Advancing Circular Economy through Smart Specialisation Strategies: A Regional Perspective in the European Union

Policy brief

Raffaele Mancuso[1], Alice Sanna[2], Luca Serafini[2], Laura Toschi[1], Stefano Usai[2]

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[1] UniBo
[2] UniCa

1. Executive Summary

This policy brief examines the key role of European regions in enhancing the Circular Economy (CE) through their Smart Specialisation Strategies (S3), that is, strategies for regional innovation aimed at boosting economic growth and competitiveness by building on the region's strengths and areas of excellence. Drawing on a detailed analysis of regional S3 documents, the research reveals the extent to which CE principles are being integrated into the European regional development planning. Also, it provides a spatial distribution of CE integration across regions, based on the documented extent of CE-related content.

2. Introduction

The Circular Economy (CE) is increasingly recognized across Europe as a strategic approach to sustainable development, focusing on decoupling economic growth from resource use. Unlike the linear model, which relies on finite resources and generates substantial waste and pollution, CE promotes waste reduction, material reuse, and recycling within a closed-loop system (Ghisellini et al., 2016). This strategy helps conserve natural resources, fosters innovation, enhances competitiveness, and reveals new economic prospects (European Parliament, 2023).

Recent studies have extensively explored the multidimensional impacts of CE across various spheres (e.g., Ellen MacArthur Foundation, 2024). According to the Ellen MacArthur Foundation (2015), CE brings substantial economic benefits by driving growth through enhanced resource productivity and reduced reliance on raw materials. Furthermore, research has demonstrated that embracing closed loops can lead to significant business cost savings and unlock new market opportunities.

Governments and international organizations have created various policy frameworks to encourage the CE. A prominent example is the EU Circular Economy Action Plan, which outlines initiatives to promote the CE, including eco-design, waste management, and the development of markets for secondary raw materials (European Commission, 2020). However, adopting the CE presents several difficulties. Transitioning to a circular model often faces regulatory barriers, such as outdated laws that favor linear economic approaches and a lack of incentives for circular practices (Almeida Neves and Cardoso Marques, 2022). Additionally, the investment needed for the shift to the CE can be a significant obstacle, particularly for small and medium-sized enterprises (SMEs) (Mura et al., 2019). Financial constraints are also among the main challenges these enterprises encounter.

In Europe, where environmental sustainability is a key policy goal, CE is essential to meeting the European Green Deal's objectives: promoting CE positions Europe as a global leader in sustainable production and consumption, and supporting a more resilient, environmentally conscious economy. Achieving these goals involves a multi-layered approach that requires collaboration among local, national, and EU authorities. Regions are crucial to this effort, as they are closest to local businesses and communities, enabling them to customize circular economy initiatives to local needs.

Scholars recognize the role of regions in experimentation, policy integration, and the creation of localized solutions (Silvestri et al., 2020). To understand the role of regions in the circular transition, Smart Specialisation Strategies (S3) offer a useful framework, as they allow evaluation of how regions have integrated circularity into their innovation and development

priorities. More precisely, S3 strategies are key to helping European regions transition to a CE by aligning regional strengths with sustainable innovation.

Engagement and progress vary across European regions due to differences in institutional capacity, economic structures, and strategic priorities. Some areas have adopted circular principles via specific policies, innovation ecosystems, and inclusion in S3 strategies, focusing on waste management, sustainable production, and resource efficiency. Meanwhile, others remain in early development stages or lack a holistic approach. To foster more uniform adoption throughout the EU, increased coordination, knowledge exchange, and financial support are essential.

This policy brief explores how circular economy principles are incorporated into the S3 strategies of European regions during both the 2014-2020 and 2021-2027 periods. Employing a twofold methodological approach, it aims to enhance current knowledge by revealing regional variations in the implementation of CE within European development strategies.

We collected the PDF describing the Smart Specialisation Strategies (S3) of the different regions in Europe. For the old round (2014-2020), PDFs were provided by the Joint Research Center (JRC), and missing PDFs were located manually. For the new round (2021-2027), the links of the PDFs were first taken from the S3 COP platform[3], and broken links or missing PDFs were retrieved manually.

