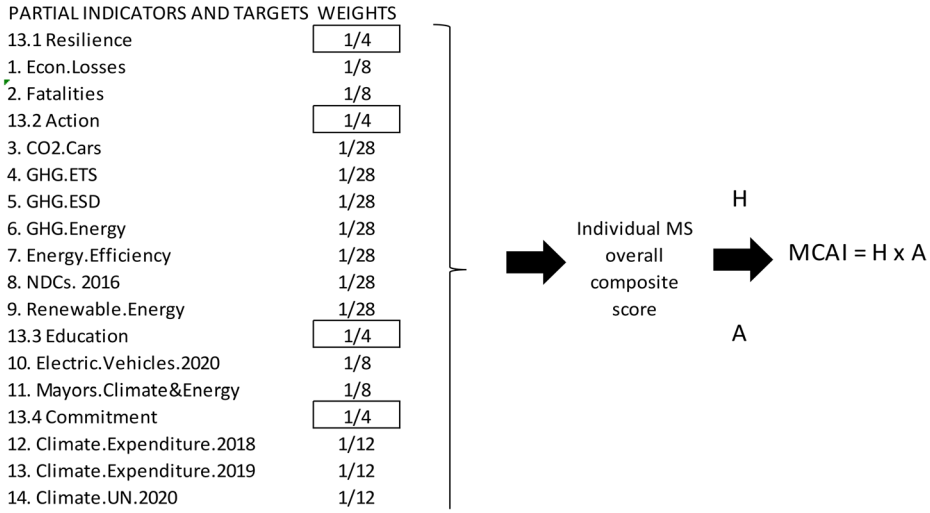

Fig. 1 The MCAI framework. *Notes* H is the proportion of MSs with overall satisfactory performance and A is the average overall performance intensity of MSs with overall satisfactory performance *Source* Own work

EU-27 as a whole and its four supranational regions. The critical cut-off values considered to assess the average performance of MSs in each territory by partial and composite (target and overall) indicators are set equal to 0.5. Thus, the average MS of a European territory performs satisfactorily on a specific partial indicator, or a composite (target or overall) indicator, if the corresponding weighted average score is strictly above 0.5;

Step 7 – Compute A, H, and the group measure MCAI That is, compute the proportion H of individuals that have been identified as having an overall composite score greater than the critical cut-off value, and the intensity A corresponding to the average overall performance of this group of individuals. The MCAI group measure is defined as the product of H times A.[10] A satisfactory performance implies a MCAI score strictly greater than 0.5.

Figure 1 illustrates the MCAI framework, showing the four targets and the 14 partial indicators considered (in addition to the corresponding weights), and the MCAI group measure score (described in Step 7 above).[11]

Partial indicators considered in the MCAI framework are based on an analysis of documents and international treaties such as the Kyoto Protocol and the Paris Agreement. Suitable data were explored on the European Commission website. Most of the objectives behind the critical cut-off values for the partial indicators are linked to the 2020 Climate & Energy Package, set by EU leaders in 2007, which is part of the action taken by the European Commission toward the goal of climate neutrality by 2050 (EU, 2022b). The data sources are the European Environment Agency (EEA), Eurostat, the UNFCCC, the World Bank, and The

[10] MCAI=H x A.

[11] Descriptions of the partial indicators in Fig. 1 are provided in Appendix A.

Lancet database. Appendix A contains the partial indicator descriptions, sources, and critical threshold values considered.

4 Results and discussion

Figure 2 illustrates the overall composite score by MS of the EU-27. Table 2, shows the overall and target scores by MS of the EU-27.[12] MSs are listed in descending order of their overall composite score.[13]

A mere 12 MSs (44%) have a satisfactory individual overall composite score (>0.5) against SDG13. Sweden has the best individual overall composite score (0.72) and Croatia has the worst (0.27). Sweden fails to exceed the critical value in only target 13.3 (Education), while Croatia exceeds it in only target 13.2 (Action).[14]

The results presented in Fig. 2 and Table 2 (and Appendices B to E) are consistent with part of the literature and are more informative. In the literature, the countries of Northern Europe have typically been the top performers. For example, in the CCPI 2022, Sweden, Denmark, and Norway[15] were the three top performers (Burck et al., 2021). In the SDG Index 2022, the top performers were Finland, Denmark, and Sweden (Sachs et al., 2022),

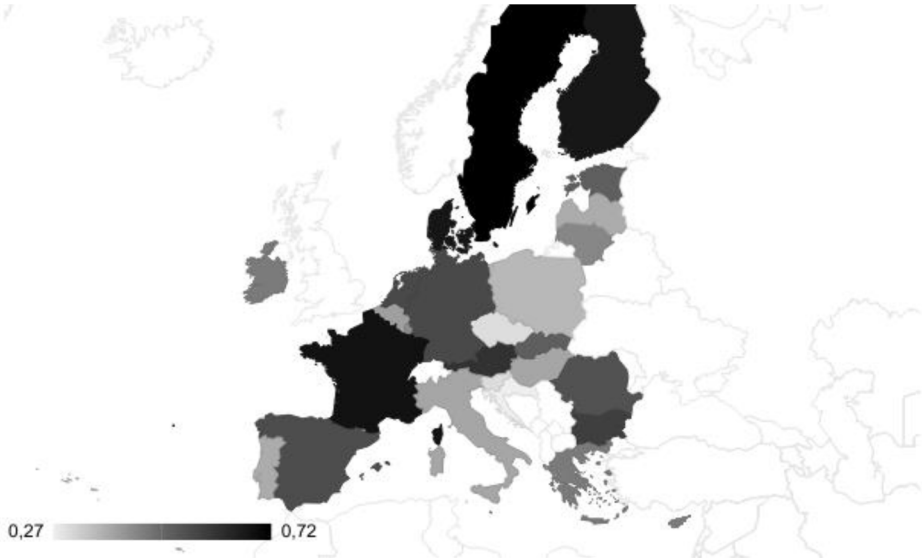

Fig. 2 Overall composite score by MS. *Source* Own work.

[12] As previously explained, missing values are set equal to 0.5. However, a sensitivity analysis was performed considering 1 and 0 for missing values. The results did not change significantly and are available upon request.

