Alliance of regional innovation ecosystems based on
smart sustainable specialization strategies

Catalogue of sustainability indicators

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Coordinator & Full partners

Associate partners

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Executive Summary

Sustainability, encompassing its three main dimensions, economic, social, and environmental, is one of the primary challenges facing territories today. Monitoring the impact of policies on these dimensions of sustainability has become a territorial priority, especially in the context of the 2030 Agenda and the 17 Sustainable Development Goals. These global frameworks emphasize the importance of sustainable development, urging regions and nations to align their policies with the SDGs to ensure a balanced and inclusive growth.

This study contributes to the monitoring of sustainability by proposing a comprehensive set of indicators to measure sustainability at the territorial level. Additionally, it introduces another set of indicators to assess how Smart Specialisation Strategies (S3) contribute to this sustainability. The results obtained can facilitate the transition from S3 to S4 by introducing a new S to this model of economic development. These indicators should account for the three dimensions, economic, social, and environmental, and their synergies and trade-offs.

The proposed indicators are derived from a literature review and a combination of quantitative and qualitative analyses of the indicators identified in the review. The goal of these analyses is to develop a compact and integrated set of indicators that will enable sub-national territories to effectively monitor their sustainability progress and the contribution of S3 to sustainability. The study provides guidance on which indicators need to be calculated and how to interpret and relate the information obtained from these indicators.

For this purpose, two particularly practical outcomes can be highlighted:

- The summary diagram linking all indicators and facilitating interpretation (Figure 19).
- Summary cards for the different blocks of indicators with definitions and links to the SDGs (Annex 6).

1. Introduction

This document presents the analysis carried out within the ARIES4 project, a broad project whose general objective is to set up a scheme of cooperation and flow of knowledge among the main actors of smart specialization strategies (HEIs, VET providers, the public sector, the business sector, and broader society) in European regions pioneering the introduction of sustainability in their strategies, to ensure the provision of the skills, tools and attitudes required for an effective transition to sustainable strategies, setting a model for other regions to follow. Four European regions are involved in this project: Navarra (Spain), Värmland (Sweden), Southern Denmark (Denmark) and Gabrovo (Bulgaria). The project is divided into five work packages (WPs). The results presented here correspond to WP2, knowledge exchange for a successful implementation of S4. Two main outcomes were expected from WP2: a catalog of sustainability indicators based on academic literature and a report on effective policy tools in the implementation of S4. The first of them is the one presented in this report.

Currently there are numerous proposals for indicators to measure sustainability. Most of these proposals contain a large number of indicators that attempt to measure each of the 169 goals included in the 17 sustainable development goals proposed by the United Nations in 2015. For example, the global sustainability framework of United Nations contains 231 indicators to monitor the SDGs. Eurostat calculates 133 indicators to monitor the SDGs in European countries. Calculating and interpreting this large number of indicators is a complex task, which can make it difficult to get clear results on what is happening on the road to sustainability. In same cases, partial analyses are carried out, focusing on a few indicators but lacking a holistic view of what is happening.

Moreover, in addition to the indicators proposed by international institutions and organizations, numerous scientific studies analyze sustainability and propose new indicators, calculate composite indicators, propose sustainability analysis methodologies or ways of selecting indicators. In this document, we take as a starting point the measurement proposals made from scientific literature. The objective is to collect the indicators proposed therein, classify them according to the pillar(s) of sustainability they represent (economic, social, environmental) and carry out a critical analysis of their relevance and pertinence. All this with the objective of selecting a minimum set of indicators to measure sustainability. Thus, the objective is to reduce the large number of indicators available to the minimum necessary to have an integrated view of sustainability. Our aim is to help territories that want to carry out a sustainability analysis and either do not know which indicators to choose from the large number of indicators available, or do not have indicators for their territory and have to make decisions on which indicators to calculate.

The existence of numerous indicators is not the only challenge of this work. It also tries to adapt this minimum number of necessary indicators to two levels of sustainability measurement. On the one hand, regions, considering regions to be the breakdown of a country into smaller territorial units. On the other hand, we look for a minimum set of indicators to measure within S4 (Sustainable Smart Specialization Strategies). The Smart Specialization Strategies (S3) are a model for economic development that involves concentrating resources in the economic areas in which each region has significant competitive advantages. According to the European Union, deepening Smart Specialisation also means encompassing the sustainability dimension (Fontana et al., 2023). This analysis tries to link the sustainability of these areas of specialization with the sustainability of the region in which they are developed. Thus, the selection of the minimum indicators necessary to measure sustainability will try to link both levels of analysis, regions and S4.

In addition to making this selection, this study poses the challenge of representing it in a summary diagram that relates all the indicators and facilitates the interpretation of the data that can be collected. This completes a comprehensive view of sustainability covering the fundamental pillars of sustainability, economic, social and environmental, and the relationships within and between pillars.

In order to make this selection properly, this deliverable begins with a brief introduction to the concept of sustainability, a word that is widely used but not always clearly defined. We describe policies, production processes, companies, cities, territories or our own decisions as consumers as sustainable, but often with different ideas of what this adjective means. Section 2 tries to shed some light on this concept.

Section 3 includes the methodology used to select indicators. Based on an extensive literature review, indicators used to monitor and/or assess sustainability were identified both at territorial level (national and sub-national) and at the level of areas of specializations (companies and sectors). After this first compilation of indicators, a critical analysis was made with the aim of creating a compact set of indicators that includes a minimum of indicators that would be necessary to have an accurate vision of sustainability at territorial and specialization areas levels.

The following two sections, 4 and 5 develop two relevant points of the methodological process followed: literature review (section 4) and critical analysis of the indicators extracted from the bibliographic review (section 5). Section 6 discusses the final choice of indicators and their integration into a holistic view of sustainability by proposing a summary diagram that can facilitate the interpretation of these indicators. Section 7 presents the conclusions and limitations of the study carried out.

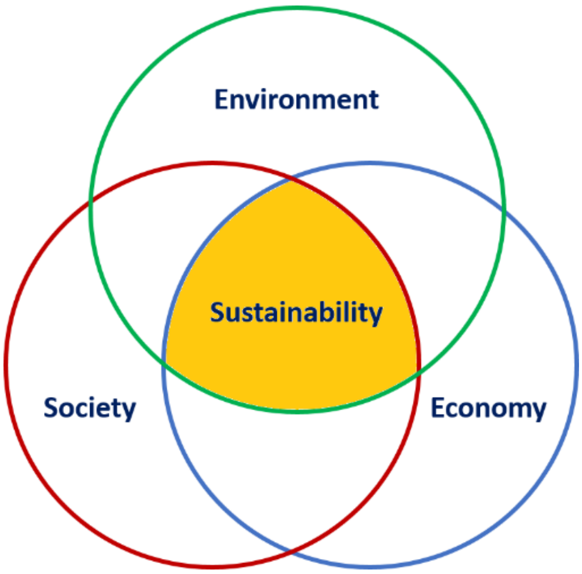
2. About sustainability

One of the most commonly accepted definitions of sustainable development comes from the Brundtland report (Our common future): "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The report highlighted the need to balance environmental, social and economic dimensions of human activity to reach sustainable development. Although it has been considered a deliberately vague and not very operational definition (EPA, 2012; Wu and Wu, 2012), it laid the foundations of what is now known as the triple bottom-line for assessing sustainability (Elkington, 1997).

The proposal of Elkington (1997) develops the concept of the triple bottom line of sustainable development stating that society depends on the economy and the economy depends on the global ecosystem, whose health represents the ultimate bottom line. Hence, sustainability is the principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations.

The triple bottom-line approach is frequently used to assess sustainability in different contexts (sustainability assessment of policies, production processes, consumption patterns, regions/countries development, among others). The model has evolved and is now commonly represented as a Venn diagram (see Figure 1) that implies that the three pillars (environment, society and economy) are all necessary and equally important to sustainability (Wu and Wu, 2012). These three pillars are also known as the 3Ps, Planet, People and Prosperity.

Figure 1 – Triple bottom line (TBL) framework for sustainability

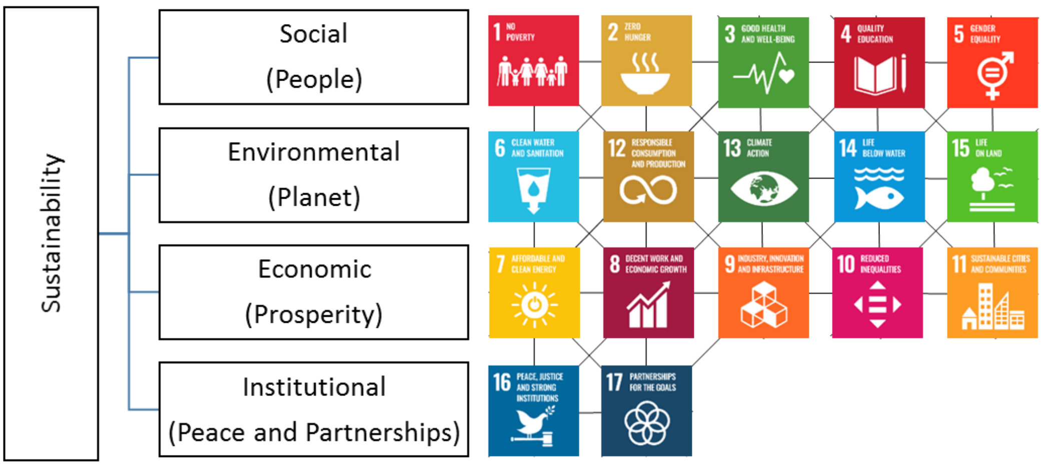


Source: Own elaboration

However, many of the sustainability assessment studies end up comparing different alternatives based on indicators chosen from among various options available in the three pillars without deepening the analysis of potential interconnections between the pillars (Sala et al. 2015). Failure to consider these interconnections leaves possible trade-offs between these indicators unanalyzed. As a result, it is not clear whether the sustainability analysis is based on a weak sustainability framework, in which the substitution of advances in one pillar to the detriment of another is allowed, or on a strong sustainability framework, where this substitution is not possible (Wu and Wu, 2012; Sala et al. 2015). It should also be noted that these sustainability studies often show a certain bias towards the environmental dimension to the detriment, especially, of the social dimension.

It is also worth mentioning that some authors extend the sustainability assessment to a fourth pillar, the institutional or political dimension (Labuschagne et al., 2005; O'Connor, 2006), following the United Nations Commission for Sustainable Development Theme Indicator Framework from 2001. In fact, the 2030 Agenda for Sustainable Development launched by UN in 2015 is a plan of action for people, planet and prosperity, strengthening peace and partnerships. These two new Ps are considered as the institutional dimension. The 17 Sustainable Development Goals within the 2030 Agenda deploy these four dimensions (see Figure 2). The interlinkages and integrated nature of the Sustainable Development Goals are of crucial importance in ensuring that the purpose of the 2030 Agenda is met (UN, 2015; Le Blanc, 2015; Nilsson, 2016).

Figure 2 – Sustainability framework within UN

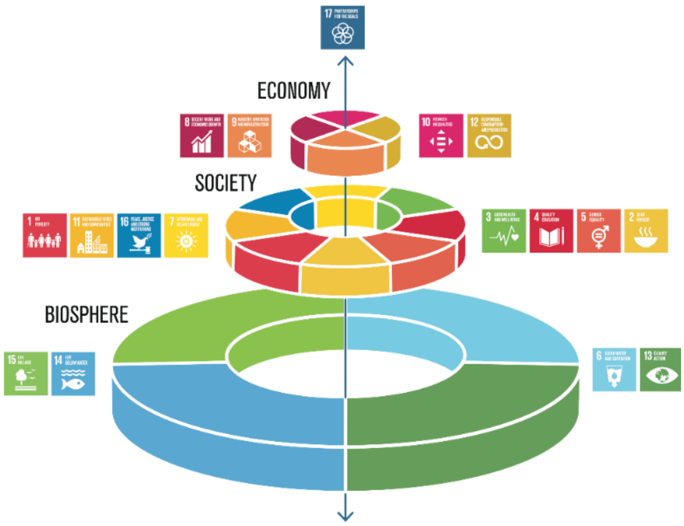


Source: Own elaboration

The UN sustainability framework includes the TBL sustainability framework adding up the institutional dimension of sustainability. This is the framework of ARIES4 on which the list of indicators will be organized, as it is particularly useful for classifying indicators. In this sense, it allows us to identify whether the indicator reports on a single dimension, or on the intersection of two or all of them. Beyond this classification, there are different alternatives as to the priority given to each of these pillars.

Prioritization and consolidation of the sustainability pillars are critical for setting a definition or strategy for sustainable development, particularly across S3 and S4 actors. The ecological/ environmental pillar of sustainable development has been benchmarked by the Planetary Boundaries framework (proposed by Rockström et al., (2009) and updated by Steffen et al., (2015) and Rockström et al., (2023)), where limits to nine planetary subsystems were identified. Anthropogenic activities and development projects and their implementations are thus not allowed to transgress these limits to ensure ecological / environmental sustainability. The social and economic pillars have been benchmarked by the “Doughnut” or “Safe and Just Operating Space” framework (Raworth, 2017), where social foundations (basic needs) and human well-being are prioritized over economic growth and are proposed to foster within ecological/ environmental limit. Both frameworks underpin the current and dominant trend of prioritizing economic growth at the cost of social wellbeing and environmental and ecological degradation.

Figure 3 – The SDG Wedding Cake Framework proposed by SRC (2016) prioritizing ecological / environmental and social well-being over economic growth.



Source: Azote for Stockholm Resilience Centre, Stockholm University CC BY-ND 3.0

A reviewed prioritization framework named as “The SDG Wedding Cake Framework” has been proposed during the Stockholm EAT Food Forum in June 2016 (SRC, 2016) (Figure 3). Four SDGs explicitly related to ecological / environmental sustainability, i.e. Biosphere, set the base of the cake and hence receive the first priority. Eight goals explicitly related to social wellbeing receive the second priority while four goals related to economic growth receive the lowest priority in this framework. The SDG 17 related to global partnership is proposed as an overarching and cross-cutting goal which should be addressed across all sectors and levels in their sustainability work and strategies. Overall, according to this prioritization framework, sustainable

Development is deemed as the development that fosters social foundation over economic growth within ecological limits.

Although there are numerous approaches to sustainability, this study does not prioritize any of the pillars. Rather, it discusses how to monitor these pillars and it is up to the users to interpret and use these indicators. Therefore, as noted above, we focus our analysis on the idea set out in Figure 2 and the three fundamental pillars of sustainability, economic, social and environmental, not forgetting the institutional pillar.

3. Methodology

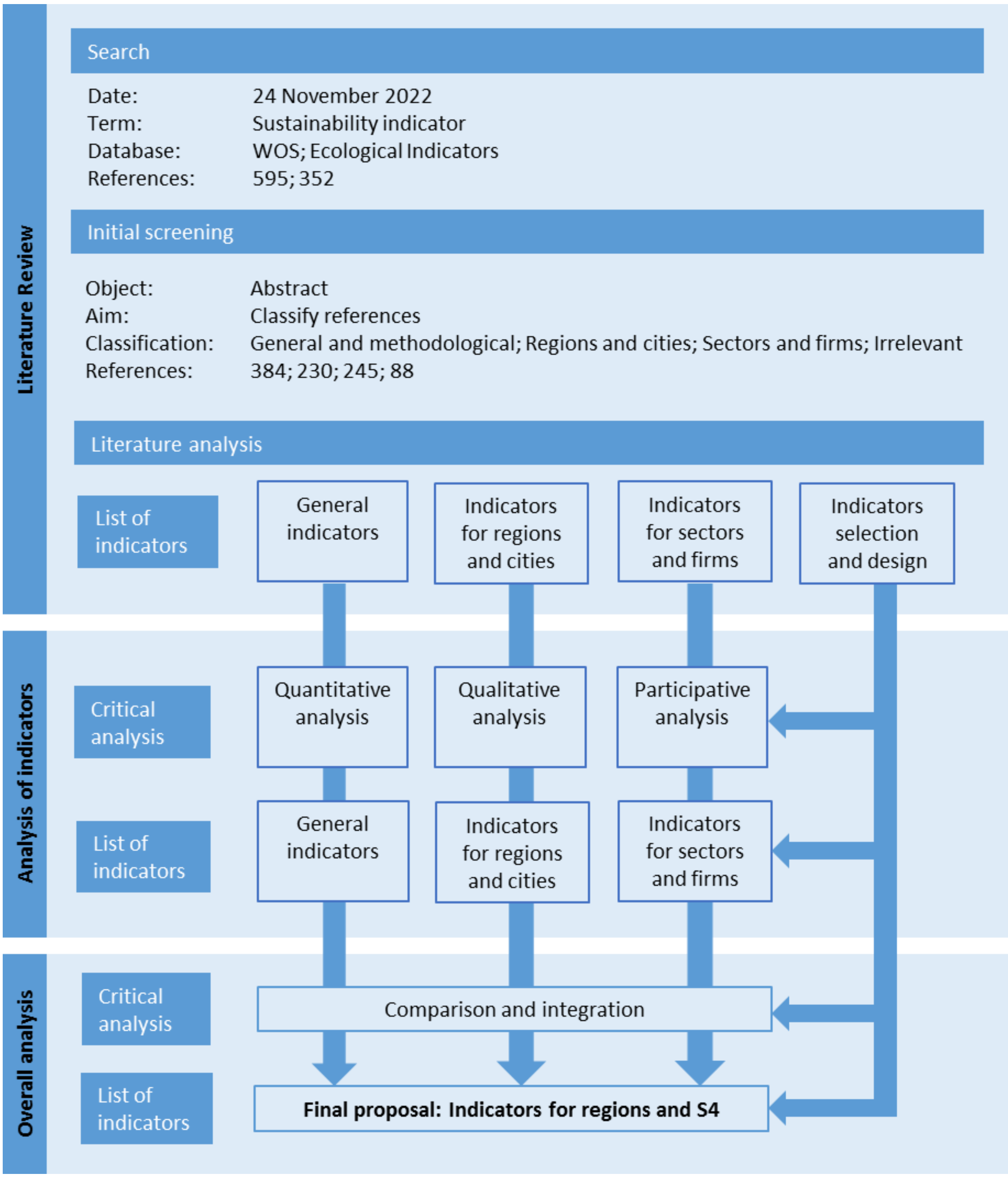
The present section describes the methodology that has been followed in the process of generating the catalogue of sustainability indicators. The analysis is outlined in Figure 4. The selection of indicators departs from a literature review on sustainability measurement.

As a result of the literature review, three lists of indicators were obtained. Additionally, the review of the articles, allowed not only to compile interesting indicators but also to carry out an extensive review of methodologies for the selection and construction of indicators, in order to outline the state of the art in indicator design.

The first list compiled generic indicators; that is, indicators commonly used to analyze sustainability. In general, these were composite indicators calculated by different institutions but available only for countries. Despite their widespread use in sustainability analysis, their calculation for smaller regions is complicated and costly. The second list, called the list of territorial indicators, included indicators that have been used in sustainability analyses for regions and cities. This meant that they were indicators that had been calculated at least once at the regional level. The question that remained was to analyze whether this calculation was done in other regions, beyond that of the study in the literature. Similarly, the question arose as to whether the indicators identified were appropriate and relevant for other regions. The third list of indicators, a list of indicators for S4 and companies, collected indicators used in sustainability analyses carried out for a certain economic sector or for specific companies.

Based on these three lists of indicators, a critical analysis is carried out in an attempt to identify synergies and trade-offs, but also to assess whether they measure things that matter and provide accurate information that can be used to take action for sustainability. Calculating indicators to measure sustainability at the regional and/or sectoral level can be a challenge. Sometimes, regions lack the statistical capacity to do so, or the resources that can be devoted to it are limited. Identifying useful and relevant indicators can be of great help in monitoring the steps taken in regions and/or economic sectors towards sustainability. Therefore, the aim of this critical analysis is to provide a synthesis of sustainability indicators at both regional and economic sector levels.

Figure 4 – Outline of the analysis



Source: Authors' own elaboration

We follow three lines of analysis. The first one departs from the list of generic indicators. Since country-level data are available for these indicators, a quantitative analysis is carried out to examine the relationship between the indicators. We intend to simplify the list and make it more manageable and easier to adjust to a regional level. In the second line of analysis, we start with the list of regional indicators and first examine whether these indicators are being systematically calculated in the regions participating in this project. Subsequently, a comparative analysis is conducted among these regions, as well as a qualitative analysis of the relevance of some of these indicators. The purpose of this comparative analysis is to investigate the transferability of territorial sustainability indicators from research to practice and assess the relevance of the sustainability indicators identified in the literature review. The first and second lines of analysis complement and inform each other. Some of the indicators identified in the literature review for the regional level are incorporated into the quantitative analysis since they are indicators for which country-level data exist. This allows for expanding the quantitative analysis to encompass a greater number of indicators. The third line of analysis conducts a more detailed examination of the list of indicators for S4 and companies. The analysis distinguishes between generic indicators (common across multiple industries) and industry-specific indicators (tailored for certain industries).

Once the critical analysis is conducted in each of the sections, all of the insights are discussed with the final objective of reaching two final catalogues of indicators, covering regional measurement of sustainability and sustainability in S4 areas. The discussion follows a sequential process based on the three pillars of sustainability. Starting from the discussion of economic indicators, it is followed by the social indicators and then dives into the environmental dimension. However, the indicators in each pillar are not discussed as independent, but rather the interaction between different pillars is analyzed, so that the indicators can be selected in the most efficient and useful way, allowing for a maximization of the information they provide and avoiding the unnecessary waste of statistical resources.

4. Literature review

To systematically identify key indicators of sustainability, an extensive literature review was conducted. On November 24, 2022, a comprehensive search was performed using the Web of Science platform, complemented by a focused search within the Ecological Indicators journal. The search term "Sustainability indicator" was applied to both the Title and Keywords fields. This search process yielded a substantial dataset: 859 articles in total, with 595 sourced from Web of Science and 352 from Ecological Indicators, following an initial screening of abstracts.

This initial review of the abstracts made it possible to classify the selected articles according to the different approaches for which indicators were proposed and/or studied. The articles were classified into three groups: 245 were included in “S4 and firms”, 230 in “regions and cities” and a third line grouped 384 articles which refer to general indicators and methodologies for indicator design.[1] The two main results of the more in-depth review of the selected articles are presented below. On the one hand, the state of the art on the design of indicators to measure or mini-monitor sustainability is discussed. On the other hand, the indicators selected from this literature review are presented.

4.1. State of the art in indicator design

Before starting to read the articles, the literature was classified into different areas of interest. Based on the information gathered from the articles corresponding to surveys, indicator design methods and indicator evaluation, the following conclusions were reached.

Firstly, there is a need to reduce the number of indicators for the sake of operativity, due to the lack of practicality of excessively large indicator sets (Lopez-Ridaura et al., 2002). One of the criteria in the construction of indicator sets is aiming for a manageable size (Hák et al., 2016). In the same direction, Hák et al. (2018) call for selecting a reduced number of indicators among the existing ones.

The impact of interlinkages on the outcome of sustainability indicators has been addressed by several authors. As Allen et al. (2018) argue, progress on a target is linked to others, which requires an integrated approach and the need for tools to assess such interlinkages. The need to address the interrelationships between the economic, social and environmental dimensions

[1] Each was assigned the “regions and cities” section, SDU reviewed the articles related to S4 and firms, and UPNA reviewed the rest of the papers. After this distribution, each of the partners carried out the corresponding classification, reading and analysis of the assigned papers in order to identify indicators used in sustainability monitoring. All the results obtained were discussed by all the partners involved in regular meetings.

of sustainability is also mentioned by Malkina-Pykh (2002), who suggests the use of models in order to understand how they interact.

Another key factor concerning sustainability indicator design is the need for reference values, in order to assess the significance of obtaining a certain result. This has been highlighted by several authors (Gilbert, 1996, Ruiz et al., 2011, Walter & Stuetzel, 2009; Lopez-Ridaura et al., 2002, Singh et al., 2012, van der Voet et al., 2014), and some proposals have been made for the definition of such reference levels.

