H2020 MSCA-ITN-2018

ReTraCE Project

Realising the Transition to the Circular Economy

D4.3

Measuring the transition towards a Circular Economy at a regional level: a review

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Innovative Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

Acronym: **ReTraCE**
Title: Realising the Transition towards the Circular Economy: Models, Methods and Applications
Coordinator: The University of Sheffield
Reference: 814247
Program: H2020-MSCA-ITN-2018
Start: 1st November 2018
Duration: 48 months
Website: www.retrace-itn.eu
Consortium:

The University of Sheffield (USFD)
Università degli Studi di Napoli Parthenope
University of Kassel (UniKassel)
South East European Research Centre (SEERC)
Academy of Business in Society (ABIS)
Högskolan Dalarna (HDA)
University of Kent (UniKent)
Tata Steel UK Limited (Tata)
Olympia Electronics SA (OE)
Erasmus University Rotterdam (EUR)

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Deliverable

Number: **D4.3**
Title: **Measuring the transition towards a Circular Economy at a regional level: a review**
Lead beneficiary: SEERC
Work package: WP4
Dissemination level: *Public (PU)*
Nature: *Report*
Due date: 30.06.2020
Submission date: 30.06.2020

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EXECUTIVE SUMMARY

The Circular Economy Action Plan (CEAP) is the European cornerstone that designates the direction towards CE (Circular Economy) and sets out concrete actions to realise the transition towards the CE. The plan shows the EU Commission's aspirations of ensuring the transition works for people, regions and cities, supports the journey towards climate neutrality and harnesses the potential of research, innovation and digitalisation. Additionally, in the CEAP, the European Commission (EC) is envisaging the broader development of a *"sound monitoring framework contributing to measuring well-being beyond GDP".* Finally, enhancements of circularity metrics at different levels not yet reflected in official statistics are foreseen (European Commission, 2020). But what exactly does measuring beyond GDP mean? Which areas of socio-economic development must be taken into consideration? And what are the other levels of implementation, aside from the national level, that are crucial for the transition? The ongoing debates aimed at answering these fundamental questions, and many others, have still not reached agreement.

This report seeks to remedy these issues by analysing the academic literature and relevant policy documents in order to provide a comprehensive review of the existing body of knowledge on the CE assessment. Additionally, the report advocates the regional level as the optimal level for CE implementation and proposes a conceptual framework for measuring circularity – **The Regional CE-Centric Assessment Framework (RCEAF)**. The RCEAF is a three-level framework, based on the objectives of the new framework for Regional Development and Cohesion Policy (Level 1) and expands into six main Building Blocks (Level 2) that need to be taken into account for developing specific indicators for measuring circular economy. These Building Blocks consider the operational (intrinsic) side of the framework. The last level (Level 3) looks into measuring the impact of regional CE implementation. In that context, consideration of three broad dimensions is proposed: economic, environmental and social CE impact areas. Finally, an attempt is made to elaborate on the two-sided relationship between the RCEAF and the stakeholders identified in the CE-centric QNH model (ReTraCe D4.2, 2020). The proposed RCEAF framework can be used to further develop indices and measurements specific to the regional context and monitor circular economy advancement for an evidence-based regional policy.

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LIST OF ABBREVIATIONS/ACRONYMS USED

BSI British Standard Institutions
CCAF Circular City Analysis Framework
CCEEIS Chinese Circular Economy Evaluation Indicator System
CE Circular Economy
CEAP Circular Economy Action Plan
CEE Circular Economy Efficiency
CEPI Circular Economy Potential Indicator
CTI Circular Transition Indicators
D Deliverable
DEA Data Envelopment Analysis
DRCSC Development Research Centre of the State Council
EAFRD European Agricultural Fund for Rural Development
EC European Commission
EIS Emergy-based Indicator System
EISCE Evaluation Indicators System of Circular Economy
EMFF European Maritime and Fisheries Fund
EPI Environmental Performance Index
ERCE Evaluation of Regional Circular Economy
ERDF European Regional Development Fund
ESF European Social Fund
ESIF European Structural and Investment Funds
EU European Union
FCIM Five Category Index Method
FCWE Fuzzy Competitiveness Weight Evaluation
GDP Gross Domestic Product
ILO International Labour Organisation
IPCEIS Industrial Park Circular Economy Indicator System
LCA Life Cycle Assessment
M Milestone
MFA Material Flow Analysis
MFCE Monitoring framework for the CE
MRE Material/Resource/Energy
NACE Nomenclature of Economic Activities
NCEIS National Circular Economy Indicator System
NUTS Nomenclature of Territorial Units for Statistics
OECD Organisation for Economic Co-operation and Development
PCA Principal Component Analysis
PCWD Pollution Controlling and Waste Disposing
QNH Quintuple Helix
RCEAF Regional CE-centric Assessment Framework
RCEDI Regional Circular Economy Development Index
RCI Regional Competitiveness Index
RDCP Regional Development and Cohesion Policy

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RP Resource Productivity
RSPR Resource Saving and Pollutants Reducing
SEPA State Environmental Protection Administration
SFA Substance Flow Analysis
UCDI Urban Circular Development Index
UK United Kingdom
UN United Nations
UNEP United Nations Environment Programme
US United States
WBCSP World Business Council for Sustainable Development
WP Work Package
WRRR Waste Reusing and Resource Recycling
WTO World Trade Organization

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1. REGIONAL CIRCULAR ECONOMY POLICIES AND STAKEHOLDERS

The Industrial Revolution marked a new era of global growth that triggered a wave of breakthroughs, technological advancements and digitalisation. All these developments were reflected in the twin forces of uncontrolled consumption and production. Nevertheless, all this growth and prosperity was not evenly distributed, which led to poverty and inequality. The visual presentation of this is depicted in Figure 1, shown as a two-sided spiral. The benefits scored on the upward side of the spiral were achieved at a cost to the environment, and they placed substantial pressures on the planet's lands, waters, forests and other natural resources. The downward spiral of environmental degradation, loss of biodiversity, accelerated resource extraction and resource scarcity was moving in the opposite direction at an equally overwhelming pace. All this was *"driving forward the new model of take-make-waste; and ever since, we have been headed in the wrong direction on circularity. As a result, the global engine of change is stuck in reverse"* (Circle Economy, 2020). However, as the World Commission on Environment and Development stated in the UN report Our Common Future in 1987: *"the environment is where we all live; and development is what we all do in attempting to improve our lot within that abode. The two are inseparable… What is needed now is a new era of economic growth - growth that is forceful and at the same time socially and environmentally sustainable."* This new era of sustainable development, whose need was acknowledged more than three decades ago, can be attained only by a deeply transformational change of the whole socio-economic system. Central to the entire idea of transitioning towards a more sustainable economy is the concept of Circular Economy (CE), which promises to yield positive societal benefits, design waste out of the system and decouple growth from resource consumption.

In a free-market economic context, characterised by limited government intervention, bottom-up innovation and entrepreneurship have a fundamental role to play in achieving economic growth and competitiveness, hence also serving as a basis for resilience and transition towards a CE. This bottom-up approach towards the CE, based on entrepreneurship and innovation, is adopted in the EU context. However, to enable the engine of entrepreneurship and innovation to flourish, proper conditions must be in place. To that end, the first Deliverable of ReTraCE WP4 (D4.1)[1] attempted to investigate the role of policies to enable an ecosystem that foster the CE transition, with a special emphasis on the role of policymaking at a regional level. In that regard, existing regional policies in the EU were considered, covering the regional resilience concept, various levels of innovation systems, the place-based approach and the Smart Specialisation Agenda. The low carbon and CE goals will be the same for each European city and region, but the timeline and implementation approaches will differ in a place-based context, depending on many factors: geographical, environmental, economic, social, and cultural. Therefore, the diversity of territorial contexts translates into different needs and opportunities that CE approaches and policies should address (CoR, 2019).

[1] Circular Economy implementation at a Regional level: a Preliminary Review (Available at: http://www.retrace-itn.eu/wp-content/uploads/2020/04/ReTraCE-D4.1.pdf)