We first conducted a textual review of how frequently keywords related to CE appear in S3 documents across various regions. The results of the textual analysis reveal a growing focus on the circular economy from 2014 to 2020, with a notable shift from 2021 to 2027, and growth differing across regions. Brittany, Île-de-France, and Emilia-Romagna initially led, but leadership shifted eastward, with regions like Opolskie and Pomorskie in Poland rising alongside Italian regions such as Lazio, Bolzano–Bozen, and Apulia. This suggests a broader interest extending beyond Western Europe, encompassing Central and Southern regions.

We then complemented this first textual investigation with a topic analysis using BERTopic. Unlike word count, topic analysis is carried out at the sentence level and clusters sentences with similar semantic meaning. This allows us to study the topic of the sentence and how it relates to the document's overall discourse, providing a deeper level of analysis and understanding.

3. The Role of European Regions in Advancing the Circular Economy

3.1. Introduction

Scholars have demonstrated that spatial factors considerably influence the achievement of economic and environmental objectives and that regions play a key role in enhancing CE (Chembessi et al., 2024). Additionally, researchers have thoroughly examined the importance of regional collaboration and customized strategies, enabling communities to develop solutions specific to their areas. Regional policies are then crucial for implementing CE principles.

[3] https://ec.europa.eu/regional_policy/policy/communities-and-networks/s3-community-of-practice_en

Arauzo-Carod et al. (2024) note that although the importance of the regional dimension in implementing circular economy principles has recently been recognized by policymakers, research on the spatial dimension remains unexplored. Moreover, they emphasize that, despite the significant role of regions, most competencies are allocated to member states, and that there is considerable heterogeneity among countries, as shown in Table 1.1. This leads to unequal progress toward sustainable goals and, consequently, a different rate of progress toward the European Green Deal.

[TABLE 1 HERE]

Many European regions have integrated CE principles into their S3 strategies, with examples like the Basque Country and Flanders. They focus on industrial symbiosis, sustainable manufacturing, and waste-to-resource initiatives (European Commission, 2019). The Basque Strategy emphasizes CE in manufacturing, with initiatives such as the Basque Ecodesign Centre fostering collaboration on sustainable products (Ellen MacArthur Foundation, 2020). Flanders promotes waste management, recycling, and material reuse through the Flanders Materials Programme, aiming to advance a circular economy.

Barbero et al. (2025) examine the distribution of EU-funded circular economy projects across European regions using a new dataset of research initiatives supported by the European Regional Development Fund. Using a fractional response model to analyze 231 regions, they find a clear geographical pattern, indicating uneven funding distribution across the EU. The study highlights that regions that foster Circular Economy policies are those with strong institutions, innovation capacity, human capital, and investment potential, such as Germany, the Netherlands, France, and Italy. These findings align with those of Silvestri et al. (2020), which address different socioeconomic dimensions.

Several studies emphasize the increasing recognition of CE as a key factor in promoting sustainable economic growth and innovation in regional strategies. Nordregio (2020) highlights how integrating bio, circular, and digital economies into the S3 framework can create growth opportunities, positioning the Baltic Sea Region as a leader in circular innovation. The CLIC Project (2020) examines how EU member states have adopted CE strategies and integrated them into regional development plans, offering insights into best practices and regional variations. McCann and Ortega-Argilés (2022) expand on this by examining the sustainability impacts within S3, suggesting that adopting CE principles can boost regional economic resilience and stimulate innovation.

Aligning CE with S3 supports sustainable growth, job creation, innovation, and environmental benefits, such as waste reduction and lower emissions. Challenges include coordinating among governments, industry, and academia, making high initial investments, securing funding, and adopting new technologies, all of which require research and knowledge sharing. Integrating CE into S3 is a promising strategy to promote sustainable regional development, foster innovation, and achieve long-term economic and environmental benefits.

3.2. The Integration of Circular Economy in S3 Strategies

3.2.1. Keyword-based textual analysis

Keyword analysis is a powerful and scalable technique for examining large amounts of textual data, making it especially useful for policy research and document review. It helps researchers detect patterns, key themes, and shifts in discourse over time and across sectors by measuring term frequency and co-occurrence. However, it is necessary to consider some limitations, such as focusing on differences rather than similarities (Baker, 2006) or failing to consider the cultural context that informs the text (Bondi & Scott, 2010). This method is particularly valuable when analyzing policy narratives or institutional language, as it reveals how important concepts are presented and emphasized in official documents (Seale, 2004). Unlike purely qualitative methods, keyword analysis provides empirical support for interpretative insights, enabling comparisons across documents and contexts (Stubbs, 2010). When combined with contextual analysis, it improves transparency and repeatability in textual research, aiding more effective policy assessment and development.

