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A primary assessment of the EU regions' transition towards bioeconomy

Georgios Maroulis[1*], Panos Kalimeris[2], Panagiotis Koronaios[3], and Antonios Rovolis[4]

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Abstract*. *Objective*:** *The European Union (EU) identifies the deployment of bioeconomy as the key factor to achieve a sustainable future. This is expected to be realized through the decarbonization of the economy and the replacement of all resources with renewables ones. The importance is also acknowledged on the EU Member State level, as there are currently ten EU member states with dedicated bioeconomy strategies and seven that are in the process of developing theirs. However, there is still more to be done on a regional level, because only 28 EU regions have in place their own dedicated bioeconomy strategies and 69 other EU regions are in the process or are implementing strategies in which the bioeconomy is one of the key elements. In any case, it has been highlighted how important and crucial the integration of bioeconomy in regional economies is. The main objective of the study is to assess and promote the transition to bioeconomy on a regional scale by analysing EU regions (NUTS II Level) with a group of selected bio-indicators. The outcome will be a better understanding of bioeconomy at a regional level. Moreover, the proposed tool could be used as a policy instrument to achieve regional development based on the unique characteristics and the comparative advantage of each region.* ***Method*: A Multi-Criteria Assessment (MCA) tool is designed and implemented. Specifically, the process that will be followed includes the conduct of an extensive review of the existing world-wide indicators, national frameworks and methodologies based on academic literature, reports, guidelines, and relevant projects. The outcome of this process is a pool-database with the most utilized bioeconomy indicators. Furthermore, these indicators are categorized in economic, social, and environmental groups, reflecting the three pillars of sustainable development. The proposed indicators are eliminated if they do not fulfil specific criteria. The selection criteria will be the meaningfulness and clear meaning i.e., description of an indicator, existence of an indicator in other policy frameworks, data availability, extended geographical coverage, comparability across countries/products or sectors, comparability over time and accessibility of data. Eventually, the final group of the remaining proposed indicators is selected based on data availability and applicability in all EU-regions. Finally, regions are ranked accordingly by using the TOPSIS MCA tool.* ***Results****: The selected bioeconomy indicators will be used to assess, initially, the current regional bioeconomy state for the eight countries-members of the consortium of the Horizon 2020 "BIO2REG" project, namely, Germany, Spain, Greece, Belgium, France, Sweden, Czech Republic, and Iceland. This initial assessment will provide the blueprint for revealing the model bioeconomy regions and the potential EU-wide pathways to promote regional bioeconomy.* ***Originality****: To our knowledge, this is the first attempt to provide an assessment of NUTS II regions based on bioeconomy- related indicators.*

[1] University Research Institute of Urban Environment and Human Resources- Panteion University of Social and Political Sciences, Athens, Greece. *Corresponding author: g.maroulis@panteion.gr
[2] University Research Institute of Urban Environment and Human Resources- Panteion University of Social and Political Sciences, Athens, Greece.
[3] University Research Institute of Urban Environment and Human Resources- Panteion University of Social and Political Sciences, Athens, Greece.
[4] University Research Institute of Urban Environment and Human Resources- Panteion University of Social and Political Sciences, Athens, Greece.

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JEL classification: *Q57, R11*

1. Introduction

The concept of bioeconomy is rather new as it was introduced at both academic and policy level quite recently, albeit various early academic contributions can be traced back from 1918 (Gould & O’Neill, 2023 - See a detailed review of the historical evolution of the term “Bioeconomy” in Figure 1 and in the Literature Review section).

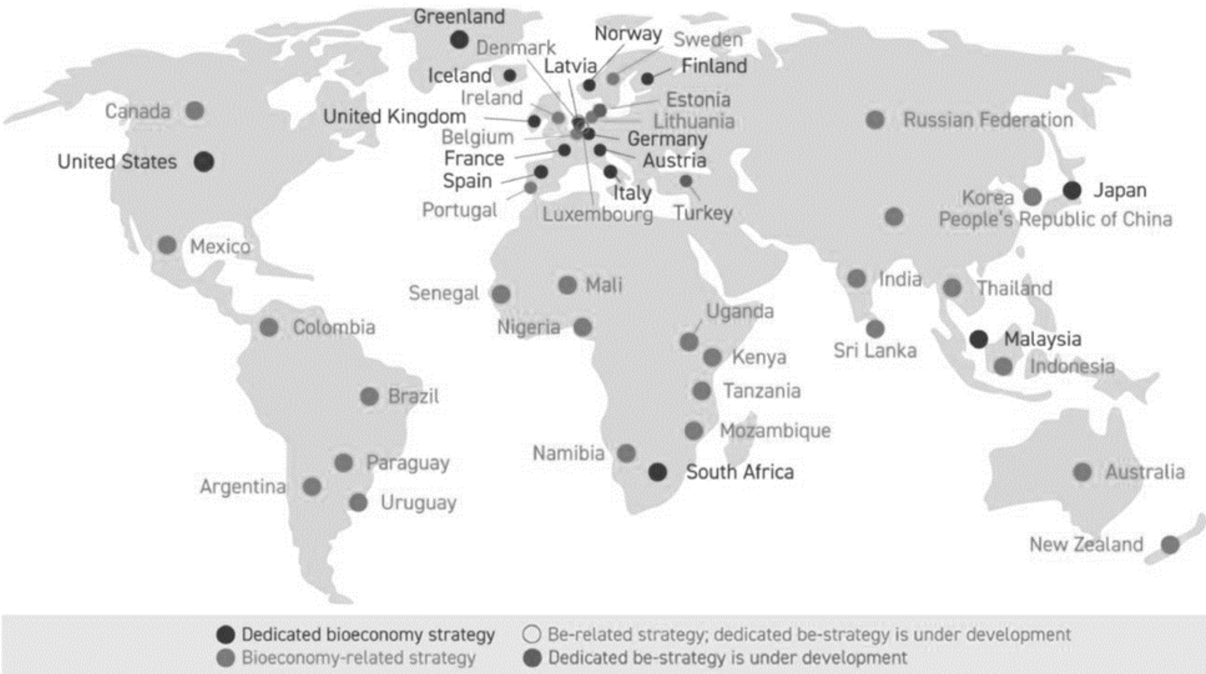
Figure 1. Evolution of the term Bioeconomy in the EU policy context

Source: Gould & O’Neill, 2023.