[13] For the partial (1 to 14), composite (targets 13.1 to 13.4 and overall), and MCAI scores by MS and EU territory (EU-27 as a whole and its four supranational regions), refer to Appendices B to E.

[14] For detailed information on these two MSs, refer to Appendices D and E.

[15] Out of our sample.

Table 2 Overall and target composite scores by Member State

Member State	Region	Composite scores				
		Overall	By target			
			13.1	13.2	13.3	13.4
Sweden (SE)	NE	**0.72**	1.00	0.71	0.50	0.67
France (FR)	WE	**0.68**	0.00	0.71	1.00	1.00
Denmark (DK)	NE	**0.67**	0.50	1.00	0.50	0.67
Finland (FI)	NE	**0.67**	1.00	0.86	0.50	0.33
Austria (AT)	WE	**0.61**	0.50	0.43	0.50	1.00
Bulgaria (BG)	CEE	**0.58**	1.00	0.64	0.00	0.67
Netherlands (NL)	WE	**0.56**	0.50	0.57	0.50	0.67
Germany (DE)	WE	**0.56**	0.00	0.57	1.00	0.67
Spain (ES)	SE	**0.55**	0.00	0.71	0.50	1.00
Romania (RO)	CEE	**0.54**	1.00	0.64	0.50	0.00
Estonia (EE)	NE	**0.51**	1.00	0.71	0.00	0.33
Slovakia (SK)	CEE	**0.51**	1.00	0.71	0.00	0.33
Malta (MT)	SE	**0.48**	1.00	0.57	0.00	0.33
Greece (EL)	SE	**0.46**	0.00	1.00	0.50	0.33
Ireland (IE)	WE	**0.46**	1.00	0.86	0.00	0.00
Lithuania (LT)	NE	**0.44**	1.00	0.43	0.00	0.33
Luxembourg (LU)	WE	**0.43**	0.00	0.57	0.50	0.67
Cyprus (CY)	SE	**0.40**	1.00	0.29	0.00	0.33
Belgium (BE)	WE	**0.40**	0.50	0.29	0.50	0.33
Italy (IT)	SE	**0.39**	0.00	0.71	0.50	0.33
Hungary (HU)	CEE	**0.39**	1.00	0.57	0.00	0.00
Portugal (PT)	SE	**0.38**	0.00	1.00	0.50	0.00
Latvia (LV)	NE	**0.38**	1.00	0.50	0.00	0.00
Poland (PL)	CEE	**0.36**	1.00	0.43	0.00	0.00
Czechia (CZ)	CEE	**0.30**	0.50	0.71	0.00	0.00
Slovenia (SI)	CEE	**0.30**	0.50	0.71	0.00	0.00
Croatia (HR)	CEE	**0.27**	0.50	0.57	0.00	0.00

Note The regions are Southern Europe (SE), Western Europe (WE), Northern Europe (NE), and Central and Eastern Europe (CEE)

Source Own work

and none of the EU countries were the lowest performers (Sachs et al., 2022). Puertas and Marti (20211), using indicators from CCPI, found that European countries were the top performers in two of the six clusters analyzed (Puertas & Marti, 2021). Meanwhile, in the "State of Climate Action 2022" report, nine countries of the world recorded an almost sufficient performance, although no EU-27 MSs featured among them (Boehm et al., 2022). Hametner and Kostetckaia (2020) investigated the EU MSs' rates of progress toward the SDGs and identified Croatia, Portugal, and Romania as top performers, with the lowest performance for Luxembourg, Denmark, and Austria. A trade-off may exist between the level and rate of progress, meaning our analysis is focused on levels and not on rates.

Fig. 3 illustrates the four European regions. Table 3 presents the results of the MCAI framework by European territory (EU-27 as a whole and its four supranational regions).[16]

[16] Descriptions of the partial indicators in Table 3 are provided in Appendix A.

Fig. 3 The four European supranational regions. *Source* EuroVoc (UN, n.d.b)

Looking at the average MS overall composite scores (Table 3), the EU-27 as a whole is not performing satisfactorily (0.48). Two regions have a satisfactory average overall composite score – Western Europe (0.55) and Northern Europe (0.57) – and two do not – Southern Europe (0.42) and Central and Eastern Europe (0.43). However, the 2017 SSI report (Sustainable Society Index, 2022),[17] which assessed the sustainability levels of countries around the world, presented contrasting findings. Although the constituent countries of Northern Europe continued to exhibit the strongest average performance in the SSI environmental well-being indicator, surpassing other European regions, countries in Central and Eastern Europe and Southern Europe recorded, respectively, the second and third strongest average performances, with the weakest average performance coming from Western Europe. These changing trends indicate significant disparities in environmental well-being performance among European countries. Nonetheless, the environmental well-being indicator included other partial indicators besides those related to SDG13, which is not the case with the MCAI. In particular, the SSI uses partial indicators related to natural resources, such as biodiversity or renewable water resources, which may explain its different results.

These average MS composite scores by target and European territory show that:

- Southern Europe (0.33) and Western Europe (0.36) need to improve on target 13.1 (Resilience). These are the regions most affected by climate risks and natural disasters;
- The EU-27 as a whole and all its supranational regions perform well on target 13.2 (Action);
- The EU-27 as a whole (0.30), Southern Europe (0.33), Northern Europe (0.25), and Central and Eastern Europe (0.08) need to improve on target 13.3 (Education);

[17] This is the latest SSI report with information on the broadest number of countries. However, it does not include information about Ireland, which is included in our sample.