Keyword search analysis enables policymakers to map the discourse on circular economy across S3 documents by identifying key terms, such as “reuse” or “recycling,” and revealing alignments or gaps with policy goals. For instance, literature shows that EU documents highlight a rise in “eco-design” and “extended producer responsibility”, showing regulatory shifts (Korhonen et al., 2018). Their approach demonstrated a systematic use of keyword-based literature analysis to track the evolution and usage of circular economy concepts, including regulatory terms. Scale-based keyword analysis supports evidence-based decisions, reveals underserved sectors, and shapes strategies, also increasing transparency and engagement. Textual analysis via keyword methods is effective for studying the CE by systematically identifying, quantifying, and understanding CE concepts across large datasets. Focusing on key terms within CE frameworks, such as the 4R framework (Kirchherr et al., 2017), reveals frequency patterns, sector engagement, and trends, thereby enriching understanding of CE practices and their evolution. This method also enables semantic and topic modelling to explore conceptual shifts and interdisciplinary links, supporting a cumulative and refined understanding of CE. Overall, keyword analysis provides a scalable, data-driven approach that deepens the understanding of the thematic development of the circular economy.

The analysis employed a comprehensive circular economy dictionary comprising seven thematic categories: (1) core CE concepts, (2) design strategies, (3) R-strategies (reduce, reuse, recycle), (4) waste management, (5) business models, (6) performance indicators, and (7) certification frameworks. The methodology uses stemming algorithms to normalize word declinations and n-gram analysis (1-3-grams) to capture both single terms and multi-word expressions. Regional Smart Specialisation Strategy (RIS3) documents were systematically processed using text extraction, cleaning, tokenisation, and dictionary lookup to quantify term frequencies across CE categories, generating both absolute counts and normalised intensity measures to facilitate comparative analysis across regions with different document volumes.

Figure 1 and Figure 2 display the results of the keyword analysis for the RIS3 waves 2014-2020 and 2021-2027. The former displays the total matches, while the latter displays the log-normalized values. At first glance, it is evident that the presence of CE-keywords in these documents has increased between the two waves. Another observation is that this increase is not uniform, nor is the distribution in the first period. In particular, the total CE keyword matches increased from approximately 300 in the first period to around 900 in the second

period. Since some strategies were redrafted for larger territories (i.e., NUTS 2 to NUTS 1 or national level), part of this rise could reflect broader coverage rather than entirely new content.

[FIGURE 1 HERE]
[FIGURE 2 HERE]

Additionally, the number of regions with zero matches decreased from 12/168 for the first wave to 4 /166 for the second wave, indicating that almost every region now contains at least one CE reference. Data show that in the first period, the leading regions were Brittany in France (338 total matches), followed by Emilia-Romagna in Italy (270 total matches) and Île-de-France in France (203 total matches). In the second period, the leadership shifted to Polish regions: Opolskie (301) and Pomorskie (299). The Italian regions Lazio (260), the Province of Bolzano-Bozen (259), and Apulia (236) also rank among the top. Between the two rounds, the median number of keyword matches increases from 19 to 49, while the maximum number drops from 338 to 301. On the log-scale maps, this flattens out the color range: more regions now sit in the middle bands.

Finally, the most significant absolute gains are observed in several Polish, Italian, Romanian, Bulgarian, Portuguese, and Spanish regions, darkening many previously pale areas on the 2021-27 map; only a handful of peripheral regions remain at the low end.

3.2.2. Topic analysis

We model the topics embedded in the S3 strategies using BERTopic (Grootendorst, 2022). The process is as follows. We split their text into sentences and translated it into English with Google Translate. We then embed the sentences into a sentence vector space using the Qwen 3 embeddings model with 0.6B parameters. BERTopic then reduces the dimensionality of the sentence vector and clusters the sentences.