The term gained popularity at the policy arena in mid-2000's, as the Organisation for Economic Co-operation and Development (OECD, 2009) published a policy agenda with various bioeconomy development scenarios towards 2030, while at the same time the European Commission (EC) developed the concept of Knowledge Based Bio-Economy (KBBE, 2010). To cover different segments of the KBBE, the EC established the European Technology Platforms (ETPs). The discussions between the ETPs and a series of open meetings with various stakeholders were captured into an important White Paper publication on the bioeconomy (Bioeconomy Technology Platforms, 2010). A few years later the EC published the very first strategy "Innovating for sustainable growth: A Bioeconomy for Europe" (European Commission, 2012). During the same period, the Obama administration in the USA introduced the term with the technical report "Bioeconomy White Paper" (Executive Office of the President, 2012).

Since then, more than 50 countries have developed national bioeconomy strategies or introduced policies that are steering towards a sustainable bioeconomy (See Figure 2).

Figure 2. National bioeconomy strategies and initiatives across the world



Source: OECD, 2018.

According to the World Bioeconomy Forum (2023), the engagement towards facilitating the bioeconomy has been very dynamic since 2022. Global leading countries, such as China and the USA have recently increased commitment and engagement towards this direction, as both have introduced strategies in bioeconomy and, furthermore, express an increasing competitive interest in becoming the world's leading bioeconomy. In terms of economic values, it is estimated that the current global value of the bioeconomy is approximately 4 trillion US$ and, according to some projections, its value is expected to rise further to 30 trillion US$ in the next decades, which is translated into a third of the global economic value (World Bioeconomy Forum, 2023).

In line with these developments, the EC is currently preparing the updated revision of the former European bioeconomy strategy which dates back in 2018. Accordingly, the European Union (EU) identifies the deployment of bioeconomy as the key factor to achieve a sustainable future. This is expected to be realized through the decarbonization of the economy and the replacement of all non-renewable resources with renewables ones (European Commission, 2021). Currently, ten EU Member States (MS) have a dedicated bioeconomy strategy but only 28 EU regions (NUTS II Level) have in place their own dedicated bioeconomy strategies and 69 other EU regions are in the process or are implementing strategies in which the bioeconomy is one of the key elements (Haarich et al., 2022). To that direction, the present study aims at assessing the potential of bioeconomy development in NUTS II regions in 7 EU MS, plus Iceland. This is done by conducting a Multi-Criteria Assessment (MCA) in those 8 countries. The assessment is carried out within the framework of the Horizon "BIO2REG" project. that aims to enable the systemic transformation of greenhouse gas-intensive regions into bioeconomy model regions[5].

2. Literature review

In the beginning of 21st century, Bioeconomy as scientific field is characterized by an increase interest among the members of scientific community, as evidenced by the growing publication number of scientific papers addressing the terms "bioeconomy" or "bio-based economy" (Gould et al., 2023; Staffas et al., 2013). However, the definition of bioeconomy has evolved over time, incorporating new visions, principles, and goals to align with the needs of various stakeholders. The term "bioeconomics" was first introduced by Russian biologist F.I. Baranoff in the 1920s to describe the optimal level of fish exploitation. By the 1950s, its meaning expanded to cover renewable resources more broadly, focusing on their sustainable use to avoid extinction (Vivien et al., 2019; Gould et al., 2023) (see also Figure 1).

In the 1970s Bioeconomy re-emerged in the scientific environment by Georgescu-Roegen. According to Georgesu-Roegen, Bioeconomy is an economic framework which is functioning under planetary boundaries. In that sense, human societies are deeply interconnected with the natural environment, and bioeconomy must consider biological constraints, making the idea of continuous economic growth seem utopic (Georgescu-Roegen, 2013; Georgescu-Roegen, 1977). The last decades of the 20th century were characterized by unprecedented technological advancements. As a result, biotechnology became an integral part of bioeconomy and, consequently, bio-based models started to become part of the political agenda (Vivien et al., 2019; Gould et al., 2023).

Early definitions of Bioeconomy focused on the ecological dimension of the economic processes, acknowledging natural limits and planetary boundaries. As the definition evolved through time, new aspects occurred leading to the creation of two basic visions which influenced the way that policy makers perceive bioeconomic reality (Vivien et al., 2019). The first is the bio-technology approach, which seeks to use biotechnology to drive economic growth, without placing sustainability at the forefront (Bugge et al., 2016). The second is the bio-resource approach, which focuses on replacing non-renewable resources with the renewable ones, to address both economic and sustainability challenges (Birner, 2018). Although bio-resource and bio-technology visions seem to have many differences, they have as a core the use of technology and innovation in the economic process, as well as the importance of natural and biological resources as an input.