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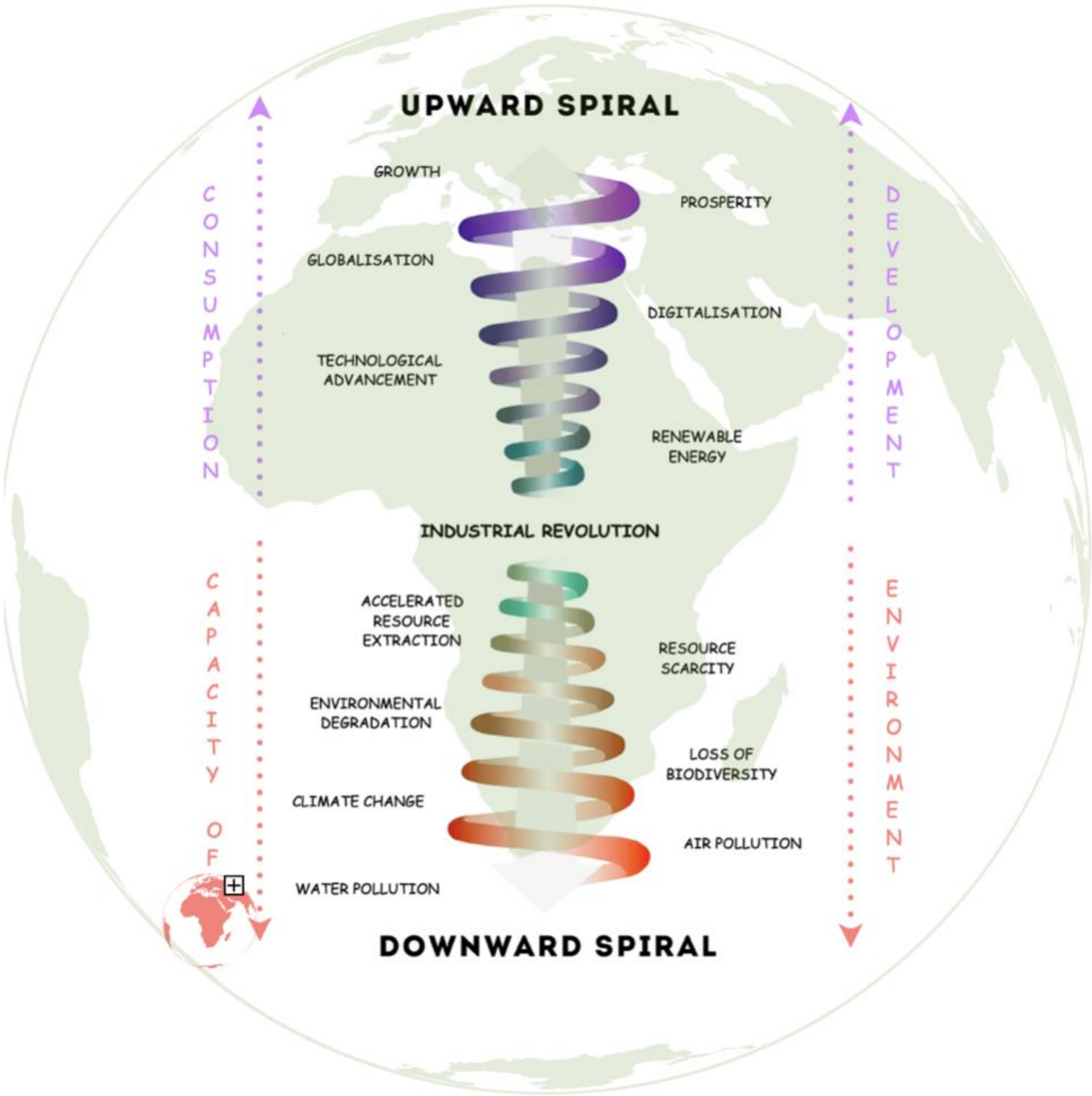

Figure 1: The Industrial Revolution Spiral

The transition to a CE is regarded as systemic, not only by policymakers, but also by academics and practitioners. Moreover, the involvement, alignment and cooperation of all stakeholders is necessary for a successful outcome. Hence, central to driving the process towards circularity is to involve all relevant actors. Nevertheless, debates continue about the best ways to achieve this. Additionally, questions have been raised about the categorisation of stakeholders, their roles and responsibilities in the transition and the essential interactions between them. Moreover, little attention has been paid to developing models for mapping and identifying stakeholders when

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implementing CE policies at a regional level. The second Deliverable of ReTRaCE WP4 (D4.2)[2] attempted to make a contribution in this respect, by analysing the academic literature and relevant policy documents and making the first attempt to adjust existing models for stakeholder mapping in the CE scenario. A new model has been proposed, the CE-centric Quintuple Helix (QNH) model, which promotes the emergence and deployment of trilateral networks, hybrid organisations and development/co-operation platforms. At the core of this model is the academia-industry-government nexus, which has been extended with the inclusion of the civil society sphere and the natural environment.

Having prepared the ground for regional CE implementation in the previous two reports (D4.1 and D4.2), related to policy and stakeholder mapping respectively, WP4 will move on to discuss the measurement of circularity at a regional level. The need for metrics and indicators on the CE has been widely acknowledged by both academics and policymakers, but there is still insufficient work that can contribute to a deeper understanding and evaluation over time (Ghisellini et al., 2016). Policymakers need robust data and information in order to make well-informed decisions and support the implementation of the CE, which is in line with the principle that *"one cannot improve what is not measured"* (OECD, 2019). For that purpose, this report will focus on devising and proposing a framework for measuring the transition to the CE at a regional level. This framework will be a multi-criteria and multi-stakeholder framework, encompassing multiple perspectives conforming with the systemic nature of the CE paradigm shift. The next section provides the rationale for establishing assessment frameworks at a regional level as well as providing a review of the existing CE measurements and indicators at a regional level. Section 2 will give an account of the supporting arguments for advocating the NUTS 2 level of regions as the most suitable level for implementing and measuring circular change.

2. MEASURING THE TRANSITION AT A REGIONAL LEVEL

The OECD (2019) sees the CE not as an end in itself, but rather, as a means to an end: better environmental quality, economic growth and social well-being. In that sense, the ultimate goal of the paradigm shift is reaching a point where the Circular Economy is just "the Economy". However, as the most recent Circularity Gap Report 2020 shows, we are a long way from that considering that the current global economy is only 8.6% circular, compared with the 9.1% circularity reported last year. Taking into account the long way we have ahead for reaching the point where the CE is just "the Economy", it is even more important to track the progress being made in that direction on different levels. For instance, countries are being seen as the key potential agents of positive change (Circle Economy, 2020). The OECD, on the other hand, is promoting cities and regions as the most suitable unit of implementation, arguing that cities represent almost two-thirds of global energy demand and produce up to 80% of greenhouse gas emissions and 50% of global waste (OECD, 2019).

[2] Maps of stakeholders and interactions for designing policies for CE implementation

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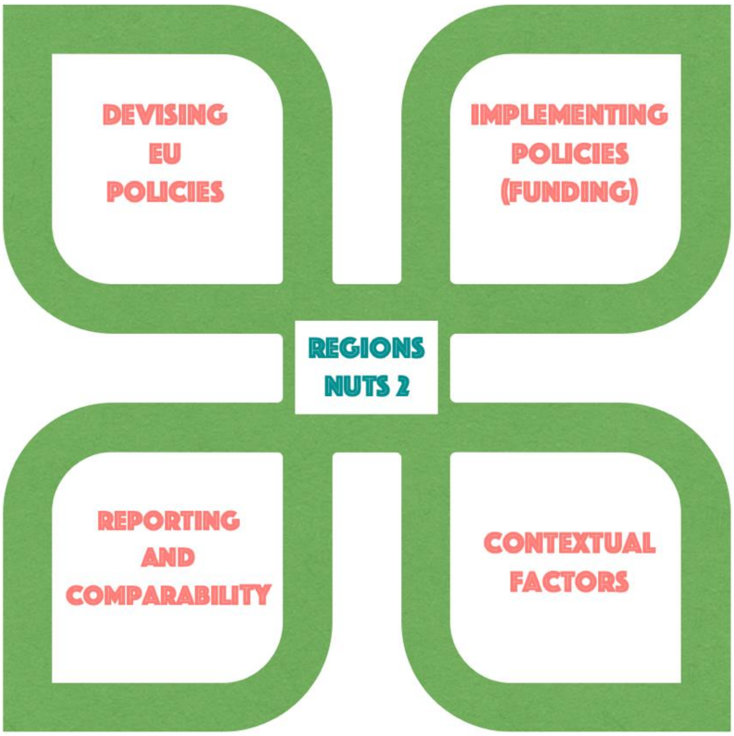

Figure 2: Regions - catalysts for circular change

WP4 is advocating regions, particularly the NUTS 2 level regions in the context of EU policymaking, as the most suitable catalysts for circular change. The reasons for that are arranged into four groups and illustrated in Figure 2. As already reasoned in D4.1, regions and cities are often seen as pioneers by practitioners in the transition towards sustainability, since they often start implementing changes before national policies have been devised. The reasons for this are their scale and controllable economic systems, proximity to environmental, social and economic issues, and ability to use local experience from relevant stakeholders (CIRCTER, 2019). All those factors are categorised as contextual factors and identify regions as the most suitable unit of implementation and analysis.

The region as an administrative component is fundamental in EU policy development (e.g. Cohesion Policy 2014–2020). More specifically, the NUTS 2 regions have been the basic regions for the application of regional policies. The regions that have been eligible for support from Cohesion Policy have been implementing those policies by the regionally oriented and distributed EU financial resources. For instance, the European Structural and Investment Funds (ESIF) are regionally oriented (Figure 3); specifically, the European Regional Development Fund (ERDF) and the European Social Fund (ESF), the Cohesion Fund, the European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF) (Avdiushchenko, 2018). Finally, any kind of comparison on a country or city level is not statistically appropriate considering the difference in population and geographical area (i.e. comparing Malta with France). On the other hand, taking into account the NUTS classification, which is done based on population, the comparison between the regions is more suitable since the units are comparable in population (i.e. Central Macedonia regions in Greece and the Emilia Romagna region in Italy).