One of such proposals for identifying reference levels is contained in the work of Ruiz et al. (2011), who propose a double reference criterion, where a distinction is made between an adequate and a desirable level to aspire to. They apply a methodology that allows the creation of synthetic indicators and the assessment of weak and strong sustainability. On the other hand, Walter and Stuetzel (2009) propose the calculation of severity ratios, as the quotient between the actual impact and the so-called "critical impact". In order to obtain a tool for choosing between different scenarios, van der Voet et al. (2014) define the acceptability of indicator values between unacceptable and desirable values. Furthermore, they define the relative importance of the indicators, allowing to combine the individual acceptability of the indicators in terms of the overall acceptability value.

On the other hand, it has been pointed out that some indicators that intend to measure similar issues produce contradictory messages (Janouskova et al., 2018; Lyytmäki et al., 2014; Ollivier et al., 2010; Borgnäs, 2017). For this reason, it is necessary to ensure that the indicators developed or selected leave no room for manipulation. Moreover, Wilson et al. (2007) point out that it is vital for users to be aware of the biases and limitations involved in the use of these indicators. In this sense, Bondarchik et al. (2016) perform a sensitivity analysis of the Happy Planet Index to study the different results obtained depending on the method used for its calculation.

In addition to the already mentioned considerations, several authors have pointed out those criteria that an indicator or a set of indicators should meet. Due to the large number of articles that include references to this issue (Ciegis et al., 2009; Fasolo et al., 2013; Burford et al., 2016; Malkina-Pykh, 2002; Niemeijer & de Groot, 2008; Doody et al., 2009; Jesinghaus, 2012; Bauler, 2012; Grainger, 2012; Hák et al., 2016; Czúcz et al., 2021), a synthesis work was carried out. On the basis of this process, the following criteria are considered relevant for indicator design. Following the classification of different criteria proposed by Czucz et al. (2021), we can identify on the one hand those criteria that apply to each indicator individually, which comprise objective or scientific criteria and practical criteria, and on the other hand the so-called "ensemble criteria", related to the whole indicator sets.

Under objective criteria, authors have mentioned that indicators should be scientifically robust, accurate, unbiased and reproducible, assess trends over time and provide early warning, be sensitive to change and be based on a sound methodology of known quality. Finally, they must have a reference value, i.e. a target level, baseline or threshold against which they can be measured.

According to the practical criteria, indicators should be easily measured, i.e., cost-effective and quick to measure, as well as being based on data that already exists and can be updated at regular intervals. They should be accessible to the indicator users, which means information should be unambiguous and easy to understand. Indicators must also be relevant; they must measure things that matter and are linked to practical action. And they must also be simple, as indicators are intended to simplify complex phenomena so that decision makers can take action. All in all, authors recommend indicator design to be user driven.

In terms of indicator sets as a whole, in addition to the aforementioned recommendation on limiting the number of indicators in the interest of practicality, Czucz et al. (2021) point out that indicator sets should meet the criteria of comprehensiveness and parsimony. These mean that the set must cover all relevant items, while avoiding redundant variables.

In order to contribute to the construction of indicator sets that meet the above-mentioned suitability criteria, several papers have addressed the issue of the indicator design process. Different methodologies have been proposed (Gustavson, 1999; Pülzl et al., 2012; Niemeijer & de Groot, 2008; Lopez-Ridaura et al., 2002; Czúcz et al., 2021). However, at least two phases can be identified in all of them. An initial identification of indicators and a subsequent selection of those that are considered the most appropriate from the initial list.

Often when discussing methodologies for the construction of indicators, Principal components analysis (PCA) and Multi-criteria analysis (MCA) are followed. While the former is usually directed into the construction of composite indices (Li et al., 2012; García-Sánchez et al., 2015; Hosseini et al., 2011), the latter is not only considered for indicator design (D'Adamo et al., 2022; Palme et al., 2005), but also for decision making processes based on indicator sets (Wolfslehner & Vacik, 2011; Labianca et al., 2022), through several methods such as the Analytical Hierarchy Process (Sajadian et al., 2017). However, both approaches share a main objective, consisting of including every relevant component into indicator-based assessment.

Another issue that has come to light in the academic literature is how indicators are used. In addition to their instrumental use, the articles also mention a conceptual and a political use. Instrumental use refers to use that implies a direct relationship between indicators and decision-making. Conceptual use involves a long-term indirect influence due to knowledge or understanding of a certain issue. Finally, political use aims to use indicators as a justification of past practices (Rinne et al., 2013). Even though instrumental use is the one that experts usually have in mind when designing indicators, all three should be considered because they affect the effectiveness of the indicators designed. In order to do so, indicators need to be user-oriented, which means that indicator design processes must adopt a participatory approach.

However, the participatory approach to indicator construction clashes with the need for indicators to be homogeneous, as Weinbaum et al. (2013) advise. These competing ideas should be integrated, as Lavapuro et al. (2008) suggest, by seeking "locally sensitive but globally coherent indicators".

Regarding the need to involve the users of indicators, several studies highlight the use of participatory processes for the construction or selection of indicators, using a bottom-up approach (Shields et al., 2002; Turnhout et al., 2007; Doody et al., 2009; Guimaraes et al., 2017; Mullender et al., 2020; Andrieu et al., 2007; Lopez-Ridaura et al., 2002).

Oleson (2011) focuses on a fundamental issue that needs to be taken into account in measurement. In a discussion of the usefulness of the Adjusted Net Savings or Genuine Savings indicator, he points out that international trade can affect the results, and therefore the analysis cannot be carried out in isolation. Instead, this bias must be considered when interpreting the results. In general, no indicator is without limitations. The key, as Wilson et al. (2007) argue, is for the users of the indicators to be aware of the biases and limitations they may entail.

4.2. Extraction of indicators from literature

As noted above, the articles selected in the literature review were grouped into three different lines: Regions and cities, sectors and firms and general. For each of line, the articles were reviewed in greater depth with the purpose of identifying relevant indicators, which were selected in order to conduct an analysis that will later conclude in the elaboration of the two sets of indicators. One for regional sustainability monitoring and one for S4 strategies.

On the one hand, the analysis of articles referring to general indicators allowed for the identification of commonly used indicators at the national level with the purpose of adapting them to the regional level. Due to the need for data in order to conduct the subsequent analysis, only indicators with open access data are selected. The extraction of indicators resulted in a list of 12 open access indicators.

On the other hand, articles covering regions and cities allowed for the identification of indicators that are already designed for measuring sustainability at the sub-national level. This way, 41 indicators were selected for further analysis. A combination of both lines of analysis is used for the final selection of regional monitoring indicators.

Finally, the third line of analysis covered articles related to S4 and firms. From the review of these articles, a preliminary set of 30 indicators was identified, to monitor sustainability in firms and S4 areas.

A table is displayed below, containing the indicators identified for each of the lines of analysis, along with the main information regarding their nature. In the columns, the pillars considered in each indicator are shown. Another column indicates the type of indicator, classifying them into simple indicators, composite indicators constructed by a combination of only simple indicators and composite indicators which are constructed by at least one other composite indicator. An additional column indicates, when applicable, the sector or theme that indicators are related with. The last column includes references to the articles from which they were extracted.

Table 1 – List of indicators selected from literature for the analysis

	Economy	Environment	Society	Indicator type	Sector or theme	References
Generic indicators						
Adjusted Net Savings/Genuine Savings (ANS)	X	X	X	CS		Mueller (2008); Uwasu and Yabar (2011); Hanley et al. (2015); Mota and Cunha-e-Sá (2019)
Sustainable Society Index (SSI)	X	X	X	CC		Saisana and Philippas (2012)
Ecological Footprint (EF)		X		CS		van den Bergh and Verbruggen (1999); Singh and Bakshi (2015); Toth and Szigeti (2016); Kaklauskas et al. (2018)
Human Appropriation of Net Primary Production (HANPP)	X	X		CS		Haberl (1997); Haberl et al. (2007); Zhang et al. (2021);
Domestic Material Consumption (DMC)		X		CS		Wang et al. (2016)
Environmental Performance Indicator (EPI)		X		CC	Generic indicators	Kaklauskas et al. (2018); Oţoiu and Grădinaru (2018)
Better Life Index (BLI)	X	X	X	CS		Mizobuchi (2017)
Happy Planet Index (HPI)	X	X	X	CC		Tausch (2011); Bondarchik et al. (2016);
Quality of Life Index (QLI)	X	X	X	CC		Kaklauskas et al. (2018)
Carbon Footprint (CF)		X		S		Singh and Bakshi (2015); Jóhannesson et al. (2020)
Human Development Index (HDI)	X		X	CS		Neumayer (2001); Assa (2021)
Planetary pressures-adjusted Human Development Index (PHDI)	X	X	X	CC		Zhang and Zhu (2022)
Indicators for regions and cities						
Average personal income (API)	X			S	Demography	Lee and Huang (2007)
Employment rate (ER)	X		X	CS	Demography	Lee and Huang (2007)
Households and public places with internet connections (IC)			X	S	Smart Specialization	Lee and Huang (2007)
Energy and utility consumption (EIC)			X	CS	Energy	Lee and Huang (2007)

Urban population density (PD)			X	S	Demography	Lee and Huang (2007)
Female/male life expectancy (LE)			X	CS	Demography	Lee and Huang (2007)
Number of households below the poverty line (HPL)	X		X	S	Demography	Lee and Huang (2007)
Wealth gap (WG)	X		X	CC	Demography	Lee and Huang (2007)
Crime rate (CR)			X	CC	Demography	Lee and Huang (2007)
Annual casualties from public disasters (CPD)	X	X	X	CC	Urban Environment	Lee and Huang (2007)
Annual number of transportation accidents (TC)			X	CC	Mobility	Lee and Huang (2007)
Per capita attendance of art and cultural activities (ACA)			X	CS	Welfare	Lee and Huang (2007)
Rate of education and engagement (REE)			X	CS	Welfare	Moreno Pires et al. (2014)
Rate of expansion of urban development lands (UDL)		X	X	CC	Urban Environment	Lee and Huang (2007)
Per capital floor area of private dwellings (PD)			X	CS	Urban Environment	Lee and Huang (2007)
Public facility area ratio to urban land areas (PFA)		X		CS	Urban Environment	Lee and Huang (2007)
Park and green areas (PGA)		X		CC	Urban Environment	Lee and Huang (2007)
Sewerage and waste removal efficiency (WRE)			X	S	Waste	Lee and Huang (2007)
Rate of sanitary sewerage to total sewerage system (SS)			X	S	Waste	Lee and Huang (2007)
Car ownership rate (COR)			X	S	Mobility	Lee and Huang (2007)
Motorcycle ownership rate (MOR)			X	S	Mobility	Lee and Huang (2007)
Areas covered with public transportation system (PTS)		X	X	S	Mobility	Lee and Huang (2007)
Per capita pedestrian walkway index (PWI)		X	X	S	Mobility	Lee and Huang (2007)
Bicycle infrastructure index (BI)		X	X	CC	Mobility	Lee and Huang (2007)
Number of bird and fish species living naturally in the environment (BFS)		X		CC	Urban Environment	Lee and Huang (2007)
Green resource index (GR)		X		CC	Urban Environment	Lee and Huang (2007)
Permeable rate in urban lands (PR)		X		S	Urban Environment	Lee and Huang (2007)

Number of days with Pollutant Standard Index > 100 (PSI)		X		S	Urban Environment	Lee and Huang (2007)
Per capita emissions (E)		X		CC	Emissions	Lee and Huang (2007)
Water quality index (WQI)		X		CC	Urban Environment	Lee and Huang (2007)
Per capita daily waste production (WP)		X		CS	Waste	Lee and Huang (2007)
Recycling ratio for solid waste (RR)		X		CC	Waste	Lee and Huang (2007)
Utilization rate for renewable resources (URR)		X		CC	Energy	Lee and Huang (2007)
Enforcement of local environmental plan (LEP)			X	CC	Welfare	Lee and Huang (2007)
Citizen participation in major planning and decision making (CP)			X	CC	Welfare	Lee and Huang (2007)
Joint international cooperation regarding SD (JIC)			X	CC	Welfare	Lee and Huang (2007)
Environmental and ecological budget ratio to total budget (EEB)	X		X	CC	Welfare	Lee and Huang (2007)
Social welfare expenditure ratio to total expenditure (SWE)	X		X	CC	Welfare	Lee and Huang (2007)
Government expenditure on pollution prevention and resource recycling (GEP)	X			CC	Monitoring & Evaluation	Lee and Huang (2007)
Ratio of completed assessments to initiated assessments (RCA)				CC	Monitoring & Evaluation	Lee and Huang (2007)
Appellate statistics of court cases related to environmental pollution (AS)				CC	Monitoring & Evaluation	Lee and Huang (2007)
Indicators for S4 and firms						
Sustainability indicator system (SII)	X	X	X	CC	Energy	Rösch et al. (2018)
Sustainability performance indicator for additive manufacturing (SPI)	X	X	X	CS	Additive manufacturing	Tadesse et al. (2020)
Benefit cost ratio and carbon stored (BCRCS)	X	X		S	Farming	Pardo Rozo et al. (2022)
Financial ratios (profitability and liquidity) (FR)	X			CS	Transversal	
Economic, social and environmental emergy indicators (ESEEI)	X	X	X	CS	Tourism	Xu et al. (2021)

Potential Embodied Power (PEP)	X	X		S		Ordoñez Duran et al. (2020)
Social impact index (SOII)			X	CC	Offshore wind power	Shiau and Chuen-Yu (2016)
Ecological footprint (EF)		X		CS	Textile	Herva et al. (2008); Costa et al. (2018)
Subjective wellbeing sustainable indicator (SWSI)	X	X	X	CS	Farming	Brown et al. (2021)
Index-Indicator of the Quality of the Use Relation and Land Management (IIQRL)	X		X	CS	Agriculture	Alves et al. (2022)
Exergy sustainability index (ESI)	X	X	X	CC		Aydin (2013); Aydin et al. (2014); Balli (2017); Farajzadeh (2019); Hossain et al. (2020)
Sustainability indicator framework (SIF)	X	X	X	S	Fishing	Angel et al. (2019)
Sustainable development indicators (SDI)	X	X	X	S	Tourism	Ceron and Dubois (2003); Kristjánsdóttir et al. (2017); Islam et al. (2021)
Inclusive impact index (III)	X	X	X	CC	Vegetable oil	Nguyen et al. (2017)
Integrated sustainability indicator in specialized dairy index (ISI)	X	X	X	CC	Dairy	Rios and Botero (2020)
The standardized sustainability energy index (SSEI)	X	X	X	CC	Energy	Schlör et al. (2013)
The index of sustainable development (ISUD)	X	X	X	CC	Energy	Schlör et al. (2013)
Water footprint (WF)		X		S	Dairy	Murphy et al. (2017)
Biodiesel yields (BY)	X	X		S	Biodiesel	Martinez-Guerra and Gude (2017)
Volume recovery index as a sustainability for logging (VRI)		X		CC	Logging	Mayaka et al. (2014)
Sustainability indicators for the assessment of the nuclear power (SIANP)	X	X	X	CS	Nuclear power	Stamford and Azapagic (2011)
Sustainability indicators for crops (SIC)	X	X	X	CS	Crops	Pretty et al (2011)
Composite Sustainable Development Index (CSDI)	X	X	X	CS		Krajnc and Glavič (2005)
Farming sustainable indicators (FSI)		X		CS	Farming	Bassanino et al. (2007)
General sustainability indicator of renewable energy (GSIRW)	X	X	X	CS	Renewable energy	Liu (2014)
SMEs Sustainability indicators (SMESI)	X	X	X	S	SMEs	Li and Mathiyazhagan (2018)

Energy performance (EP)	X	X	X	CC	Construction	Berardi (2011); Chen et al. (2015)
Sustainability context index (SCI)	X	X	X	S	Coffee	Bradley and Botchway (2018)
Sustainability indicators for decision-making (SIDM)	X	X	X	CS	Petrochemical	Al-Sharra et al. (2010)
Sustainability key performance indicators (SKPI)	X	X	X	CS	Industrial	Linke et al (2013); Zharfpeykan and Akroyd (2022)

S: Simple indicator; CS: Composite indicator containing only simple indicators; CC: Composite indicator containing composite indicators.

Source: author's own elaboration.

5. Critical analysis of indicators

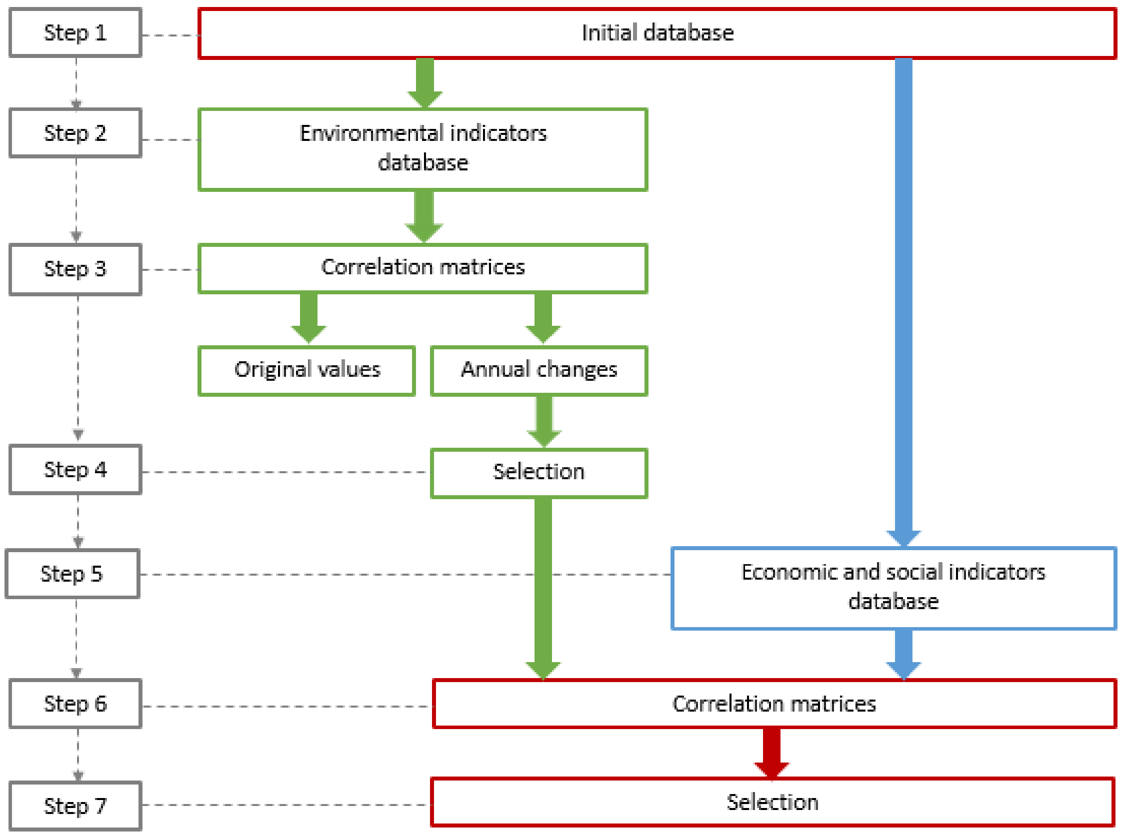
Given the different nature of the three lines of analysis into which the literature review was divided, the critical analysis of the indicators identified in each of them was developed differently. For the so-called generic indicators, a large amount of data was available, so it was decided to carry out a quantitative analysis, analysing the existing relationships between the different indicators. For the indicators identified under the heading of regions and cities, we opted for a more qualitative analysis in which we tried to find the intersection between what was proposed in the literature and the reality of what was calculated in the regions. For this purpose, the four regions participating in the ARIES 4 project, namely Navarre, Värmland, Southern Denmark and Gabrovo, were taken as a reference. Finally, for the indicators related to different productive sectors and companies, an analysis was carried out to adapt these indicators to the smart specialisation strategies. The following subsections detail each of these processes.

5.1. Analysis of general indicators

The generic indicators obtained from the literature review are mostly composite indicators whose calculation requires information on the simple indicators of which they are composed. The large amount of information required, together with the often complex calculation, means that these indicators are not available at the regional level. In some cases, the problem lies in the lack of information on some components of the composite indicator; in others the problem lies in not having access to the calculation algorithm of the composite indicator; in others it is a combination of both.

However, there is a large amount of national-level data on these indicators and their components. Based on these data, we conducted a quantitative analysis to study the relationship between the different composite indicators but also with their components. The analysis will allow us to see whether some indicators are giving us redundant information or information similar to that given by another indicator. In this way, we manage to reduce the number of indicators and come closer to defining a set of indicators that provide the minimum information necessary to monitor sustainability. Identifying synergies and trade-offs can help us reduce the demand for data needed to monitor sustainability, while ensuring that sufficient information is still provided to monitor progress towards sustainability. This reasoned reduction in the number of indicators will allow us to make a proposal for calculating indicators that is more easily reproducible at regional level. On the one hand, we avoid as far as possible the use of composite indicators and, on the other hand, we facilitate the decision on which indicators to consider. Figure 5 summarizes the different steps followed to carry out the analysis. In the following, we explain each of these steps and the results obtained.

Figure 5 – Generic indicators. Steps of the analysis



Source: Authors' own elaboration

5.1.1. Initial database

The indicators are extracted from Table 1, from the list of generic indicators. When generic indicators where identified from the literature review, two types of indicators were found. For some of them, data was openly available, but not for others. Table 1 only includes indicators with open access data because the rest, despite being interesting, were not useful for an analysis based in data. Therefore, for this analysis, only open access indicators have been considered, since this open character is a necessary condition for obtaining the data and carrying out the analysis.

A deep inspection of the 12 indicators included in this list leads to the elimination of four of them from the analysis: Better Life Index, Quality of Life Index, Sustainable Society Index and Human Appropriation of Net Primary Production. The decision was based on the limitations identified in their methodologies or data availability (in the case of the former three) or the lack of potential for the needs and purposes of this stage of the project (for the latter).

For the rest of the indicators, data was retrieved from their corresponding sources, which are detailed in Table 2. After inspecting the available data for each of them, the space and time scope was determined; having in mind that different data sources are being used, data availability varies among indicators. Considering the spatial scope of the project (European regions), a decision was made to limit the database to Europe. It comprises data from 36 European countries, including the 27 member states of the EU and 9 European countries outside the EU. A list of the countries considered, along with their corresponding ISO 3166 codes, which are used in the figures for the analysis, can be found in Annex 1. A large variability is identified in the time coverage of the indicators (a few starting in 1950, many up to 2022) as well as in their frequency of calculation (most of them calculated annually but others every five years).

When it comes to composite indicators, the database includes all its components. A particular situation occurs with the EPI, because due to definition changes there is no historical data for this indicator. Thus, the components that have been considered are those where data for a range of years is available.

Table 2 – Data sources

Indicator	Source
Adjusted Net Savings	https://databank.worldbank.org/source/adjusted-net-savings/
Domestic Material Consumption	https://ec.europa.eu/eurostat/databrowser/view/ten00137/
Ecological Footprint	https://footprint.info.yorku.ca/data/
Environmental Performance Index	https://epi.yale.edu/downloads
Happy Planet Index	https://happyplanetindex.org/trends/?cc=&ps=null&am=hpi_score&tt=false
Human Development Index	https://hdr.undp.org/data-center/documentation-and-downloads
Planetary Adjusted Human Development Index	https://hdr.undp.org/data-center/documentation-and-downloads
Carbon Footprint[2]	https://footprint.info.yorku.ca/data/

Source: Authors' own elaboration

After a brief examination of the indicators included in the database, they were classified in the pillar of sustainability they belong to. The results show an unbalanced classification, where most of the variables (66) measure environmental issues, while the variables related to economic and social aspects are far more reduced; 4 and 6, respectively.

[2] It is a component of the Ecological Footprint.

The large number of environmental variables in the database calls for a first analysis that is focused on this pillar. This way, a reduction of the number of environmental indicators is sought so that data become more manageable.

5.1.2. Environmental indicators database

The sample of environmental indicators includes 66 variables at first. A list with their full titles and abbreviations is provided in the Annex 2 for reference. In the following, abbreviations will be used. After a first review, some of the indicators are excluded from the analysis for several reasons detailed below.

Some indicators are measured at a five-year frequency (OCP and REC). This frequency is not considered appropriate for a continuous monitoring of developments. The same occurs when the indicators are measured at an irregular frequency and contain many missing data in-betweens (PAR). Therefore, these variables are excluded from the analysis.