To address the challenges of assessing the bioeconomy concept at the European regional (thus, NUTS II) level, the present study is primarily based on four (4) main pillars for conducting an extensive literature review of both bio-resource and bio-technology visions (See Figure 3):

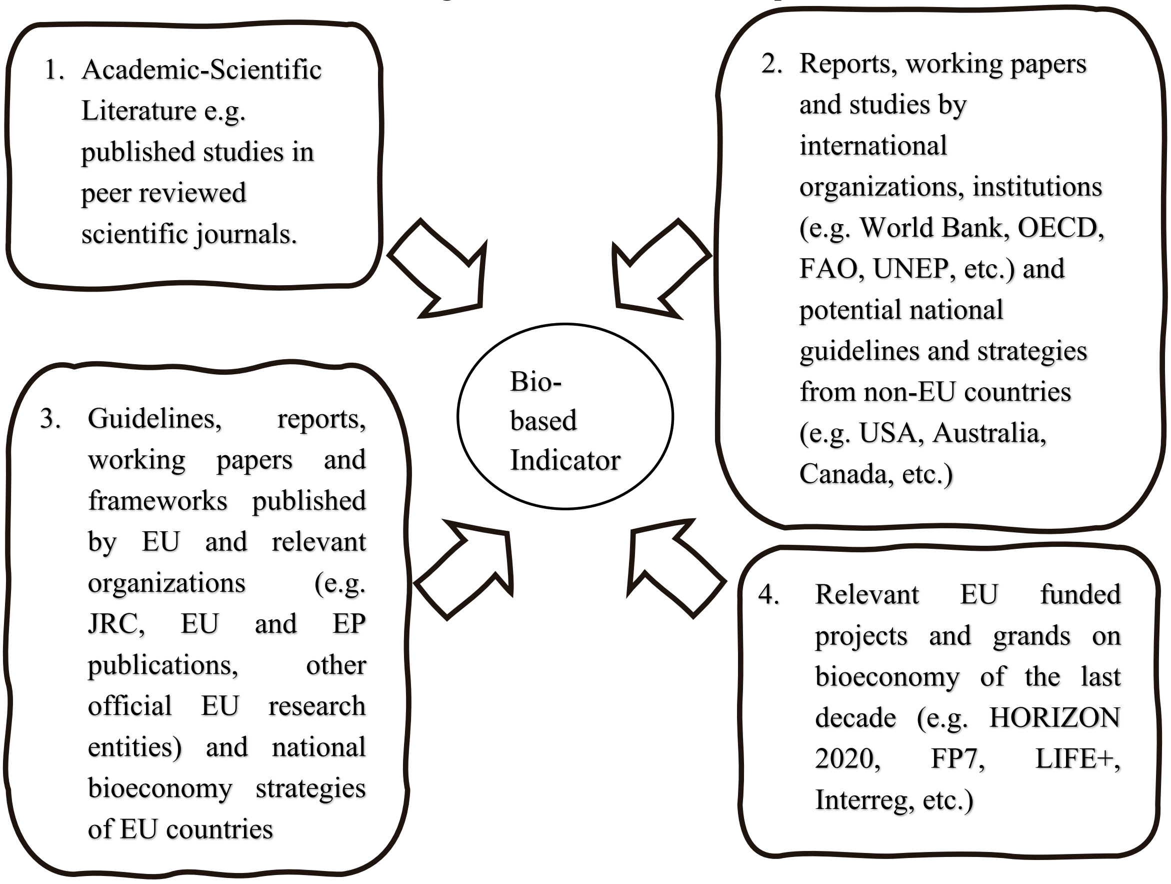
1. Academic-Scientific Literature e.g. published studies in peer reviewed scientific journals. This first pillar aspires to capture essential theory and practice, methodological contributions, data availability and, most importantly, proposed and utilized bioeconomy indicators at both national and potential regional levels (e.g., see D'Adamo, 2020a; 2020b; Ronzon et al., 2018).
2. Reports, working papers and studies by international organizations, institutions (e.g. World Bank, OECD, FAO, UNEP, etc.) and potential national guidelines and strategies from non-EU countries. (e.g. USA, Australia, Canada, etc.). The second pillar aspires to incorporate in the present analysis the most important contributions of the international institutions and organisations on bioeconomy, in both theoretical (criteria, methodologies) and practical (bio-indicators, databases) aspects (e.g., see Bogdanski et al., 2021; Golden et al., 2018; Lima et al., 2022).
3. Guidelines, reports, working papers and frameworks published by EU and relevant organizations (e.g. JRC, EU and EP publications, other official EU research entities) and potential national guidelines and strategies from EU countries. The third pillar of literature review focuses explicitly on the European level. Again, both theoretical and practical contributions are expected to be a

[5] Source: https://bio2reg.eu/

substantial added value to the present deliverable (e.g., see European Commission, 2022; Giuntoli et al., 2020; Republic of Austria, 2019).

4. Relevant EU funded projects and grands on bioeconomy of the last decade. (e.g. HORIZON 2020, FP7, LIFE+, Interreg, etc.). This final fourth pillar of literature review anticipates revealing past good practices, databases, indicators, methodologies, guidelines and other contributions on the conception of bioeconomy, by investigating current and past relevant EU funded programs (e.g., see POWER4BIO Project[6]; Interreg BERST-building regional Bioeconomies[7]).

Figure 3. The literature review process



Source: own elaboration based on Horizon BIO2REG project.

3. Methodology and data

Defining the boundaries of the system – selecting criteria for bio-indicators

The methodological framework in a nutshell

The - four pillars - extensive literature review, presented in the previous section, provides the essential input for the next steps of our analysis. These next steps could be briefly summarized as follows:

1. The first critical step of our analysis was to specify the borders of the examined system. In our case, the border is set exclusively at the European regional level, thus in terms of Eurostat, is the **NUTS 2 level**. We use the most up to date Eurostat's classification, valid from 1 January 2024, which lists 244 (Eurostat, 2024) regions at the EU - NUTS 2 level. In our case, we provide an EU-wide assessment by using as a sample the regions of all 8 countries participating into the BIO2REG's consortium. These 8 countries, namely, Belgium, Germany, Greece, France,

[6] https://power4bio.eu/
[7] https://berst.databank.nl/jive

Czech Republic, Spain, Sweden and Iceland[8] provide a good representative case study of the EU regional level, in terms of geospatial, population and economy's size levels.