We obtain a total of 4,047 topics for 392,205 sentences in our corpus. We identify circular economy topics by searching for terms similar to “circular economy”, retaining only those with a similarity score of 70% or higher. We identified 10 topics related to the circular economy. Table 2 reports the topic number, the topic representation, the words that compose the topic, and the similarity with the "Circular Economy" concept.

We then counted the total number of topics and the number of Circular Economy topics in each NUTS region, and computed the ratio between the latter and the former (i.e., the CE topics' *incidence*). Figure 3 and Figure 4 are choropleth maps of the total number of CE topics in the region (upper subfigure) and the percentage of these topics relative to the total number of topics in the documents (lower subfigure) for the old and new rounds of policies, respectively.

In the old round, only 58/169 regions (34%) have at least one sentence about the circular economy in their documents. There is an average of 1.23 CE sentences over 1,733.39 mean number of sentences per document (0.071%). The region with the highest percentage of CE sentences was DK04 (Midtjylland) with 2/122 (1.63%) sentences, followed by ES24 (Aragon) (37/2418, or 1.53%), SE212 (Kronobergs län) (5/393, or 1.27%), EL (Greece) (10/1,545, or 0.64%), and LU (Luxembourg) (2/310, or 0.64%). The regions with the largest absolute count of

CE sentences are ES24 (Aragon) (37/2,418), EL (Greece) (10/1,545), FRH0 (Brittany) (10/4,976), ITH5 (Emilia-Romagna) (9/3684), and ES52 (Valencian Community) (8/3,028).

In the new round, 131/170 regions (77.05%) have at least 1 sentence about CE in their Smart Specialization Strategy. The average number of sentences about the CE equals 3.85 per document, compared to an average of 2,614 sentences per document (0.14%). The regions with the highest absolute number of CE sentences are DEA (North Rhine-Westphalia) (23/1453), ITF4 (Puglia) (23/2028), FRI (Nouvelle-Aquitaine) (17/987), ITH1 (South Tyrol) (16/3199), and BE2 (Flemish Region) (13/3196). The ones with the highest percentages are ES42 (Castile-La Mancha) (1/24=4.16%), EL (Greece) (7/188=3.72%), DE9 (Lower Saxony) (1/52=1.92%), FI1D2 (Pohjois-Savo) (11/587=1.87%), and FRI (Nouvelle-Aquitaine) (17/987=1.72%).

An analysis of the choropleth maps reveals interesting patterns. While in the old round only a few regions were concentrated in CE, in the new round the distribution is much more widespread (Aragon, Greece, Brittany, Emilia-Romagna). The Circular Economy concept has gained widespread adoption in Italy, France, Spain, Germany, the Netherlands, Sweden, and Finland. Concentration metrics provide evidence that discussions about the Circular Economy are more widespread in the new round. In the old round, the Herfindahl–Hirschman index computed on CE sentences was 5.16%, while in the new round it was 1.28%, indicating a wider dispersion of CE topics.

4. Conclusions

Results of the textual analysis show that awareness of circular economy issues has grown across European regions between 2014–2020 and 2021–2027, though the growth has been uneven. In 2014–2020, the leading regions were Brittany and Île-de-France in France, as well as Emilia-Romagna in Italy. In the subsequent period, leadership shifted eastward, with Polish regions such as Opolskie and Pomorskie gaining prominence, alongside continued strong representation from Italian regions like Lazio, the Province of Bolzano–Bozen, and Apulia. This shift indicates a broader diffusion of interest in circular economy practices, reaching beyond the traditionally dominant Western European regions and reflecting increased engagement from Central and Southern Europe.

The topic analysis confirms an increase in the number of documents discussing the circular economy over time. Moreover, while the focus on the Circular Economy in the previous round was scarce and concentrated in a few regions (mainly Spain's Aragon and France's Brittany), the current round shows a wider spread, with France, Germany, and Spain also catching up. Finally, concentration metrics indicate that conversations about the Circular Economy are more evenly distributed in the recent round.

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6. Figures

Figure 1. Total CE-keywords matches (2014-2020 and 2021-2027).