Another problem occurs when the indicator is built using unknown models (GHN).[3] These are not considered useful since they entail problems in the interpretation of results. There is a group of indicators where no data is recorded from 2019 onwards (FSS, FTD, SHI, SNM, LCB). This means that either a long delay exists in data collection, or the indicators are no longer monitored. Either way, this fact prevents their usefulness. Finally, some indicators contain many values that are equal to zero or remain constant (MD, NFD, MPA, TBG, TBN, GRL, WTL). They are excluded because they do not offer relevant information for the analysis. In Annex 2, the environmental indicators that have been discarded are shown in grey.

After the variables mentioned are excluded, a total amount of 50 variables is analyzed. For doing so, the time scope is limited to 2003-2019, so that relevant information is available for a larger number of countries.[4] We do not include data from 2020, although they are available, to avoid the distorting effects of the pandemic.

An important consideration of the sample is that while some of the indicators use specific units of measure of some environmental issue, others are measured as annual rates of change. This fact affects the interpretation of the results, so it has been taken into account when conducting the analysis. Therefore, to build the database, we distinguish between what we call the original values of the indicator and the annual changes of the indicator.

- *Original value of the indicator* are the values obtained from the data sources (see Table 2). The data can be in different units of measurement. For example, the ecological footprint and its different components, both in the consumption perspective and in the production perspective, are in global hectares while the components of the Adjusted Net Savings are in

[3] These are indicators that use prediction models that are not specified in the calculation methodology and are therefore difficult to reproduce.

[4] This could seem a contradiction with the previous paragraph in which indicators were discarded that were not calculated from 2019. As already indicated in said paragraph, they were ruled out by delay in the calculation or because it is not calculated anymore. Limit the analysis period to 2019 is not done not because they do not have data from later years, if not to avoid the year 2020 since, due to the pandemic and its effects, it can distort the data

current dollars. The original values for other indicators are expressed in annual changes, e.g. some components of the EPI that measure annual growth of pollutants.

- *Annual changes of the indicator* show the change experienced by an indicator from one year to the next (Indicator in t minus indicator in $(t-1)$). It must be considered that there is a group of indicators (NXA, SDA, BCA, CDA, CHA, FGA, GIB, NDA, LCB) that by their definition already represent the annual change; in this case, the original value of the indicator and the annual change of the indicator takes the same value.

5.1.3. Correlation matrices with environmental indicators.

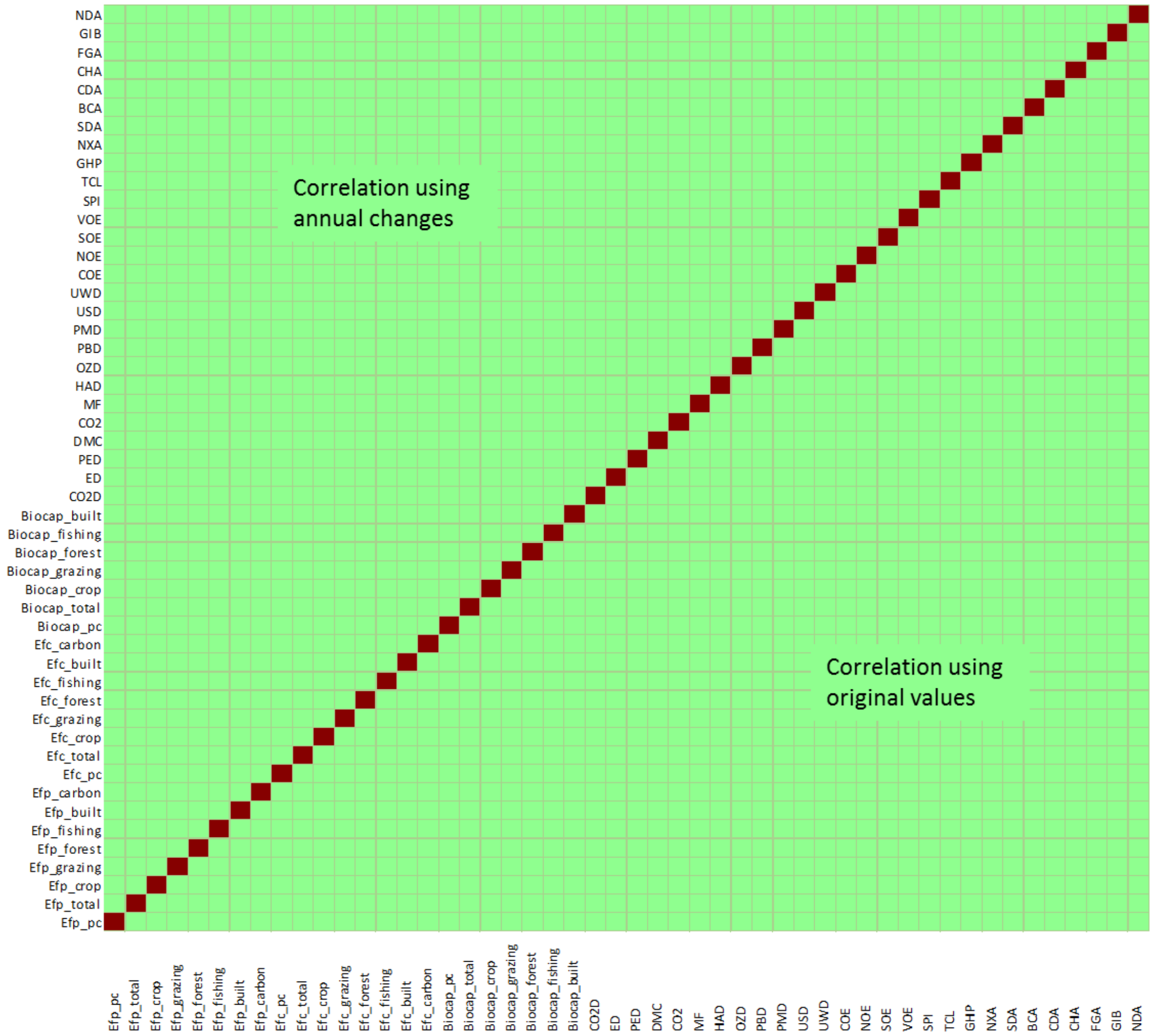
To analyze the relationship between the different indicators, correlation matrices between the indicators are calculated for each country. Correlations are calculated using both the original values and annual changes, using the common sample for each indicator pair. In this way, as much information as possible can be used to obtain the correlation; but there are some drawbacks to be taken into account.

On the one hand, the uncertainty with which the cross-correlations of an indicator with the rest of the indicators are obtained is not going to be the same. There are indicators that have data for all or almost all the periods of the sample (from 2003 to 2019), while others only cover part of the sample (2007 to 2019). Thus, there will be correlations that are obtained with 17 observations and others that are calculated with 13 observations. Moreover, since in most cases when few observations are available it is because they have started to be recorded later, some correlations will pick up only more recent behaviour. On the other hand, the condition of the correlation matrix will also be affected, so that it cannot be used to perform other statistical analyses such as principal components analysis.

We present the results as follows. For each country, we build a matrix with the structure shown in Figure 6. The indicators appear in both rows and columns. Below the diagonal of the matrix, the correlations are calculated using the original values of the indicators and above the diagonal, the correlations between indicators are calculated using the annual changes of the indicator. In this way, we have in one matrix the complete information on correlations between indicators for a country.

Each box in Figure 6 contains the correlation between the indicator in the row and the indicator in the column. Therefore, the boxes in the diagonal represent the correlation between an indicator and itself, that is, perfect correlation.

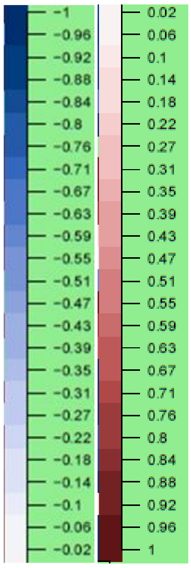
Figure 6 – Correlation Matrix per country. Structure



Source: Authors' own elaboration

We use colors to represent the different correlation values, we use a color transition: from dark blue (perfect negative correlation, -1) to dark red (perfect positive correlation, 1) going through white (correlation zero, 0). Figure 7 shows this color transition and the corresponding correlation values. In addition, a background color (green) is used to distinguish between a zero-correlation value (typically, it will be white because of the color scale used) and the situation where the correlation between that pair of indicators could not be calculated (not available). This may be because there is no information for that variable in that country or because, even if data are available, they do not show variation for the period available.

Figure 7- Correlation values and color scale



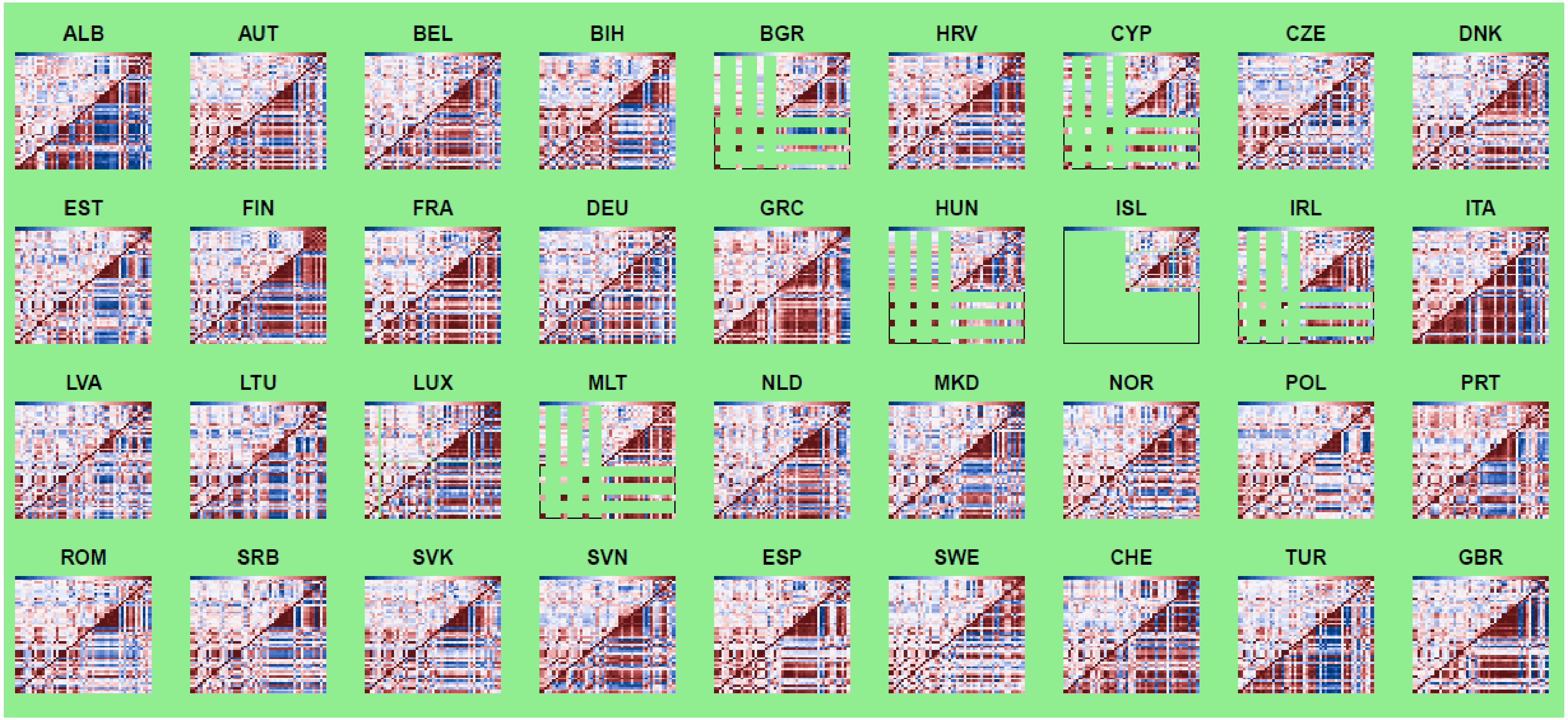
Source: Authors' own elaboration

Figure 8 shows the graphical representations of the correlation matrices between indicators obtained for each of the 36 European countries included in the analysis. The names of the indicators do not appear in these matrices, but the order in which they are shown in Figure 6. These graphs allow us to carry out a first analysis. One of the first things that stand out when looking at these correlations is the lack of information on several indicators for some countries. In addition, we highlight the following ideas.

1. For some countries there is no information on the ecological footprint (ISL) or on its components (BGR, CYP, HUN, IRL, MLT).
2. Looking at the graph from the bottom left corner, especially with the original data, two groups of countries can be distinguished. On the one hand, those with high positive correlations between carbon footprint indicators and, on the other hand, those with lower correlations, which in some countries and indicators can be negative.
3. From the middle of the diagonal towards the upper end, there are two groups of indicators that normally have high correlations between them.
4. Among the groups of indicators described in the previous points, in quite a few countries, there are also significant cross-correlations, in some cases positive and in others negative.
5. As expected, the values of the correlations are higher when obtained with the original values than when calculated with the annual changes. To some extent they are maintained for the group of indicators referred to in point 1, while they decrease considerably for the groups referred to in point 2.
6. The correlations obtained with the original data are usually much larger, in absolute terms, than those obtained with the annual changes. This is not surprising when working with time series, since two series that share a trend, even if they are not functionally similar, will have a high positive correlation. However, if the functional form of the trend is not similar, significant negative correlations can be obtained when analysing the annual changes.

Given these observations obtained from this first correlation analysis, we consider it is more relevant and informative to focus the analysis on the study of the correlations of the annual changes of the indicators. To confirm this intuition, a non-stationarity analysis is performed using the Augmented Dickey Fuller test (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS). The non-stationarity analysis is performed for 42 of the 50 indicators for each of the 36 countries, a total of 1512 series, since 8 of them are defined in annual rates of change. The results of the analysis for the environmental indicators are summarized in Table 3. The "Valid" column shows the number of series that meet the conditions for the tests to be performed. The "Unit-root" column shows the number of series with at least one non-rejection of the non-stationarity hypothesis for ADF and at least one rejection of the stationarity hypothesis for KPSS. In both cases, a significance level of 10 % has been used to compensate for the non-rejection bias caused by the small sample length. The high frequency with which non-stationarity is detected in the original data, and the low presence of non-stationarity in the difference data, indicate that, in order to ensure good statistical properties and correct interpretation of the statistics, it is necessary to perform the correlation analysis using the series in annual changes (first differences).

Figure 8 – Correlation matrices for all the countries.



Source: Authors' own elaboration

Table 3 – Stationarity analysis. Augmented Dickey Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

Test	Data	Valid	% valid	Unit-root	% unit-root
ADF	Original	1401	92.66 %	1386	98.93 %
	Annual change	1399	92.53 %	243	17.36 %
KPSS	Original	1401	92.66 %	1168	83.37 %
	Annual change	1399	92.53 %	232	16.58 %

Source: Authors' own elaboration

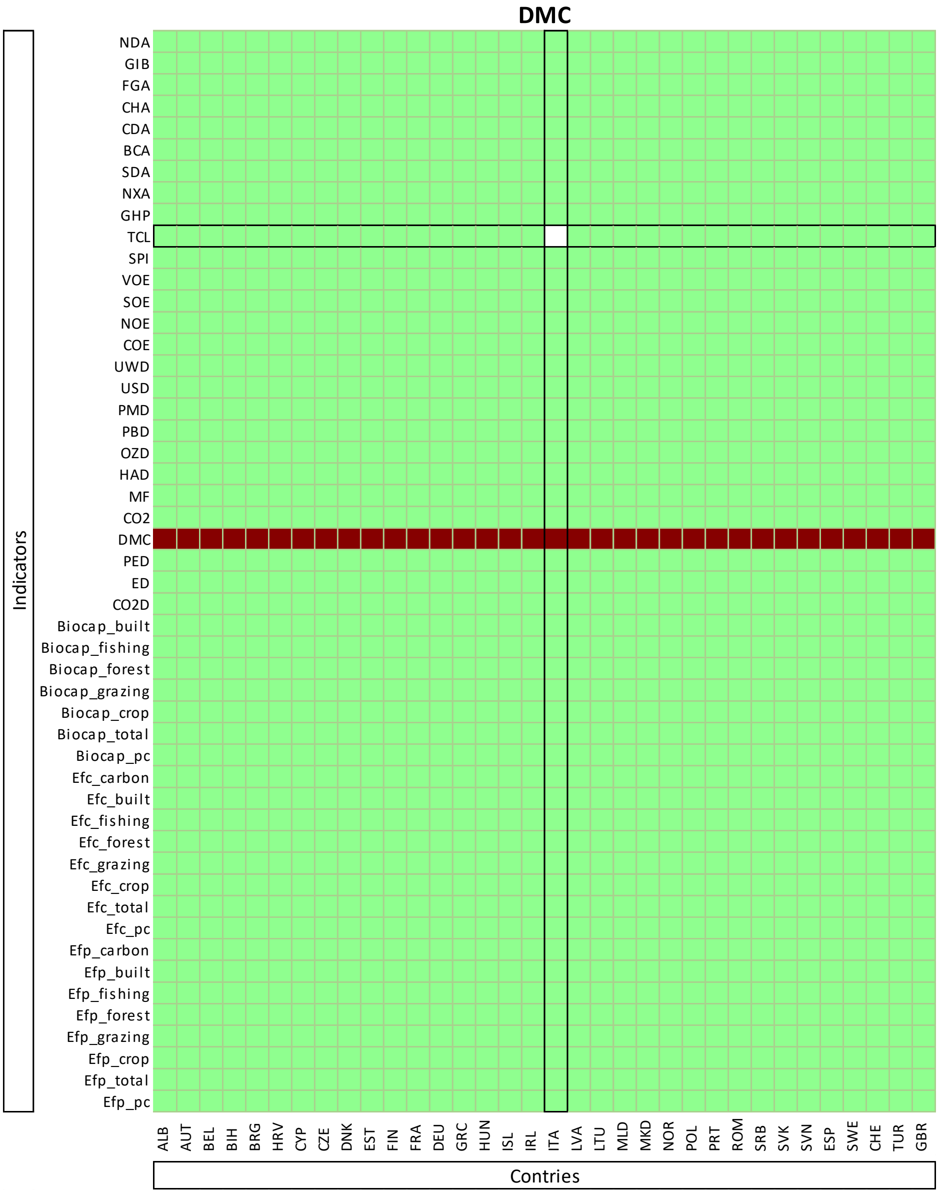
To carry out this new analysis, new correlation matrices are constructed. The correlation of each indicator with the rest of the indicators for each of the countries is represented in one matrix. Therefore, we have one matrix per indicator (50 matrices). Figure 9 depicts the structure of one these matrices for a specific indicator, in this case DMC, which gives the matrix its name. The indicators are in the rows, and the countries are in the columns. In each row, we observe the correlations of the indicator that names the matrix with the indicator in that row for each of the countries. Thus, in Figure 9, the line highlighted with the black border would reflect in each box the correlation of DMC with indicator TCL for each country. For example, the white box would show the correlation between DMC and TCL for country Italy (ITA). It is worth mentioning that in the row that corresponds to indicator that names the matrix, DMC, we will have perfect positive correlation (correlation 1). Using the color scale in Figure 7, line DMC shows the perfect correlation between indicator DMC and itself. Finally, if we read the columns, we see the correlations of the indicator that names the matrix with the rest of the indicators for a particular country. The column highlighted with a black border in Figure 9 would reflect these correlations for Italy (ITA). In each of these matrices, we will use the color scale in Figure 7.

The 50 matrices obtained (one per each environmental indicator) can be consulted in Figure 10. Based on these matrices, we highlight some interesting points.

1. Both in total and per capita changes in ecological footprint, measured by consumption or by production, have high positive correlations with Efp_carbon, CO2D, CO2 and GHP, for all or almost all countries. Thus, the evolution of these indicators could be captured, without much error, with some simple CO2 or GHG indicator.
2. There is a positive and high correlation between Efp and Biocap
3. There is a positive and generally high correlation between HAD and OZD, PBD, PMD, COE, NOE, SOE and VOE. It should be noted that all these indicators are inverse indicators, the higher the value, the worse the situation they describe. All of them are exposure indicators.
4. There is a high positive relationship between UWD and USD. There are also high correlations, in absolute value, although not in all indicators and not in all countries with the same sign, between UWD, USD, on the one hand, and NDA, GIB, FGA, CHA, CDA, BCA, SDA, NXA, on the other hand. All these indicators are inverse indicators.

5. For indicators related to measures of exposure to pollutants (COE, NOE, SOE, VOE) high correlations between them are observed. However, differences are observed in their relationship with other indicators.
6. SOE has high correlations with adjusted emissions growth rate indicators for different pollutants, not all of the same sign (NDA, FGA, CHA, CDA, BCA, SDA, NXA).
7. There are high correlations, albeit of different signs by indicator and by country, between the variables in the group of emission growth variables (NDA, GIB, FGA, CHA, CDA, BCA, SDA, NXA). There are also high correlations, generally negative, between this group and exposure variables (OZD, PBD, PMD, USD and UWD).

Figure 9 – Correlation matrix for one indicator (I_n). Structure.



Source: Authors' own elaboration

Figure 10 – Correlation matrices for all the environmental indicators

Source: Author's own elaboration

5.1.4. Selection of environmental indicators

Following the analysis described above, the following table contains the reduced list of environmental indicators that are going to be used for subsequent analyses. From the 50 indicators arrived at in step 2, the analysis carried out in step 3 results in a list of 18 environmental indicators.

As Table 4 shows, the selected indicators have been grouped by their coverage or subject. As a result, we have 9 indicators for measuring global pollutants, 7 that correspond to local pollutants, and finally two indicators related to sanitation.

Table 4 – Selection of environmental indicators

Indicator (full name)	Abbreviation
Global pollutants	
Ecological Footprint of production per capita (gha)	Efp_pc
Ecological Footprint of production (gha)	Efp_total
Ecological Footprint of production, carbon demand on land (gha)	Efp_carbon
Ecological Footprint of consumption per capita (gha)	Efc_pc
Ecological Footprint of consumption (gha)	Efc_total
Ecological footprint of consumption, carbon demand on land (gha)	Efc_carbon
Carbon dioxide damage (current US$)	CO2D
CO2 emissions per capita index (production based)	CO2
Greenhouse gas emissions per capita	GHP
Local pollutants	
Ozone exposure	OZD
Lead exposure	PBD
PM2.5 exposure	PMD
CO exposure	COE
NOx exposure	NOE
SO2 exposure	SOE
VOC exposure	VOE
Sanitation	
Unsafe sanitation	USD
Unsafe drinking water	UWD

Source: Authors' own elaboration

5.1.5. Economic and social indicators database.

Once the environmental indicator list is reduced, it is time to consider the other two pillars of sustainability, social and economic, in the analysis. While environmental indicators selected from the literature review were numerous and called for a reduction, the opposite situation is noted when it comes to economic and social indicators. As it was stated before, 4 economic indicators and 6 social indicators were identified in the first list of indicators.

Therefore, a lack of sufficient variables is identified, and a further search is required. In this case, the work conducted on regional indicators was useful since it enabled the identification of additional economic and social indicators. Specifically, parting from the regions and cities indicator list in Table 1, those that are monitored by the regional database from Eurostat were considered. Whenever regional data is available, country level data is also monitored, so it was relatively easy to extract the necessary information for these additional indicators at national levels. The specification of the additional indicators extracted from the Eurostat database is explained below, and further detail on the sources is included in Annex 3 and 4.

<u>Extension of the economic indicators' list</u>

The process that was followed to expand the list of economic indicators can be easily followed by observing Table 5. Initially, only 4 indicators were selected from the generic indicators found in the literature review (Table 1): CFC, GS, GNIpc and GDP. The regional indicator list was analysed to identify economic indicators that covered our data availability requirements, but only three indicators were identified for which regional information was available in Eurostat (ER, SPV and SMC). In this case, even though the initial list was extended, the economic indicators found in the regional analysis were not enough to generate sufficient information for the analysis. That is why 10 additional indicators were extracted from the Eurostat database, which are included at the bottom of Table 5. Therefore, a final list of 17 economic indicators is used for the analysis.