2. The second crucial step was to translate the output of the four-pillars literature review into a useful dataset of the vast majority of the available bioeconomy indicators. To do so, we have utilized the so-called **Traffic Light decision-making assessment**, to classify and manage the derived bio-indicators. This step was the first part of the overall Multi-criteria Assessment (MCA) methodology employed. A more detailed representation of this first part of MCA is provided in the following section.
3. The third and final critical step of our analysis was to estimate the final group of the selected bio-indicators for the 125 NUTS-2 regions of the 8 countries of the project's consortium and perform the second part of the employed MCA, namely, to provide a robust and practical ranking methodology which could potentially reveal some "champion" regions, in terms of bioeconomy, that could be provide essential information and best practices about the criteria required to build the profile of a model region, as a prototype of promoting bioeconomy. The present essay concludes with a detailed representation of the results of this final step.

The criteria for selecting the set of bio-indicators

According to various academic studies in peer-reviewed scientific journals (see 1st pillar of the literature review), FAO and OECD (see 2nd pillar of the literature review), as well as EU and EP (see 3rd pillar of the literature review) it is essential to first define specific criteria for the selection of appropriate bio-indicators. In this context, we adopt the following important criteria that the final bio-indicators included in our dataset must fulfil:

1. Ought to be meaningful and clear meaning.
2. Ought to be well-established and already used in other policy frameworks.
3. Their calculation should be based on timely and frequently collected data
4. Their Geographical coverage (explicitly in NUTS 2 EU regional level, in our case)
5. Ought to be comparable across countries and/or products and/or sectors
6. Ought to be comparable over time
7. The data should be only openly available (accessible) and clearly documented (transparent).

Furthermore, FAO and EU/EP reports, to achieve sustainable bioeconomy at the country and/or macro-regional level suggest the division of the selected bio-indicators into three broad groups: Economic bio-indicators, social bio-indicators, and environmental bio-indicators. For the purposes of our analysis, we adopt this categorisation throughout the construction of our dataset and the performance of the two-steps MCA methodology.

The traffic light decision making assessment – The first part of the MCA

The traffic light decision making methodology is a widely used tool in MCA for classifying data according to their applicability (or not) in a broad variety of purposes. The method usually evaluates three specific outcomes (just like a traffic light has three colours, thus, three potential outcomes). However, due to the high complexity of our case, we introduced a four potential outcomes traffic light assessment.

First, we constructed an overall database which included all the bioeconomy indicators derived from the 4 pillars of the extensive literature review, separated into three main groups: Economy, Society, and Environment.

Secondly, each bio-indicator was individually validated if it compromises with the assessments fundamental criteria, presented in the previous section. The final classification of this, unique per indicator, process had four potential outcomes, each expressed by a unique colour (See also Figure 5):

- **Green:** The bio-indicator meets all the adopted criteria, especially the data availability for all EU regions (NUTS 2), hence approved for inclusion to our dataset.

[8] Albeit a non-EU country, the contribution of Iceland, especially to the fisheries sector, remains of paramount importance for its potential contribution to the EU bioeconomy strategy.

- **Orange:** The bio-indicator meets some of the adopted criteria, hence rejected. More specifically, in most of this category's cases, there was data availability only for some specific EU regions but not for all EU regions. However, the indicators included in this category could potentially be utilized in other more targeted analyses where the total regional coverage is not a prerequisite.
- **Red:** The bio-indicator meets some of the adopted criteria and there is data available only at the national (NUTS I) EU level, hence rejected. However, the indicators of this category could be used for potential bioeconomy analysis at the national EU level.
- **Grey:** This is a special category included in our analysis for classifying those indicators that do not fulfil most of the adopted criteria, do not have data availability for most regional and/or national level, yet their data could be useful for other purposes (e.g. variables in modelling scenarios, geospatial analysis, mapping, more abstract descriptive analysis etc.).

Figure 3. The traffic light decision making assessment in a nutshell – the first part of MCA

Proposed Indicator	Typology	Type of indicator	Source	EU Regional Availability (Traffic Light Assessment)	Source
A. Economy					
e.g., turnover	In thousand €/ year	Quantitative		Existing in all EU regions	EU Eurostat
B. Society		Qualitative			
e.g., employment	In FTEs			Not available data in All EU-regions	
C. Environment		Descriptive			
e.g., biomass production	In kg/hectare		A	Available in some EU regions	
e.g., biomass production	In kg/ year		B	Grey (potential) indicators	

Source: own elaboration based on Horizon BIO2REG project.

A final deep dive processing of the classified variables was anticipated for ensuring that all the approved (green category) bio-indicators do complete the data availability criteria for all EU regions. Furthermore, this deep dive process re-evaluated the orange category as well, in case that some of these indicators could be transferred to the green category.

After the conclusion of this final checking process, the final dataset comprised by the final groups of available (green) bio-indicators was constructed and implemented in estimating the regional bioeconomy indicators for the regions of 8 countries participating to the BIO2REG project. (See a detailed depiction of the process in Figure 5).