Table 3 Partial indicator (1 to 14), composite indicator (13.1 to 13.4 and overall), and MCAI group measure scores by European territory

Partial indicator, composite indicator, and MCAI group measure scores	EU-27	Southern Europe	Western Europe	Northern Europe	Central and Eastern Europe
13.1-Resilience	**0.61**	**0.33**	**0.36**	**0.92**	**0.92**
1-Econ.Losses	0.59	0.33	0.43	0.83	0.83
2-Fatalities	0.63	0.33	0.29	1.00	1.00
13.2-Action	**0.65**	**0.71**	**0.57**	**0.70**	**0.62**
3-CO2.Cars	0.50	0.33	0.57	1.00	0.17
4-GHG.ETS	0.81	0.83	0.71	0.83	0.83
5-GHG.ESD	0.57	0.67	0.29	0.42	0.83
6-GHG.Energy	0.41	0.67	0.29	0.50	0.33
7-Energy.Efficiency	0.67	0.83	0.57	0.67	0.50
8-NDCs.2016	0.63	0.67	0.71	0.50	0.67
9-Renewable.Energy	0.94	1.00	0.86	1.00	1.00
13.3-Education	**0.30**	**0.33**	**0.57**	**0.25**	**0.08**
10-Electric.Vehicles.2020	0.33	0.17	0.71	0.50	0.00
11-Mayors.Climate&Energy	0.26	0.50	0.43	0.00	0.17
13.4-Commitment	**0.37**	**0.30**	**0.68**	**0.41**	**0.10**
12-Climate.Expenditure.2018	0.33	0.25	0.71	0.33	0.08
13-Climate.Expenditure.2019	0.37	0.25	0.71	0.50	0.08
14-Climate.UN.2020	0.41	0.39	0.62	0.39	0.13
Overall composite score	**0.48**	**0.42**	**0.55**	**0.57**	**0.43**
MCAI group measure score	**0.27**	**0.09**	**0.34**	**0.43**	**0.20**
H	0.44	0.17	0.57	0.67	0.38
A	0.60	0.55	0.60	0.64	0.54

Source Own work

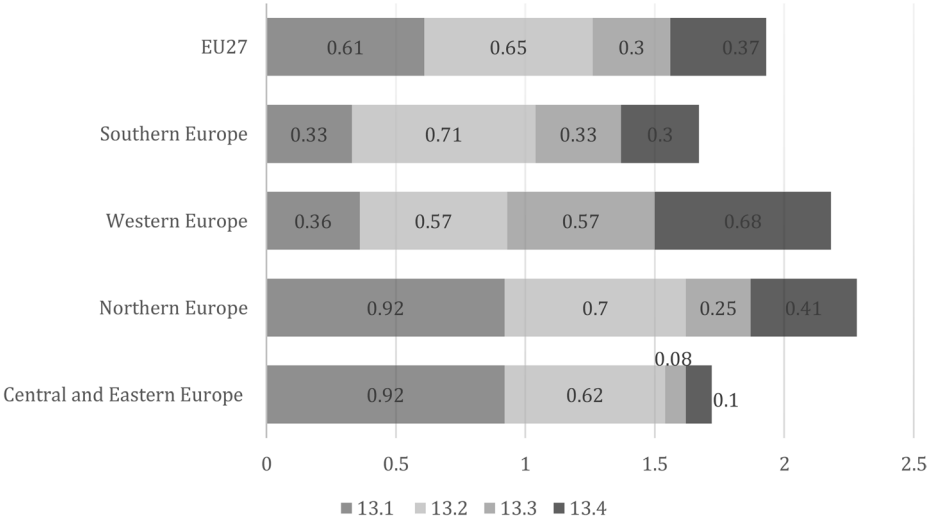

Fig. 4 Average MS composite score by target and European territory. *Source* Own work

– The EU-27 as a whole (0.37), Southern Europe (0.30), Northern Europe (0.41), and Central and Eastern Europe (0.10) need to improve on target 13.4 (Commitment).

The territorial heterogeneity described above shows how the SDG13 targets may require different efforts in different territories. This is an important policy implication of our results. The detailed characterization of the territories shown in Appendices B to E indicates exactly where action is needed. For instance, a specific target can largely contribute to lowering the average MS overall composite score, as target 13.1 (Resilience) does in Southern and Western Europe, and targets 13.3 (Education) and 13.4 (Commitment) do in Central and Eastern Europe. In other words, the results show the low Resilience (or high vulnerability) of Southern and Western European countries to climate change, suggesting the need to strengthen climate change adaptation policies in these countries, and a weak performance in Education and Commitment for Central and Eastern European countries, suggesting the need to invest in public policies that promote environmental education and awareness among the population and institutions, strengthening the quality of the latter, and encouraging support to developing economies in these countries. Moreover, there is also a need for Education and Commitment policies in Southern and Northern Europe. In addition, target 13.2 (Action) performs well in all regions (and in the vast majority of MSs), which appears to show the relevance of European institutions' policies related to climate change.

Furthermore, by comparing the average MS target composite scores of the supranational regions with the EU-27 as a whole, we find that:

– Northern Europe and Central and Eastern Europe perform better on target 13.1 (Resilience) than the EU-27 as a whole;
– Southern Europe and Northern Europe perform better on target 13.2 (Action) than the EU-27 as a whole;
– Southern Europe and Western Europe perform better on target 13.3 (Education) than the EU-27 as a whole; and.
– Western Europe and Northern Europe perform better on target 13.4 (Commitment) than the EU-27 as a whole.

Therefore, European regions that perform poorly relative to the EU-27 as a whole in some targets may perform better in other targets.

The scores for the MCAI group measure depict an even worse picture, with all scores below the critical cut-off value of 0.5. These scores add to the previous analysis as they surpass simple averages, providing insights into the variability of MS performance across the EU-27 as a whole and its four supranational regions.

The MCAI group measure is a product of two numbers: (i) H – the proportion of MSs in a given territory with a satisfactory individual overall composite score; and (ii) A – the mean intensity or average group score of these MSs in relation to their overall composite scores. The product of two numbers between zero and one is always less than the smaller of those numbers. Therefore, a low MCAI group measure score can be determined by a low H, a low A, or both.