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Figure 3: The European Structural and Investment Funds (**Source:** The European Parliamentary Research Service Blog, 2015)

3. MEASURING CE IMPLEMENTATION AT A RERGIONAL LEVEL: A PRELIMINARY REVIEW

This section of the report will give an overview of the current and proposed measurements for CE implementation at a regional level. The relevant indicators and metrics, emerging from both grey literature and the proposals from the academic literature, were collected for the purpose of this report. The search methodology included inspection of the literature (in English) by searching for terms such as "circular economy", "indicator", "measurement", "Europe", "China" and so on. Additionally, Google searches were performed in order to identify the grey literature and websites containing relevant information. This chapter will critically review the measurements gathered in order to assess the existing body of knowledge. The outcome of this review will be the starting point for designing the regional framework in Chapter 4. which will address limitations in the existing academic and grey literature. The focus of the report will be the efforts to measure CE implementation that have been developed in the EU. Therefore, the EU perspective will be examined first. China's perspective will also be covered, considering the progress that the Chinese government has achieved in this field.

3.1 The European Perspective

According to Strat et al., (2018), the regional circular economies are the foundation stones of a functional global circular economy. In order to ensure worldwide implementation of the CE, national interrelated circular economies must be in place, but that can be constructed incrementally

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only if interconnected regional circular economies are established (see Figure 4 for visual representation). The introduction of the CE-enabling policies will have a re-allocation effect, meaning the activities and competitiveness of the resource-intensive regions and sectors will be negatively impacted. Other sectors and regions that have the potential to thrive in a resource-efficient direction will benefit from this transition, and their activities and competitiveness will increase (OECD, 2017). These re-allocation effects will not only have economic implications for employment, GDP, investment and public spending, but they will also have accompanying social and environmental implications as well. Measuring the regional performance towards CE will guide local policy strategies and decision-making processes and it will help evaluate whether a region is heading in the right direction (OECD, 2019). Furthermore, by measuring the transition towards the CE on a smaller scale than the national, i.e. the regional, will enable going beyond the national average and indicate disparities within the country, but also show the front runners in this route – highlighting their best practices which can then be exemplars for the regions still catching up with the transition.

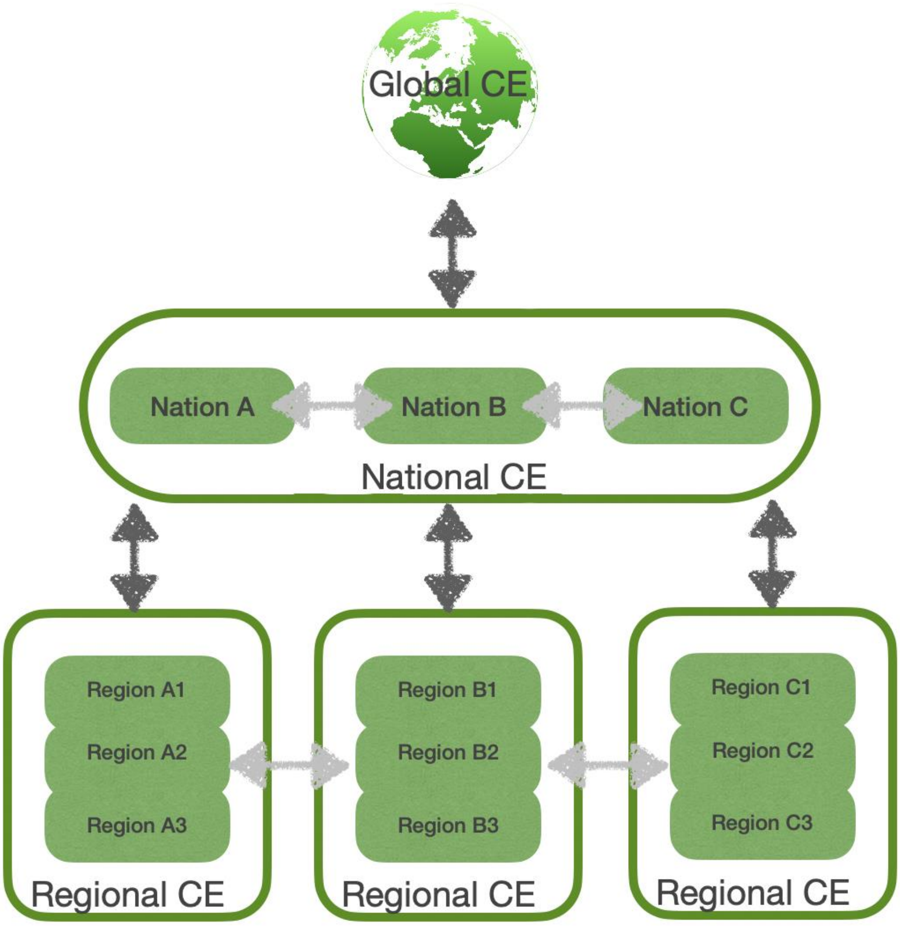

Figure 4: The importance of the regional circular economies and their interconnectedness – cascading upwards (Source: own elaboration)

3.1.1 Regional Measurement Systems

Even though there has been progress in the development of measures, indicators and frameworks for measuring the CE, there is still a knowledge shortage associated with regional indicators

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(Avdiushchenko et al., 2019; Virtanen et al., 2019). Additionally, to date, there is no overarching methodology to compare the degree of transition of regions towards CE (Smol et al., 2017). Despite this, in the following paragraphs the efforts related to the development of regional CE measurement systems are analysed in more detail, and the main conclusions are drawn. The first two studies are advocating the use of the NUTS 2 regional level, while the next two are developed and tested on a more granular level – the NUTS 3 regional level. Finally, the work of the OECD has been considered, in the context of the OECD Circular Economy Scoreboard for Cities and Regions.

Avdiushchenko (2018) made the first step in proposing a CE-based regional development monitoring framework. The monitoring framework was based on five CE focus areas: economic, environmental, social, spatial and cultural development. The first three elements, economic, environmental and social, were already part of the sustainable regional development policy, and spatial and cultural development areas were added by the author into the new CE-based regional development monitoring framework. The integration of the spatial area of CE-based regional development could bring such advantages as integration of CE ideas into public transport infrastructure and public space organisation. The integration of cultural regional development can be beneficial from two perspectives: on the one hand, it can be considered as being related to social development because CE (as a new way of thinking and acting) is important for changing the existing value system in society and altering consumption patterns; on the other hand, the CE notion stimulates transformations in architecture and design, generating new forms of art motivated by CE thinking.

Considering that the CE concept in the EU is diverse in scope, focusing not only on resource efficiency, but also on issues like innovation, circular business models, new consumption patterns, eco-design, green jobs and so on, twelve main pillars of CE-based regional development were proposed (Avdiushchenko, 2018).These pillars are: economically prosperous, innovative economy, zero waste economy, energy efficient and renewable energy-based economy, bio-economy, service/performance economy, social oriented economy, smart economy, low carbon economy, resource and material efficient economy, spatial effective economy and collaborative/sharing economy. Each pillar's assessment aspects were suggested as variables that could be evaluated. This work is pivotal in terms of developing the conceptual framework for the CE regional development monitoring framework. However, the practical side of actual implementation depends on the development of concrete indicators and the potential to operationalise them, which in turn depends mostly on the availability of data

Avdiushchenko et al., (2019) built upon the previous conceptual study and suggested a wide range of specific indicators for each of the pillars. The conceptual contribution to the design of CE indicators was related to the main features of the regional CE indicators. Namely, the chosen indicators should be relevant for CE implementation at a regional level, they should ensure comparability (using the NUTS level), they should be transparent and understandable for a larger group of stakeholders, and they should be based on official and accessible data. Considering the last of these, potential sources for the creation of a database of indicators were recommended. This included EUROSTAT, the National and Regional Statistical Offices of the Member States, Regional Environmental Agencies, European Environmental Agency, OECD, UN (UNEP plus

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other programmes related to CE), the World Bank, WTO and ILO. From the twelve proposed pillars, also referred to as dimensions, only seven were chosen for the final recommended evaluation indicator system for the CE based on the NUTS 2 regional level. The dimensions, along with a specific set of 25 indicators, are presented in Table 1. The indicators proposed by the authors were selected considering the specifics of the region, availability of data and the assumptions for creating the system of CE indicators for European regions. All the indicators form part of the CE index, which was constructed using Principal Component Analysis (PCA) and tested in the Malopolska region (a NUTS 2 region in Poland). Nevertheless, the inability to compare regions of different countries was pointed out, due to the lack of available data.

The study by Avdiushchenko et al., (2019) is the most relevant in the context of this report, particularly considering that the theoretical development and application in this study was grounded on the NUTS 2 level that was advocated in Section 2. Nevertheless, social effects are not fully grasped in the final set of indicators, and as a result, they are not represented in the CE index either. Additionally, even though the spatial dimension is considered, available infrastructure is not taken into account.

Strat et al., (2018) proposed an aggregated indicator called Circular Economy Potential Indicator (CEPI), to quantify the potential for the development of a CE. This indicator is developed at the county[3] level in the context of the Romanian economy, in order to identify those areas where resources need to be concentrated for developing a CE. A six-dimensional approach is adopted to develop this indicator and evaluate CE potential. The six dimensions were measured against various indicators, as presented in Table 2. Additionally, the municipal waste recycling rate and packaging recycling rate were taken into consideration, but the data were only available at a national level. Even though CEPI is giving an account of the social dimension represented mostly by the fifth dimension, it still has a long way to go from being an overarching indicator that can measure the three dimensions: economic, social and environmental. The main weaknesses of CEPI is the selection of the dimension and individual variables for computing the dimensions (Strat et al., 2018). However, the main limitation highlighted by the authors is the lack of granular data at the county level so that the physical value (or economic value) of the recycling and reuse levels could be projected.