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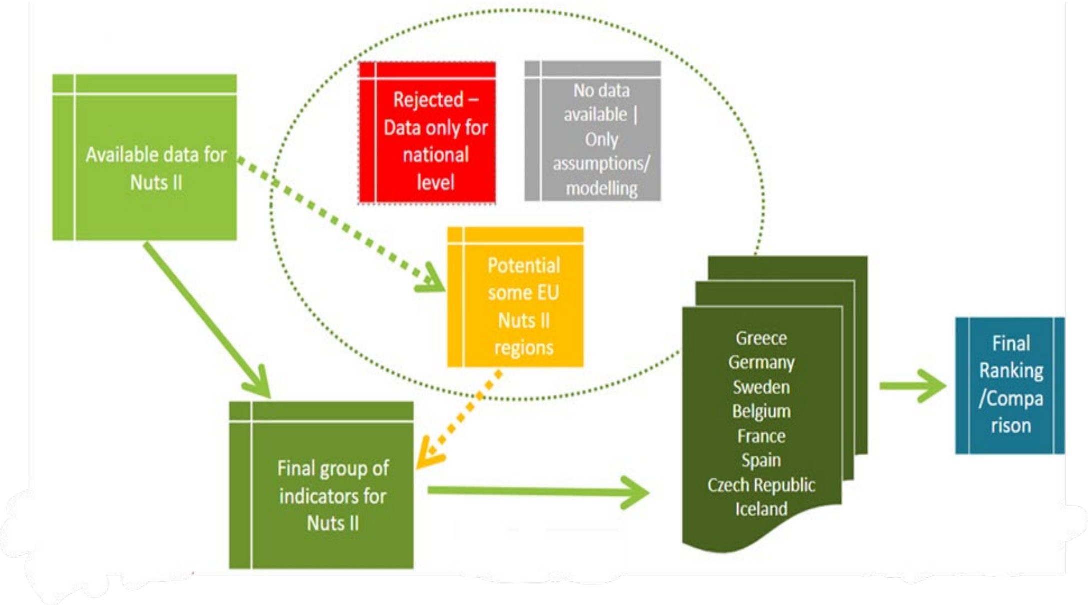
Figure 4. Classifying the data towards the constructing the final dataset – the first part of MCA



Source: own elaboration based on Horizon BIO2REG project.

4. Research results and comments

The first part of MCA revealed in total 897 indicators, out of which only a final circa 5% (37 green bio-indicators) meet all the adopted criteria and, thus are available for estimating the regional bioeconomy status of the 8 countries of the consortium, and further implement the second part of the MCA, namely the final ranking and the comparison of all regions. The orange category included 223 indicators (24%), the red category 241 (27%) and, finally, the grey category 396 (44%). The total dataset of 897 bio-indicators is not publicly available. It could be provided by the authors upon reasonable request and under specific conditions foreseen by the data process agreement of BIO2REG project. The following Tables 1-3 provide the final bio-indicators dataset, grouped into three distinct categories, economy, society, and environment:

Apart from the bio-indicators of Tables 1-3, we have included in our analysis two more qualitative indicators. In regional analysis, it is expected that a dedicated national bioeconomy strategy could have a positive effect in promoting bioeconomy. Moreover, if this national bioeconomy strategy is followed also by a dedicated regional bioeconomy strategy, per region of a country, then there is a good probability to expect a more increased bioeconomy potential, dynamics and commitment at both regional and national level. Under this assumption, we further included the below qualitative criteria, to be considered and weighted accordingly, in the second part of the MCA (see also Figure 6):

1. Is there a National Bioeconomy Strategy? (Yes/No)
2. Is there a Regional Bioeconomy Strategy? (Yes/No). If the answer is yes then there are three potential outcomes: fully dedicated regional bioeconomy, strong regional bioeconomy focus, minimum regional bioeconomy content.

Table 1. The final dataset of the regional bio-economy indicators- The Economy Group

A/A	Indicators	Typology	Type of Indicator	Short Description	Initial Source (Review)
1	Turnover	€	Quantitative	Turnover of every sector by region	https://www.unitelmasapienza.it/sustain//wp-content/uploads/2021/05/DAdamo2020_Article_ExploringRegionalTransitionsTo.pdf
2	Value Added	€	Quantitative	Value added in bioeconomy services	https://www.sciencedirect.com/science/article/pii/S0954349X21001375?via%3Dihub
3	Real Labour Productivity	Number	Quantitative	Index=100[9]	https://www.sciencedirect.com/science/article/pii/S0954349X21001375?via%3Dihub
4	Patents	Number	Quantitative	Average Number[10]	https://www.mdpi.com/2071-1050/12/11/4692
5	Employment	%	Quantitative	Sectoral approach	https://www.mdpi.com/2071-1050/16/5/1975
6	Productivity of crop production	Hectares	Quantitative	Crop Production (Total)[11]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
7	Change in turnover of bio-based sectors	%	Quantitative		https://www.fao.org/3/ca6048en/CA6048EN.pdf
8	Gross fixed capital formation	€	Quantitative	Million Euros[12]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
9	Regional Gross Domestic Product	€	Quantitative	Million Euros[13]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
10	Household income	€	Quantitative	Million Euros[14]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
11	At risk of poverty rate	%	Quantitative	[15]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
12	Employment Rate	%	Quantitative	Employment Rate/Total	https://www.fao.org/3/ca6048en/CA6048EN.pdf

[9] Year of Data 2022, Iceland 2023. For Iceland the following exchange rates were applied: 1 EUR = 142,24 ISK in 2022 and 1 EUR = 149,12 ISK in 2023.
[10] Year of Data 2022, Greece 2017-2018
[11] Year of Data 2022, Iceland 2023
[12] Year of Data 2021, Iceland 2023, Czech Republic 2022
[13] Year of Data 2022, Iceland 2023
[14] Year of Data 2021, Belgium and Czech Republic 2022
[15] Year of Data 2023, Iceland 2019, France 2022