The EU-27 as a whole has an MCAI group measure score of 0.27. In this territory, as in most European supranational regions, with the exception of Northern Europe, H is smaller than A. Furthermore, the two supranational regions with the lowest H scores (Southern

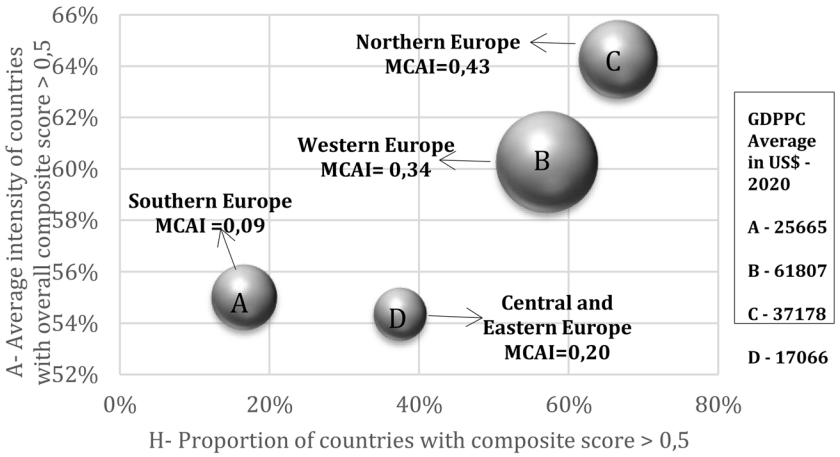

Fig. 5 Bubble chart showing, by region, the relationship between A and H, MCAI group measure scores, and GDP per capita (GDPPC). *Source* Adapted from the World Bank Group (2022).

Europe and Central and Eastern Europe) also have the lowest A scores and the lowest average GDP per capita (see Fig. 5). Thus, the MCAI group measure scores expand the previous analysis by identifying the main drivers of each territory's performance: H, A, or both.

5 Conclusions

How are the EU-27 and its supranational regions and MSs performing against SDG13 of the UN 2030 Agenda and its set of targets? To answer this question, the AF method was applied (Alkire & Foster, 2011), enabling the development of the MCAI framework to assess the performance against SDG13 and its corresponding targets for the EU-27 as a whole, its supranational regions, and MSs.

The MCAI framework results show that:

- Only 12 MSs (44%) have a satisfactory individual overall composite score. Sweden has the highest individual overall composite score and Croatia the lowest;
- The EU-27 as a whole is not performing satisfactorily, although its average MS overall composite score is close to the critical cut-off value. Regarding the supranational regions, two have a satisfactory average MS overall composite score – Western Europe and Northern Europe – and two do not – Southern Europe and Central and Eastern Europe;
- With regard to the SDG13 targets, Southern Europe and Western Europe need to improve on target 13.1 (Resilience). The EU-27 as a whole and all its supranational regions perform well in target 13.2 (Action). The EU-27 as a whole, Southern Europe, Northern Europe, and Central and Eastern Europe require improvement in targets 13.3 (Education) and 13.4 (Commitment). Furthermore, the European supranational regions that perform poorly in some targets may still perform better than the EU-27 as a whole in other targets;

- The results also reveal wide variation in the individual MS overall composite scores, in the EU-27 as a whole and its supranational regions. This territorial heterogeneity illustrates how the SDG13 targets may require different efforts in different territories;
- The MCAI group measure scores paint a less satisfactory picture. All are below the critical cut-off value, suggesting a small proportion of MSs with a satisfactory individual performance and/or a small intensity of the satisfactory performance in those same MSs. Southern Europe and Central and Eastern Europe have the worst MCAI group measure scores compared to the other two European supranational regions and the EU-27 as a whole. Except for Northern Europe, this is mainly due to H being lower than A, although the two supranational regions with the lowest H scores (Southern Europe and Central and Eastern Europe) also have the lowest A scores and the lowest average GDP per capita.

The MCAI framework results are consistent with other results from the literature but more informative. They provide insights for policymakers into the path the EU-27 must take concerning SDG13 and its targets by:

- Highlighting the strengths and weaknesses of the EU-27 as a whole, its supranational regions, and MSs in relation to SDG13 and its targets, and the goals and efforts that require greater attention in each territory:
- Indicating the need for Southern and Western Europe to strengthen climate change adaptation policies (target 13.1, Resilience) and the requirement for Central and Eastern, Southern, and Northern Europe to invest in public policies that promote education and climate awareness (target 13.3, Education) and encourage the countries in these regions to support developing economies (target 13.4, Commitment);
- Indicating the success of EU policies addressing climate change (target 13.2, Action); and.
- Showing the drivers of bad performance for Southern and Central and Eastern Europe, namely a low H and a low A.

The MCAI framework results are driven by the partial indicators adopted, which were chosen based on the availability of data, and by the weights assigned to the different targets and indicators. These are the limitations of the research.

To improve the accuracy and applicability of the MCAI framework, we suggest the following as avenues of future research:

- Considering other partial indicators, when more data is available;
- Testing different sets of weights, particularly for the SDG13 targets;
- Deepening the analysis, by exploring further the links between the results of the proposed MCAI framework and variables such as education, the quality of institutions, political leadership, available resources, and others;
- Focusing the analysis on rates of progress instead of levels;
- Using cities of the EU-27 as the basic units of analysis, instead of MSs, once data becomes available; and.
- Extending the MCAI framework to other countries and cities of the world.

Appendix

Appendix A Descriptions of partial indicators 1 to 14 and the criteria adopted for a satisfactory MS performance