Table 5 – List of economic indicators

Indicator (full name)	Abbreviation
Literature review (generic indicators)	
Consumption of fixed capital (current US$)	CFC
Gross savings (current US$)	GS
Gross National Income per capita	GNIpc
Gross Domestic Product	GDP
Literature review (regional indicators)	
Employment rates	ER
Stock of vehicles. Passenger vehicles	SPV
Stock of vehicles. Motorcycles	SMC
Additional indicators	
Unemployment rates	UR
Gross Domestic Product, Chain linked volumes, 2010=100	GDP_CLV
Final consumption expenditure of general government (CLV)	FCEGG_CLV
Household and NPISH final consumption expenditure (CLV)	FCEH_CLV
Gross capital formation (CLV)	GCF_CLV
Exports of goods and services (CLV)	EXPGS_CLV
Imports of goods and services (CLV)	IMPGS_CLV
Compensation of Employees. Percentage of GDP	CEE_PGDP
Gross operating surplus. Percentage of GDP	GOS_PGDP
Real labour productivity per hour worked	RLPH

Source: Authors' own elaboration

Extension of the social indicators' list

Once the economic indicators are fixed, the list of social indicators is inspected. We part from the 6 indicators extracted from the literature review on generic indicators and included in Table 1 (EE, Ladder, LE, EYS, MYS and GDI). In the case of LE, it is present in both the HDI and the HPI, but present slightly different values. Since the database extracted from the HPI for this component includes some outliers, the LE from HDI will be used for the following analysis.

From the list of territorial indicators, there are many that cover the social pillar of sustainability. Among those, there are 9 for which data is available for the regional scope and are therefore also available at national level. With the addition of these indicators to the previous list, a total amount of 15 indicators (presented in Table 6) is gathered, which is considered enough for the analysis, so no further search of indicators is considered necessary.

Table 6– List of social indicators

Indicator (full name)	Abbreviation
Literature review (generic indicators)	
Education expenditure (current US$) (ANS)	EE
Ladder of life (HPI)	Ladder
Life expectancy at birth (HDI)	LE
Expected years of schooling (HDI)	EYS
Mean years of schooling (HDI)	MYS
Gender Development Index (HDI)	GDI
Literature review (regional indicators)	
Households with access to the internet at home. Percentage	AIH
Households with broadband access. Percentage	HBA
At-risk-of-poverty rate	ARPR
Severe material and social deprivation. Percentage	SD
Persons living in households with very low work intensity. Percentage	LWI
AROPE (At risk of poverty or social exclusion)	AROPE
Police-recorded offences per hundred thousand inhabitants	PRO
Victims in road accidents	VRA
Participation rates in education, pre-primary to tertiary	EPR

Source: Authors' own elaboration

With this selection, for an analysis that covers the three pillars of sustainability, a total amount of 50 indicators is considered (18 environmental, 17 economic, 15 social). A correlation analysis is conducted to identify relationships among them. For this second analysis, the same time period is maintained for the analysis.

There are a few points to note about the data on social and economic indicators:

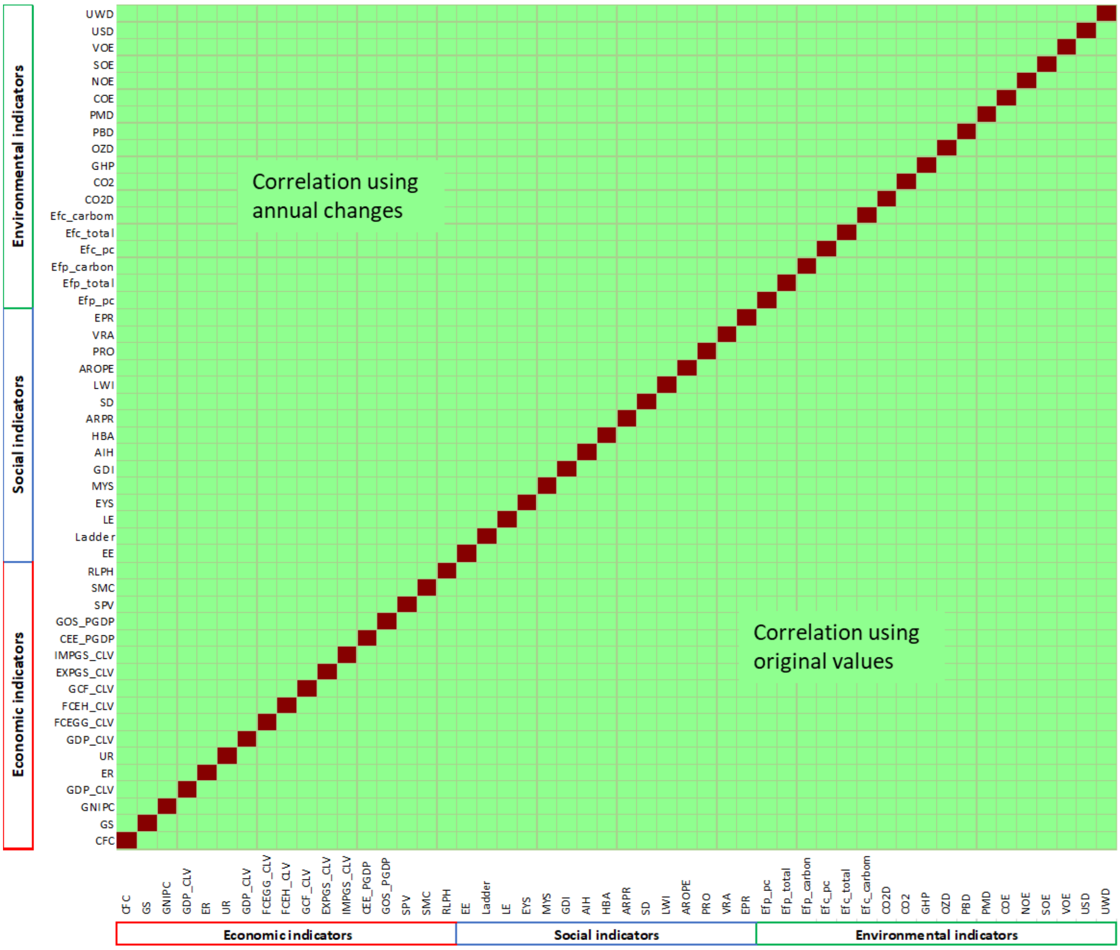
- There are indicators with too short sample. For example, EPR (participation rates in education, pre-primary to tertiary) starts in 2013. For the same reason, poverty indicators (SD, LWI, AROPE) are taken from the definition of the Europe 2020 strategy and not from the definition of Europe 2030 targets. In this way we have a larger sample.

- There are indicators with little or no information for some countries. For the social indicator PRO there are 7 countries with no data, 7 countries with less than 7 data and 3 countries with no intermediate data. For another social indicator such as AIH there is 1 country with no information, 3 countries with less than 3 data, and 3 countries with no intermediate data. For the VRA and HBA indicators the situation is similar to AIH.
- For some indicators, lack of homogeneity or extreme variations are observed. This is the case for SPV and SMC (point variations with an order of magnitude much higher than the rest of the period, higher than 10e5, for 10 countries).

5.1.6. Correlation matrices with the three pillars of sustainability

Following the analysis in step 3, we first present the correlation matrices for all indicators in each country, both in absolute values and in annual changes. Secondly, we present the correlation matrices by indicator for all countries.

Figure 11 - Correlation Matrix per country. Structure



Source: Authors' own elaboration

Figure 11 shows the structure of a matrix for a country. It shows economic indicators, social indicators, and environmental indicators. The order of the indicators is indicated in the figure. Above the diagonal the correlations between the indicators will be presented using annual changes and below the diagonal the correlations of the indicators for their original values. We obtained 36 correlation matrices, one for each country, which can be seen in Figure 12.

Figure 12 – Correlation matrices per country. The three pillars of sustainability

Source: Authors' own elaboration

To interpret the correlations shown in Figure 12, care must be taken with the variables mentioned in the previous step (short time series), as in countries with little data the estimates are not reliable (they tend to appear with extreme values in both level and differences). Three regularities can be derived from this figure, which are outlined below.

1. In general, the variables of the different pillars have high correlations with each other and with the rest of the pillars.
2. In the more developed countries (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Malta, the Netherlands, Norway, Spain, Sweden, Switzerland and Great Britain), the correlations of the original variables have the desired sign, getting economic growth, social improvements and environmental improvements. This observation is supported by the time plots as the observed trends in the variables are consistent with the hypothesis.
3. Correlations are much lower when indicators in first differences (annual changes) are used.

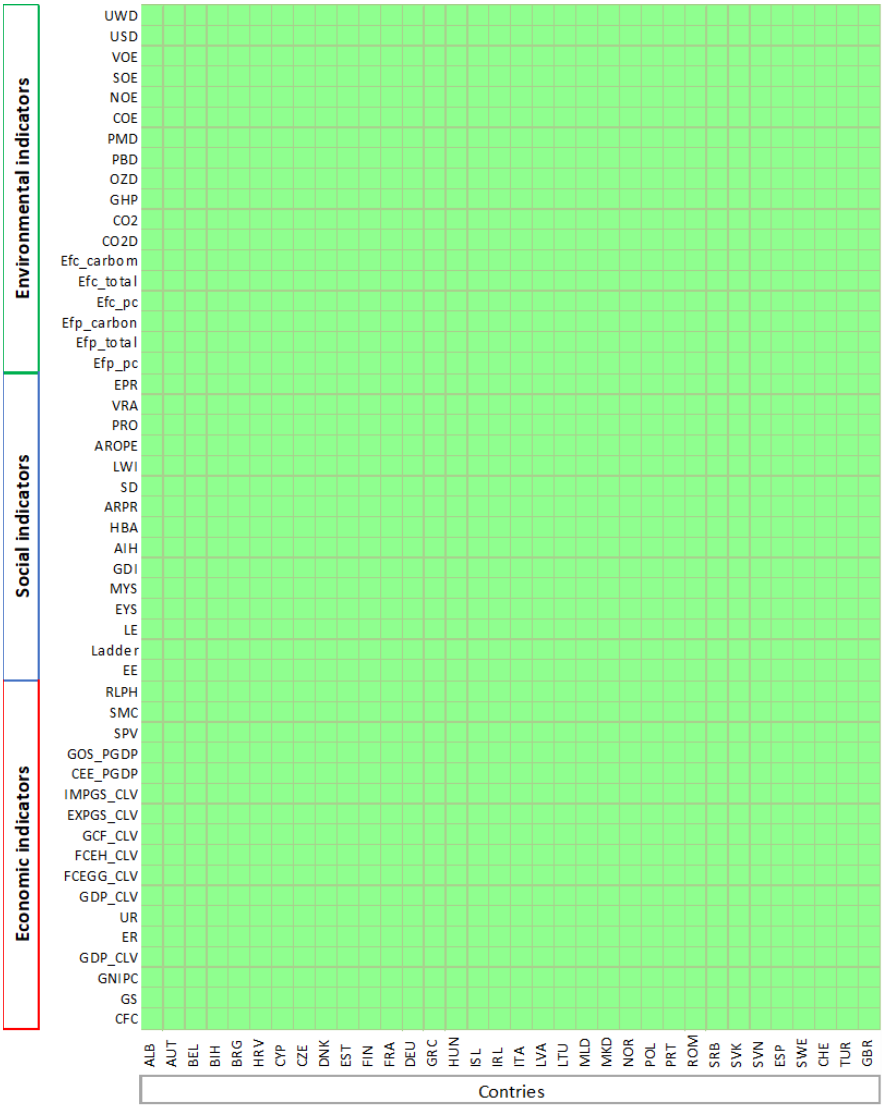
Once this analysis has been carried out both in original values and in annual changes, we focus on the analysis of each indicator in annual changes or first differences. We construct a matrix for each indicator and jointly look at the correlation with the other indicators for all countries. Figure 13 shows the structure of the correlation matrix of one indicator. As in the previous matrices (see Figure 9), each indicator occupies a row while the countries are in the columns. The order of the indicators is the same as that used in Figures 11 and 12, that is bottom rows correspond to the economic indicators, the top rows to the environmental indicators and in the middle are the rows corresponding to the social indicators. We construct a matrix for each indicator, i.e. we construct a total of 50 matrices.

In the correlation matrix of one indicator, each row represents the correlation of that indicator with the indicator in this row. In the row of that indicator, the correlation will be perfect and will appear in bright red. On the other hand, each column represents the correlation of that indicator with the rest of the indicators for the country that is in the column. We constructed a correlation matrix for each of the 50 indicators (Tables 4, 5 and 6). Figure 14 shows each of these 50 matrices. This figure shows the correlations for the annual changes (first differences) of the indicators.

We highlight some ideas from the correlation matrices shown in Figure 14.

1. With the exception of CFC (Consumption of fix capital), FCEGG_CLV (Final consumption expenditure of general government), SPV and SMC (Stock al vehicles, passenger cars and motorbikes) and RLPH (Real labour productivity per hour worked) which present smaller correlations, the rest of the variables of the economic pillar present relatively high positive correlations (negative in the case of UR, the Unemployment rate) with the rest of the variables in this pillar, positive with different intensity with the variables related to global pollutants, negative with higher dispersion of values with the variables related to “social deprivation” and positive with those related to “social welfare”.

Figure 13 – Correlation matrix for one indicator. Structure.



Source: Author' own elaboration

2. There are two variables, related to the distribution of income between compensation of employees and corporate profits (CEE_PGDP and COS_PGDP), which evolve in the opposite direction to each other, which seems logical. These variables, although to a lesser extent than the previous ones, have some relation with global pollutants and do not present a clear sign with those related to the social pillar.
3. The relationships between the economic pillar variables and the local pollutant variables do not show a clear sign between countries. In general, the correlations are small.
4. The variables of the social pillar, in general, show small correlations among themselves and of different signs by country.
5. AROPE-related variables (ARPR, SD, LWI) have relatively high correlations with each other.
6. Special mention should be made of LE (Life expectancy), which in general shows negative correlations of varying magnitude with local pollutants, especially with PMD and PBD.

7. Those related to Internet access (AIH and HBA) show positive correlations with each other, as would be expected, although there is no clear pattern with the rest.
8. In education, EYS and EPR are positively correlated for most countries, although this correlation is not observed with MYS.
9. In the local pollutants there are two groups, on the one hand, PBD and PMD with relatively high correlations with each other and lower correlations with the rest of the pollutants, but with different ways of relating to the rest of the pillars. On the other hand, VOE, SOE, NOE and COE have positive correlations with each other and different ways of relating to the rest of the pillars. Thus, PBD, COE and SOE have mostly negative correlations with the variables related to "social welfare", although neither is it uniform across countries nor do they have large values. These relationships are not observed with those related to "social deprivation".

Figure 14 - Correlation matrices for the three pillars of sustainability

Source: Authors' own elaboration

5.1.7. Selection of indicators: economy, environment, and society

The correlation relationships established allow us to group indicators into different groups according to the information they collect. Each group contains similar information on the evolution towards sustainability. Calculating one of them could be sufficient for a regional analysis of sustainability. The groups of indicators are summarized in Table 7. The indicators of the economic pillar are summarized in two groups, one that we can call overall economic activity and the other that monitors payments to factors of production. In the social pillar, we group the indicators into 5 groups, four with objective indicators to measure poverty, education, access to technology and life expectancy and a fifth with a subjective component as it is an indicator of well-being based on social perception surveys.[5] Finally, for the environmental dimension of sustainability we obtain 4 groups of indicators. The first one covers global pollutants while the next two cover local indicators of different nature. The last group covers indicators related to public sanitation.

Table 7 – Overview of selected indicators

ECONOMY		
Economic I	Overall economic activity	GDP, GNI, GS, UR, ER, FCEH, GCF, EXPGS, IMPGS
Economic II	Payment of productive factors	RLPH, CEE,GOS
SOCIETY		
Social I	Poverty-related indicators	AROPE, LWI, SD, ARPR
Social II	Education	EYS, MYS, EPR
Social III	Access to technology	AIH, HBA
Social IV	Life expectancy	LE
Social V	Ladder of life	Ladder
ENVIRONMENT		
Environmental I	Global pollutants	EF, CO2
Environmental II	Local pollutants I	COE, NOE, SOE, VOE
Environmental III	Local pollutants II	PMD, PBD
Environmental IV	Sanitation	UWD, USD

Source: Authors' own elaboration

[5] Ladder of life question collected as part of the Gallup World Poll and use in the calculation of the Happy Planet Index. It is used as a measure of wellbeing, and it is commonly used as an indicator of how people's lives are going overall (WEAll, 2021).

5.2. Sustainability indicators for territories. A regional comparison

The purpose of this comparative analysis is to investigate the transferability of territorial sustainability indicators from research to practice and assess the relevance of the sustainability indicators identified in the literature review for to the four regions in the ARIES4 project (Navarra in Spain, Värmland in Sweden, Southern Denmark in Denmark and Gabrovo in Bulgaria).

The starting point was the list of indicators collected via a scientific literature review of peer-reviewed articles in Sustainability in Cities and Regions (Table 1). This list consisted of 41 indicators and indexes with a variety of foci – socioeconomic data, land use, transportation, sanitation, culture, fauna etc. It is important to note that this list comes from different academic articles, projects and empirical cases from all over the world. Also, they might have the purpose of testing or developing new indicators or indexes rather than presenting the best or most useful or accessible indicators. The list does not tell us the reason for choosing to present the specific indicator(s) or index, it only tells us that these indicators/indexes are in the academic literature on sustainable cities and regions.

From the policy and practice perspective, there is accessible data on many focus areas that is used by regional policy and practice – on income distribution, employment, education etc. But – are they the best indicators for measuring how a region is developing in a sustainable way? And are they always immediately comparable across countries and regions?

Finally, if we want to measure sustainable regional development, perhaps we need new indicators? It is clear from the literature review that territorially, sustainability research is mostly focusing on the cities and urban level and not on the regional level. Regional practice uses the data available depending on their areas of responsibility in the specific country. If there is a mismatch here between published peer reviewed research and policy/practice, it is obvious that there is a need for more research on the underpinnings of regional sustainability. Guiding questions were - What are the central indicators of a sustainable region? What are the relevant indicators that support or guide a regions' sustainable development and thereby can be implemented by the S4 actors? And following climate change, European regions might need to measure factors that we haven't been primarily interested in previously, e.g. relating to droughts, floods, natural hazards etc.

5.2.1. Methods

To carry out the analysis of transferability of indicators the regional partners reported:

1. What is available as open, accessible data on regional level for your region/country in relation to the indicators from the literature review? (it might not be the exact same indicators as the indicators in the literature review)

2. And if it is not available on regional level, what is available as open, accessible data on municipal/local level for your country, that can be aggregated? (It might not be the exact same indicators as the indicators in the literature review)

The alignment of the indicators to the global Sustainable Development Goals (SDGs) and SDG pillars were analyzed and compared across regions to identify regional potentials and gaps. The indicators for which data is available on European Statistics (Eurostat) were delineated to identify potentially comparable indicators.

The result of this data collection can be found below. It, however, needs to be commented on.

1. There are many gaps. They are likely explained by a variety of factors, but they must be considered when drawing conclusions. (could not find data, data is not available, indicator was not understandable, etc.).
2. It can be relevant to compare across regions, but it is important to make sure that differences between e.g. indicators, ways of measuring or the frequency of the data, are presented and explained and if possible, handled. If e.g. employment or education levels are measured in different ways, the differences must be handled to be able to make a solid comparison.

5.2.2. Results

Regions are diverse and so are the sustainability indicators

Out of the 41 indicators identified in the literature review, we find that 25 indicators are measured in at least one of our regions (Table 8) while only eight indicators are measured in all of the four regions (see Table 9 and Figure 15 for details).

The diversity of context and priorities of European regions leads to diverse needs of indicators to monitor the progress of sustainable development. Hence, only a few (eight in our case) indicators allow for comparison across all four regions, which also align well with the indicators reported in the Eurostat repository (see Table 10).

The measured indicators cover a majority of the global SDGs but important social SDGs such as SDG2 Zero Hunger and SDG5 Gender Equality are not measured separately (Table 8). Important environmental SDG14 Life Below Water is also not covered by the measured indicators in any of the regions. This is likely because none of our regions represents coastal area.

The indicators that are common across the four regions and are also reported in the Eurostat repository cover the conventional aspects of sustainability, such as demography (life expectancy), economy (employment, income and wealth gap) and security (crime rate). However, the common focus on education and engagement illustrates an important development area of sustainability in the studied regions.

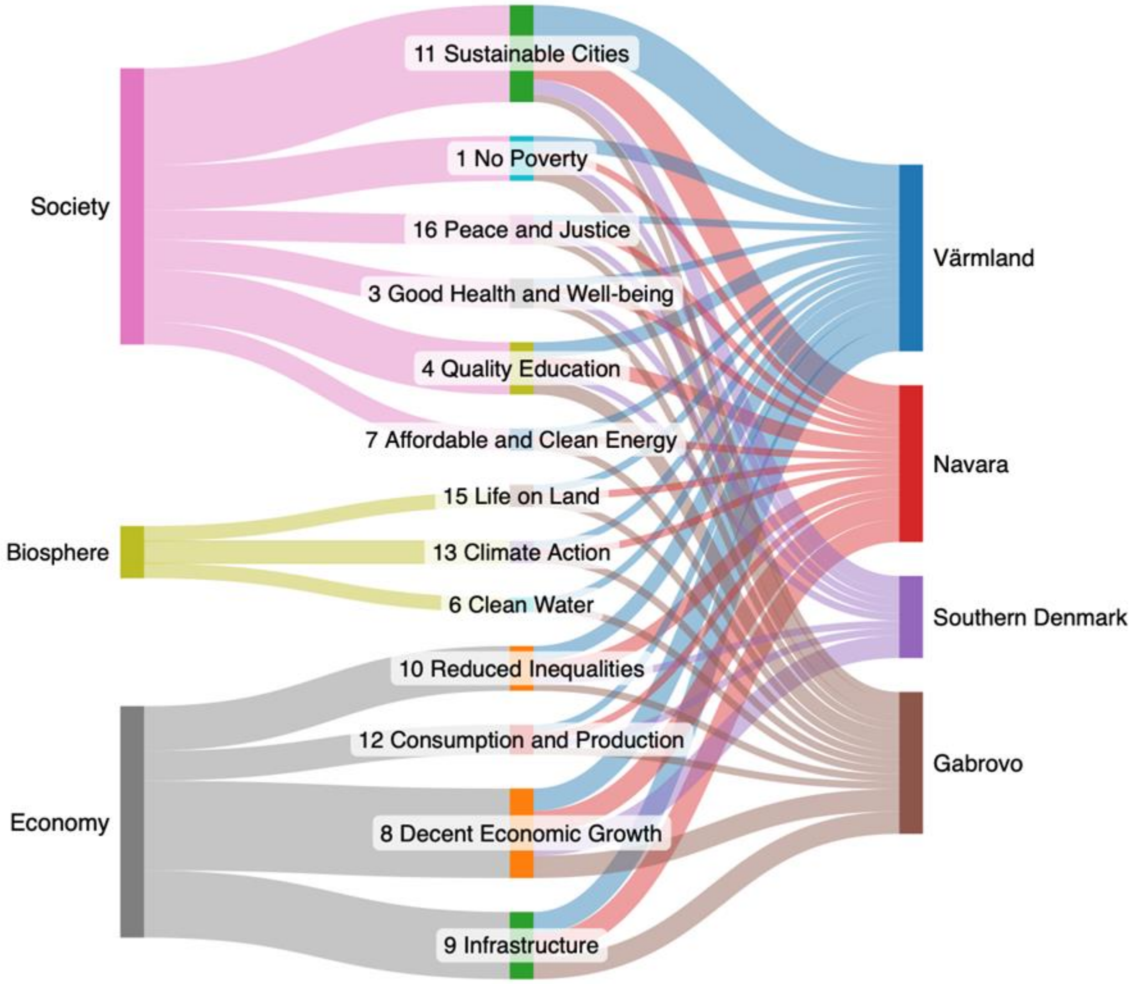
The conclusion from Tables 8 and 9 is that looking only at easily available indicators for the four regions, a lot of sustainability aspects are missing. Consequently, this is not enough. Table 10 adds data on e.g. poverty and transportation to the list of functioning indicators. However, many important environmental and social indicators identified in the literature review are also not monitored in our regions, such as air pollution and environment related court cases.

Table 8 – Sustainability indicators measured in at least one of the four regions and the aligned global Sustainable Development Goals (SDGs) and SDG pillars.