				Population 15-64[16]	
13	Unemployment rate, by sex, age and persons with disabilities	%	Quantitative	All ISCED 2011 levels Sex: Total 15 years or over[17]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
14	GERD by sector of performance	€	Quantitative	Total GERD Million euros[18]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
15	SME birth rate	%	Quantitative	% of total firms[19]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
16	R&D Personnel and Researchers	%	Quantitative	% of total employment[20]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
17	R&D expenditure in the business sector	€	Quantitative	Million Euros[21]	https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/04797497-25de-11ee-a2d3-01aa75ed71a4
18	Employment in technology and knowledge-intensive activities	%	Quantitative	[22]	https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/04797497-25de-11ee-a2d3-01aa75ed71a17
19	Sales of new-to-market and new-to-enterprise innovations	% turnover	Quantitative	[23]	https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/04797497-25de-11ee-a2d3-01aa75ed71a21
20	Regional Competitiveness Index	number	Quantitative	[24]	https://ec.europa.eu/regional_policy/assets/regional-competitiveness/index.html#/

Source: own elaboration based on Horizon BIO2REG project.

[16] Year of Data 2023
[17] Year of Data 2023
[18] Year of Data 2021, Iceland 2022, Czech Republic 2022
[19] Iceland 2023; Germany, France, Spain 2021; Sweden, Czech Republic 2020; Greece, Belgium not available
[20] Year of Data 2021, Iceland and Czech Republic 2022
[21] Year of Data 2021, Czech Republic and Iceland 2022
[22] Year of Data 2019
[23] Year of Data 2022
[24] Year of Data 2022

Table 2. The final dataset of the regional bio-economy indicators- The Society Group

A/A	Indicators	Typology	Type of Indicator	Short Description	Initial Source (Review)
1	Life expectancy at birth	Years	Quantitative	(Number of years a new-born infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life)[25]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
2	Gender pay gap	%	Quantitative	[26]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
3	Basic Education	Number	Quantitative	INDEX=100 RCI Sub-indicator[27]	https://ec.europa.eu/regional_policy/assets/regional-competitiveness/index.html#/
4	Health Pillar	Number	Quantitative	INDEX=100 RCI Sub-indicator[28]	https://ec.europa.eu/regional_policy/assets/regional-competitiveness/index.html#/
5	Higher Education	Number	Quantitative	INDEX=100 RCI Sub-indicator[29]	https://ec.europa.eu/regional_policy/assets/regional-competitiveness/index.html#/
6	Population 15-64 years	Number	Quantitative	[30]	https://cnbbsv.palazzochigi.it/media/1953/bit-ii-2019-en.pdf

Source: own elaboration based on Horizon BIO2REG project.

[25] Year of Data 2022
[26] Year of Data 2023
[27] Year of Data 2022
[28] Year of Data 2022
[29] Year of Data 2022
[30] Year of Data 2023

Table 3. The final dataset of the regional bio-economy indicators- The Society Group

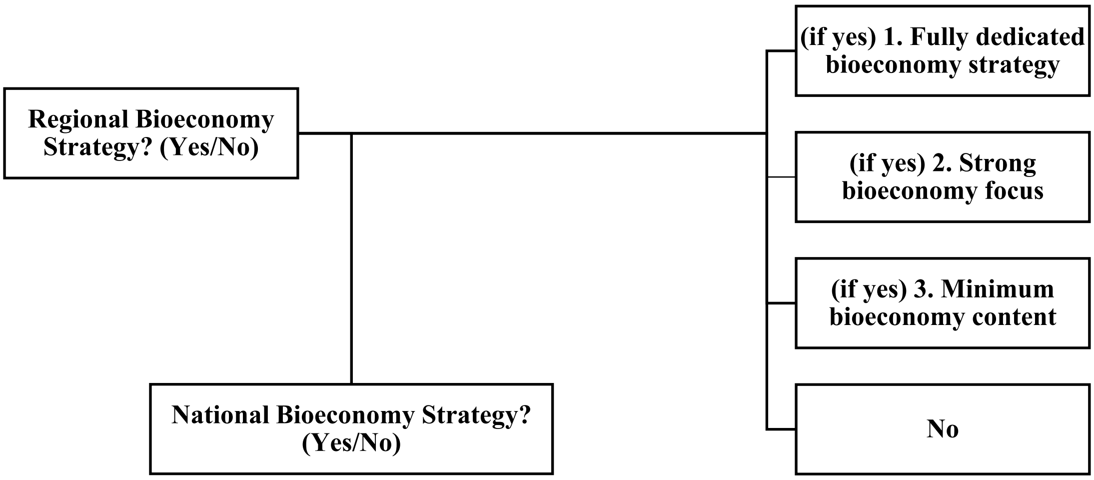
A/A	Indicators	Typology	Type of Indicator	Short Description	Initial Source (Review)
1	Land cover	%	Quantitative	Sub-indicators (Cropland, Woodland, Shrubland, Grassland, Water, Wetland)[31]	https://land.copernicus.eu/en/products/corine-land-cover
2	Organic farming	Hectares	Quantitative	[32]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
3	Artificial land cover	%	Quantitative	% out of total land[33]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
4	Soil erosion	Tonnes	Quantitative	tonnes/ha[34]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
5	Change in forest area	%	Quantitative	[35]	https://www.fao.org/3/ca6048en/CA6048EN.pdf
6	Livestock density index	Number	Quantitative	LSU[36]	https://publications.jrc.ec.europa.eu/repository/handle/JRC136620
7	Utilised Agricultural Area (UAA)	Hectares	Quantitative	Sub-indicators (Low-input, Medium-input, High-inputs farms)[37]	https://publications.jrc.ec.europa.eu/repository/handle/JRC136634
8	Bioenergy/Total Energy	%	Quantitative	Low, Medium High[38]	https://www.sciencedirect.com/science/article/pii/S2211467X19300720
9	Total Land Available for Bioenergy	Hectares	Quantitative	3 scenarios (low, medium, high)[39]	https://www.sciencedirect.com/science/article/pii/S2211467X19300720
10	Total GHG Emissions	kilotonnes CO_2 equivalences	Quantitative	[40]	https://openknowledge.fao.org/server/api/core/bitstreams/95937318-a0be-40d5-82b2-2277dd98add5/content
11	Domestic Material Consumption	Tonnes	Quantitative	[41]	https://onlinelibrary.wiley.com/doi/10.1111/jiec.13000

Source: own elaboration based on Horizon BIO2REG project.