[3] A Romanian County is equal to a region in the NUTS 3 level.

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Table 1: Recommendations for evaluation indicator system for the CE on NUTS 2 level

No.	Dimension	Indicators	Units
1.1	Economic prosperity economy	GDP	Per capita, fixed prices, PLN
1.2		Average life expectancy at birth for men	Years
1.3		Registered unemployment rate	%
1.4		At-risk-of-poverty rate	%
2.1	Zero-waste economy	Municipal waste collected selectively in relation to the total amount of municipal waste collected	%
2.2		Municipal waste collected per one inhabitant	Tons/person
2.3		Industrial and municipal wastewater purified in wastewater requiring treatment	%
2.4		Outlays on fixed assets serving environmental protection and water management related to recycling and utilization of waste	Per capita, fixed prices, PLN
3.1	Innovative economy	Expenditures on research and development activities	Per capita, fixed prices, PLN
3.2		Average share of innovative enterprises in the total number of enterprises	%
3.3		Adults participating in education and training	%
3.4		Patent applications for 1 million inhabitants	-
4.1	Energy-efficient and Renewable energy-based economy	Share of renewable energy sources in total production of electricity	%
4.2		Outlays on fixed assets serving environmental protection and water management related to electricity saving	Per capita, fixed prices, PLN
4.3		Electricity consumption	kWh/person
5.1	Low carbon economy	Carbon dioxide emission from plants especially noxious to air purity	Tons/person
5.2		Emission of particulates	Tons/1 km2
5.3		Passenger cars	Cars/1000 population
5.4		Pollutants retained or neutralised in pollutant reduction systems in total pollutants generated from plants especially noxious to air purity	%
5.5		Outlays on fixed assets serving environmental protection and water management related to protection of air and climate	Per capita, fixed prices, PLN
6.1	Smart economy	Households with personal computer with broadband connection to Internet	%
6.2		Enterprises with access to the Internet via a broadband connection	%
7.1	Spatially effective economy	Forest cover indicator	%
7.2		Street greenery and share of parks, lawns and green areas of the housing estate areas in the total area	%
7.3		Urbanisation rate	%

Source: Avdiushchenko et al., (2019)

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Table 2: The six-dimensional approach for CEPI

Dimension	**Basis of the measure**
County's performance in the recycling sector (NACE 38 class[4])	- number of active companies in the NACE 38 class - number of employees of the active companies of the NACE 38 class - turnover of the companies in class 38
Economic strength of the county (the development level)	- GDP per capita - number of employees/1000 inhabitants - number of companies/1000 inhabitants
Development level of the utilities' infrastructure	- measures the county's infrastructure in terms of access to utilities (% of localities with access to the water, gas, sewerage and thermal energy network)
Urbanization level and its concentration	- the percentage of the population located in the urban area - the size of the main urban agglomeration at the county level
Development of the educational and cultural sector	- measures for the level of education (school population) - measures for the level of culture (number of museums per 100,000 inhabitants)
Development level of the touristic sector	- represented by the size of the tourism sector (tourist accommodation capacity and number of overnights)

Source: Strat et al., (2018)

Another attempt at developing indicators for regional circularity was focused on evaluation of the circularity of regional material flows (Virtanen et al., 2019). The material flows taken into account were phosphorous, plastics, textiles, waste wood and ash. The indicator was tested using data from the Päijät-Häme region in Finland, which is a NUTS 3 level region. The challenge of gathering regional-level data on material flows was also relevant in this case, since the available statistics were related mainly to waste flows at the national level which do not necessarily reflect regional characteristics. Due to that, instead of focusing the indicator of the material circulation for the whole value chain, it is based on the circulation of waste materials. Additionally, some of the data was available only at national level, but due to the differences in regional practices and treatment of waste in different regions, computing the average based on the national figures will not reflect the real situation and regional disparities (Virtanen et al., 2019). Finally, it is evident that this attempt completely disregarded the social dimension and focused solely on the circulation of certain waste materials.

The OECD proposes a self-assessment scoreboard to evaluate the level of advancement towards a circular economy under the OECD Circular Economy Scoreboard for Cities and Regions. The ten key dimensions include: circular economy framework, co-ordination mechanisms, policy coherence, economy and finance, innovation, stakeholder engagement, capacity building, green public procurement, data and information, and monitoring and evaluation. The cities and regions can assess the level of advancement based on the above dimensions to determine governance

[4] NACE is the Nomenclature of Economic Activities - the European statistical classification of economic activities. Number 38 refers to waste collection, treatment and disposal activities, and materials recovery.

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conditions to advance towards a circular economy. The self-assessment scoreboard is designed so that the regions and cities can identify gaps and set their own targets for improvement in the circular transition. In the policy recommendation and actions for a circular economy in Umea, Sweden (OECD, 2020), the OECD Scoreboard is again emphasised to evaluate the existing circular economy strategies in cities and regions. The OECD policy report suggests that a monitoring and evaluation framework for a circular economy strategy in cities and regions needs to be developed based on three key broad aspects: environmental (e.g. resources, waste and circulation processes), flows (e.g. water, energy, products, food, transportation, information, people) and social (e.g. number of circular jobs created) (OECD, 2020). Furthermore, the OECD is in the process of developing a set of tools to monitor the cities and regions' transition to a CE, aiming to launch a report in September 2020. The indicators included in the tool include key input, process and output indicators, and a scoreboard and a self-assessment tool to examine whether the government conditions in cities and regions are favourable towards the implementation of circular strategies.

3.1.2 Measurement Systems at other spatial scales

Taking into account that there is a lack of knowledge associated with the regional level specifically, other levels of implementation are also considered. Moraga et al. (2019) state that even though the three levels of CE implementation are defined as micro, meso and macro, the sub-levels within these three main levels are not generally agreed upon. More specifically, in the Chinese CE Promotion Law, regions are considered macro scale being situated between cities and countries. However, according to Smol et al., (2017), regions are the linkage between macro and micro scales when evaluating CE eco-innovation, representing a meso scale. To overcome these dissimilarities in the treatment of regions, Moraga et al. (2019) propose that the micro, meso, and macro terminology should be followed by the precise array of analysis (i.e. consumer, product, service, business, technology, city, park, region, nation, continent, or globe). Their proposal has been adjusted based on the aim of this report (see Figure 5), hence measurement systems at other scales have also been considered. Measurement systems at larger scales than the regional scale were taken into account, with the rationale that they can be scaled down. In addition, smaller-scale

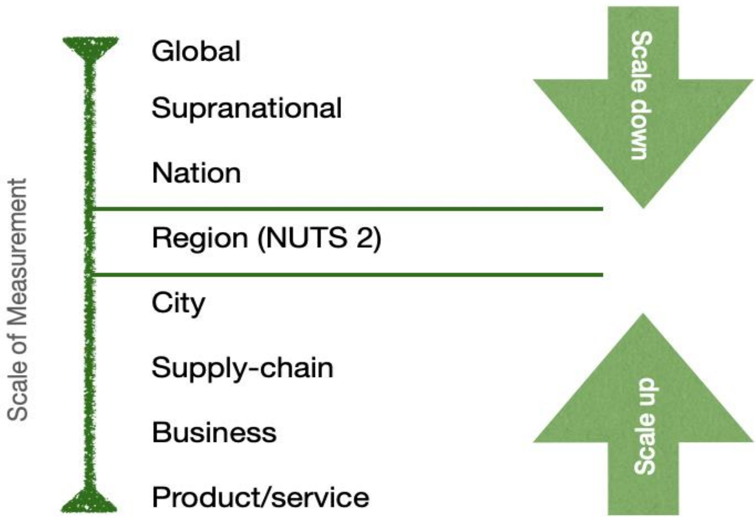

Figure 5: Scale of Measurement (Source: adapted from Moraga et al., 2019)

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measurement systems were reviewed given their potential to be scaled up and applied at the regional level.

3.1.2.1 Measurement Systems with scaling down potential

The monitoring framework for the CE (MFCE) developed by the European Commission in 2018 is tracking the progress towards CE at the EU and country level. It has ten indicators grouped into four categories: production and consumption, waste management, secondary raw materials and competitiveness and innovation. However, these selected indicators are mostly concerned with the EC's priorities on material self-sufficiency and recycling, overlooking the more transformative systemic and social dimensions of the CE concept. Hence, measurements linked to the use of energy, water, land, greenhouse gas emissions, environmental footprints, product lifespan, institutional drivers and socio-economic implications of the shift towards CE, or the effect of activities associated with eco-design, reuse and collaborative consumption, and sharing economy are currently absent from the MFCE. Additionally, not all data are available for every country or every indicator, which implies new data sources must be created and procedures for the gathering of new statistical data must be put in place. Another debatable trait is the elucidation of the data related to employment and CE activities. The association of CE solely with recycling, waste management, repair and reuse overlooks the impact of the whole productive system and neglects the importance of having circular design as the first priority. Furthermore, in order to evaluate the actual effect on employment related to CE activities, the net effect must be taken into account, along with the quality of the created jobs linked to CE activities (Llorente-Gonzalez and Vence, 2019).