SDG Pillars	SDGs	Regional Indicators and indexes
Biosphere	13 Climate Action	Emissions
	15 Life on Land	Environmental Budget
	6 Clean Water	Water Quality
Society	1 No Poverty	Households Below the Poverty Line
		Social Welfare Expenditure
	11 Sustainable Cities	Bicycle Infrastructure
		Park and Green Areas
		Pedestrian Walkway
		Private Vehicle Ownership
		Public Transportation
		Urban Population
	16 Peace and Justice	Crime Rate
	3 Good Health and Well-being	Life Expectancy
	4 Quality Education	Art and Cultural Activities
		Education and Engagement
	7 Affordable and Clean Energy	Energy and Utility
Economy	10 Reduced Inequalities	Citizen Participation
		Wealth Gap
	12 Consumption and Production	Sewerage and Waste
	8 Decent Economic Growth	Employment
		Gross Domestic Product
		Income
	9 Infrastructure	Casualties from Public Disasters
		Internet Access
		Transportation Accidents

Source: Authors' own elaboration

Figure 15 - A Sankey diagram representing the alignment of the regionally measured indicators with global Sustainable Development Goals (SDGs) and SDG pillars.



Source. Authors' own elaboration

Table 9 - Sustainability indicators measured in all four regions and their data sources.

Indicators	Specific Regional Indicators				Data and Information			
	Värmland	Navarra	Southern Denmark	Gabrovo	Värmland	Navarra	Southern Denmark	Gabrovo
Crime Rate	Reported violent crimes, number per 100,000 inhabitants.	Police-recorded offences (per 100,000 inhabitants) (2008-2021)	Crime reported	Number of crimes against the person and property per 10,000 people (2001-2021)	Link to Kolada database	Link to Eurostat	Odense I TAL and Danmarks Statistik	freely available @ regionalprofiles.bg
		Recorded offences by criminal typology (2010-2022)	Crime charges			Link to Crime statistics database	Odense I TAL and Danmarks Statistik	
			Convictions					
			Convicted persons					

Employment	Employed residents aged 20-64, percentage (%)	Employment rate (15-64 years) (1999-2022)	Population by working professions	Employment rate (15-64 years) (2003-2022)	Link to Kolada database	Link to Eurostat	Odense I TAL and Danmarks Statistik	freely available @ infostat.nsi.bg
	Youth aged 16-24 not in employment, education, or training (NEET), percentage (%)		Discharge rate	Employment rate (15+ years) (2003-2022)	Link to Kolada database		Odense I TAL and Danmarks Statistik	freely available @ infostat.nsi.bg
	Long-term unemployment, annual average, percentage (%) of population aged 25-64		Full-time unemployment	Unemployment rate (2018-2022)	Link to Kolada database		Odense I TAL and Danmarks Statistik	freely available @ az.governmen t.bg
	Youth aged 16-24 not in employment or education, percentage (%)		Gross unemployment		Link to Kolada database		Odense I TAL and Danmarks Statistik	
			Net unemployment				Odense I TAL and Danmarks Statistik	

Education and Engagement	Inhabitants aged 25-64 with post-secondary education, percentage (%)	Participation rates in selected education levels at regional level (2014-2021)	Number of classes	Net enrolment rate of the population by level of education	Link to Kolada database	Link to Eurostat	Odense I TAL and Danmarks Statistik	freely available @ regionalprofiles.bg
	Inhabitants aged 25-64 with pre-secondary education, percentage (%)	Participants in the educational programs developed by the Environmental Education Service (Pamplona)	Private schools	Relative share of the population aged 25 to 64 with tertiary education	Link to Kolada database	Environmental Education Service Annual Reports	Odense I TAL and Danmarks Statistik	freely available @ regionalprofiles.bg
	Students in grade 9 eligible for vocational programs, total county, percentage (%)		Municiple schools		Link to Kolada database		Odense I TAL and Danmarks Statistik	
	Highly educated residents aged 25-64, percentage (%).		Library lending		Link to Kolada database		Odense I TAL and Danmarks Statistik	

			Library visitor numbers				Odense I TAL and Danmarks Statistik	
			Number of pupils				Odense I TAL and Danmarks Statistik	
Gross Domestic Product	GDP per inhabitant	GDP per inhabitant in euros (2000-2021)	GDP and GDP Per Capita by part of the country	GDP per capita at current market prices by NUTS 2 regions (2001-2021)	Link to Kolada database	Link to Eurostat	Danmarks Statistik	freely available @ ec.europa.eu/ eurostat/
	Gross Regional Product, region (GRP), 1000 SEK/inhabitants	GDP per inhabitant PPS, EU27 from 2020 (2000-2021)		GDP per capita in PPS by NUTS 2 regions (2001-2021)		Link to Eurostat		freely available @ ec.europa.eu/ eurostat/
Income	Median net income, SEK per inhabitant aged 20 and above.	Average net annual income in euros (2019-2021)	Households' income	Average gross monthly wage in BGN (2017-2022)	Link to Kolada database	Link to Nastat	Danmarks Statistik	partly available @ nsi.bg
	Women's median net income as a percentage of		Income for people (14+) by region		Link to Kolada database		Danmarks Statistik	

	men's median net income.							
	Women's median net income as a percentage of men's median net income, 65 years and older, percentage (%)		Pre-tex income for people (14+) by region		Link to Kolada database		Danmarks Statistik	
			Disposable income for people (14+) by region				Danmarks Statistik	
Life Expectancy	Life expectancy for women, years	Life expectancy at birth by sex (2010-2021)	Life expectancy for new born babies by sex	Life expectancy at birth by sex (2008-2022)	Link to Kolada database	Link to Eurostat	Danmarks Statistik	freely available @ infostat.nsi.bg
	Life expectancy for men, years				Link to Kolada database			

Sewerage and Waste	Collected municipal waste total, kg per capita (adjusted).	Volume of treated wastewater in m3/inhabitant /day (2000-2013 annually, 2014-2018 biennially)	Waste entering landfills	Municipal waste by statistical region and district (2017-2021)	Link to Kolada database	Link to Nastat	Odense I TAL and Danmarks Statistik	freely available @ nsi.bg
	Municipal waste collected for material recycling, including biological treatment, share (%)	Urban waste collected kg per capita (2010-2021)			Link to Kolada database	Link to Nastat		
	Satisfied Citizen Index - Water and Sewerage (-2020)	Household and commercial waste (2010-2022)			Link to Kolada database	Link to data from Government of Navarre		

	Collected food and residual waste, kg per capita (adjusted).	Waste valorization ratio (2010-2022)			Link to Kolada database	Link to data from Government of Navarre		
Wealth Gap	Income and Wealth - Regional Index	Gini index (2019-2021)	Avg. equivalised disposable Income in decile groups, by decile and municipality (first, second... and tenth decil)	Inequality of income distribution Gini coefficient (2018-2022)	Link to Kolada database	Link to Nastat	Danmarks Statistik	freely available @ infostat.nsi.bg
		S80/S20 ratio (2019-2021)		Inequality of income distribution S80/S20 income quintile share ratio (2018-2022)		Link to Nastat		freely available @ infostat.nsi.bg

Source. Authors' own elaboration

Table 10 – Regionally indicators for which data is available in the European Statistics (Eurostat) repository.

Indicators in literature review	Indicator in Eurostat	Link	SDG
Average personal income	Income of households by NUTS 2 regions	Link to data in Eurostat	10
Employment rate	Employment (thousand hours worked) by NUTS 2 regions	Link to data in Eurostat	8
	Employment rates by sex, age, educational attainment level, citizenship and NUTS 2 regions	Link to data in Eurostat	
Households and public places with internet connections	Households with broadband access	Link to data in Eurostat	9
	Households with access to the internet at home	Link to data in Eurostat	
Urban population density	Population density by NUTS 2 region	Link to data in Eurostat	11
	Population density by NUTS 3 region	Link to data in Eurostat	
Female/male life expectancy	Life expectancy by age, sex and NUTS 2 region	Link to data in Eurostat	3
Number of households below the poverty line	At-risk-of-poverty rate by NUTS regions	Link to data in Eurostat	1
	Persons at risk of poverty or social exclusion by NUTS regions	Link to data in Eurostat	
	Persons living in households with very low work intensity by NUTS regions (population aged 0 to 64 years)	Link to data in Eurostat	
Crime rate	Police-recorded offences by NUTS 3 regions	Link to data in Eurostat	16
Annual number of transportation accidents	Victims in road accidents by NUTS 2 regions	Link to data in Eurostat	11
Rate of education and engagement	Participation rate in education and training (last 4 weeks) by NUTS 2 regions	Link to data in Eurostat	4
	Students by level of education, orientation, sex and NUTS 2 regions	Link to data in Eurostat	
Car ownership rate	Stock of vehicles by category and NUTS 2 regions (passanger cars)	Link to data in Eurostat	11
Motorcycle ownership rate	Stock of vehicles by category and NUTS 2 regions (motorcycles)	Link to data in Eurostat	11
Recycling ratio for solid waste	Recycling rate of municipal waste	Link to data in Eurostat	12

Source: authors' own elaboration

5.2.3. Lessons to be learned for the development of a set of indicators

It was mentioned above that the purpose of the indexes presented in academic literature might be to challenge existing measures, or to discuss the possibilities or needs for new ways of measuring. Therefore, in this section we would like to point to a few specific indicators used only in one of our case study regions that might be relevant for all four, as well as for a set of sustainability indicators.

Both supply and demand of sustainable options matter

In both Navarra and Värmland there is data on the preconditions for cycling that relates to the "*Bicycle infrastructure index*" that is presented in the literature. It strengthens the usability of a cycling related index to be able to point not only to the ownership rate of bicycles or to the kilometers cycled, but to the supply of lanes. In Navarra there is spatial data, and in Värmland there is information on kilometers of bike lanes. Simply measuring the numbers of bicycles is not measuring sustainable development.

A similar added aspect can be seen when it comes to the indicators "*Car ownership rate***"** and "*Areas covered with public transportation system*" from the literature review. For Värmland there is data not on ownership, but the actual use of cars measured in kilometers driven per year. There is also data on the share of cars that can use fuel from renewable sources. Both variables contribute to a measurement of change and to a development that a regional authority can influence. Regarding public transport there is data available on both the supply of public transport in kilometers and in numbers of trips taken in the case of Värmland. That means that both the supply and demand side of public transportation can be included in a measurement, which would be ideal. In addition to this there is data on the share of inhabitants that live near public transport. More specifically, the share of population in the geographical area that has a public transport stop within 500 meters from their home, and the stop needs to be trafficked at least once every hour between 6am and 8pm. Simply having a bus stop nearby is not enough in the long term for development to move towards less car use on a societal level, you need to be able to trust that the option is in fact usable.

Social welfare data is complex

Southern Denmark stands out in the overview when it comes to data related to social welfare. In the literature, the suggested indicator is "*Social welfare expenditure***".** The Danish regions have data on several social welfare indicators that is both of economic and of other types (e.g. pensioners, residents of nursing homes, recipients of home care, parental leave benefits, housing allowance, a quality-of-life index etc.) This shows the complexity of social welfare data. There is so much that could be measured, and a composite "social welfare expenditure index" can be constructed using many different indicators. It can be assumed that there is similar information for other European regions regarding social welfare expenditure, but it can also be assumed that the types of indicators differ a lot. An important reason for this is policy and politics. A change in government might mean new policy tools and new classifications. Simply measuring a total of "social welfare expenditure" might consequently obscure more than it explains. In addition, you need to decide if a low or high expenditure is what matters to the index. A high expenditure might mean an unsustainable social situation in the region, but it might also mean that the region is making a strong social sustainability effort. Correspondingly, low social welfare expenditure might mean few social sustainability problems or not aiming to solve the problems.

New environmental risks, new indicators

In Navarra, there is regional data on "*Deaths attributed to natural disasters per 100,000 inhabitants (2010-2021)"*. This is an indicator that might become important for all regions to be able to measure and compare the serious risks of e.g. floods or landslides in relation to climate change, or to be able to specifically point out the health risks of climate change. Regardless of the current situation in a region or country, it is important to be able to discuss these types of risks to sustainable development.

Central aspects of sustainability are hard to measure

Navarra has data on "Proportion of cities with a direct civil society participation structure in urban planning and management that functions regularly and democratically" which would work for the indicator from the literature review concerning **"***Citizen participation in major planning and decision making***"**. The key here is the characterization of "functions regularly and democratically". It is a challenging thing to measure, but it points to the fact that it matters not only that the structure is there, but also that it *functions*. Relating this to the Swedish context there are legally binding forms of public consultations in urban planning, but there is no way to measure of these practices in all cases work as a democracy tool. Simply indicating that there are tools for participation is not telling us enough, consequently. It is like having a bus stop where no buses stop.

Include aspects of land use, renewable resources and regional budgeting

Looking only at the list of indicators from the academic literature review without taking availability in our case study regions into account, there are a few potential lessons to be learned. For example, if we could measure and compare *"land expansion rate"* we would potentially be able to compare the development of urban sprawl, or the share of public versus other facilities in new developments. Similarly, it would be very useful if there was a good and comparable measurement for *"parks and green areas"* that would tell us more than just the share of green space out of total land.

In one academic paper they present a sustainability index for Taipei that among other things has data on *"utilization rate for renewable resources"* (percentage share of renewables in primary resources)". Another academic paper uses the indicator *"Environmental and ecological budget ratio to total budget"***.** In the same way as was discussed above for social welfare, this is a challenge to compare, since there are many ways to categorize environmental and ecological in a budget. Also, the normative discussion on costs of sustainability efforts is hard to fit into an indicator.

5.2.4. Outlook and concluding remarks

It is clear from the above that the data provided by the four regions is not enough basis for measuring regional sustainability. It is also clear that Eurostat is a good source for additional data on indicators for all four regions, although perhaps still not enough as a basis for measuring regional sustainability. But, they do collect and mainstream according to good standards. However, are the indicators available in Eurostat the best measurement of regional sustainability? That can be discussed. Using quantitative indicators for regional sustainability we consider that it is necessary to have indicators measuring economy (e.g. income, poverty/wealth gap, employment), social welfare and public health, transportation and land use (e.g. use of sustainable transport, supply of sustainable transport options, share of qualitative green space), pollution and waste (e.g. water pollution, air pollution, recycling of waste). However, exactly which indicators cannot be concluded from this analysis. We have tried above to use the literature review and the information from the four case study regions to learn something new about relevant indicators and the challenges of measuring sustainability. Among the lessons learned is that simple measurements of numbers of cars or bicycles are not always useful, that spatial data of different kinds are important (mapping coverage, networks, land use and expansion etc.) and that measuring and comparing social aspects of sustainability is complex since it is political and context specific. An interesting next step would be to present the indicators identified in the analysis to regional officials in Värmland, Navarra, Southern Denmark and Gabrovo, but not used by all four regions, to see if they are perceived as possible new indicators in the regional context and as support for improving a monitoring tool for smart sustainable development.

The usefulness of the indicators is dependent on yet another issue; whether the purpose is to follow the development in one region over time or to compare across regions. Sound comparisons need data that has been mainstreamed according to good standards, which might mean fewer indicators. But if the central purpose is the development in one region, there might be more specific and updated data. However, despite the challenge to compare the same indicators, there is the possibility of learning and inspiration across regions.

5.3. S4 areas and firm indicators

The purpose of this analysis is to refine the list of S4 areas and firm sustainability indicators identified from the systematic literature review and offer a comprehensive yet parsimonious set of indicators that is practically relevant and manageable at the firm level.

The starting point was a list of S4 areas and firm indicators extracted from a systematic literature review (Table 1). Among the list of indicators, some of them may be transversal across sectors, but most of the identified indicators are specific to sectors such as agriculture, fishing, energy, tourism, and manufacturing sectors. It is clear from the systematic literature review that the energy sector has received the most attention. Most of the S4 areas and firm indicators are composite indicators containing either simple indicators or composite indicators. While 20 indicators addressed all three pillars of sustainability, 4 indicators covered two dimensions of sustainability (3 for economic and environment and 1 for economic and society) and 5 addressed only one sustainability pillar.

This list of indicators only informs us what firm indicators have been included in the academic literature, but it does not synthesize and streamline redundancy among the indicators. In the next section, we detail each of the steps to carry out the analysis. In Table 11, we can see the roadmap and the steps of the analysis.

Table 11 - Steps of the analysis

Step 1	Initial Classification and Separation into Pillars
Step 2	Creating Categories within Each Pillar
Step 3	Segregation into Generic and Industry-Specific Groups
Step 4	Customization for SME Relevance
Step 5	Thematic Analysis for Sustainability Dimensions

Source: Authors' own elaboration

Step 1: Initial Classification and Separation into Pillars

In this first stage, all indicators were classified into three main pillars—social, environmental, and economic variables—based on what each indicator measured. Following this classification, the indicators were separated into distinct pillars, creating social, environmental, and economic groups, providing a clear thematic delineation.

Step 2: Creating Categories within Each Pillar

Specific categories were established within each pillar to organize the indicators further based on thematic similarities.

Step 3: Segregation into Generic and Industry-Specific Groups

The comprehensive table was divided into two separate groups: one for generic indicators (common across multiple industries) and another for industry-specific indicators (tailored for certain industries). From the generic group, variables tailored explicitly for SMEs were selected and listed separately. Given that the priority areas selected in an S4 may include companies of very different sizes, and given that small and medium-sized enterprises may be more limited in terms of calculating indicators, the selection focuses on the latter. Indicators identified for SMEs can also be calculated for larger enterprises.

Step 4: Customization for SME Relevance

This customization was crucial, acknowledging that SMEs often face resource constraints. Considering their potential limitations, the chosen indicators needed to be pragmatic and feasible for SMEs to measure and improve sustainability in three dimensions: environmental, social, and governance/economic sustainability. Key criteria for selection included applicability to SMEs, industry neutrality, and ease of measurement, ensuring practicality for smaller businesses.

- *Applicability to SMEs*: The selected indicators must be pragmatic and feasible for SMEs to measure and improve. Considering that SMEs may lack the extensive resources available to larger corporations, our focus is on indicators that align with the operational realities of smaller businesses.
- *Industry Neutrality*: To cater to SMEs across various sectors, we prioritize broadly applicable indicators, ensuring relevance irrespective of the industry in which a business operates.
- *Ease of Measurement*: Recognizing the potential constraints SMEs face in terms of resources and infrastructure, we opt for relatively straightforward indicators to measure. We ensure that the data collection process is manageable for smaller organizations.

Table 12 presents sustainability indicators for firms derived from step 4. This comprehensive list of indicators for companies can be adapted for the study of an industry and thus serves as a reference for the measurement of sustainability in areas of smart specialisation. It is important to consider how smart specialisation strategies contribute to the sustainable development of regions and Table 12 presents a starting point for developing indicators to monitor this contribution (see Section 6).

Table 12 – Sustainability indicators for firms

	Economic	Environmental	Social
1	**Profitability** Net profitability Return on assets Return on equity Operating profit margin ratio	**Waste Management:** Waste for recycling and disposal Waste for recycling Reduction of production waste in percentage in the last three years	**Community Engagement and Events:** Number of community initiatives. Social events organized.
2	**Liquidity** Current ratio Working capital Gross revenues ratio Cash flow ratio	**Energy Consumption:** Total energy consumption Energy efficiency	**Quality of Life and Wellbeing:** Life satisfaction. Wellbeing Standard of living.
3	**Efficiency** Asset turnover ratio Operating expense ratio Depreciation expense ratio	**Wastewater and Water Quality** Wastewater COD emissions into surface waters	**Community and Workforce Wellbeing:** Employee education and skills. Health and safety. Job creation.
4	**Stability and solvency** Fixed assets-total assets ratio Equity fixed-assets ratio Debt-equity ratio	**Resource Consumption:** Water consumption Natural gas consumption	**Education and Skills Development** Training and expertise. Childhood education.
5	**Resource mobilization** Access to finance Fundraising Microcredit	**Biodiversity and Conservation:** Number of strategies for managing impacts on biodiversity Ecosystem conservation Wildlife protection Ecosystem conservation Soil erosion	**Equality and Empowerment:** Gender equality/empowerment.
6	**Financial accountability** Economic transparency Economic traceability	**Climate Change and Carbon Management:** Climate change	**Health and Well-being:** Medical/health care Clean water

		Carbon reduction Carbon footprint Carbon neutral Carbon emission Carbon impact Greenhouse gas emission	Nutrition
7	**Sales and market share** Total sales Net sales Market share Market growth	**Environmental Performance Metrics:** Energy intensity Non-renewable materials intensity Waste Environmental compliance Supplier environmental assurance	**Working Conditions:** Conditions and hours.
8	**Cost** Inventory turnover Delivery costs Transportation costs Investment cost	**Material Consumption:** Material consumption - Efficiency Material consumption - Availability Material consumption - Recycling Material consumption - Value recovery Material consumption - Renewables	**Livelihood and Standards of Living:** Living standard. Poverty alleviation.
9	**Productivity** Added value per employee	**Environmental Impact:** Emission Effluent Waste	**Child Welfare and Labor Practices:** Child labor.
10	**Value creation** Added Value (Net Sales - Cost of Purchases)	**Emission:** CO2 emissions Dust emissions emissions in percentage in the last three years	**Community Infrastructure:** Sewer system. Security offense
11	**Economic growth and stability** Firm contribution to GDP		**Demographic and Human Metrics:** Mortality. Income Disparity.
12	**Market development** Market presence		**Health and Safety Metrics:** Recordable injury rate. Safety.
13	**R&D and innovation** Innovation frequency (e.g., sales of products within less than three years in the markets) Total innovation R&D expenditure		**Human Rights and Labor Practices:** Human rights assessment. Non-discrimination.
14	**Community and commercial investments** Donations and other community investments Commercial investments		**Occupational Health and Safety:** Occupational health & safety - Injury rate.
15	**Business ethical practices** Anti-corruption Contract default		**Labor Practices and Productivity:** Labor productivity.
16			**Governance:** Governance - Transparency.
17			**Compliance with Social Standards:** Compliance with social standards - Values.
18			**Marketing & Communication:** Marketing benefits.
19			**Training & Education:**

			Training.
20			**Employment:** Employment type. Job creation.

Source: Authors' own elaboration

Step 5: Thematic Analysis for Sustainability Dimensions in SMEs

This last step moves away from the objectives of this work to propose a selection of indicators to measure the sustainability of companies in its three dimensions. We distinguish this result from the previous ones as it does not attempt to monitor the contribution of the S4 to regional sustainability but rather the sustainability of the companies themselves.[6]

Economic Dimension

Following a thematic analysis focused on economic sustainability for SMEs, indicators such as profitability, liquidity, efficiency, stability, resource mobilization, and financial accountability have been chosen. This analysis identified these indicators as directly reflecting SMEs' financial health, operational efficiency, and resilience, aligning with the core objectives of economic sustainability. For instance, indicators like market development and R&D and innovation were excluded based on the thematic analysis findings. These indicators primarily measure external market factors and innovation investments, rather than internal economic sustainability outcomes identified as priorities for SMEs. Our focus remains on selecting indicators directly relevant to SMEs' financial performance and resource management, ensuring actionable insights for sustainable business practices.

Social Dimension

Through a thematic analysis focused on social sustainability for SMEs, indicators such as community engagement, quality of life, workforce wellbeing, education and skills development, equality and empowerment, and health and wellbeing have been prioritized. These indicators directly reflect SMEs' social impact on their employees, communities, and stakeholders, aligning with the core objectives of social sustainability. For instance, indicators related to human rights, labor practices, and child welfare were excluded based on the thematic analysis findings. These indicators overlap with existing indicators such as workforce wellbeing and equality and empowerment, thus streamlining the list to ensure clarity and focus on essential aspects of social sustainability relevant to SMEs.

Environmental Dimension

Through a thematic analysis focused on environmental sustainability for SMEs, indicators such as waste management, energy consumption, wastewater and water quality, resource consumption, biodiversity and conservation, and climate change and carbon management have been prioritized. These indicators directly reflect SMEs' environmental impact and efforts to

[6] In another work package (WP3) of the ARIES4 project, work is being done on sustainability monitoring at company level. The selection made in Table 13 is the contribution of this work (WP2) to this work package (WP3).

reduce resource usage, minimize pollution, and address climate change, aligning with the core objectives of environmental sustainability. We excluded indicators related to environmental performance metrics such as energy intensity, material consumption, environmental impact, and emissions due to identified overlaps with broader indicators already included in our refined list. Our analysis indicated that these metrics may not adequately capture the specific environmental challenges SMEs encounter. For example, SMEs often face unique operational constraints and resource limitations compared to larger corporations, which can influence how environmental sustainability is measured and managed. Therefore, indicators like energy intensity and material consumption, while valuable, may not fully capture the environmental challenges faced by SMEs.