[31] Year of Data 2018, Iceland 2022
[32] Year of Data 2020
[33] Year of Data 2018
[34] Year of Data 2016
[35] Year of Data: 2015-2018
[36] Year of Data 2020, Iceland 2023
[37] Year of Data 2021
[38] Year of Data 2020
[39] Year of Data 2020
[40] Year of Data 2021, Iceland 2022
[41] Year of Data 2015, Iceland 2022

All data for constructing these qualitative bio-indicators were derived by a recent report of the EC (Lopez et al., 2022).

Figure 5. The two qualitative bio-indicators included in the final dataset



Source: own elaboration based on Horizon BIO2REG project.

The ability to perform a robust ranking analysis of numerous different qualitative and quantitative variables is the primary prerequisite for choosing an appropriate method for multiple criteria decision-making (MCDM). For the purposes of the second part of our MCA, we have selected the widely used TOPSIS methodology, a very common tool utilized for solving similar problems of decision making based on many different criteria and indicators (Chakraborty, 2022; Madanchian &Taherdoost, 2023; Shannon, 2001). In a nutshell, TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution, thus, to be closer to the best regional performance in our case, and the longest geometric distance from the negative ideal solution, thus, to be as far as possible by the worst regional performance. TOPSIS method compares all the available alternatives, by giving normalising scores for each criterion and calculates the geometric distance between each alternative and the ideal/worst alternative, resulting in the best score in each criterion.

In our case, we have four groups of criteria (Economy, Society, Environment + two qualitative indicators). An equally weighted ranking was performed as the base scenario (with equal weights assigned to all variables).

During the first ranking efforts, various shortcomings revealed that affected substantially the ap-propriate ranking of the regions. To overcome these obstacles and to tackle data gap problems for specific regions that negatively affecting the ranking and the weight process, we had to perform the following normalising assumptions that substantially improved the performance of the process:

- We excluded the variables/indicators with the poorest regional data e.g. if two or more countries of our dataset presented substantially low regional data availability, then we totally removed the specific indicator. Following this reasoning, we excluded from the "Economy" group the indicators "Productivity of crop production" and "Passenger and freight volumes, by mode of transport" (Motorways & Railways), and, from the "Environment" group, the indicators "Crop yield area" and "Agricultural Land Renting Prices".
- Few data gaps in specific regions (based on their spatial proximity with neighbouring regions, etc.) were filled with the value of the national average of the respective variable.

For regions with zero values in some specific variables (e.g. fisheries turnover, value added and employment for regions without sea proximity), a very low value was entered (e.g. 0.01), to overcome the problem caused by zero values in the process, and, consequently, keeping these regions out of ranking (to the last place of ranking for these specific variables).

In an effort to estimate the total ranking of all groups of bio-indicators (Economy, Society, Environment, and Qualitative indicators), unified as one dataset, was performed.

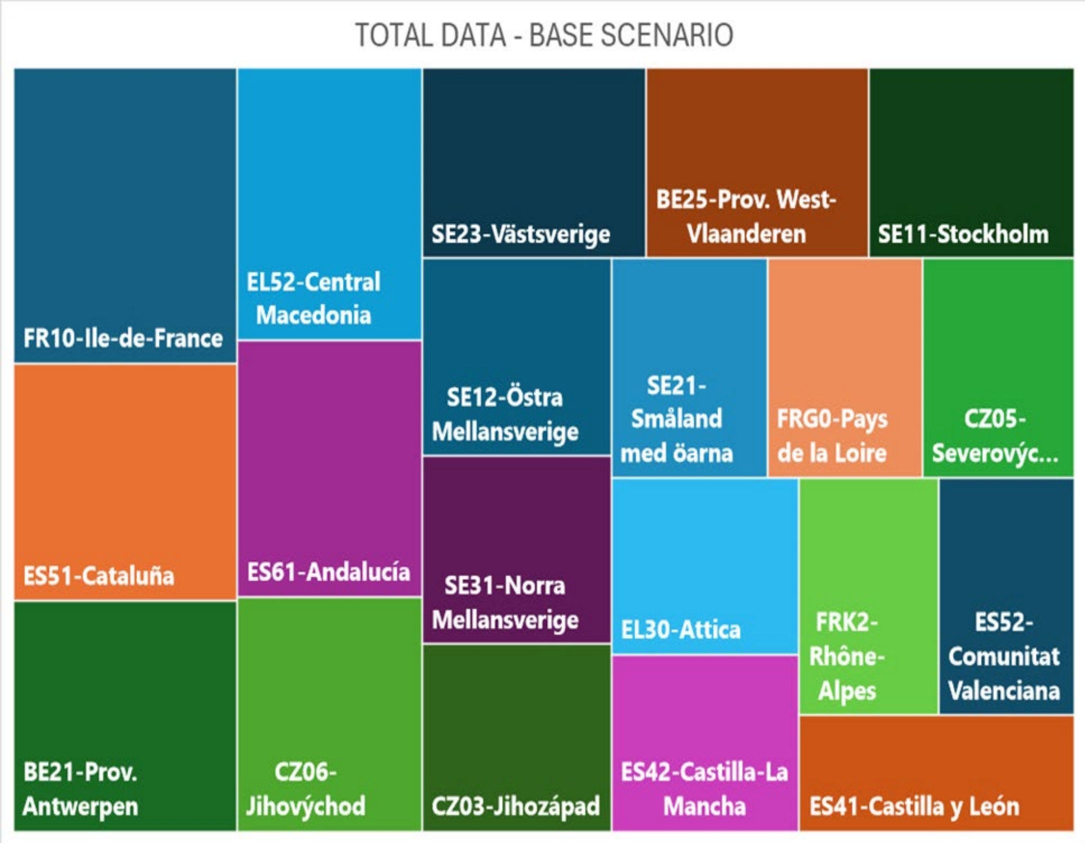
The preliminary results of the analysis provided in Table 4 and Figure 7.