The report from Think 2030 (2018) has also highlighted some recommendations for the MFCE. Namely, the use of Domestic Material Consumption[5] is not mirroring the material intensity of the economy, because imported resources are not factored into the equation. The comparison between Domestic Material Consumption with material footprint uncovers a large reliance of the EU on materials outside of Europe, which are not captured with this indicator. The funding at the EU level is transparent and clear, though this is not so obvious at member state or regional level. Finally, they are suggesting the inclusion of more reformist measures of socio-economic performance like the ones identified in the Beyond GDP initiative[6], which could play a key role in breaking the link between development and unsustainable resource use, as well as providing a driver for economic transition.

The Directorate-General for Environment in the EC also launched a set of CE indicators to measure the performance in several areas that directly or indirectly contribute to CE development at country level. There are sixteen indicators grouped into three categories, looking at sustainable

[5] Measures the amount of materials (excluding water and air) directly and actually used in a national economy

[6] initiative about developing indicators that are as clear and appealing as GDP, but more inclusive of environmental and social aspects of progress

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resource management, societal behaviour and business operations (see Table 3). The issue with data availability is still evident even with this measurement attempt, since the period of the data for various indicators is different, and not all countries have all the data for each indicator.

Table 3: Circular Economy Indicators by the European Commission

Group	Indicator
Sustainable resource management	Material footprint (Domestic Material Consumption, t per capita)
	Resource productivity (Purchasing power standard per kg)
	Municipal solid waste – generation and recycling (kg per capita)
	Municipal waste recycled (kg per capita)
Societal behaviours	Citizens who have chosen alternatives to buying new products
	Coverage of the CE topic in electronic mass media and published articles
	Turnover in repair of computers and personal goods
	Number of enterprises and employment in repair of computers and personal and household goods
	Number of enterprises in repair of computers and personal and household goods (timeseries)
	Number of employees in repair of computers and personal and household goods (timeseries)
Business operations	Difficulties implementing CE activities experienced by companies
	Financing sources for CE activities
	Availability of information that can help to access finance for CE related activities, as reported by SMEs
	Share of enterprises that facilitated recycling of products after use
	Enterprises that extended product life through more durable products by innovation
	Enterprises that recycled waste, water or materials for own use or sale within enterprises by innovation

Source: European Commission - Directorate General Environment

The POLITICO CE Index comprises of seven indicators, measuring circularity at the country level and ranking the EU Member States. The chosen indicators are: municipal waste, food, waste, municipal recycling rate, share of goods traded that are recyclable raw materials, patents related to CE and investment in CE sectors. The data used for the rankings are taken from EUROSTAT and a report from the European Parliament (POLITICO, 2018). Another index at the national level is the 2018 Environmental Performance Index (EPI), comprised of 24 performance indicators covering environmental health and ecosystem vitality. The EPI, developed by Yale University and Columbia University in collaboration with the World Economic Forum, ranks 180 countries on environmental tendencies and development, providing the ground for effective policymaking (Wendling et al., 2019).

The EPI and the measurement systems, indexes and scoreboards/scorecards covered in the next paragraphs are not directly phrased as CE measurements. However, the areas of measurement they are covering are linked to the CE umbrella term, hence they are taken into consideration as ancillary CE measurements (Figure 6).

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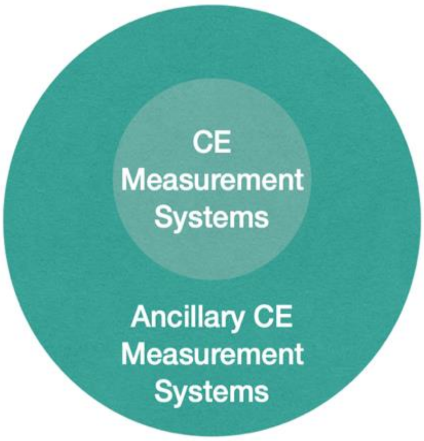

Figure 6: CE and Ancillary CE Measurement Systems (Source: adjusted from Moraga et al., 2019)

Avdiushchenko et al., (2019) suggest that EU Scoreboards may be useful in the development of the measurement and monitoring system for CE. More precisely, the following scoreboards can be used as data sources:

- Resource Efficiency Scoreboard,
- Raw Materials Scoreboard,
- European Innovation Scoreboard,
- Regional Innovation Scoreboard,
- Digital Agenda Scoreboard,
- EU Transport Scoreboard,
- Consumer Conditions Scoreboard,
- Consumer Markets Scoreboard, and
- Social Scoreboard.

However, the level of the data collected and presented is at the EU and Member State level. Moreover, the Eco-Innovation Scoreboard (Eco-IS) and the Eco-Innovation Index are other valuable data sets that measure the eco-innovation performance within the EU Member States. There are sixteen indicators covering a range of five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes. Even though the measurements are at country level, they provide a holistic view on the economic, environmental and social performance of the country (European Commission – Environment).

Additionally, specific indicators from the Regional Competitiveness Index (RCI) can be taken into account. RCI is measuring the key factors of competitiveness for all the NUTS 2 level regions across the EU and it is updated every three years. The index evaluates, using over 70 comparable indicators, the ability of a region to offer an attractive and sustainable environment for companies and citizens to live and work. The RCI scorecards enable easy comparability among any EU region with a similar level of GDP per person. Being easy to use, users from different fields can see where their region is situated in the eleven RCI pillars: institutions, macroeconomic stability,

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infrastructure, health, basic education, higher education and lifelong living, labour market efficiency, market size, technological readiness, business sophistication and innovation (European Commission, 2019).

3.1.2.2 Measurement Systems with scaling up potential

The Circular City Analysis Framework (CCAF) adopts a multi-sectorial and macro-meso level framework to establish and monitor goals for CE implementation in cities (Cavaleiro de Ferreira and Fuso-Nerini, 2019). It incorporates important CE conceptions like flexibility, modularity and transparency, and gives an account of different agents involved in different sectors. Thirteen different sectors were identified and arranged into three categories: inner, intermediate and outer circle (see Table 4). Each of the sectors had a set of indicators, 27 in total, and they were tested in the Porto region. Additionally, a goal was proposed for each of the indicators. The issue with data availability was also encountered at the city level.

Table 4: CCAF with indicators

Category	Field	No.	Indicator	Goals
Inner circle	Local Resources	1	Wind potential (m/s)	-
		2	Solar potential (W/m2)	-
		3	Green Roofs (%)	10
		4	Imports/Exports (€/€)	1
Intermediate circle	Renewable Energy	5	Renewable penetration (%)	100
		6	Access to electricity (%)	100
		7	Energy intensity (GWh/M€)	1.4
	CE innovation	8	CE innovation budget (%)	0.5
	Food	9	Food waste treated (%)	100
		10	Food waste treated in SMSs (%)	30
	Buildings	11	Retrofitting (%)	50
		12	Very degraded buildings (%)	0
	Transport	13	Public transport usage (%)	50
		14	Electrical energy consumed in transport sector (%)	10
	Specific Industry – Cork	15	Recycling rate (%)	100
		16	Synergies (%)	100
	Water Management	17	Safe water accessibility (%)	100
		18	Water efficiency (%)	85
	Waste Management	19	Landfilled waste (%)	0
		20	Separated waste (Kg/capita*year)	70
Outer circle	Education	21	Basic education quitting (%)	0
		22	Superior course (%)	50
	Digitalization	23	Accessibility to smartphones (%)	10
	Demographics	24	Balance between men & women (%)	-
		25	Heaviest age group (%)	-
	Policies	26	Active population (%)	-
		27	Man-woman balance in politics (%)	>30

Source: Cavaleiro de Ferreira and Fuso-Nerini, (2019)

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The past research that has conducted a systemic review of existing circularity metrics and indicators have pointed out the lack of consistency and overabundance of circularity metrics (Pauliuk, 2018; Corona et al., 2019; Saidani et al., 2019). Saidani et al., (2019) conducted a systemic literature review of both academic and grey literature and identified 55 sets of circularity indicators featuring different purposes, scopes, and usages. In addition, the general consensus seems to be that the research on CE assessments and indicators is lacking, especially at the micro level. Elia et al. (2017) introduced a four-level framework to support the measurement of CE adoption. The four levels include the processes to monitor, requirements to be measured, actions involved, and the implementation levels. Since the circular economy is a newly emerging paradigm, and the tools and criteria for measuring circularity of products, services, companies or regions are lacking, the authors reviewing the circularity indicators and metrics analysed the usability of the existing assessment tools and measures to capture the level of adoption of circular strategies. Of the proposed framework, the systemic framework for guiding the assessment of a CE strategy suggested by Elia et al. (2017) as well as the systems approach emphasised by Pauliuk (2018) provide a scale-up potential to enrich the framework to evaluate circularity at a regional level.