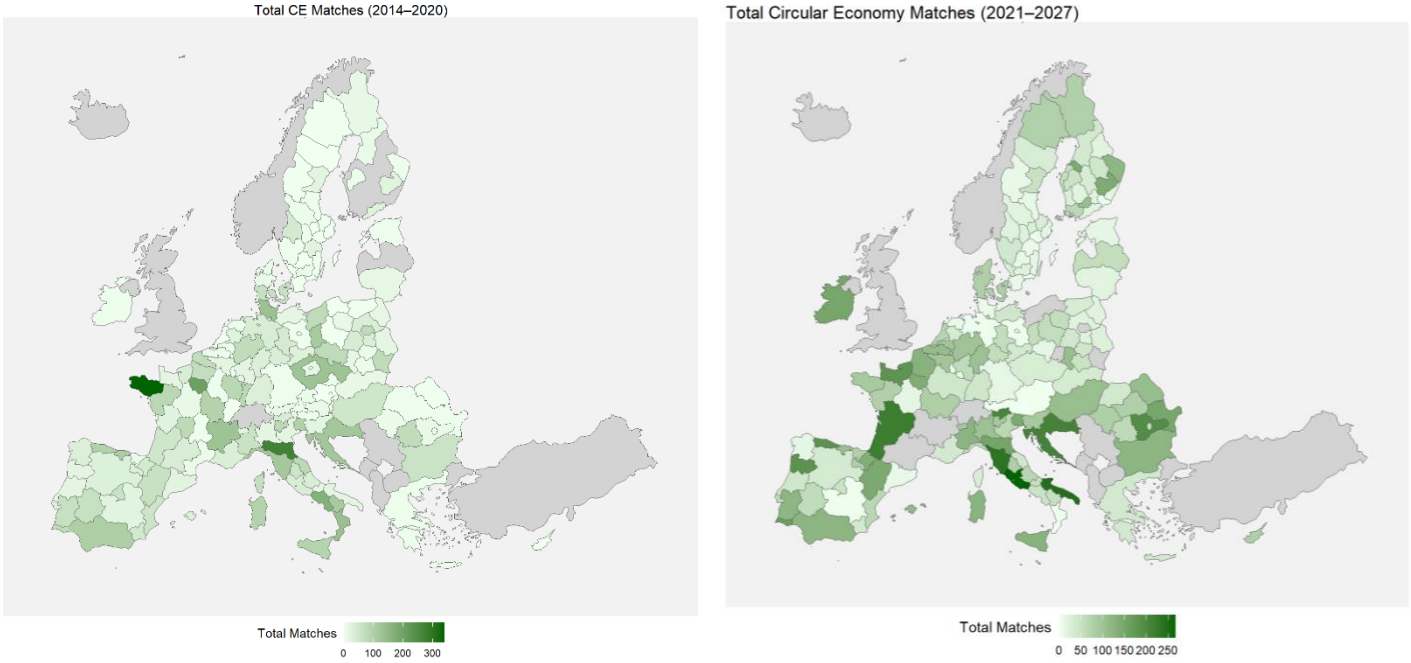


Figure 2. Total CE-keywords matches (2014-2020 and 2021-2027) – log normalization.