Partial indicators and sources	Description and source	Satisfactory performance = 1.0
13.1 Resilience		
1-Econ.Losses	Economic losses per capita from climate-related extremes in the period 1980 to 2020, to be compared with average EU-27 corresponding losses (€843.78 per capita). Source: EEA.	Economic losses per capita from climate-related extremes < €843.78 per capita.
2-Fatalities	Fatalities per 1000 inhabitants from climate-related extremes, from 1980 to 2020, to be compared with average EU-27 corresponding fatalities (0.18). Source: World Bank.	Fatalities per 1000 inhabitants < 0.18.
13.2 Action		
3-CO2.Cars	Reduction of average CO2 emissions per km from new passenger cars, from 2005 to 2020, to be compared with average EU-27 corresponding reduction (33%). Source: Eurostat.	Reduction of average CO2 emissions per km from new passenger cars > 33%.
4-GHG.ETS	Reduction of GHG emissions under the Emissions Trading System (EU-ETS), from 2005 to 2019. Due to a lack of data for 2020, the 2020 goal (21%) set by the 2020 Climate & Energy Package was adjusted to that of 2019 (20%). Source: EEA.	Reduction of GHG emissions under the ETS > 20%.
5-GHG.ESD	Reduction of GHG emissions under the Effort Sharing Decision (ESD), from 2005 to 2019. Due to a lack of data for 2020, the specific goal set by the 2020 Climate & Energy to each country for 2020 was adjusted to that of 2019. Source: EEA.	Reduction of GHG emissions under the ESD > the 2020 country goal adjusted to 2019.
6-GHG.Energy	Reduction of GHG emissions intensity of energy consumption (index, with 2000 = 100), from 2005 to 2020 (or 2019, depending on data availability), to be compared with corresponding average EU-27 reduction (16%). Source: Eurostat.	Reduction of GHG emissions intensity of energy consumption > 16%.
7-Energy.Efficiency	Increase in final energy consumption efficiency (%) in 2020, to be compared to the country-specific goal set under the 2008 Climate Action and Renewable Energy Package, to achieve the EU's 20% energy efficiency goal by 2020. Source: Eurostat.	Increase in final energy consumption efficiency in 2020 > the country goal.
8-NDCs.2016	Submission of Nationally Determined Contributions (NDCs) in 2016 (yes or no) under the Paris Agreement. Source: UNFCCC.	NDCs were submitted in 2016.
9-Renewable.Energy	Share of renewable energy in gross final energy consumption (%), to be compared with the goal set by the 2020 Climate & Energy Package for 2020 to each individual country. Source: Eurostat.	Share of renewable energy in gross final energy consumption > the country goal for 2020.
13.3 Education		

Appendix A Descriptions of partial indicators 1 to 14 and the criteria adopted for a satisfactory MS performance

Partial indicators and sources	Description and source	Satisfactory performance = 1.0
10-Electric.Vehicles.2020	Share of new registrations of electric vehicles in 2020 (Battery and Plug-in Hybrid electric cars) (%), to be compared with the average EU-27 share of new registrations of electric vehicles in the same year (8%). Source: EEA.	Share of new registrations of electric vehicles in 2020 > 8%.
11-Mayors.Climate&Energy	Share of the country's population in 2020 living in municipalities that signed the Covenant of Mayors for Climate & Energy (%), to be compared with the average EU-27 corresponding share (7%). Source: Eurostat.	Share of the country's population in 2020 living in municipalities that signed the Covenant of Mayors for Climate & Energy > 7%.
13.4 Commitment		
(13.A Commitment A)		
12-Climate.Expenditure.2018	Contribution to the international commitment of USD 100 billion in climate-related expenditure in 2018 (GDP %), to be compared with the corresponding EU-27 average (0.035%). Source: Eurostat.	Contribution as a percentage of GDP to the international commitment of USD 100 billion in climate-related expenditure in 2018 > 0.035%.
13-Climate.Expenditure.2019	Contribution to the international commitment of USD 100 billion in climate-related expenditure in 2019 (GDP %), to be compared with the corresponding EU-27 average (0.04%).	Contribution as a percentage of GDP to the international commitment of USD 100 billion in climate-related expenditure in 2019 > 0.04%.
(13.B Commitment B)		
14-Climate.UN.2020	Number of times national governments mentioned health and climate change at the United Nations General Debate of the General Assembly in 2020 (#), to be compared with the corresponding EU-27 average of 4 times.	Number of times national governments mentioned health and climate change at the United Nations General Debate of the General Assembly in 2020 > 4.

Source Own work

Appendix B Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Southern Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Southern Europe	PT	ES	IT	MT	EL	CY
13.1-Resilience	**0.61**	**0.33**	**0.00**	**0.00**	**0.00**	**1.00**	**0.00**	**1.00**
1-Econ.Losses	0.59	0.33	0	0	0	1	0	1
2-Fatalities	0.63	0.33	0	0	0	1	0	1
13.2-Action	**0.65**	**0.71**	**1.00**	**0.71**	**0.71**	**0.57**	**1.00**	**0.29**
3-CO2.Cars	0.50	0.33	1	0	0	0	1	0
4-GHG.ETS	0.81	0.83	1	1	1	1	1	0
5-GHG.ESD	0.57	0.67	1	1	1	0	1	0
6-GHG.Energy	0.41	0.67	1	1	0	1	1	0

Appendix B Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Southern Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Southern Europe	PT	ES	IT	MT	EL	CY
7-Energy.Efficiency	0.67	0.83	1	1	1	0	1	1
8-NDCs.2016	0.63	0.67	1	0	1	1	1	0
9-Renewable.Energy	0.94	1.00	1	1	1	1	1	1
13.3-Education	**0.30**	**0.33**	**0.50**	**0.50**	**0.50**	**0.00**	**0.50**	**0.00**
10-Electric.Vehicles.2020	0.33	0.17	1	0	0	0	0	0
11-Mayors.Climate&Energy	0.26	0.50	0	1	1	0	1	0
13.4-Commitment	**0.37**	**0.30**	**0.00**	**1.00**	**0.33**	**0.33**	**0.33**	**0.33**
12-Climate.Expenditure.2018	0.33	0.25	0	1	0	0	0	0.5
13-Climate.Expenditure.2019	0.37	0.25	0	1	0	0	0	0.5
14-Climate.UN.2020	0.41	0.39	0	1	1	1	1	0
Overall composite score	**0.48**	**0.42**	**0.38**	**0.55**	**0.39**	**0.48**	**0.46**	**0.40**
MCAI group measure score	**0.27**	**0.09**						
H	0.44	0.17						
A	0.60	0.55						