Elia et al. (2017) evaluates several index-based methodologies to determine how appropriate they are for measuring circularity. The authors found that scientific literature adopts indicators that are limited to the resource use dimension at a micro level. The other important aspects of CE strategies, such as product durability, are not considered reflecting the resource-oriented characterisation of the CE concept. To overcome these limitations, Elia et al. (2017) introduce a systemic framework to assess the CE strategy at a product or a company-level. According to the authors, the assessment should begin with the identification of the system and process to analyse. For example, the assessment can cover a single process or the whole supply chain. In the second step, the CE activities that will have an impact need to be identified. These include circular product design and production, circular business models, cross cycle and cross sector collaboration, and other CE-oriented activities. For instance, if the company introduces a product-service system to reduce material intensity, the use of natural resources and material losses need to be primarily monitored along with other performance measurements that evaluate the impact of the CE strategy on environmental dimensions. As illustrated, the third step involves identifying CE requirements aligned with the selected CE activities. The last step is to choose an appropriate methodology to assess circularity of the CE strategies and their impacts on the environments. Elia et al. (2017) suggest four classification of the CE requirements to select the appropriate methodologies. These include reducing input and use of natural resources; increasing share of renewable and recyclable resources; reducing valuable material losses; reducing emissions. Based on the focus requirements, methodologies can be selected that are either/or material flow based, energy flow based, land use based, or life cycle based. These four-step systemic approach illustrated by the authors can be further enhanced to guide the assessment of CE activities at a regional level. The regional initiatives can be identified, and their processes can be monitored. The CE requirements can be further classified based on the regional CE activities and combination of different methodologies can be chosen to provide a comprehensive assessment of circularity at a regional level.

Pauliuk (2018) provides a critical appraisal of a newly launched standard, "BS 8001 Framework for implementing the principles of the circular economy in organisations" by the British Standard

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Institution (BSI, 2017). Based on the critical appraisal, he acknowledges that the standard does not provide comprehensive and concrete guidance on monitoring CE strategy implementation. To fill this gap, the author proposes a systems approach to developing CE indicators. Based on the systems definition of the CE strategies, the existing quantitative tools such as Life Cycle Assessment (LCA) and material flow cost accounting (MFCA) are presented for CE assessment at an organisational and products systems level. The author strongly emphasises the importance of a systems perspective to monitor CE strategies at an organisational level. The systems approach proposed by Pauliuk (2018) illustrates the possibility that the product and service-level indicators and existing assessment tools can be scaled up to develop CE assessment tools at a regional level when the regional system to monitor circularity is identified.

Corona et al. (2019) review the existing circularity metrics that measure the impacts or benefits generated from adopting the circular strategies at a product or a service level. The review focuses on the frameworks, indicators, and indices that are exclusively developed to quantitatively measure circular strategies in products and services, but also discusses the monitoring framework beyond the product or service level including regional, country and global levels. When the existing metrics were evaluated based on the set of requirements put forward by the authors, which include validity, reliability, and utility criteria, they found that none of the current circularity metrics addressed all the requirements. As pointed out by Elia et al. (2017), the authors warn against using the metrics in a narrow scope that focuses on only the measures related to a material recirculation. Based on the review, they conclude that the method used the most to assess the circular strategies was LCA, and most of the metrics are still not equipped to reflect the benefits of different waste valorisation strategies.

In the grey literature, indices for measuring progress towards a circular economy are also proposed by global think tanks or institutions. The Ellen MacArthur Foundation proposes a company-level measuring tool, Circulytics, that is designed to comprehensively capture the level of circularity across a company's entire operations. The indicators are categorised by enablers and actual outcome measures. The 'enablers' capture the aspects that allow company-wide transformation. The 'outcome' indicators measure beyond the materials flows to include product and service design outcomes and energy use. The World Business Council for Sustainable Development (WBCSD) has also provided a tool that captures company-level CE indicators. The Circular Transition Indicators (CTI) proposed by WBCSD is based on an assessment of material flows within company boundaries. The CTI framework also combines additional indicators on resource efficiency and efficacy, as well as the value added by the circular business models. The CTI tracks the mass flows, either circular or linear, within the company boundary and the efficiency of the flows to determine full sustainability performance. The logic behind the CTI methodology is to derive single indicators by calculating how circular flows are maximised and linear flows are minimised, considering also the intensity of product use by material types. For instance, percentage of circular inflows, percentage water circularity, and percentage critical material type are calculated. Under the three categories of closing, optimising and valuing the loop, the level of circular flows and resource recovery or productivity are represented by quantitative indicators.

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3.1.3 Socio-institutional indicators

SUMMA CE Centre (2018) distinguish between technology-related indicators and socio-institutional indicators. The former are evaluating the so-called hard parameters expressed in volumes like kg or environmental impacts, while the latter refer to governance and infrastructure aspects, such as what systems are in place for sharing, repairing or reusing products. What has been noticed is that most of the measurement systems at the regional level fall into the first category, focusing primarily on physical parameters since they are more easily evaluated; however, the issue of data availability is limiting those in some instances. The socio-economic indicators are equally important but might not be easily 'measurable'. As a result, they are less defined and therefore less commonly integrated in monitoring frameworks. Some of the socio-institutional indicators suggested by SUMMA CE Centre are presented in Table 5.

Table 5: Socio-institutional CE indicators

Socio-institutional indicator
The degree to which collection, repair, reuse and recycling infrastructure is in place.
Degree to which economic incentives, legislation or comparable rules are in place and enforced regarding product standards, standards for reused or recycled products/raw materials, waste management, better materials management
Degree to which business is involved in managing material cycles in a circular way and is empowered to make the right decisions, either on an obligatory or voluntary basis
Degree to which circular business models are adopted
Degree to which citizens are involved in managing material cycles in a circular way and are empowered to make the right decisions
Degree to which systems are in place for making more efficient use of resources, such as arrangements for sharing products or repairing and reusing them, exchange of information on availability of reusable or recyclable materials (for instance for enhancing industrial symbiosis)
Degree of information, education and awareness about circular economy (integration into school and university curricula, public communication and information campaigns)
Degree to which there are voluntary collaboration schemes in place encouraging value chain and cross-sectoral initiatives and information sharing;
The integration of circular aspects in public procurement schemes
Product standards related to the defined circular strategies

Source: SUMMA CE Centre, (2018)

3.2 The Chinese Perspective

China's socioeconomic context has meant a more systemic approach to the implementation of CE policies and practices (Geng et al., 2013). Their efforts towards a CE are more centrally implemented (top-down), compared to those in European nations (bottom-up) (Ghisellini et al., 2016). As a result of the more systemic perspective, the CE is serving as a wider "lens" through which other national strategies and goals (e.g waste treatment, energy saving and emissions reduction among others) are being explored. On the other hand, the socioeconomic environment of Europe and the US, among others, has favoured the growth of perspectives that are more short-sighted, such as Germany's original prioritisation in addressing the waste-management aspects of

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the CE (von Köller, 1996). The case of China is particularly well suited to the systemic perspective, making it an ideal setting for observation and investigation of the potential impacts of a top-down approach to the transition towards a CE (Geng et al., 2013).

In their literature review, Saidani et al. (2019) find that 50% of the indicator sets addressing the CE at the macro level originate in Chinese sources. This is particularly relevant for the present report given its focus on measuring the regional (macro) level of the CE. In fact, had the aforementioned review not only targeted texts in the English language, this percentage would have been higher. That is, considering that there are numerous sources on the topic that are only available in Chinese (e.g. Zhou, Peng and Cao, 2013, Zhou and Liu, 2005). This is also consistent with the finding that academic literature considering the CE at the macro level is dominated by cases and considerations from China (Sacchi Homrich et al., 2018). Therefore, in order to review existing measures and indicators that may be relevant for measuring the CE at a regional subnational level, it is necessary to also explore the work that has already been done, particularly at the macro level, in China.

Although China clearly dominates the existing knowledge at the macro level of circularity measurement, it has shown little interest in measuring the CE at the micro level. This is, of course, not surprising given their top-down approach to CE-implementation. The rest of this section starts by offering an account of the methods for the identification of circularity-indicator set propositions in China, as well as some general findings (Section 3.2.1). Then, the meso-level indicators are concisely discussed in Section 3.2.2. Next, urban- and regional-level indicators are discussed providing an overview of their typical methods and areas considered (Section 3.2.3). Finally, Section 3.2.4 provides a general overview of the macro-level indicator sets, highlighting the main gaps that were encountered. A particular focus will be placed on the subsystems that the different indices consider.

3.2.1 Identifying indicators and metrics from China: general findings

In the work by Saidani et al. (2019), they identify 55 different circularity-indicator sets with different scopes and purposes in order to develop a taxonomy of circularity indicators. The systematicity and transparency of their methods ensures the reliability of the taxonomy they develop. The taxonomy is based on 10 differentiating factors, the most relevant for this report's purposes being: level (micro, meso and macro), target loops (maintain, reuse/remanufacture and recycle), target performance (internal vs. impacts), usage (tracking, action-oriented, communication, learning) and transversality (generic vs. specific). In this way, the indicators' varying functionality is better defined. Furthermore, they develop a comprehensive tool for the identification of indicator systems that can be "programmed" to identify circularity indicators based on specified desirable attributes. This tool was utilised to identify all indicator sets that Saidani et al. (2019) gathered from Chinese sources and applications. Moreover, their taxonomy classes were used as a fundamental framework through which the identified indicators are considered. On top of these, given that Saidani et al. (2019) only capture indicators up to the year 2018, further indicators from Chinese sources were identified through inspection of the literature (in English) by searching for terms such as "circular economy", "indicator", "China" and so on. The combination of these methods yielded a total of

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14 relevant sources. The sources were assessed individually, and the corresponding indicator sets classified to match the scope of this chapter's discussion (see Tables 6-8).