Furthermore, these excluded indicators overlap with broader categories already covered in our refined list. For instance, energy intensity and material consumption correlate with waste management and resource consumption, while environmental impact indicators such as emissions overlap with biodiversity and conservation, and climate change and carbon management efforts. The final list of indicators related to three dimensions are presented in Table 13.

Table 13 – Final list of sustainability indicators for SMEs

Economic	Environmental	Social
Profitability Net profitability Return on assets Return on equity Operating profit margin ratio	**Waste Management:** Waste for recycling and disposal Waste for recycling Reduction of production waste in percentage in the last three years	**Community Engagement and Events:** Number of community initiatives. Social events organized.
Liquidity Current ratio Working capital Gross revenues ratio Cash flow ratio	**Energy Consumption:** Total energy consumption Energy efficiency	**Quality of Life and Wellbeing:** Life satisfaction. Wellbeing Standard of living.
Efficiency Asset turnover ratio Operating expense ratio Depreciation expense ratio	**Wastewater and Water Quality** Wastewater COD emissions into surface waters	**Community and Workforce Wellbeing:** Employee education and skills. Health and safety. Job creation.
Stability and solvency Fixed assets-total assets ratio Equity fixed-assets ratio Debt-equity ratio	**Resource Consumption:** Water consumption Natural gas consumption	**Education and Skills Development** -Training and expertise. Childhood education.
Resource mobilization Access to finance Fundraising Microcredit	**Biodiversity and Conservation:** Number of strategies for managing impacts on biodiversity Ecosystem conservation Wildlife protection Ecosystem conservation Soil erosion	**Equality and Empowerment:** Gender equality/empowerment
Financial accountability Economic transparency Economic traceability	**Climate Change and Carbon Management:** Climate change mitigation Carbon reduction Carbon footprint Carbon neutral Carbon emission Carbon impact Greenhouse gas emission	**Health and Well-being:** Medical/health care Clean water Nutrition

Source: Authors' own elaboration

6. Regions and S4: measuring sustainability

Interesting results on the measurement of sustainability are obtained from the three analyses in the previous section. The comparison and integration of these analyses is now necessary to extract the indicators that can be considered as minimum indicators for measuring sustainability. Although it is necessary to consider the three pillars together, we first conduct an analysis of findings in each pillar and then proceed with their integration into a single proposal. In each sub-section we present a graphical summary of the selected indicators, grouped in thematic blocks; this summary is explained in detail in the text. The summary cards for each of these blocks can be found in Annex 6.

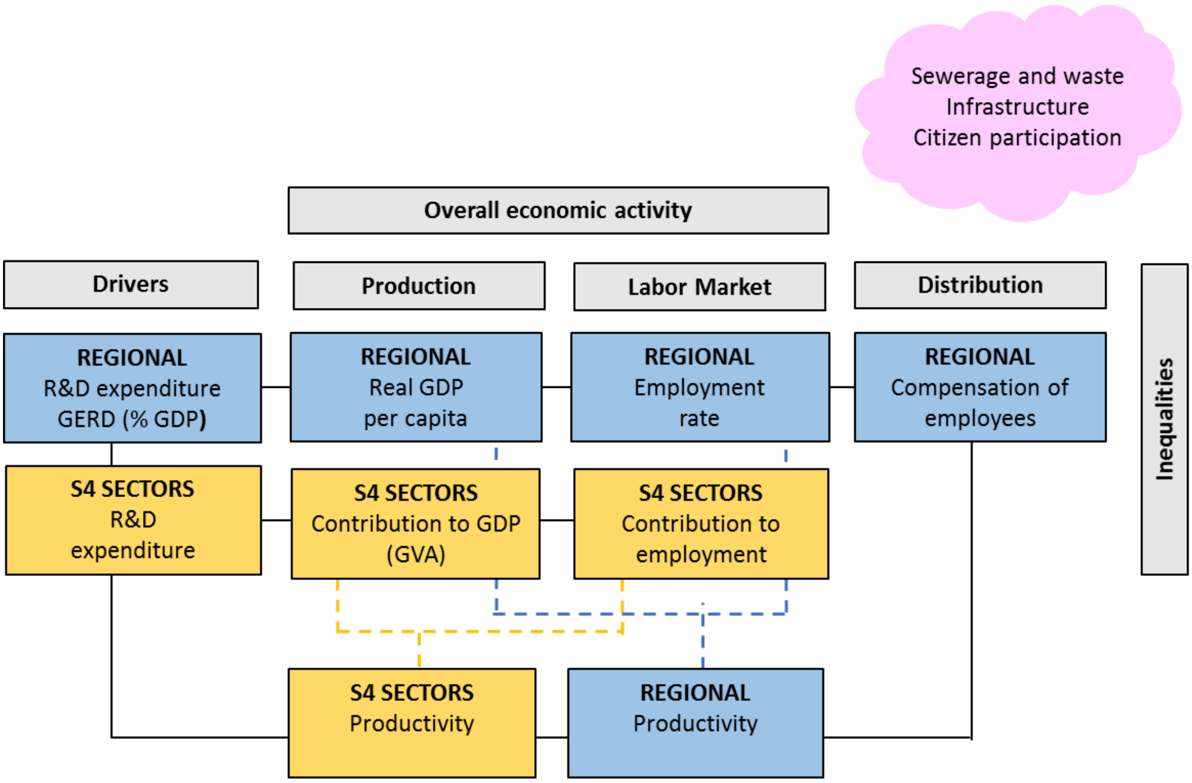
6.1. Economic pillar

Figure 16 shows a graphical summary of the indicators that we have selected as the minimum necessary to monitor the sustainability of the territories and/or areas of specialisation. The indicators selected for monitoring economic sustainability in territories appear in blue boxes and in areas of specialisation appear in yellow boxes. Below, we develop the content and reflections that have allowed us to reach these results.

The results presented in the previous sections allow us to select relevant indicators to monitor sustainability from an economic point of view. Thus, the quantitative analysis has allowed us to identify two groups of indicators that provide relevant and different information on this pillar. A close analysis of these two groups (see Table 7) shows that most of them are related in one way or another to the measurement of a territory's GDP. On the one hand, we have GDP itself but also GNI, which are well-known measures of global economic activity whose calculation is widely spread and harmonized across territories. This can be seen in the analysis carried out by regional comparisons, where GDP is calculated in the four territories.

On the other hand, in the quantitative analysis we also find indicators related to the estimation of GDP, both on the demand side (household final consumption, gross capital formation, exports and imports) and on the income side (compensation of employees, gross operating surplus or even real labour productivity per hour worked). The first group (demand-side estimation) has high correlations with GDP itself, while the second group (income-side estimation) provides different information on economic performance. In this analysis, however, there are no indicators related to GDP in its supply-side estimation (gross value added of different economic activities). But these indicators do have relevance in the analysis carried out on the areas of specialisation (see Table 12). In fact, the contribution of the areas of specialisation to the GDP of the territory can be important drivers of this GDP.

Figure 16 – Economic Pillar. Graphical summary.



Source: Authors' own elaboration

In relation to the monitoring of the economy at the regional level, the regional comparative analysis identified, in addition to GDP, the employment rate (see Table 7). In the case of the quantitative analysis, correlations were high between the unemployment rate and GDP, concluding that they provided similar information. However, based on the regional comparative analysis and due to the relevance of the labour market in the economy of any territory, we also propose to use an indicator related to this market to analyse the sustainability of the economy in a territory. In this case, following the regional comparative analysis, we select the employment rate as an indicator. Following the previous idea of measuring regional GDP and the contribution of the areas of specialisation to GDP, in this case we also propose as an indicator the contribution to employment of the areas of specialisation of the territory. Thus, we propose two blocks to measure the overall economic activity, production and labor market, with the corresponding indicators:

- *Block*: Production.
  - *Proposal for territorial indicator*: Real GDP.
  - *Proposal for S4 indicator*: Gross value added (GVA) by area of specialisation.
- *Block*: Labor Market.
  - *Proposal for territorial indicators:* Employment rate
  - *Proposal for S4 indicator:* Employment by area of specialisation.

The estimation of output and employment related indicators allows productivity estimates to be made. Therefore, the combination of these two blocks makes it possible to obtain additional information on the evolution of economic activity through the analysis of productivity. The dotted lines linking these blocks in Figure 16 reflect this possibility and lead to these additional indicators.

- *Block Combination*: Production + Employment
  - *Proposal for territorial indicator*: Productivity.
  - *Proposal for S4 indicator*: Productivity.

As we have pointed out above, the calculation of GDP on the income side has been shown to give different information from that given by the evolution of GDP. This estimate of GDP provides information on the distribution of income among different factors of production in the economy, labour (compensation of employees) and capital (gross capital formation). Therefore, we add an additional block in the monitoring of the economy, which we call distribution and as an indicator we choose compensation of employees (as a percentage of GDP).

- *Block*: Distribution.
  - *Proposal for territorial indicator:* Compensation of employees.

These distributional issues lead us to raise the need to measure economic inequalities, both in terms of income distribution and in terms of employment (e.g. in relation to the gender gap, age gap or other social issues). We will return to these distributional ideas in the next section on the social pillar of sustainability.

In addition to the contribution of the areas of specialisation to GDP, another indicator identified in the analysis of these areas is R&D investment. It is worth mentioning that innovation is at the core of smart specialization strategies (Fontana el al., 2023). This could also be complemented with R&D expenditure in the region, which could also be a relevant indicator in the analysis of the evolution of GDP and its drivers. R&D can also influence productivity. Therefore, we come to an additional block of analysis, drivers of the economic activity with the indicators on R&D. It should be noted that productivity is also related to employee compensation (see the continuous connecting lines between blocks and/or indicators in Figure 16).

- *Block*: Drivers.
  - *Proposal for territorial indicator:* Gross R&D expenditure (GERD) as a percentage of GDP.
  - *Proposal for S4 indicator:* R&D expenditure in areas of specialization.

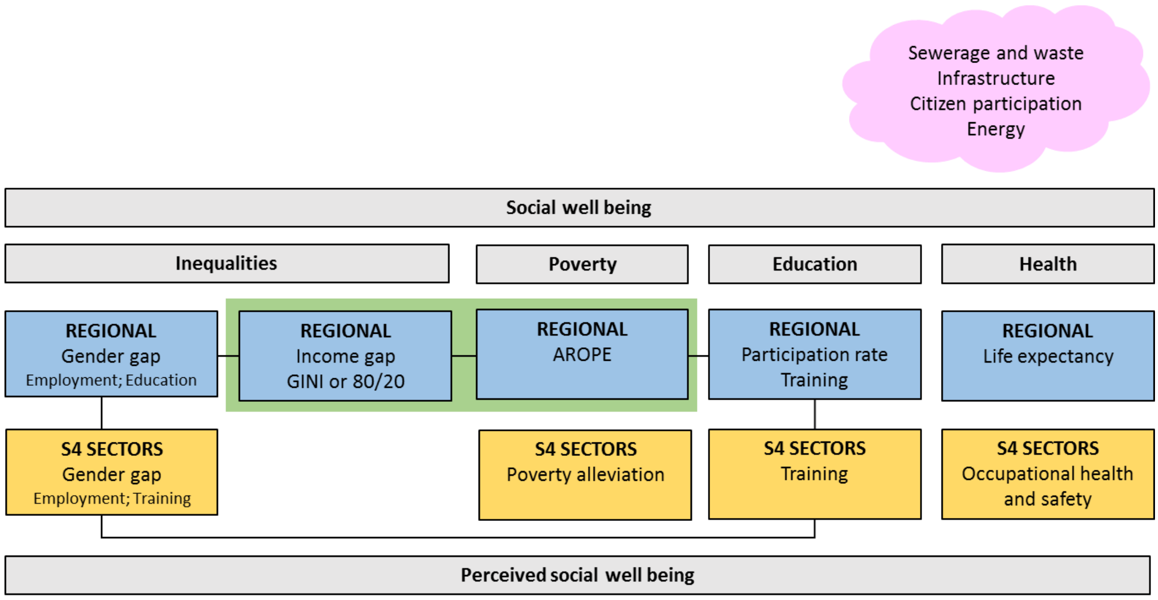
As we have pointed out in this analysis, some economic issues are related to issues that are also considered social, such as inequalities between different groups (gender, age, disability, ethnicities or others). We have also identified indicators (especially thanks to the regional comparative analysis) that have an economic concern but involve more issues. These are indicators related to physical infrastructure (transport, access to information and communication technologies, sewerage, public sanitation) but also to social infrastructure (citizen participation). In the graphical summary in Figure 16, we keep these indicators in a pink bubble given their relevance and their scope that goes beyond the economic pillar. As we will see later, the analysis of the social and economic pillars of sustainability and their interrelationships will allow us to further elaborate and clarify what appears in this pink bubble.

6.2. Social pillar

Following a similar process to that used for the economic pillar, Figure 17 presents a graphical summary of indicators selected for monitoring social sustainability both in territories (blue boxes) and in areas of specialisation (yellow boxes). In what follows, we develop the meaning and interpretation of this graphical summary.

The analyses carried out have allowed us to group the indicators into four blocks that are clearly related to social welfare. These are poverty, education, health and inequalities. Therefore, these four broad blocks are considered relevant for a social sustainability analysis. It should be noted that each of these broad social blocks corresponds to at least one SDGs: SDG1: No Poverty, SDG3: Good health and Well-being, SDG4: Quality Education, and SDG5: gender equality and SDG10: Reduced Inequalities.

Figure 17 – Social Pillar. Graphical summary.



Source: Authors' own elaboration

Starting with the first of these blocks, poverty, we propose the well-known AROPE (At Risk Of Poverty and social Exclusion) as an indicator. One of the reasons for this choice is that this indicator is an aggregate of other poverty indicators such as at risk of poverty rate, severe material deprivation rate and low work intensity indicator. As expected, the changes in these three indicators give similar information to that obtained by analysing AROPE, as can be seen in the results obtained from the quantitative analysis (see Table 7). In the case of the regional comparative analysis, the results show Households below the poverty line as an indicator. As we have just pointed out, this is an indicator included in the AROPE calculation, so we have opted to keep the latter. Along the same lines, it might be interesting in poverty analysis to consider how areas of specialisation can contribute to poverty alleviation. However, the analysis carried out for companies and productive sectors has not yielded clear conclusions on concrete indicators that can be used for this purpose. Another reason supporting the use of this indicator is that its statistical definition is sound, and its use is widespread.

This poverty measurement should also be complemented by indicators that assess income inequality. This is a point that we had already arrived at from economic analysis, the need to assess inequalities. To measure income inequality, we propose two possible well-known indicators, the GINI index and/or the 80/20 ratio. Variations in poverty can be accompanied by variations in income inequality. The relationship between these two factors in a region can be particularly relevant for policy implementation. Do redistributive policies aimed at reducing income inequality also reduce poverty? Do policies aimed at reducing poverty influence inequality? We therefore consider that these two factors, poverty and income inequality, should be analysed jointly. Thus, in the graphical summary in Figure 17 the corresponding indicators are linked by a green box.

How firms can contribute to reducing inequality is not well defined. Even if it were possible to have firm-level information on the difference or ratio between the highest and the lowest wage within the firm, changing it has no clear effect on inequality at the regional level. For example, if the lowest wage in the firm or sector is at the average wage level at the regional level, an overall increase in wages in these firms, without changing the ratio between the highest and the lowest wage, may lead to a change in inequality at the regional level. Therefore, it has been decided not to reproduce the inequality analysis at the S4 level, but to keep it at the regional level.

Other indicators related to poverty that may be relevant are those linked to expenditure on social programmes and the effectiveness of these programmes, as pointed out in the regional comparative analysis. But this idea of social expenditure is also related to other important social blocks which we will discuss below, such as education and health. There are other public expenditures that could be relevant for sustainability analysis like expenditure on environmental programmes. Therefore, public expenditure can be related to something more generic that addresses sustainability in general and not just one of its pillars, something we could call the "social infrastructure" that includes the structure of public expending. We keep this idea in the pink bubble in the graphical summary to indicate its relevance beyond the sphere under consideration, in this case the social one.

Therefore, from these reflections we obtain:

- *Block*: Poverty.
  - *Proposal for territorial indicator:* AROPE (At risk of poverty or social exclusion).
  - *Proposal for S4 indicator:* Poverty alleviation.

If we focus our attention on the education block, we propose two indicators at territorial level: the participation rate at different educational levels and what we have called training. The first one tries to monitor the education that we can consider more formal: primary, secondary, tertiary (general or vocational). By training we refer more to lifelong learning: training courses throughout professional life and development of new competences and skills. This training takes place outside more formal education and for age levels outside education standards (over 25 years old). In this sense, it is important to assess the contribution of the areas of specialisation to this lifelong learning (training of their employees). Therefore, this training indicator is also proposed for the sustainability assessment of specialization areas, as shown in the graphical scheme in Figure 17.

An important point within the education block, is the possible gender inequality in educational participation (especially at non-compulsory educational levels, such as tertiary or vocational) and in lifelong learning. Gender inequality in education, but also in other spheres of life, is an important issue for social sustainability. Therefore, we link education indicators, both territorial and areas of specialisation, to gender gap.

From these reflections on education, we get:

- *Block*: Education.
  - *Proposal for territorial indicator:* Participation rate in different educational level; Training (lifelong learning).
  - *Proposal for S4 indicator:* Training (lifelong learning).

We now turn to the health block. From both the quantitative analysis and the comparative analysis between regions, life expectancy is obtained as an indicator that provides relevant information (the correlation analysis with other indicators reflects this relevance due to its relationship with other social indicators, but also with economic and environmental indicators) and as an indicator whose availability is general between territories. On the other hand, in the analysis carried out for companies and productive sectors, "Health and safety" is selected as a social indicator. Although no specific indicator is provided for this idea, we propose to monitor health and safety by measuring the number of occupational accidents (fatalities and injuries) in each area of specialisation.

Thus, for the health block we propose:

- *Block*: Health.
  - *Proposal for territorial indicator*: Life expectancy
  - *Proposal for S4 indicator*: Occupational accidents (fatalities and injuries).

Having reached this point, we can also draw conclusions about the inequalities block. We have already pointed out the importance of measuring income inequalities and analysing their evolution together with poverty indicators. We have also pointed out the need to calculate possible gender gaps in education. We have also come to inequality-related issues from economic indicators (distributional issues). Therefore, we select to measure gender gap for social indicators, such as education, but also for economic indicators such as employment. For a correct analysis of social sustainability, we must also take into account that inequalities can affect other social groups, not only gender groups. Gaps due to age, ethnic groups or different abilities may be relevant in some territories.

- *Block*: Inequalities.
  - *Proposal for territorial indicator*: Gini index; Ratio 80/20; Gender gap (employment, education).
  - *Proposal for S4 indicator*: Gender gap (employment, education).

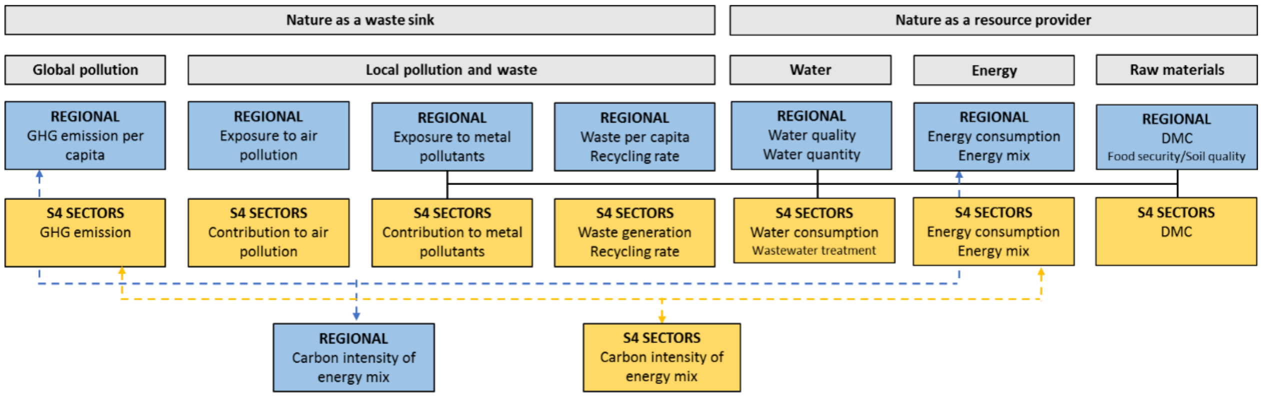
All in all, we can point out that, in order to monitor social sustainability, it is necessary to measure what can be generically called social well-being. This social well-being has multiple dimensions. In our proposal, these dimensions are four: poverty, education, health, and inequality. It should be noted that inequality also has multiple dimensions, both in terms of the aspect being measured (income inequality, inequality in employment or inequality in education) and in terms of the social blocks in which inequality is measured (general for society, gender, or age, among others). We represent this idea in the graphical overview with the upper grey box covering all social dimensions.

Another relevant issue is the perception that citizens have of this social well-being. In fact, the quantitative analysis has detected a social indicator whose evolution is different from other social indicators. This is the Ladder of life indicator, a subjective indicator based on a survey on perception and expectations of well-being and used in some composite indicators such as the Happy Planet Index. The ladder of life is commonly used as an indicator of how people's lives are going overall (WEAll, 2021). Therefore, we consider that, in addition to the objective indicators we have selected, indicators on the perception of social well-being should be incorporated in territorial analyses, as the perception may show different information from that shown in other indicators. Involving society in the need to be sustainable is a key issue for the future of our societies. We represent this idea in the graphical overview with the grey box below which also covers all social dimensions.

6.3. Environmental pillar

The environmental pillar of sustainability has become particularly relevant in recent times in view of the major environmental problems we are facing, such as climate change, the loss of biodiversity or the scarcity of such fundamental natural resources as water. In fact, we often speak of green sustainability, precisely to emphasize the relevance of this pillar. Some sustainability models, such as the Russian doll model or the wedding cake model, put this pillar first, pointing out that the other two dimensions of sustainability will only be achieved if we ensure environmental sustainability. But this emphasis on environmental sustainability has also triggered phenomena such as green washing. In this context, the choice of environmental indicators to monitor the green sustainability of territories and areas of specialisation becomes more relevant. However, this analysis is on the same level as those presented above, as sustainability will only be achieved if we ensure all three dimensions of sustainability (see Figure 1). As in the previous sub-sections, this analysis is graphically summarized in the diagram in Figure 18.

Figure 18 – Environmental Pillar. Graphical summary.



Source: Authors' own elaboration

Considering the results of both the quantitative analysis and the comparative analysis between regions, we observe that the indicators obtained for the environmental pillar are related to two of the functions that nature performs in our daily lives. Nature acts as a waste sink and as a provider of natural resources. In the first case, we all know that many of our day-to-day activities result in the generation of waste and pollution that sooner or later end up in nature. In the second case, nature provides us with resources, renewable and non-renewable, and amenity services that we use to produce and consume. Not forgetting, of course, the provision of life support services and the services that hold the whole functioning system together (Perman et al., 2011).

If we focus our analysis on the role of nature as a waste sink, we have to distinguish between different types of waste. On the one hand, we discharge so-called global pollutants into the atmosphere, pollutants that have a global impact. For example, greenhouse gases are global pollutants that cause damage all over the planet, regardless of the point of emission. On the other hand, we have local pollutants whose emissions mainly affect the immediate vicinity of the emission source. For example, air pollutants such as sulphur dioxide or particulate matter are considered local pollutants. Also, heavy metals are generally considered as local pollutants.

In this context, the analyses carried out point to the importance of measuring the contribution of territories, but also of areas of specialisation, to the problem of climate change. Greenhouse gas emissions or the carbon footprint were selected as good indicators to monitor the environmental sustainability of both territories and productive sectors. It should also be noted that the quantitative analysis has shown that the evolution of these emissions provides different information to that provided by other types of pollutants. Thus, from the point of view of global pollution, our proposal for sustainability indicators is as follows:

- *Block*: Global pollution.
    - *Proposal for territorial indicator*: Greenhouse gas emissions (GHG) per capita.
    - *Proposal for S4 indicator*: Greenhouse gas emissions (GHG).