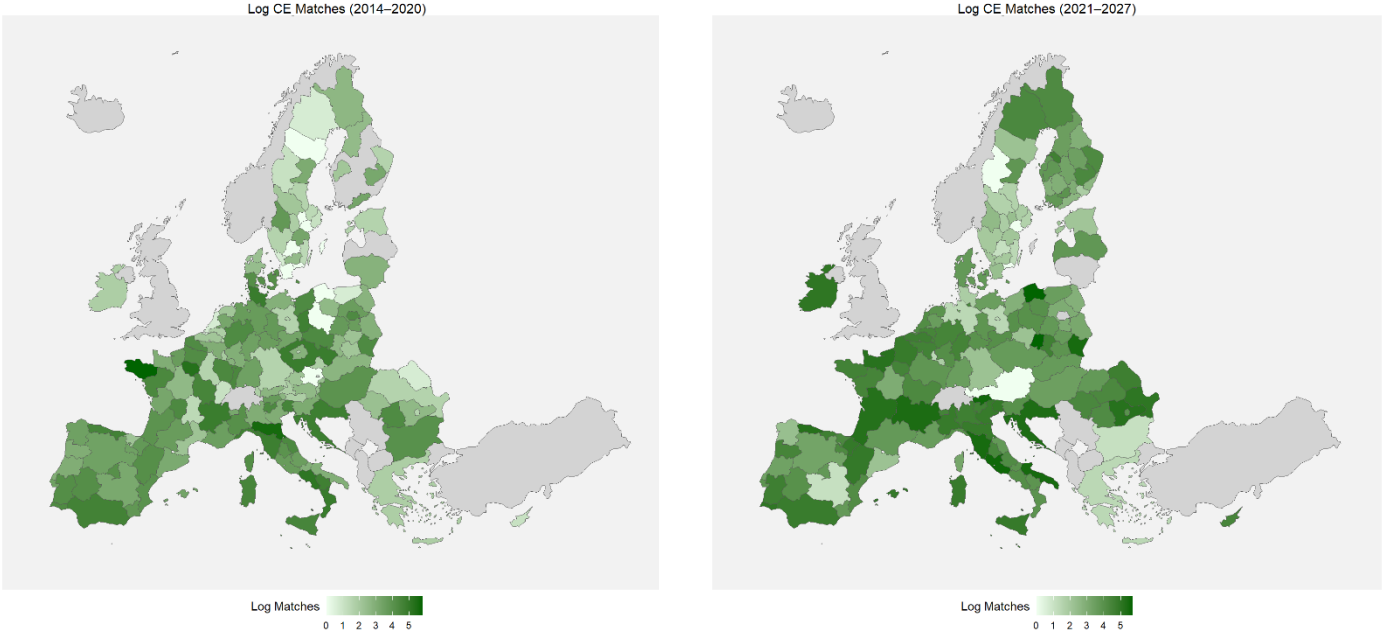


Figure 3. CE topics incidence in the old round.