The most common methods for data analysis and aggregation into indices in China are: analytic hierarchy process, principal component analysis, grey correlation degree method, fuzzy synthesis appraisal, obstacle analysis, average weighting and data envelopment analysis. Although these are not discussed in detail in this report due to its more general scope, a more detailed review of these can be found in Su et al.'s (2013) work. Moreover, some general trends can be identified by inspection of Tables 6–8. A particularly salient trend can be seen in the lack of a consideration for the "maintain" CE-loop at all (micro/meso/macro) levels of assessment. In particular, this refers to the processes by which product lifetime is enhanced and its value is maintained. This, and other concepts that characterise the CE being overlooked, results in fundamentally incomplete perspectives of the CE. Finally, common to all identified indicator sets is their quantitative nature, with the exception of Geng et al.'s (2010, 2013) proposition of an Emergy-based Indicator System (EIS). EIS is still mostly quantitative but is also able to capture qualitative differences between resources that are not perceptible with other methods. This offers great potential to address circularity measurement at all levels and to diverge from concepts of value that are purely monetary (Geng et al., 2013). A more detailed, per-level discussion is provided in the following sections.

3.2.2 Meso-level systems of indicators in China

In Table 6, the identified meso-level circularity-indicator sets are presented. Each indicator is presented along with the scale of application, the performance of interest (intrinsic vs. impacts), the loops it considers and the reference to its source in English. More specifically, the "performance of interest" mentioned previously refers to whether the target measure considers operational aspects of the CE or the level of attainment of the CE's impact-related goals. Given the focus on the regional level of the current report, these will not be discussed in detail. However, it is worth mentioning Resource Productivity (RP) (Wen and Meng, 2015). It uses substance flow analysis (SFA) to delimit the system of interest prior to the exploration of resource productivity of the system. Although RP offers too narrow a view of the CE for the measurement of regional-level circularity, the required data for the SFA is usually available at the macro (national, regional and urban) level. Therefore, this method could offer some inspiration to regional-level considerations.

Out of the four meso-level circularity-indicator sets identified (see Table 6), two are specifically oriented towards the Chinese context. First, the Evaluation Indicator System of Circular Economy (EISCE) is specifically contextualised to the Iron and Steel Enterprise (Zhou, Chen and Xiao, 2013). Second, the Five Category Index Method (FCIM) is specifically meant for the assessment of circularity of chemical enterprises in China. Therefore, they are unlikely to offer much inspiration for measuring circularity at the macro (regional) level. The most promising method for cross-fertilisation into the macro-level is the Emergy-based Indicator System. This uses emergy analysis to provide a wide account of the processes, flows and impacts of the system considered. Due to the systemic nature of emergy accounting, rooted in systems thinking, it could, in principle, be meaningfully applied to all scales (Geng et al., 2013). It is the most fundamentally different measurement method and requires a level of expertise and data availability that is more challenging

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than other, more common methods. However, its potential to be applied at all levels, as well as the perspective it offers on the CE concept (among other strengths) (see Geng et al., 2013), make it highly desirable. As a result, there have been calls for the creation of CE-level emergy databases and resources capable of driving the shift of EIS into the practical policy tool territory (Geng et al., 2013). In sum, China's existing meso-level circularity indicators are, in most cases, unlikely to offer much inspiration to the EU-regional level. However, they do include an application of one of the most promising propositions for CE indicator systems at all levels – the EIS (Geng et al., 2010).

Table 6: China's meso-level circularity indicator sets. *Target loops are: Maintain (M), Remanufacture/Reuse (R/R) and Recycling (RC).

Indicator set (reference)	Meso-level scale	Target performance	Target loops*			Source
			M	R/R	RC	
Resource Productivity (RP)	Industrial symbiosis	Intrinsic		X	X	Academic (Wen and Meng, 2015)
Evaluation Indicator System of Circular Economy (EISCE)	Enterprise	Intrinsic			X	Academic (Zhou, Chen and Xiao, 2013)
Five Category Index Method (FCIM)	Chinese Enterprise	Impacts			X	Academic (Li and Su, 2012)
Industrial Park Circular Economy Indicator System (IPCEIS)	Industrial park, China	Intrinsic & Impacts		X	X	Academic (Geng et al., 2012), Chinese gov., public sector initiative
Evaluation of CE Development in Cities (ECEDC)	Process industries	Impact			X	Academic (Li et al., 2010)
Emergy-based Indicator System (EIS)	Industrial park	Intrinsic & Impacts	X	X	X	Academic (Geng et al., 2010)

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3.2.3 Regional and urban level circularity indicators from China

China has about 180 cities whose populations exceed 300,000 (GeoNames, 2020) (the lower limit for the NUTS 2 classification). Therefore, cross-fertilisation from the Chinese urban scale into the European regional scale is likely. At this level, two indicators were identified. First, the Development Research Centre of the State Council (DRCSC) developed an indicator set founded on resource efficiency, environmental impact and social progress indicators (Li et al., 2010, Zhou and Liu, 2005). The strengths of this system come mainly from the salient consideration of the social impacts dimension. With measures addressing population growth, lifespan, and education aspects, it offers a fairly balanced view of the target social impacts. On the other hand, its main limitations come from its purely impact-oriented focus: it overlooks the loops and operational factors that characterise the CE, as well as the lack of a consideration for absolute (as opposed to relative) material, energy and water consumption levels.

Second, and more recently, efforts to measure the urban scale of the CE in China have yielded the Urban Circular Development Index (UCDI) (Wang et al., 2018). This index uses expert and entropy weightings to construct an index capturing four criteria: resource output, industrial circularity, residential circularity, and mechanism and culture (Wang et al., 2018). The index does not, however, include considerations about impacts. Absolute measures of resource and material consumption are also overlooked. On the other hand, its considerations of cultural aspects may offer an avenue for capturing micro-level factors that have significant impact at the macro level. The UCDI is applied to several cities (or potentially, regions) at once. The weights of its sub-items then depend on how much they vary across regions, as well as on experts' views. This allows for a framework well suited for the comparison between cities/regions. In fact, Wang et al. (2018) conduct the analysis for 40 cities in China and conclude that the differences are significant enough. This highlights the different needs that different cities have for achieving circularity, together with the importance of measuring circularity at the urban and regional scales.

At the regional level, four indicator sets were identified in China. These are laid out in Table 7 showing their target loops and performance. Initial efforts resulted in an indicator framework based around eco-efficiency by the State Environmental Protection Administration (SEPA). It is oriented towards capturing regional economic benefits, resource and energy efficiency, ecological benefits and loop characteristics. Although it addresses important aspects of the CE, the low number of underlying items (namely 8, i.e. 2 per criterion) is insufficient for capturing intrinsic and impact-based elements. The Regional Circular Economy Development Index (RCEDI) is based on the following four criteria (Guo-Gang, 2011): 1) resource consumption, with a focus on water consumption and a consideration of energy efficiency; 2) environmental disturbance; 3) recycling, showing an explicit "preference" for the recycling loop; and 4) social development, based mostly around economic growth. The authors utilise fuzzy comprehensive weight evaluation (FCWE) methods to identify the "overall" classification of circularity, out of five available categories, based on the prior classification of each individual item into the same five categories. The same methods are employed by the Evaluation of Regional Circular Economy (ERCE) (Chun-Rong and Jun, 2011). However, they diverge from the consideration of impacts and focus only on the intrinsic aspects of circularity. Their criteria are based around the 3R framework (reduce, recycle, reuse) but

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are limited by the availability of data. The result is a set of sub-indicators that is not balanced among the 3Rs and does not include any consideration of impacts.

Finally, Wu et al. (2014) introduce the Super-efficiency Data Envelopment Analysis Model (DEA). The main purpose of this indicator is to assess the efficiency of regional CE. It is based around three subsystems: resource saving and pollutant reduction (RSPR), waste reuse and resource recycling (WRRR), and pollution control and waste disposal (PCWD). This shows the inspiration from the 3R framework. The DEA is used to calculate circular economy efficiency (CEE), which considers both the efficiency of the energy-economy environment as a whole and the efficiency of its three subsystems independently, at the regional level. As the name suggests, this is a measure of CEE and not circularity as such. However, the model developed shows potential for being useful in other considerations too. In particular, the authors apply the model to 30 Chinese regions in order to then aggregate the results to find a national level of CEE. Therefore, this could offer a framework for aggregating measures of urban-level circularity into a regional-level measure.

In sum, the two indicators identified at an urban level could offer inspiration for regional-level circularity assessment through DRCSC's balanced perspective on social impacts and the UCDI's consideration of cultural aspects. Additionally, the 3R-based perspective that dominates at a regional level has limited the applicability of such indicators due to the unavailability of suitable data. The DEA, however, does offer potential inspiration for assessing the efficiency of CE as part of a regional-level circularity assessment.

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Table 7: China's macro-level circularity indicator sets at the urban and regional scales. *Target loops are: Maintain (M), Remanufacture/Reuse (R/R) and Recycling (RC).