Source Own work

Appendix C Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Western Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Western Europe	IE	FR	LU	BE	NL	DE	AT
13.1-Resilience	**0.61**	**0.36**	**1.00**	**0.00**	**0.00**	**0.50**	**0.50**	**0.00**	**0.50**
1-Econ.Losses	0.59	0.43	1	0	0	1	1	0	0
2-Fatalities	0.63	0.29	1	0	0	0	0	0	1
13.2-Action	**0.65**	**0.57**	**0.86**	**0.71**	**0.57**	**0.29**	**0.57**	**0.57**	**0.43**
3-CO2.Cars	0.50	0.57	1	1	0	0	1	1	0
4-GHG.ETS	0.81	0.71	1	1	1	1	0	1	0
5-GHG.ESD	0.57	0.29	0	1	0	0	1	0	0
6-GHG.Energy	0.41	0.29	1	0	0	0	0	0	1
7-Energy.Efficiency	0.67	0.57	1	1	1	0	1	0	0
8-NDCs.2016	0.63	0.71	1	1	1	0	0	1	1
9-Renewable.Energy	0.94	0.86	1	0	1	1	1	1	1
13.3-Education	**0.30**	**0.57**	**0.00**	**1.00**	**0.50**	**0.50**	**0.50**	**1.00**	**0.50**
10-Electric.Vehicles.2020	0.33	0.71	0	1	1	0	1	1	1
11-Mayors.Climate&Energy	0.26	0.43	0	1	0	1	0	1	0
13.4-Commitment	**0.37**	**0.68**	**0**	**1**	**0.67**	**0.33**	**0.67**	**0.67**	**1.00**
12-Climate.Expenditure.2018	0.33	0.71	0	1	1	0	1	1	1
13-Climate.Expenditure.2019	0.37	0.71	0	1	1	0	1	1	1
14-Climate.UN.2020	0.41	0.62	0	1	0	1	0	0	1
Overall composite score	**0.48**	**0.55**	**0.46**	**0.68**	**0.43**	**0.40**	**0.56**	**0.56**	**0.61**
MCAI group measure score	**0.27**	**0.34**							
H	0.44	0.57							
A	0.60	0.60							

Source Own work

Appendix D Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Northern Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Northern Europe	DK	SE	FI	LT	LV	EE
13.1-Resilience	**0.61**	**0.92**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
1-Econ.Losses	0.59	0.83	0	1	1	1	1	1
2-Fatalities	0.63	1.00	1	1	1	1	1	1
13.2-Action	**0.65**	**0.70**	**1.00**	**0.71**	**0.86**	**0.43**	**0.50**	**0.71**
3-CO2.Cars	0.50	1.00	1	1	1	1	1	1
4-GHG.ETS	0.81	0.83	1	1	1	1	0	1
5-GHG.ESD	0.57	0.42	1	1	0	0	0.5	0
6-GHG.Energy	0.41	0.50	1	1	1	0	0	0
7-Energy.Efficiency	0.67	0.67	1	0	1	0	1	1
8-NDCs.2016	0.63	0.50	1	0	1	0	0	1
9-Renewable.Energy	0.94	1.00	1	1	1	1	1	1
13.3-Education	**0.30**	**0.25**	**0.50**	**0.50**	**0.50**	**0.00**	**0.00**	**0.00**
10-Electric.Vehicles.2020	0.33	0.50	1	1	1	0	0	0
11-Mayors.Climate&Energy	0.26	0.00	0	0	0	0	0	0
13.4-Commitment	**0.37**	**0.41**	**0.67**	**0.67**	**0.33**	**0.33**	**0.00**	**0.33**
12-Climate.Expenditure.2018	0.33	0.33	1	1	0	0	0	0
13-Climate.Expenditure.2019	0.37	0.50	1	1	1	0	0	0
14-Climate.UN.2020	0.41	0.39	0	0	0	1	0	1
Overall composite score	**0.48**	**0.57**	**0.67**	**0.72**	**0.67**	**0.44**	**0.38**	**0.51**
MCAI group measure score	**0.27**	**0.43**						
H	0.44	0.67						
A	0.60	0.64						

Source Own work

Appendix E Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Central and Eastern Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Central and Eastern Europe	CZ	SI	HR	HU	SK	PL	BG	RO
13.1-Resilience	**0.61**	**0.92**	**0.50**	**0.50**	**0.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
1-Econ.Losses	0.59	0.83	0	0	1	1	1	1	1	1
2-Fatalities	0.63	1.00	1	1	0	1	1	1	1	1
13.2-Action	**0.65**	**0.62**	**0.71**	**0.71**	**0.57**	**0.57**	**0.71**	**0.43**	**0.64**	**0.64**
3-CO2.Cars	0.50	0.17	0	0	0.5	0	0	0	0.5	0.5
4-GHG.ETS	0.81	0.83	1	1	1	1	1	0	1	1
5-GHG.ESD	0.57	0.83	1	1	1	1	1	0	1	1
6-GHG.Energy	0.41	0.33	1	0	0	0	1	0	0	0
7-Energy.Efficiency	0.67	0.50	1	1	1	0	0	1	0	1
8-NDCs.2016	0.63	0.67	0	1	0	1	1	1	1	0
9-Renewable.Energy	0.94	1.00	1	1	0.5	1	1	1	1	1
13.3-Education	**0.30**	**0.08**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.50**
10-Electric.Vehicles.2020	0.33	0.00	0	0	0	0	0	0	0	0
11-Mayors.Climate&Energy	0.26	0.17	0	0	0	0	0	0	0	1
13.4-Commitment	**0.37**	**0.10**	**0.00**	**0.00**	**0**	**0**	**0.33**	**0.00**	**0.67**	**0.00**
12-Climate.Expenditure.2018	0.33	0.08	0	0	0	0	0	0	0.5	0

Appendix E Partial scores (1 to 14), composite scores (targets 13.1 to 13.4 and overall), and MCAI group measure scores by MS in Central and Eastern Europe

Partial indicator, composite, and MCAI group measure scores	EU-27	Central and Eastern Europe	CZ	SI	HR	HU	SK	PL	BG	RO
13-Climate.Expenditure.2019	0.37	0.08	0	0	0	0	0	0	0.5	0
14-Climate.UN.2020	0.41	0.13	0	0	0	0	1	0	1	0
Overall composite score	**0.48**	**0.43**	**0.30**	**0.30**	**0.27**	**0.39**	**0.51**	**0.36**	**0.58**	**0.54**
MCAI group measure score	**0.27**	**0.20**								
H	0.44	0.38								
A	0.60	0.54								

Source Own work

Acknowledgements This work was supported by the European Regional Development Fund (ERDF), through project HAC4CG- Heritage, Art, Creation for Climate change. Living the city: catalysing spaces for learning, creation, and action towards climate change (NORTE-01-0145-FEDER-000067), Norte Portugal Regional Operational Programme (NORTE 2020), under the PORTUGAL 2020 Partnership Agreement. It was also supported by FCT - Fundação para a Ciência e Tecnologia, I.P., by project reference UIDB/00731/2020 and DOI identifier 10.54499/UIDB/00731/2020 (https://doi.org/10.54499/UIDB/00731/2020).