Table 4. Total bioeconomy ranking for the Base Scenario – 20 best performing regions out of 125 (equal weights TOPSIS)

Ranking	Base scenario (equal weights)	
	Region	**Score**
1	FR10-Ile-de-France	0.560
2	ES51-Cataluña	0.450
3	BE21-Prov. Antwerpen	0.437
4	EL52-Central Macedonia	0.427
5	ES61-Andalucía	0.401
6	CZ06-Jihovýchod	0.367
7	SE23-Västsverige	0.362
8	BE25-Prov. West-Vlaanderen	0.358
9	SE11-Stockholm	0.333
10	SE12-Östra Mellansverige	0.317
11	SE31-Norra Mellansverige	0.302
12	CZ03-Jihozápad	0.300
13	SE21-Småland med öarna	0.290
14	FRG0-Pays de la Loire	0.288
15	CZ05-Severovýchod	0.284
16	EL30-Attica	0.281
17	ES42-Castilla-La Mancha	0.281
18	FRK2-Rhône-Alpes	0.280
19	ES52-Comunitat Valenciana	0.273
20	ES41-Castilla y León	0.271

Source: own elaboration based on Horizon BIO2REG project.

Figure 6. Ranking of the "Total Bioeconomy" dataset, with TOPSIS base scenario – top 20 performing regions out of 125.



Source: own elaboration based on Horizon BIO2REG project.

5. Conclusion

The preliminary results of the present essay are part of the initial effort to design, establish, and empirically evaluate a first blueprint for assessing the EU wide regional MCA. In that sense, the EU wide essence was captured by testing the regions of the eight (8) countries participating to the consortium of the BIO2REG project, indeed being a very representative case study for the EU wide regional level, as it covers, in terms of geography, economy and population, the north, the Mediterranean south, as well as major eastern, central and western areas of the EU. The preliminary results of this ongoing process reveal strong bioeconomy potential for specific regions of France, Spain, Belgium and Greece, concerning the first five places of the ranking. However, these preliminary ranking efforts should be considered with caution and critical thinking.

It goes without saying that this initial effort could be substantially benefited by further research. It should be underlined that these are the main results of the base scenario examined for the purposes of the present study, thus, equal weights ranking with the TOPSIS tool. Further attempts with different scenarios, distinct sectoral rankings, and especially, different weighting methods for various variables, will reveal more interesting aspects. It is anticipated that all these aspects will bring forward new knowledge and a better understanding of the elements and the attributes that could increase bioeconomy potentials at the EU regional level, and thus, further improve this initial assessment. Incorporating these new evidences will increase the robustness of the initial MCA blueprint, while at the same time, it may lead into the reconstruction of the database, either by including new indicators (composite, qualitative, etc.), or by excluding other indicators causing negative disturbances to the final outcome, even by testing other weight methodologies such as Shannon entropy weights auto-generated method, in order to reveal certain aspects that this primary assessment misleads.

It is worth mentioned that one of the most critical shortcomings that the present essay revealed was the lack of EU regional data for many crucial indicators, which, irrevocably, ended up into the rejected group of indicators. This outcome should be seriously considered for future bioeconomy planning and strategy implementation at the regional (NUTS 2), and, more importantly, at the municipality (NUTS 3) level. Lack of data availability for these levels of analysis might compromise an essential and a more-in-depth comprehension of the bioeconomy's actual capacity and potentials and, thus, lead in not well planned and weakly implemented relevant policies and strategies. On the contrary, the systematic collection of more detailed data could substantially improve the understanding of bioeconomy's hidden potentials and support the design of more effective and targeted policies, at the regional, local level.

Consequently, there are two axes on which the study can be further elaborated. The first axis targets at specialising the MCA framework in the same EU regions on sectoral level. The focus on sectors aspires to provide the research with more accurate estimations and to highlight NUTS II level regions that perform high on a specific sector, thus showing that this region is taking advantage of its regional characteristics and strengths and builds upon them. In that way, sectoral regional bioeconomic champions may be identified. The second axis aims to extend the MCA assessment to the remaining NUTS II regions in other EU Member States, since the countries covered by this primary assessment are more than half of the total NUTS II regions of the EU MS (125 out of 242 NUTS II regions in total). This extension will provide a more comprehensive picture of the bioeconomy across the entire EU.

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Authors contribution*: "Introduction, Kalimeris P.- Koronaios, P..; Literature review, Kalimeris P.- Koronaios, P.- Maroulis G..; Methodology and data, Kalimeris P.- Koronaios, P.- Maroulis G..; Research results and comments, Kalimeris P.- Maroulis G..; Conclusion, Kalimeris P.- Maroulis G.- Rovolis A."*

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