In the case of local pollutants, the analyses conducted show a great variety of local pollutants. Rather than the emissions of these pollutants, the indicators measure the exposure to these pollutants or the loss of life years due to this exposure (see quantitative analysis). Indeed, indicators measuring the concentration of these pollutants showed a high correlation with health indicators such as life expectancy. We therefore propose indicators of exposure to local pollutants as a measure of the environmental sustainability of territories. Quantitative results showed similar behavior for the different local pollutants, with differences only between two major groups, air pollutants and heavy metals. Therefore, two pollutant concentration indicators are proposed, distinguishing between these two groups.

In this line, it is interesting to consider the contribution of specialisation zones to this concentration of pollutants. In this case, we propose to measure emissions, although the contribution to the concentration of these emissions may depend on more factors, such as meteorological conditions and various physical and chemical processes that determine the transfer coefficients (Perman et al., 2011).

In addition, within this group of pollutants that can be considered local, we also include urban waste, given that its management is generally local. We propose to monitor the amount of waste generated per inhabitant as well as the recycling rate. It should be noted that, in this context, the available infrastructure can be decisive, e.g. whether there is an adequate infrastructure for separate waste collection in the region under analysis. In fact, waste and sewage had already appeared in the analysis of the previous pillars and we had placed them in the pink bubble. With the analysis of the environmental pillar, waste is incorporated into the sustainability framework, but the infrastructure that conditions waste management is still a factor to be considered globally. Waste issues are also relevant in the areas of specialisation. In this case, the type of waste to be considered will depend on the area of specialisation.

Therefore, we incorporate to our sustainability framework the following indicators (see also graphical summary in Figure 18):

- *Block*: Local pollution.
  - *Proposal for territorial indicator*: Concentration of air pollutants; Concentration of heavy metals; Waste per capita; Recycling rate.
  - *Proposal for S4 indicator*: Emissions of air pollutants; Emissions of heavy metals; Waste per capita; Recycling rate

Returning to the role of nature as a provider of natural resources, we again find important references to this role in the analyses carried out, the quantitative one, the regional comparison, and the analysis of companies and sectors. Two of the most frequently mentioned resources are energy and water. To these, we can add a more general block that we call raw materials. Thus, the three blocks will be relevant both for the analysis of the environmental sustainability of the territory and for the analysis of the sustainability of the areas of specialisation.

In the case of water, there are two issues to take into account in a sustainability analysis, quantity and quality. According to the European Environmental Agency, clean water is critical for nature, and people’s health and well-being. It is also a crucial resource for many economic sectors. Due to over-exploitation and climate change, many areas in Europe increasingly suffer from water scarcity. At the same time, pollution puts additional pressure on this finite resource.

The analysis based on regional comparison has identified water quality as relevant for sustainability. There are different factors that can condition this quality, such as the emission of pollutants. For example, in many occasions, high concentration of heavy metals is found in water bodies, but also in soil (see the graphical summary in Figure 18, the lines that relate the emission of these pollutants to water and also to raw materials, which we will analyze later). Another factor that can affect water quality is agricultural uses (fertilizers), but also water quantity (Sinclair Knight Merz, 2013).

Water quantity is already a key element to take into account in any sustainability analysis. The current climate context confronts us with abrupt changes in precipitation systems, rainfall concentration and heat waves that are lengthening drought periods and the location of droughts. Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. As UN points out, water basin level data on water stress allows for an analysis of water scarcity and its impact on the population, the economy and the environment. Water consumption and wastewater treatment in specialization areas are key for the sustainability analysis of both, the specialization area and the region.

Thus, we propose the following indicators:

- *Block*: Water.
  - *Territorial indicators*: Water quality; Water quantity.
  - *S4 indicators*: Water consumption; Wastewater treatment

Energy is a resource as necessary as water for sustainability. In thermodynamics, energy is the potential to do work or provide heat. The supply and use of energy is fundamental to maintaining human well-being, but it is also behind some of the major problems we face today, such as climate change. Problems that, in turn, threaten our well-being and thus sustainability. Therefore, we propose as indicators the energy consumption both at regional level and at the level of the different areas of specialisation, as well as the corresponding energy mix (percentage of renewable energies, for example). Within the environmental analysis, we find a relationship between these two indicators and GHG emissions, as the use of fossil fuels as a source of energy generates CO2 emissions, which is the main GHG in Europe. Therefore, in the graphical summary in Figure 18, the global pollution block is linked to the energy block. As we will see below, by linking these indicators to the economic indicators, we obtain additional information on relevant variables such as energy intensity or carbon intensity.

Thus, we propose the following indicators:

- *Block*: Energy.
  - *Territorial indicators*: Energy consumption; Energy mix.
  - *S4 indicators*: Energy consumption; Energy mix.

Finally, in the block we have called raw materials, we refer to domestic material consumption (DMC), but also to issues such as food security and soil quality. Some of these issues have emerged from the comparative analysis between regions, others from the analysis of companies and sectors. Some conclusions on DMC are drawn from the quantitative analysis, but the limited availability of data on food security or soil quality has prevented the incorporation of these variables into this analysis. However, food security and soil quality, which are closely related to agricultural activity and agricultural productivity, are fundamental to sustainability. It is an economic activity, which generally has little weight in the regions' GDP, but it is strategic. It is also fundamental for social welfare. It is therefore in conjunction with the other two pillars of sustainability, economic and social. This triple perspective places agriculture at the heart of sustainability.

Thus, we propose the following indicators:

- *Block*: Raw materials.
  - *Territorial indicators*: DMC; Food security; Soil quality.
  - *S4 indicators*: DMC.

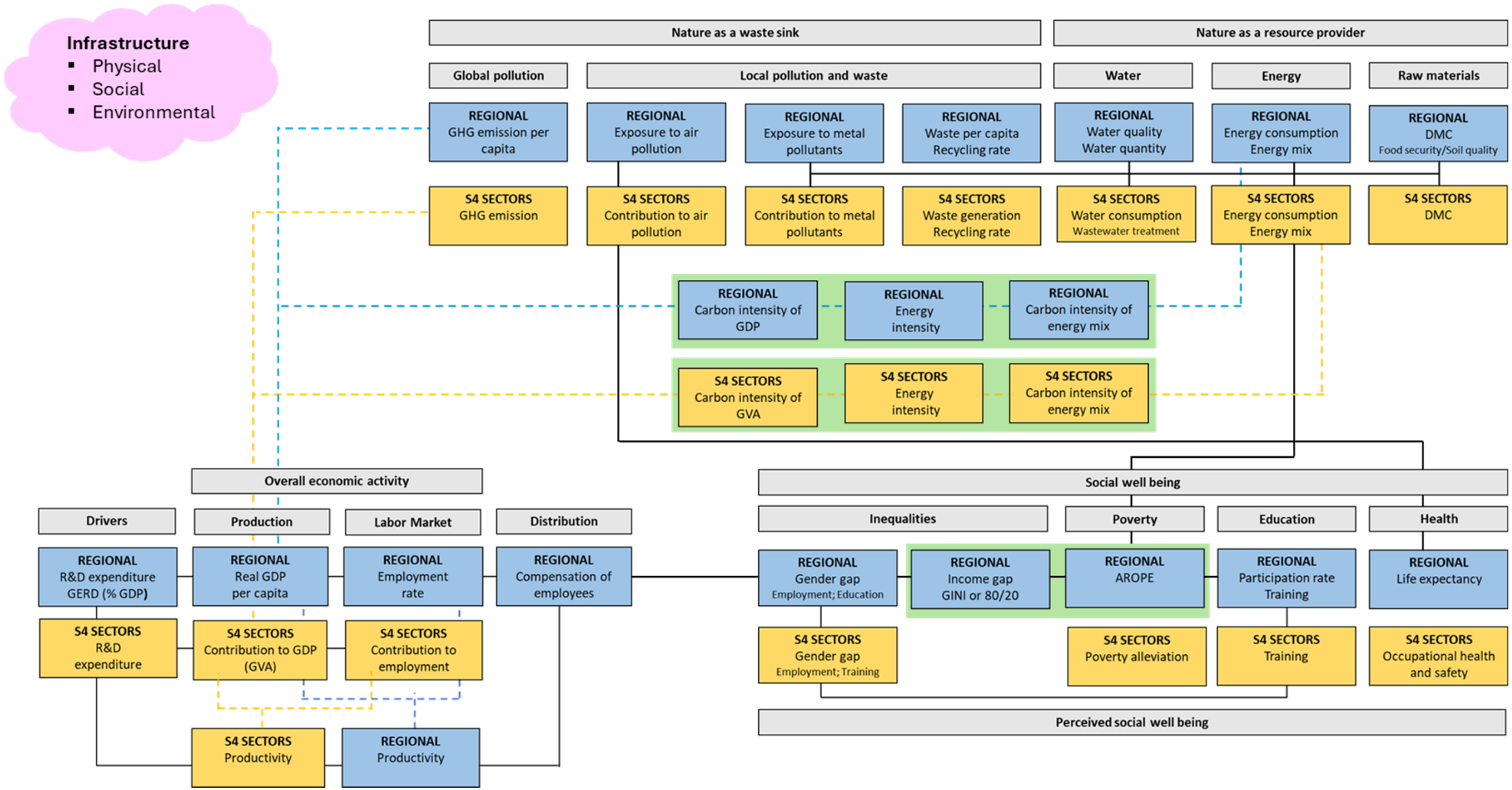
Taking an overview of this entire environmental proposal, we see that it is possible to calculate additional indicators by combining some of the proposals. In this case, one of the most used links is the one that can be made between energy consumption and GHG emissions. One of the main GHGs, CO2 comes mainly from the burning of fossil fuels for energy consumption. In fact, a clean energy transition is one of the main points of the European Green Deal. As the European Commission points out, the production and use of energy account for more than 75 % of the EU's greenhouse gas emissions. Decarbonizing the EU's energy system is therefore critical to reach our 2030 climate objectives and the EU's long-term strategy of achieving carbon neutrality by 2050. Combining energy consumption and GHG emissions, we can measure the energy intensity of the carbon mix (GHG/Energy consumption) which is a good indicator to measure the energy transition.[7] It must also be considered that the change in this indicator may be due to a transition towards renewable energies such as solar or wind but also to a transition towards nuclear. Therefore, the energy mix indicator proposed above (percentage of energy that comes from renewable resources) is also necessary to have a more complete picture of the energy transition.

6.4. Interactions among pillars

As we already pointed out in the initial reflection carried out in this report on the concept of sustainability, it is essential to consider the three pillars, economic, social and environmental, in order to have a complete picture of sustainability. Figure 19 graphically summarizes this complete vision. This figure is the aggregation of the three previous figures, Figure16 (economic pillar), Figure 17 (social pillar) and Figure 18 (environmental pillar), with the corresponding links between the pillars and indicators.

[7] A better indicator will be CO2/Energy consumption, as CO2 is the GHG more closely related to fossil fuel consumption.

Figure 19 – Sustainability: Overall graphical summary



Source: Authors' own elaboration

In this figure, we observe the following relationships. Firstly, the economic pillar is linked to the social pillar through inequalities. In the economic pillar, we propose some distribution indicators such as employee compensation. But, as we had already pointed out, this distributive measurement is not sufficient. It is also necessary to calculate the inequality of income distribution. For this reason, we link the distributive aspects of the economy with the analysis of income inequality proposed in the social pillar. There are also other economic indicators such as employment that need an analysis from the perspective of inequality, especially from the gender gap, but without forgetting inequalities in other social groups.

The joint analysis of the economy and the environment also allows for a more complete analysis of sustainability. We find the most relevant links between energy, GHG emissions and production. In the environmental analysis, we had already proposed to jointly analyze energy and GHG emissions. However, this relationship may be conditioned by economic growth. Territories and areas of specialization can work towards decarbonization by changing the energy mix and by improving energy efficiency. These efforts must be sufficient to compensate for the scale effect, that is, the fact that economic growth, which increases both production and consumption, leads to greater environmental damage (Grossman and Krueger, 1995). We can see these ideas using a decomposition analysis of GHG emissions.

$$\frac{GHG}{Pop} \equiv \frac{GDP}{Pop} \times \frac{Energy}{GDP} \times \frac{GHG}{Energy}$$

where $GHG/_{Pop}$ are GHG emissions per capita, $GDP/_{Pop}$ is GDP per capita, $Energy/_{GDP}$ is energy intensity[8] and $GHG/_{Energy}$ is the carbon intensity of energy mix. In other to decrease GHG emissions per capita the improvement in energy intensity and carbon intensity of energy mix should compensate economic growth (change in GDP per capita). We can also write this decomposition analysis in terms of carbon intensity of GDP ($GHG/_{GDP}$).

$$\frac{GHG}{GDP} \equiv \times \frac{Energy}{GDP} \times \frac{GHG}{Energy}$$

This relationship is shown in Figure 19 with a green box in which we have carbon intensity of GDP, energy intensity and carbon intensity of energy mix. As can be seen, this analysis can be done for the territories but also for the S4 areas.

Other links that should be considered in the overall sustainability analysis are the link between air pollution and life expectancy. We have identified a clear negative relation between these two in the quantitative analysis. Also, the link between energy consumption and poverty. In addition, there are all the links that we have indicated within each of the pillars.

Finally, it is important to note the idea summarized in the pink bubble in Figure 19. We have already considered other bubbles in previous subsections and have pointed out that they included aspects that encompass the three pillars. Something similar happens with this final

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[8] The inverse of energy intensity is energy efficiency, $GDP/_{Energy}$. An improvement (that is, a decrease) in energy intensity is an improvement (that is, an increase) in energy efficiency.

bubble. In it we have included a generic concept of infrastructure. The values of all the indicators that we have proposed will be conditioned in one way or another by factors such as transportation infrastructure, sanitation infrastructure, social and health services infrastructure or communication and information technology infrastructure (physical infrastructure). Also, the structure of public spending or the institutions that allow citizen participation in decision-making (social infrastructure) or simply the natural capital of the territory (environmental infrastructure). A description of these infrastructures can help us make a correct interpretation of all the indicators we have selected and their evolution.

7. Discussion and conclusions

The objective of this work was to select a minimum set of indicators necessary to monitor sustainability at the regional level and to monitor sustainability in smart specialization strategies. Smart Specialization Strategies (S3) is an economic development model that involves concentrating resources in the economic areas in which a region has significant competitive advantages. Adding a fourth S to the model highlights the need for these specialization strategies to contribute not only to the economic development of the region where they are implemented but to do so in a sustainable way, that is, contributing also to the social and environmental well-being of the region.

With these indicators, it is possible to adequately characterize the sustainability of a region, and, above all, how smart specialization strategies are integrated into the path towards this sustainability. Analyzing the relationship between regional and S4 indicators will help to identify whether or not the S4 helps the sustainability of the region. This proposal should be seen as a minimum set of indicators. It does not rule out that, depending on the specific interests of a region, this germinal set could be expanded.

We can highlight that this proposal considers the three basic dimensions of sustainability, economic, social and environmental. But it also underlines that these three dimensions are linked. The proposal becomes valuable when the indicators are interpreted together. This is perhaps one of the biggest challenges we face today as a society: we have a lot of data but it is difficult to interpret them in a way that is both informative and operational for decision-makers. Understanding socio-economic models, social structures or physical and natural constraints within a region can be key to this interpretation. We have come to call this contextualization 'infrastructure' in the broad sense. By doing so, we want to emphasize that the interpretation of similar data may be different in different regions, that is, contextualization matters.

The proposal also has some limitations, particularly with regard to the definition of indicators. While some are well known and well defined, especially the economic and social ones, others are less well known, there is no clear consensus on how to measure them or they are difficult to measure at the sub-national level. The challenge for regions is to develop this measurement capacity, or rather to focus measurement efforts on indicators that can help monitor sustainability, such as those proposed here. It is not a question of measuring many things, but of measuring those things that help us to analyze what is happening and why. Moreover, the indicators show their real value the second time you collect information for them and see the progress of your efforts.

The results of this report could be used for a discussion with regional stakeholders. Comparing this proposal with current monitoring practices, seeing its advantages and disadvantages could add value to the proposal. The exchange of ideas can help raise awareness of sustainability issues and encourage different groups to get involved in the effort. The road to sustainability concerns us all, everyone can do their bit in the process.

It is also worth noting that the proposal we make can be easily interpreted within the current context of the SDGs and the 2030 agenda. The selected indicators relate to specific SDGs (see summary of indicators by blocks in Annex 6, where indicators are linked to the SDGs) and the overview depicted in Figure 19 shows a holistic view of sustainability following the foundations underpinning the SDGs. In this sense, the steps followed for indicator selection could be interpreted as a 'translation tool' to adapt the SDGs to the regional context and its priorities.

Our analysis has focused on linking the implementation of smart specialisation strategies to regional sustainability. But we should not lose sight of the fact that the effects of these development models go beyond the regional impact. It would be of interest to consider the effects they may have in a broader context. The analysis could be extended to capture both the positive and negative effects that various sectors have outside the region by measuring the impact throughout the entire corresponding value chain: extraction of materials, manufacturing, distribution, end consumer, and finally waste.

We have tried to propose simple indicators, avoiding the complexity inherent in the calculation and interpretation of composite indicators. But we also recognise that composite indicators summarise a lot of information in a single index and are widely used. In fact, some regions are developing their own indicators. Such is the case of the Värmland region, a participant in this project (see Annex 5).

All in all, this report can be summarised in two main results: a global analysis of the indicators, their relationships with the different pillars of sustainability and the interactions between them, summarised in Figure 19, and a complete list of indicators with their characteristics, whose fact sheets, given their length, are included in Annex 6.

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Annexes

Annex 1- Countries and ISO 3166 codes.

Country	Code	Country	Code
Albania	ALB	Latvia	LVA
Austria	AUT	Lithuania	LTU
Belgium	BEL	Luxembourg	LUX
Bosnia and Herzegovina	BIH	Malta	MLT
Bulgaria	BGR	Netherlands	NLD
Croatia	HRV	North Macedonia	MKD
Cyprus	CYP	Norway	NOR
Czechia	CZE	Poland	POL
Denmark	DNK	Portugal	PRT
Estonia	EST	Romania	ROM
Finland	FIN	Serbia	SRB
France	FRA	Slovakia	SVK
Germany	DEU	Slovenia	SVN
Greece	GRC	Spain	ESP
Hungary	HUN	Sweden	SWE
Iceland	ISL	Switzerland	CHE
Ireland	IRL	Turkey	TUR
Italy	ITA	United Kingdom	GBR

Annex 2 - Main environmental indicators.

The following list contains all the environmental indicators (66). We distinguish between indicators discarded before correlation analyses (Step 2, in grey, 16 indicators) and indicators used in correlation analyses (Step 3, in bold, 50 indicators).

Indicator	Abbreviation
Ecological Footprint of production (in global hectares) per capita	Efp_pc
Ecological Footprint of production (gha)	Efp_total
Ecological footprint of production, cropland (gha)	Efp_crop
Ecological footprint of production, grazing land (gha)	Efp_grazing
Ecological footprint of production, forest area (gha)	Efp_forest
Ecological footprint of production, fishing grounds (gha)	Efp_fishing
Ecological footprint of production, built-up land (gha)	Efp_built
Ecological footprint of production, carbon demand on land (gha)	Efp_carbon
Ecological Footprint of consumption (in global hectares) per capita	Efc_pc
Ecological Footprint of consumption (gha)	Efc_total
Ecological footprint of consumption, cropland (gha)	Efc_crop
Ecological footprint of consumption, grazing land (gha)	Efc_grazing
Ecological footprint of consumption, forest area (gha)	Efc_forest
Ecological footprint of consumption, fishing grounds (gha)	Efc_fishing
Ecological footprint of consumption, built-up land (gha)	Efc_built
Ecological footprint of consumption, carbon demand on land (gha)	Efc_carbon
Biocapacity per capita (in global hectares)	Biocap_pc
Biocapacity (gha)	Biocap_total
Biocapacity of cropland (gha)	Biocap_crop
Biocapacity of grazing land (gha)	Biocap_grazing
Biocapacity of forest area (gha)	Biocap_forest
Biocapacity of fishing grounds (gha)	Biocap_fishing
Biocapacity of built-up land (gha)	Biocap_built
Carbon dioxide damage (current US$)	CO2D
Energy depletion (current US$)	ED
Mineral depletion (current US$)	MD
Net forest depletion (current US$)	NFD
Particulate emission damage (current US$)	PED
Domestic Material Consumption	DMC
CO2 emissions per capita index (production based)	CO2
Material footprint per capita index	MF
Household solid fuels	HAD
Ozone exposure	OZD
Lead exposure	PBD
PM2 5 exposure	PMD
Unsafe sanitation	USD
Unsafe drinking water	UWD
Ocean Plastics	OCP
Recycling	REC
CO exposure	COE
NOx exposure	NOE

SO2 exposure	SOE
VOC exposure	VOE
Species Protection Index	SPI
Tree cover loss	TCL
Greenhouse gas emissions per capita	GHP
Adjusted emissions growth rate for nitrous oxides	NXA
Adjusted emissions growth rate for sulfur dioxide	SDA
Marine protected areas	MPA
Terrestrial biome protection (global weights)	TBG
Terrestrial biome protection (national weights)	TBN
Grassland loss	GRL
Wetland loss	WTL
Fish Stock Status	FSS
Fish caught by trawling	FTD
Species Habitat Index	SHI
Sustainable Nitrogen Management Index	SNM
Protected Areas Representativeness Index	PAR
Adjusted emissions growth rate for black carbon	BCA
Adjusted emissions growth rate for carbon dioxide	CDA
Adjusted emissions growth rate for methane	CHA
Adjusted emissions growth rate for F-gases	FGA
Projected GHG Emissions in 2050	GHN
Greenhouse gas intensity growth rate	GIB
Adjusted emissions growth rate for nitrous oxide	NDA
Growth rate in carbon dioxide emissions from land cover	LCB

Annex 3 – Data sources for additional economic indicators.

Indicator	Source
ER	https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfe2emprtn/default/table?lang=en
SPV	https://ec.europa.eu/eurostat/databrowser/view/tran_r_vehst__custom_9488375/default/table?lang=en
SMC	https://ec.europa.eu/eurostat/databrowser/view/tran_r_vehst__custom_9488400/default/table?lang=en
UR	https://ec.europa.eu/eurostat/databrowser/view/lfsa_urgan__custom_9342976/default/table
GDP_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343035/default/table
FCEGG_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343054/default/table
FCEG_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343061/default/table
GCF_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343065/default/table
EXPGS_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343071/default/table
IMPGS_CLV	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9489208/default/table?lang=en
CEE_PGDP	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343116/default/table
COS_PGDP	https://ec.europa.eu/eurostat/databrowser/view/nama_10_gdp__custom_9343124/default/table
RLPH	https://ec.europa.eu/eurostat/databrowser/view/nama_10_lp_a21__custom_9343369/default/table

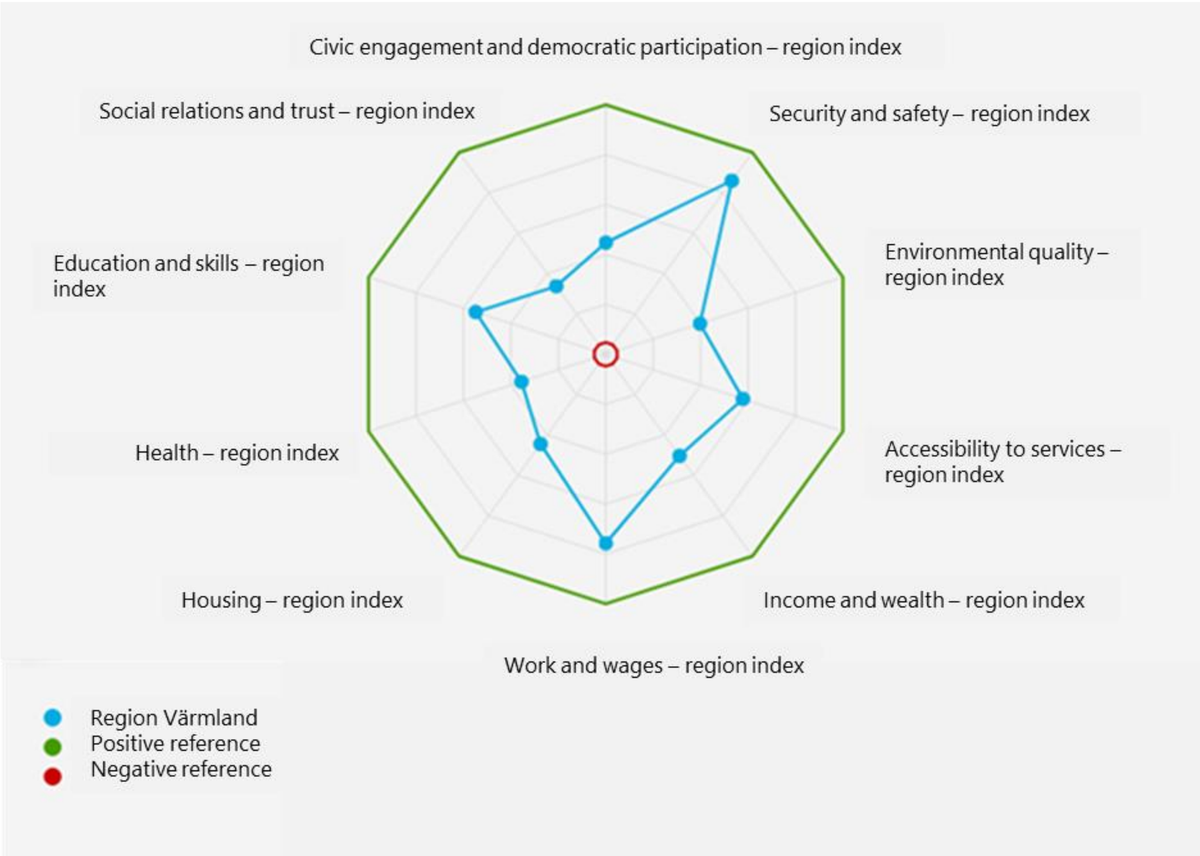
Annex 4 – Data sources for additional social indicators.