Funding Open access funding provided by FCT|FCCN (b-on).

References

Abid, N., Ahmad, F., Aftab, J., & Razzaq, A. (2023a). A blessing or a burden? Assessing the impact of climate change mitigation efforts in Europe using quantile regression models. *Energy Policy*, *178*, 113589. https://doi.org/10.1016/j.enpol.2023.113589.

Abid, N., Ceci, F., & Razzaq, A. (2023b). Inclusivity of information and communication technology in ecological governance for sustainable resources management in G10 countries. *Resources Policy*, *81*, 103378. https://doi.org/10.1016/j.resourpol.2023.103378.

Adedoyin, F. F., Alola, A. A., & Bekun, F. V. (2021). The alternative energy utilization and common regional trade outlook in EU-27: Evidence from common correlated effects. *Renewable and Sustainable Energy Reviews*, *145*, 111092.

Alkire, S., & Foster, J. (2011). Counting and multidimensional poverty measurement. *Journal of Public Economics*, *95*(7–8), 476–487. https://doi.org/10.1016/j.jpubeco.2010.11.006.

Alkire, S., & Santos, M. E. (2010a). Acute multidimensional poverty: A new index for developing countries. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1815243.

Alkire, S., & Santos, M. E. (2010b). Multidimensional poverty index. *Oxford Poverty and Human Development Initiative*. https://ophi.org.uk/publications/ophi-briefings/.

Alkire, S., Kanagaratnam, U., & Suppa, N. (2018). *The Global Multidimensional Poverty Index (MPI): 2018 revision*. The Oxford Poverty and Human Development Initiative.

Baettig, M. B., Brander, S., & Imboden, D. M. (2008). Measuring countries' cooperation within the International Climate Change Regime. *Environmental Science & Policy*, *11*(6), 478–489. https://doi.org/10.1016/j.envsci.2008.04.003.

Baker, S. (2016). *Sustainable development* (2nd ed.). Routledge.

Bernauer, T., & Böhmelt, T. (2013). National climate policies in international comparison: The Climate Change Cooperation Index. *Environmental Science & Policy*, *25*, 196–206.

Biermann, F., Kanie, N., & Kim, R. E. (2017). Global governance by goal-setting: The novel approach of the UN Sustainable Development Goals. *Current Opinion in Environmental Sustainability*, *26–27*, 26–31. https://doi.org/10.1016/j.cosust.2017.01.010.

Boehm, S., Jeffery, L., Levin, K., Hecke, J., Schumer, C., Fyson, C., Majid, A., Jaeger, J., Nilsson, A., Naimoli, S., Thwaites, J., Cassidy, E., Waite, R., Wilson, R., Castellanos, S., Singh, N., Lee, A., & Geiges, A. (2022). State of climate action 2022. *Bezos Earth Fund Climate Action Tracker Climate Analytics ClimateWorks Foundation NewClimate Institute the United Nations Climate Change High-Level Champions and World Resources Institute*. https://doi.org/10.46830/wrirpt.22.00028.

Burck, J., & Bals, C. (2011). *The climate change performance index—background and methodology*. Germanwatch and CAN Europe.

Burck, J., Uhlich, T., Bals, C., Höhne, N., & Nascimento, L. (2021). *The Climate Change Performance Index 2022: Results*. Climate Action Network.

Burck, J., Uhlich, T., Bals, C., Höhne, N., Nascimento, L., Tamblyn, A., & Reuther, J. (2022). *The Climate Change Performance Index 2022*. Climate Action Network International.

Campbell, B. M., Hansen, J., Rioux, J., Stirling, C. M., Twomlow, S., & Wollenberg, E. (2018). Urgent action to combat climate change and its impacts (SDG 13): Transforming agriculture and Food systems. *Current Opinion in Environmental Sustainability*, *34*, 13–20. https://doi.org/10.1016/j.cosust.2018.06.005.

Codal, K. S., Ari, I., & Codal, A. (2021). Multidimensional perspective for performance assessment on climate change actions of G20 countries. *Environmental Development*, *39*, 100639.

ECB (November 2020). ECB report on institutions' climate-related and environmental risk disclosures.

Epule, T. E., Chehbouni, A., Dhiba, D., & Moto, M. W. (2021a). The Readiness Index for Climate Change Adaptation in Africa: The role of climate and adaptive capacity proxies. *Applied Sciences*, *11*, 9413. https://doi.org/10.3390/app11209413.

Epule, T. E., Chehbouni, A., Dhiba, D., Moto, M. W., & Peng, C. (2021b). African climate change policy performance index. *Environmental and Sustainability Indicators*, *12*, 100163. https://doi.org/10.1016/j.indic.2021.100163.

Eren, E., Merten, F., & Verhoeven, N. (2022). *Pricing of climate risks in financial markets: A summary of the literature*. [Bank for International Settlements, Monetary and Economic Department, BIS Papers No 130].

EU (2021). Regulation 2021/1119 of the European Parliament of 30 June 2021.

EU (2022a). *Browse by eurovoc*. C7206%2C914#arrow_914. https://eur-lex.europa.eu/browse/eurovoc.html?params=72%2C7206%2C914#arrow_914.

EU (2022b, March 23). *A European green deal. European Commission - European Commission*. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

Fu, L., Cao, Y., Kuang, S. Y., & Guo, H. (2021). Index for climate change adaptation in China and its application. *Advances in Climate Change Research*, *12*(5), 723–733. https://doi.org/10.1016/j.accre.2021.06.006.

Guo, H., Liang, D., Sun, Z., Chen, F., Wang, X., Li, J., Zhu, L., Bian, J., Wei, Y., Huang, L., Chen, Y., Peng, D., Li, X., Lu, S., Liu, J., & Shirazi, Z. (2022). Measuring and evaluating SDG indicators with Big Earth Data. *Science Bulletin*, *67*(17), 1792–1801. https://doi.org/10.1016/j.scib.2022.07.015.