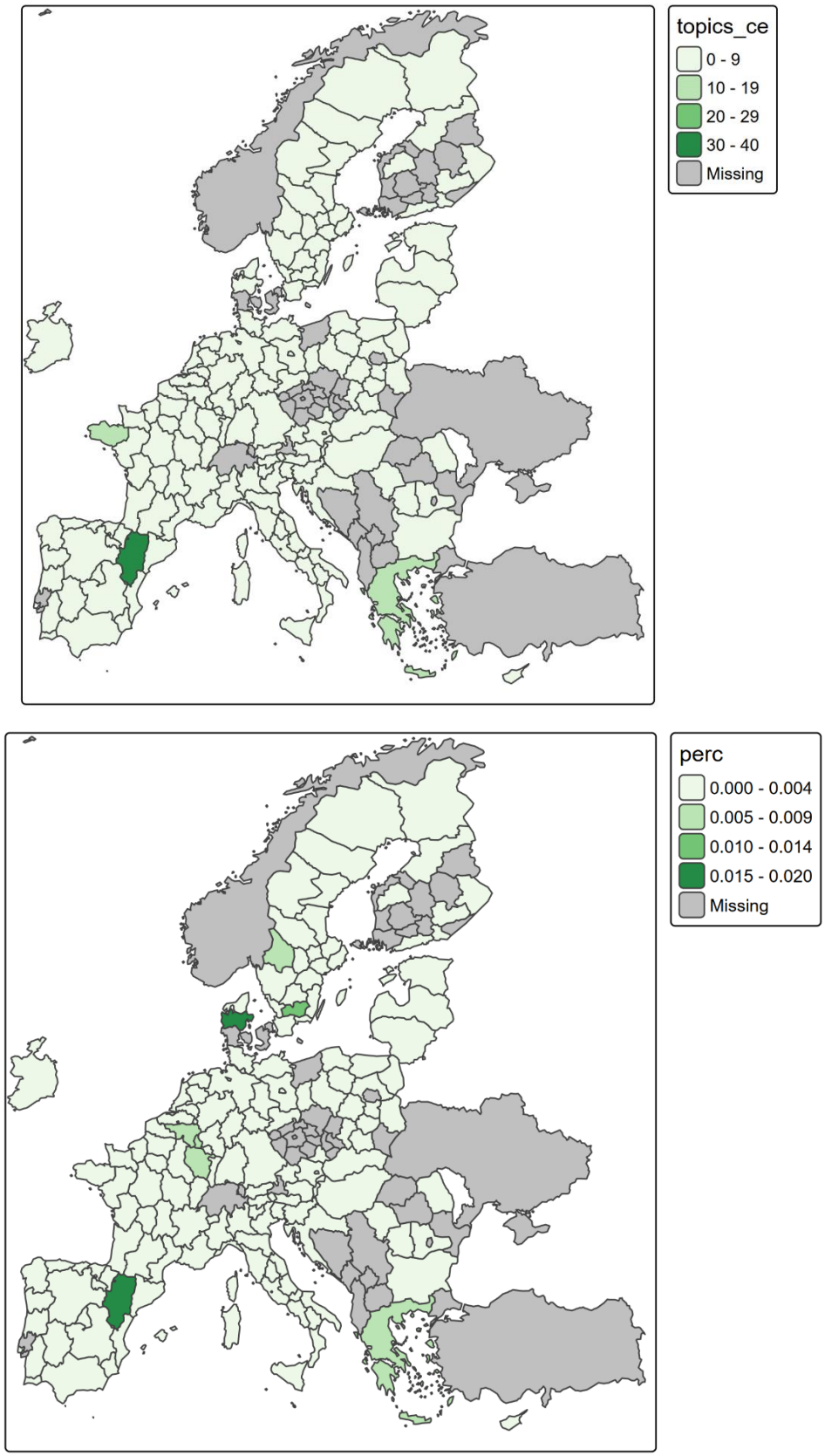
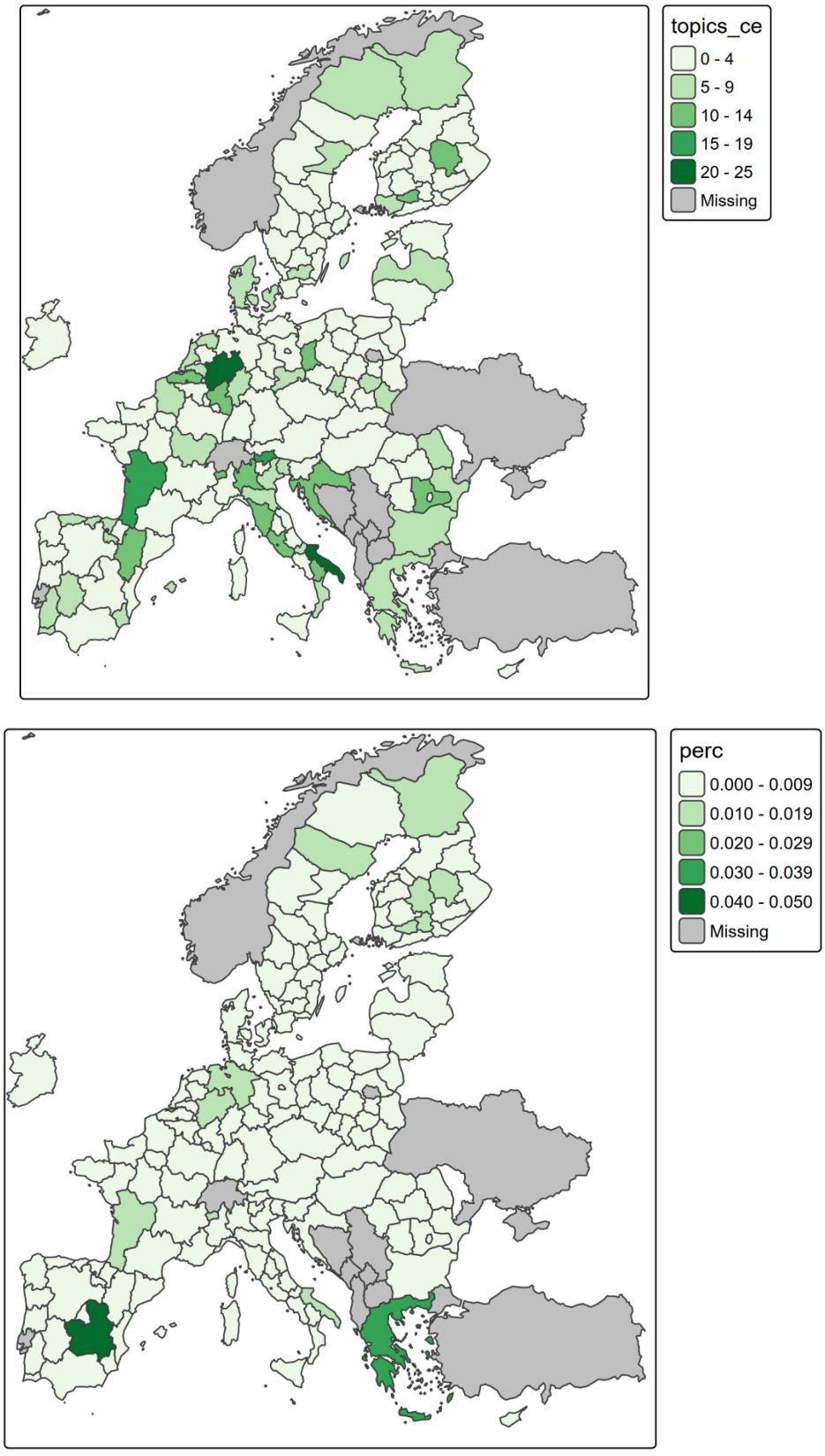