Indicator	Source
AIH	https://ec.europa.eu/eurostat/databrowser/view/isoc_r_iacc_h/default/table?lang=en
HBA	https://ec.europa.eu/eurostat/databrowser/view/isoc_r_broad_h__custom_9488461/default/table?lang=en
ARPR	https://ec.europa.eu/eurostat/databrowser/view/ilc_li41/default/table?lang=en
SD	https://ec.europa.eu/eurostat/databrowser/view/ilc_mddd11__custom_9452840/default/table
LWI	https://ec.europa.eu/eurostat/databrowser/view/ilc_lvhl21__custom_9452586/default/table
AROPE	https://ec.europa.eu/eurostat/databrowser/view/ilc_peps01__custom_9452450/default/table
PRO	https://ec.europa.eu/eurostat/databrowser/view/crim_gen_reg/default/table?lang=en
VRA	https://ec.europa.eu/eurostat/databrowser/view/tran_r_acci/default/table?lang=en
EPR	https://ec.europa.eu/eurostat/databrowser/view/educ_uoe_enra15/default/table?lang=en

Annex 5 - Can a developed GRP work as a measurement of sustainable regional growth?

There is an interesting example from Sweden and the region Värmland where they recently have constructed an index called **“BRP+” (translated to Gross Regional Product+)**. The index is based on several indicators regarding e.g. political participation, income, housing, social welfare, health and psychological well-being and it is inspired by OECD’s Better Life Initiative, adding a life quality aspect to the regional growth measure. The figures are normalized to place all regions' values on a scale from 0 to 100. The normalized indicator values are then aggregated to form an index presented in a radar chart.

Indicators that comprise the Gross Regional Product+ (BRP+) measured in the Värmland region of Sweden.



Source: adapted from www.kolada.se

Description of the indicators that comprise the index BRP+ in the radar chart

Regional index from BRP+	
Work and wages	The regional index for the theme Work and Wages is based on the indicators Employment intensity among foreign-born individuals aged 20-64, percentage (%), Women's share of the wage sum (work municipality), percentage (%), Employees aged 20-64 working in occupations closely matching their education, percentage (%), Long-term unemployment among individuals aged 25-64, percentage (%) of the population, Employed residents aged 20-64, percentage (%), Paternity leave days taken by men, percentage of total days (%), Residents aged 16-84 who are worried about losing their jobs, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (in some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within six aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket) based on data from the Swedish Public Employment Service (Arbetsförmedlingen), the Swedish Social Insurance Agency (Försäkringskassan), the Public Health Agency of Sweden (Folkhälsomyndigheten), and Statistics Sweden (SCB).
Income and wealth	The regional index for the theme Income and Wealth is based on the indicators Residents aged 0-19 in economically disadvantaged households, percentage (%), Residents aged 18-64 with low income, percentage (%), Net Income, median income for residents in Sweden aged 20 and over living throughout the year, SEK, Residents aged 16-84 who have experienced financial crisis, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (in some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within two aspects). This is done using means, with all indicators weighted equally within each aspect. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket) based on data from Statistics Sweden (SCB), and the Public Health Agency of Sweden (Folkhälsomyndigheten)
Education and skills	The regional index for the theme Education and Skills is based on the indicators Residents aged 25-64 with post-secondary education, percentage (%), Residents aged 25-64 with at least secondary education, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (in some indicators, an inverted scale is used). In the next step, the standardized indicator values are combined into aspect-level indices (the theme is currently based on indicators within one aspect). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket) based on data from Statistics Sweden (SCB).
Accessibility to services	The regional index for the theme Accessibility to Services is based on the indicators Access to broadband of at least 100 Mbit/s, percentage (%), Population in proximity to public transportation, percentage (%), Residents within a distance of less than 2 km to the nearest grocery store, percentage (%), Residents aged 0-16 within a distance of less than 2 km to the nearest school, percentage (%), Completed doctor visits within seven days in primary care, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (in some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within two aspects). This is done using means, with all indicators weighted equally within each aspect. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket) based on data from Statistics Sweden (SCB), Tillväxtverket - PIPOS, the Swedish Post and Telecom Authority (Post och telestyrelsen), and Healthcare in Figures (Vården i siffror).

Health	The regional index for the theme Health is based on the indicators Life expectancy for women, years, Life expectancy for men, years, Residents with obesity, percentage (%), Long-term sick leave due to mental illness and disorders, percentage (%), Prevalence of type 2 diabetes, percentage (%), Incidence of cancer, age-standardized, number/100,000 inhabitants, Incidence of heart attacks, age-standardized for individuals aged 20 and above, number/100,000 inhabitants, Residents aged 16-84 with good or very good self-rated health, percentage (%), Residents with good self-rated dental health, percentage (%), Residents aged 16-84 with impaired mental well-being, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (in some indicators, an inverted scale is used). In the next step, the standardized indicator values are combined into aspect-level indices (the theme is currently based on indicators within three aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket) based on data from the Swedish Public Health Agency (Folkhälsomyndigheten), the Swedish Social Insurance Agency (Försäkringskassan), the National Diabetes Register (Nationella diabetesregistret), Statistics Sweden (SCB), and the National Board of Health and Welfare (Socialstyrelsen).
Quality of life	The regional Index for Quality of Life is a composite of all the constituent themes measuring quality of life. Individual indicators are normalized so that values for all regions are placed on a scale from 0 to 100, where 0 represents the lowest quality of life and 100 represents the highest (for certain indicators, an inverted scale is used). In the next step, the standardized indicator values are aggregated into aspect-level indices. This is done using means, with all indicators given equal weight within each aspect. The values also fall within the range of 0 to 100 at this level. Subsequently, the aspect-level indices are aggregated into theme-level indices following the same principle, and these values also range between 0 and 100. Finally, the values for all themes are aggregated according to the same principle, with equal weight, to produce an overall index for quality of life. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket), based on data from the Swedish Public Employment Service (Arbetsförmedlingen), the Swedish Public Health Agency (Folkhälsomyndigheten), the Swedish Social Insurance Agency (Försäkringskassan), County Administrative Boards (Länsstyrelserna) - VISS, the Swedish Agency for Youth and Civil Society Issues (Myndigheten för ungdoms- och civilsamhällesfrågor), the National Diabetes Register (Nationella diabetesregistret), the Swedish Post and Telecom Authority (Post och telestyrelsen), Statistics Sweden (SCB), the Swedish Schools Inspectorate (Skolinspektionen), the Swedish National Agency for Education (Skolverket), the National Board of Health and Welfare (Socialstyrelsen), Tillväxtverket - PIPOS, the Swedish Sports Confederation (Riksidrottsförbundet), and the Swedish Election Authority (Valmyndigheten).
Subjective well-being	The regional index for the theme Subjective Well-being is based on the indicator Residents aged 16-84 with good mental well-being, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (for some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within six aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket).
Social relations and trust	The regional index for the theme Social Relations and Trust is based on the indicators Residents aged 16-24 who are neither employed nor in education, percentage (%), Residents aged 16-84 with a lack of trust in others, percentage (%), Residents aged 16-84 with a lack of emotional support, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (for some indicators, an inverted scale is used). In the next step, the standardized indicator values are combined into aspect-level indices (the theme is currently based on indicators within three aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket), based on data from the Swedish Public Health Agency (Folkhälsomyndigheten) and the Swedish Agency for Youth and Civil Society Issues (Myndigheten för ungdoms- och civilsamhällesfrågor)

Civic engagement and democratic participation	The regional index for the theme Civic Engagement and Democratic Participation is based on the indicators Voter turnout in the latest regional election, percentage (%), Districts with the lowest voter turnout in the latest regional election, percentage (%), Women in chair positions in the region, percentage (%), Residents aged 16-84 with low social participation, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (for some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within three aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket), based on data from Statistics Sweden (SCB), the Swedish Public Health Agency (Folkhälsomyndigheten), and the Swedish Election Authority (Valmyndigheten).
Security and safety	The regional index for the theme Security and Safety is based on the indicator Residents aged 16-84 who refrain from going out alone, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (for some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within one aspect). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket), based on data from the Swedish Public Health Agency (Folkhälsomyndigheten).
Environmental quality	The regional index for the theme Environmental Quality is based on the indicators Green areas within 200 meters from residence, percentage of urban population (%), Lakes with good ecological status, percentage (%), Rivers with good ecological status, percentage (%), Groundwater bodies with good chemical and quantitative status, percentage (%). The key figures are normalized so that all regions' values are placed on a scale from 0 to 100 where 0 is the worst and 100 is the best (for some indicators, an inverted scale is used). In the next step, the normalized indicator values are combined into aspect-level indices (the theme is currently based on indicators within two aspects). This is done using means, with all indicators weighted equally within each aspect. The values also fall within the range of 0 to 100 at this level. Then, the aspect-level index is combined into a theme-level index following the same principle, and these values also fall between 0 and 100. The weighting is the same for all aspects within the theme. Source: Calculations by the Swedish Agency for Economic and Regional Growth (Tillväxtverket), based on data from Statistics Sweden (SCB) and County Administrative Boards (Länsstyrelserna) - VISS.

Source: www.kolada.se

Annex 6 – Indicators' cards by block

<table>
<tr><th></th><th colspan="4">OVERALL ACTIVITY</th></tr>
<tr><td></td><td>Definition</td><td colspan="3">Measurement of the overall economic performance of certain region and/or specialization area.</td></tr>
<tr><td></td><td>Contribution</td><td colspan="3">Economy being one of the three pillars of sustainability, we need to measure how regions and sectors perform in economic terms in order to monitor the progress on this pillar.</td></tr>
<tr><td></td><td>How do we measure it?</td><td colspan="3">Economic activity can be measured from different perspectives. Two important elements were identified which provide different and novel information on the overall economic activity of a region or sector: production and the labour market.</td></tr>
<tr><td></td><td colspan="2">Production</td><td colspan="2">Labour market</td></tr>
<tr><td></td><td colspan="2">GDP from the production perspective adds up the value added from the industries of the region. This is interesting from the perspective of S4 sectors, since we can measure the value added of these specific sectors and thus measure their contribution to the overall activity of the region.</td><td colspan="2">Information about the labour market provides additional information about the overall economic activity of the region or sector.</td></tr>
<tr><td></td><td colspan="4">PROPOSED INDICATORS</td></tr>
<tr><td></td><td>Region</td><td>S4 sectors</td><td>Region</td><td>S4 sectors</td></tr>
<tr><td>Name</td><td>Real GDP per capita</td><td>Gross value added (GVA) by area of specialisation</td><td>Employment rate</td><td>Employment by area of specialisation</td></tr>
<tr><td>Definition</td><td>The ratio of the value of total final output of goods and services produced by the region to the average population of the year.</td><td>Output minus intermediate consumption, broken down by industry.</td><td>Percentage of employed persons in relation to the population of working-age.</td><td>Employment rate broken down by industry.</td></tr>
<tr><td>Unit of measure</td><td>Constant prices</td><td>Constant prices</td><td>Percentage (%)</td><td>Percentage (%)</td></tr>
<tr><td>Frequency</td><td>Annual</td><td>Annual</td><td>Annual</td><td>Annual</td></tr>
<tr><td>SDGs</td><td></td><td></td><td></td><td></td></tr>
</table>

DRIVERS	
Definition	Measurement of drivers of economic activity that allow for the analysis of the evolution of GDP.
Contribution	The measurement of the drivers of economy is useful because it shows the effort that is being made for future economic development and together with the evolution of GDP, it shows the efficiency of those efforts.
How do we measure it?	The drivers of economic activity are measured as the expenditure made for research and development since it provides an opportunity to improve processes and thus influence economic performance.

	PROPOSED INDICATORS	
	Region	S4 areas
Name	**GERD as a percentage of GDP**	**R&D expenditure in areas of specialization**
Definition	Gross R&D expenditure of the region as a percentage of GDP	Expenditure on R&D by specialization areas as a percentage of GDP
Unit of measure	Percentage (%)	Percentage (%)
Frequency	Annual	Annual
SDGs		

DISTRIBUTION	
Definition	Distribution measures how income is distributed among the different factors of production.
Contribution	Information on income distribution among different factors of production offers a more complete information on economic activity as it includes the perspective of the income side for GDP calculation.
¿How do we measure it?	Parting from the GDP from an income perspective and looking at its components, distribution can be measured by looking at the share of GDP that corresponds to compensation of employees

	PROPOSED INDICATORS
	Region
Name	**Compensation of employees**
Definition	Share of compensation of employees over total GDP
Unit of measure	Percentage (%)
Frequency	Annual
SDGs	

	INEQUALITIES					
	Definition	Measurement of differences in social well-being due to belonging to a certain social group.				
	Contribution	The need to assess inequalities is one of the keys to achieving sustainable development, which is included among the SDGs (SDG5, SDG10), because it measures the extent to which any individual, no matter the social group they belong to, can achieve the same level of social well-being as any other.				
	How do we measure it?	It is important to take into consideration that inequalities affect different social groups (gender, age, disability, ethnicity, etc.) and it affects different dimensions of well-being (employment, income, education, etc.). That is why different elements require measurement and monitoring. We focus our attention on three key dimensions: income, employment and education. Although the proposed indicators refer to gender-based inequalities, it would be desirable to monitor similar indicators for other vulnerable social groups.				
	Income		*Employment*		*Education and training*	
	Income inequality is a useful complement to poverty indicators in order to assess the effects of policies on this matter.		Gaps in employment rates contribute to assess how equally employment can be accessed by different social groups.		Since education has a direct impact on the social well-being of citizens, the differences on access to education and training should be measured.	
	PROPOSED INDICATORS					
	Region		Region	S4 sectors	Region	S4 sectors
Name	**GINI index**	**80/20**	**Gender gap (employment)**	**Gender gap (employment)**	**Gender gap (education)**	**Gender gap (training)**
Definition	It measures the extent to which the distribution of income within the region deviates from a perfectly equal distribution.	Ratio of the income of the richest 20% of the region to the poorest 20%.	The difference between the employment rates of men and women.	The difference between the employment rate of men and women within an industry.	The difference on education rates of men and women.	The difference on education rates of men and women within an industry.
Unit of measure	Index (0-100)	Ratio	Percentage (%)	Percentage (%)	Percentage (%)	Percentage (%)
Frequency	Annual	Annual	Annual	Annual	Annual	Annual
SDGs	10	10	10, 5, 8	10, 5, 8	10, 5, 4	10, 5, 4

POVERTY	
Definition	It measures the number of households or citizens whose resources are insufficient to achieve certain level of well-being.
Contribution	Poverty is a clear barrier to the social well-being of citizens. In order to quantify the amount of the population affected by this condition and control the effects of policies or programs aimed at poverty reduction, it is essential to measure it.
¿How do we measure it?	Poverty is measured by several indices, which tend to offer similar information about the evolution of poverty in a region. Apart from measuring the level of poverty, it is also important to measure the contribution of S4 sectors to poverty alleviation, to monitor the potential of these sectors to improve the former.

	PROPOSED INDICATORS	
	Region	S4 sectors
Name	**AROPE**	**Poverty alleviation**
Definition	The share of total population that is either at risk of poverty, or severely materially and socially deprived or living in a household with a very low work intensity.	------
Unit of measure	Percentage (%)	------
Frequency	Annual	-------
SDGs	1 NO POVERTY	1 NO POVERTY

EDUCATION	
Definition	The measurement of levels of education in the region and sectors, both formal and non-formal.
Contribution	Measuring education is necessary to measure sustainability, since it conditions the future opportunities of population for achieving well-being and thus constitute a key element of the social pillar.
How do we measure it?	Although education is considered as a general question to be measured, it actually can be divided into two measurable questions, depending on the target group and type of education considered.

Education	*Training*
Education properly considered, only accounts for formal education: primary, secondary and tertiary (general or vocational) education.	Training refers to lifelong learning, formal and non-formal, and refers to ages outside education standards (over 25 years old).

	PROPOSED INDICATORS		
	Region	Region	S4 sectors
Name	**Participation rate in different educational levels**	**Training (lifelong learning)**	**Training (lifelong learning)**
Definition	Participation rates by educational level as percentage of total population.	Share of people aged 25 to 64 in the EU who had participated in education or training in the previous 4 weeks prior to the survey (LFS).	Share of people aged 25 to 64 in the EU who had participated in education or training in the previous 4 weeks prior to the survey (LFS).
Unit of measure	Percentage (%)	Percentage (%)	Percentage (%)
Frequency	Annual	Annual	Annual
SDGs	4 QUALITY EDUCATION	4 QUALITY EDUCATION	4 QUALITY EDUCATION

HEALTH	
Definition	Quantitative measures that contribute to evaluating the health status of the population of a region.
Contribution	The measurement of health indicators do not only provide information about an essential part of human well-being, but it is also useful due to the relationship it shares with other pillars of sustainability.
How do we measure it?	We measure health in two aspects. On the one hand the health of the population of the region, and on the other hand measuring the risk for the health of employees in the different specialization areas.

	PROPOSED INDICATORS	
	Region	S4 sectors
Name	**Life expectancy**	**Occupational accidents (fatalities and injuries)**
Definition	Average years of life remaining at birth	The number of occupational accidents (fatalities and injuries) in certain specialization area. Work accidents that have resulted in sick leave (for at least 1 day, not counting the day of the accident) or the death of the injured worker. Work accidents can occur either during the working day or during the trip between the worker's home and the place of work or vice versa (in itinere).
Unit of measure	Years	Fatalities/injuries per 1000 workers
Frequency	Annual	Annual
SDGs		 

GLOBAL POLLUTION		
Definition	Global pollutants are the ones that cause damage all over the planet, regardless of the point of emission	
Contribution	Measuring global pollutants offers information about the contribution of the region or the sector to global environmental problems, mainly climate change.	
How do we measure it?	There are many indicators that measure the emission of global pollutants (especially carbon) that show similar trends. We propose to measure greenhouses gases (GHG) emissions per capita to capture this information.	
PROPOSED INDICATORS		
	Region	S4 sectors
Name	**GHG emissions per capita**	**GHG emissions**
Definition	Emission of greenhouse gasses (converted into CO2 equivalents) over the population of the region	Emission greenhouse gasses by specialization areas
Unit of measure	CO2-eq per capita	CO2-eq
Frequency	Annual	Annual
SDGs	13 Climate Action	13 Climate Action; 12 Responsible Consumption and Production

LOCAL POLLUTION	
Definition	Local pollution refers to gases that concentrate in the places where they are released.
Contribution	Local pollution is interesting to measure because it shows different trends to global pollution, and because it has direct effects on the local environment, affecting other aspects of sustainability such as population's health.
How do we measure it?	There are several local pollutants that follow different trends and thus should be separately measured in order to have a complete image of local pollution, both regarding the regional performance and how specialization areas are doing.

Air pollutants	*Metal pollutants*	*Waste*
Air pollutants are measured by exposure indicators rather than emissions, due to their negative effects on life years.	Emissions of metal pollutants such as PBD are considered relevant because of their toxicity.	Waste is also considered local since its management is generally local. In this case, similar indicators are used for both regional and sector-based measuring.

PROPOSED INDICATORS

	Region	S4 sectors	Region	S4 sectors	Region/S4 sectors	
Name	**Concentration of air pollutants**	**Emission of air pollutants**	**Concentration of heavy metals**	**Emissions of heavy metals**	**Waste per capita**	**Recycling rate**
Definition	Exposure to concentration of PM2.5	Emissions of PM2.5	Exposure to concentration of heavy metals	Emissions of heavy metals	Total municipal waste generated over total population	Recycling rate of municipal waste over total municipal waste
Unit of measure	µg/m3	Kg or tons	$\mu g/m^3$	Kg or tons	Kg per capita	Percentage (%)
Frequency					Annual	Annual
SDGs	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11 SUSTAINABLE CITIES AND COMMUNITIES; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION

WATER	
Definition	The measurement of water quantity and quality.
Contribution	Clean water is critical for nature and people’s health and well-being, as well as a necessary resource for many sectors.
How do we measure it?	The analysis pointed out that both water scarcity and water quality have been proven relevant questions to measure.

	PROPOSED INDICATORS			
	Region		S4 sectors	
Name	**Water quality**	**Water quantity**	**Water consumption**	**Wastewater treatment**
Definition	Proportion of bodies of water with good ambient water quality	How much freshwater is being withdrawn by all economic activities, compared to the total renewable freshwater resources available (Water stress)	Water withdrawn by all economic activities	Proportion of total, industrial and domestic wastewater flows safely treated in compliance with national or local standards
Unit of measure	------	------	------	------
Frequency	------	------	------	------
SDgs				

ENERGY	
Definition	Energy is defined as the potential to do work or provide heat, we look for the measurement regarding its consumption and impact.
Contribution	Energy is both necessary for human well-being and a problem towards climate change, so its measurement is key for achieving sustainability in all economic, social and environmental dimensions.
How do we measure it?	Energy measurement must address consumption of energy resources, but also the proportion in which renewable resources are being used for generating such energy.

	PROPOSED INDICATORS			
	Region		S4 sectors	
Name	**Energy consumption**	**Energy mix**	**Energy consumption**	**Energy mix**
Definition	Final energy consumption of households	Percentage of renewable energies over energy production in the region	Total energy consumed by the industry	Percentage of renewable energies over total consumption for the specialization area
Unit of measure	Thousand tonnes of oil equivalent	Percentage (%)	Thousand tonnes of oil equivalent	Percentage (%)
Frequency	Annual	Annual	Annual	Annual
SDGs				

RAW MATERIALS	
Definition	Raw materials refer to the measurement of other resources that come from nature besides water and energy.
Contribution	Nature is the main provider of resources. Measuring the use of these resources is essential for securing long-term sustainability..
How do we measure it?	We measure on the one hand the consumption of raw materials, but also indicators related to agricultural activity, such as food security and soil quality, due to its strategic nature.

	PROPOSED INDICATORS			
	Region			S4 sectors
Name	**DMC**	**Food security**	**Soil quality**	**DMC**
Definition	The quantity of raw materials extracted from the region, plus imports minus exports	Food availability, food access, utilization and stability	Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils	The quantity of raw materials extracted from the region, plus imports minus exports
Unit of measure	Thousand tonnes	------	------	Thousand tonnes
Frequency	Annual			Annual
SDGs		 		

ARIES4

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