Hák, T., Janoušková, S., & Moldan, B. (2016). Sustainable development goals: A need for relevant indicators. *Ecological Indicators*, *60*, 565–573. https://doi.org/10.1016/j.ecolind.2015.08.003. /archive.ipcc.ch.

Hametner, M., & Kostetckaia, M. (2020). Frontrunners and laggards: How fast are the EU member states progressing towards the Sustainable Development Goals? *Ecological Economics*, *177*, 106775. https://doi.org/10.1016/j.ecolecon.2020.106775.

Hickel, J. (2020). The sustainable development index: Measuring the ecological efficiency of human development in the Anthropocene. *Ecological Economics*, *167*, 106331. https://doi.org/10.1016/j.ecolecon.2019.05.011.

ICS & SDSN. (2021). *O Índice De Desenvolvimento Sustentável das Cidades - Brasil (IDSC-BR)*. Instituto Cidades Sustentáveis & Sustainable Development Solutions Network.

IPCC (2021). *Climate change 2021: The physical science basis: 6th assessment*. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

IPCC (2022a). *Climate change 2022: Impacts, adaptation and vulnerability*https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf.

IPCC (2022b). *Climate change 2022: Mitigation of climate change*https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf.

Kona, A., Monforti-Ferrario, F., Bertoldi, P., Baldi, M. G., Kakoulaki, G., Vetters, N., Thiel, C., Melica, G., Lo Vullo, E., Sgobbi, A., Ahlgren, C., & Posnic, B. (2021). Global Covenant of mayors, a dataset of greenhouse gas emissions for 6200 cities in Europe and the Southern Mediterranean countries. *Earth System Science Data*, *13*, 3551–3564. https://doi.org/10.5194/essd-13-3551-2021.

Lindsey, R. (2023). *Climate change: Atmospheric carbon dioxide*https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

Luomi, M., Fuller, G., Dahan, L., Lisboa Båsund, K., de la Mothe Karoubi, E., & Lafortune, G. (2019). *Arab region SDG index and dashboards report 2019*. SDG Centre of Excellence for the Arab Region/Emirates Diplomatic Academy and Sustainable Development Solutions Network.

McCarthy, N., Winters, P., Linares, A. M., & Essam Office, T. (2012). Indicators to assess the effectiveness of climate change. Inter-American Development Bank. https://publications.iadb.org/publications/english/document/Indicators-to-Assess-the-Effectiveness-of-Climate-Change-Projects.pdf.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, I. I. I., W. W (1972). *The limits to growth: A report for the Club of Rome's project on the predicament of Mankind*. Universe Books.

Moosmann, L., Siemons, A., Fallasch, F., Schneider, L., Urrutia, C., Wissner, N., & Oppelt, D. (2021). The COP26 Climate Change Conference, Status of climate negotiations and issues at stake, Study for the committee on the Environment, Public Health and Food Safety, Policy Department for Economic, Scientific and Quality of Life Policies. *European Parliament*. https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695459/IPOL_STU(2021)695459_EN.pdf.

Pereira, N. C., Araújo, N., & Costa, L. (2018). A counting multidimensional innovation index for SMEs. *Benchmarking: An International Journal*, *25*(1), 2–23. https://doi.org/10.1108/bij-06-2016-0090.

Project Everyone (2022, March 15). Goal 13: Climate action. *The Global Goals*https://www.globalgoals.org/goals/13-climate-action/.

Puertas, R., & Marti, L. (2021). International Ranking of Climate Change Action: An analysis using the indicators from the Climate Change Performance Index. *Renewable and Sustainable Energy Reviews*, *148*, 111316. https://doi.org/10.1016/j.rser.2021.111316.

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., & Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *19*(37). https://doi.org/10.1126/sciadv.adh2458.

Sachs, J., Lafortune, G., Kroll, C., Fuller, G., & Woelm, F. (2022). *Sustainable development report 2022*. https://doi.org/10.1017/9781009210058.

Stern, N. (2006). *The Economics of Climate Change - The Stern Review*. Cambridge University Press.

Sustainable Society Index (2022). 2017 scores. https://ssi.wi.th-koeln.de.

Swiss Re Institute (April 2021). *The economics of climate change: No action not an option*https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf.

The World Bank Group (2022). *GDP per capita (current US$)—European Union*. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=EU.

Tóthová & Heglasová. (2022). Measuring the environmental sustainability of 2030 agenda implementation in EU countries: How do different assessment methods affect results? *Journal of Environmental Management*, *322*, 116152. https://doi.org/10.1016/j.jenvman.2022.116152.

UN. (2015, September 25). *Transforming our world: The 2030 agenda for sustainable development* [General Assembly, 17th Sess, UN Doc A/70/L.1]. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf.

UN (2021, April 23). *Países: União Europeia*. https://europa.eu/european-union/about-eu/countries_pt.

UN (n.d.a). *Millennium summit*. https://www.un.org/en/conferences/environment/newyork2000.

UN (n.d.b). *United Nations Conference on Sustainable Development, Rio+20: sustainable development knowledge platform*. https://sustainabledevelopment.un.org/rio20.

UNDP & OPHI. (2019). *How to build a national multidimensional poverty index (MPI): Using the MPI to inform the SDGs*. University of Oxford.

United Nations (UN) (1972). Declaração da Conferência de ONU no Ambiente Humano. *Cetesb*. https://cetesb.sp.gov.br/posgraduacao/wp-content/uploads/sites/33/2016/09/Declara%C3%A7%C3%A3o-de-Estocolmo-5-16-de-junho-de-1972–Declara%C3%A7%C3%A3o-da-Confer%C3%AAncia-da-ONU-no-Ambiente-Humano.pdf.

van de Kerk, G., Kleinjans, R., & Manuel, A. (2014). *Sustainable Society Index 2014*. Sustainable Society Foundation.

WCED. (1987). *Our common future*. Oxford University Press.

WEF (2023). *The global risks report 2023 (18th ed.).* https://www.weforum.org/reports/globalrisks-report-2023/.