Figure 4. CE topics incidence in the new round.



7. Tables

Table 1. Competence of selected member states across different levels of government.

	Waste management	**Industrial Emissions**	**Water Management**	**Urban Infrastructure**
Spain	Local, regional, national	Local, regional	Local, regional, river basins	Local, regional
Slovakia	Local, national	Local	Local, national	Local, regional
Italy	Local, regional, national	Local, regional, national	Local, regional, river basins, national	Local, regional
Czechia	Local, national	Local, regional	Local, national	Local, regional
Bulgaria	Local, national	Local	Local, river basins	Local

Source: Arauzo-Carod et al., 2024

Table 2. The 10 topics found by searching "Circular Economy" with a 70% threshold.

Topic	Count	Name	Representation	Similarity
59	427	59_circular economy_circular_economy circular_circularity	['circular economy', 'circular', 'economy circular', 'circularity', 'transition circular', 'economy', '975', '975 975', 'long possible', 'linear']	0.857034
136	206	136_waste_recycling_waste management_recycled	['waste', 'recycling', 'waste management', 'recycled', 'waste collection', 'recovery', 'reuse', 'collection', 'recovery waste', 'waste recycling']	0.75028
3503	8	3503_recyclability_improving recyclability_increasing service_material cycles	['recyclability', 'improving recyclability', 'increasing service', 'material cycles', 'closing material', 'reducing material', 'service life', 'recyclability repairability', 'close material', 'assembly reuse']	0.74539
3314	10	3314_economy adopted_roadmap circular_regeringens_adopted june	['economy adopted', 'roadmap circular', 'regeringens', 'adopted june', 'strategy circular', 'circular production', 'circular economy', 'circular', 'baek', 'coordination capabilities']	0.734798
1894	19	1894_striving reuse_consumption processing_stages design_processing collection	['striving reuse', 'consumption processing', 'stages design', 'processing collection', 'life cycle', 'cycle products', 'leads extension', 'materials raw', 'end life', 'reuse materials']	0.72683
943	35	943_resource efficiency_efficiency resource_negative environmental_environmental impacts	['resource efficiency', 'efficiency resource', 'negative environmental', 'environmental impacts', 'addition negative', 'reducing negative', 'reduced environmental', 'impacts products', 'resource', 'products life']	0.722102
1945	19	1945_plan circular_new action_economy action_action plan	['plan circular', 'new action', 'economy action', 'action plan', 'circular economy', 'new circular', 'eu action', 'circular', '6388', 'b735']	0.720056
3749	6	3749_based circular_bio circular_2022 promote_automation planning	['based circular', 'bio circular', '2022 promote', 'automation planning', 'biobased circular', 'need expertise', 'functional bio', 'responsibility develop', 'mali', 'importance society']	0.71862
2090	18	2090_transformation circular_circular economy_entrepreneurs qualified_generation entrepreneurs	['transformation circular', 'circular economy', 'entrepreneurs qualified', 'generation entrepreneurs', 'transition supporting', 'digitalization circular', 'circular', 'economy digitalization', 'projects changing', 'regard digitalisation']	0.712155
1090	32	1090_bioeconomy development_bioeconomy_biotechnologies oriented_waste recovery	['bioeconomy development', 'bioeconomy', 'biotechnologies oriented', 'waste recovery', 'circular bioeconomy', 'pollution reduction', 'environment pollution', 'oriented protection', 'based biogenic', 'circular']	0.706056