Indicator set (reference)	Macro-level scale	Target performance	Target loops*			Source
			M	R/R	RC	
Development Research Centre of the State Council's (DRCSC) indicator set	Urban (city)	Impacts		X		Academic (Zhou and Liu, 2005) [In Chinese] *mentioned in Li et al. (2010)*
Urban Circular Development Index (UCDI)	Urban (city)	Intrinsic		X	X	Academic (Wang et al., 2018)
Regional Circular Economy Development Index (RCEDI)	Regional	Intrinsic & Impacts			X	Academic (Guo-Gang, 2011)
Evaluation of Regional Circular Economy (ERCE)	Regional	Intrinsic			X	Academic (Chun-Rong and Jun, 2011)
Super-efficiency Data Envelopment Analysis Model (DEA)	Regional (& National)	Intrinsic & Impacts		X	X	Academic (Wu et al., 2014)
State Environmental Protection Administration (SEPA) index	Regional	Intrinsic & Impacts		X	X	Academic (Zhou, Peng and Cao, 2013) [In Chinese] *mentioned in Li et al. (2010)*

3.2.4 National level circularity indicators in China

The Chinese national level, although very different in scale to EU regions, is worth considering given the macro nature of its goals. Table 8 provides a summary of all the identified propositions. Of particular interest is the widely accepted focus on both intrinsic processes and impacts of circularity, which is necessary at the macro-level to provide a complete conception of the CE.

Much like at the regional level, most of China's national circularity indicators are inspired by the 3R framework. However, there have been calls for indicators that not only capture the 3Rs and the environmental aspects, but also include measures of actual economic development (e.g. GDP per capita, growth of economy), potential economic development (e.g. export share, technology development, capital investment) and considerations for the social dimension (e.g. unemployment rate, living area, Engel's coefficient or residents' disposable income) (Guo-gang, 2011). Moreover, like in other geographical locations (e.g. US, EU), Material Flow Analysis (MFA) serves as the basis for quantifying the relationship between environmental issues and human activity at the national level in China. MFA is able to provide a wide, systemic picture for diagnosis and a platform for the

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design of management-oriented measures, as well as, the assessment of the efficacy of those measures (Geng et al., 2012). However, data collection may be challenging for developing nations and it fails to give information on the quality of materials considered. This problem can be overcome through, for instance, the use of an Emergy-based Indicator System (EIS) (such as the one already developed for the meso-level) that is able to capture qualitative aspects of resources/materials/substances.

The National Circular Economy Indicator System (NCEIS) (Geng et al., 2012) is part of a wider Chinese Circular Economy Evaluation Indicator System (CCEEIS), which also contains the Industrial Park Circular Economy Indicator System (IPCEIS). It is the Chinese government's effort in evaluating national (NCEIS) and industrial-park-level (IPCEIS) circularity (Geng et al., 2012). Therefore, the CCEEIS offers a practical illustration of the Chinese government's view of the CE concept. The NCEIS (national level) shares its four sub-systems of indicators with the IPCEIS (industrial level). More specifically, these are: resource output, resource consumption, integrated resource utilisation and waste disposal/pollutant emission. Although these subsystems offer a potential source of inspiration, their focus on relative measures, together with the disregard for absolute measures, fails to give a complete picture of the real concept of circularity. Geng et al. (2012) find that the involvement of more stakeholders (and not only the Ministry of Environmental Protection and the National Statistics bureau) in the design of the CCEEIS may have yielded a different set of foci. This may have contributed, for instance, to the inclusion of indicators addressing the social dimension, which is of particular interest at the regional level, or given a more balanced consideration for both the reuse and the recycle loops (as opposed to the clear priority given to recycling). This highlights the importance of considering of all stakeholder perspectives that are relevant to the CE.

Table 8: China's macro-level circularity indicator sets at the national scale. *Target loops are: Maintain (M), Remanufacture/Reuse (R/R) and Recycling (RC).

Indicator set (reference)	Macro-level scale	Target performance	Target loops*			Source
			M	R/R	RC	
Emergy-based Indicator System (EIS) proposition	National	Intrinsic & Impacts		X	X	Academic (Geng et al., 2013)
National Circular Economy Indicator System (NCEIS)	National, China	Intrinsic & Impacts		X	X	Academic (Geng et al., 2012), Chinese gov., public sector initiative
Environmental Protection Indicators (EPICE) in a context of CE	National	Intrinsic & Impacts			X	Academic (Su et al., 2013)
Integrative Evaluation on the Development of CE (IEDCE)	National	Intrinsic & Impacts		X	X	Academic (Qing et al., 2011)

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4. REGIONAL CE MEASUREMENT SYSTEM: A CONCEPTUAL PROPOSAL

The following section aims to introduce a conceptual framework for assessing the level of implementation of the circular economy (CE) and its impacts at the regional subnational level in Europe – namely, the Regional CE-centric Assessment Framework (RCEAF). The framework has at its core three fundamental principles: (1) it should take into consideration the priorities of the new Regional Development and Cohesion Policy Framework, (2) it should provide a full, unbiased picture of the concept of the CE, and (3) it should take a multi-stakeholder perspective in line with the CE-centric Quintuple Helix Model proposed in D4.2. The first principle is necessary in order to capture the success or failure of the policies that are aiming to enable the adoption of CE-initiatives. The second principle acknowledges that all main characteristics of the CE operating at the regional level should be captured to provide an unbiased picture of the effects of its implementation. Finally, the third principle highlights the importance of all stakeholder perspectives being considered when making a decision of what to measure in order to define a CE concept that is *for* everyone.

The EU Cohesion Policy is designed to foster an inclusive congruous development of the EU by strengthening its economic, social and territorial cohesion (Eurostat, 2019). The new framework of the Regional Development and Cohesion Policy (RDCP), the EU's main investment policy, sets five main objectives that will drive EU investment for the period 2021–2027 (see Figure 7). The first two regional development investment priorities will be the focal point. A portion between 65% to 85% of the ERDF and Cohesion fund[7] resources will be regionally redistributed to these priorities, according to the relative wealth of the Member States. The allocation of the funding is being done at the NUTS 2 regional level. The first priority aims to achieve **Smarter Europe** through innovation, digitalisation, economic transformation and support to SMEs. A **Greener and carbon free Europe** relates to the implementation of the Paris Agreement and investment in energy transition, renewables and the fight against climate change. The strategic transport and digital networks will contribute to a more **Connected Europe**. A more **Social Europe** will not merely deliver on the European Pillar on Social Rights but will, more importantly, encourage quality employment, education, skills, social inclusion and equal access to healthcare. Last but not least, the Commission wants to bring **Europe closer to citizens**, by supporting locally-led development strategies and sustainable urban development across the EU (European Commission, nd). By considering these new priorities for the development of the **RCEAF**, a coherency between the two policies at a regional level can be achieved, which in turn can facilitate the monitoring progress between regions.

Having addressed the first fundamental principle of the RCEAF framework, we go on to discuss the necessary components for providing a full picture of the CE. First, intrinsic (operational) aspects of the CE should be assessed. This is crucial to understanding the extent to which the CE is being implemented. Moreover, these should aim to properly reflect the **mechanisms** that characterise the CE concept. For example, all the CE-loops (maintenance, reuse/refurbish, repair, remanufacture) should be considered to reflect the CE concept proportionately. Similarly, more regional-specific concepts (i.e. concepts that are more characteristic of the CE at the regional level)

[7] ERDF and the Cohesion fund are the funds for implementation of the RDCP

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such as eco-innovation should also be addressed. Second, and equally important, is to assess the impacts of the CE's implementation. This effort should aim to properly reflect the **goals** of the CE concept. Hence, it is essential that all three dimensions of sustainability (environmental, social and economic) are assessed in a balanced and transparent manner. For example, the inclusion of absolute measures of environmental impacts, and not only relative ones, is necessary. In a similar fashion, social impacts should not only include measures of wellbeing, they should also consider societal involvement, CE awareness and culture. A schematic summary of this consideration of CE-characterising mechanisms (intrinsic) and goals (impacts) is given in Figure 7. The contents of the figure are discussed in more detail below.

Avdiushchenko and Zajaç (2019) identify 12 main areas of implications that CE-implementation has for societal development at the regional level. These are listed below:

1) Economically prosperous economy
2) Zero-waste economy
3) Innovative economy
4) Energy-efficient and renewable-energy-based economy
5) Low carbon economy
6) Smart economy
7) Spatially effective economy
8) Bioeconomy
9) Service/performance economy
10) Collaborative/sharing economy
11) Resource and material efficient economy
12) Socially oriented economy

These areas are used as a basis for constructing the building blocks and impact levels of assessment of the present framework (see Figure 7). The authors' concept for CE indicator design (Avdiushchenko and Zajaç, 2019) focuses primarily on "headline" indicators, which offer a high educational and communicative value and ensure a high degree of data-availability. However, the RCEAF proposed here, aims to take more comprehensive view of regional CE-assessment by explicitly considering intrinsic (operational) and impact-based aspects of the CE. Intrinsic aspects can then be measured by both what Avdiushchenko and Zajaç (2019) call "operational" and "headline" indicators (without hindering data-availability), while impacts would be measured primarily by headline indicators. This classification will also prove useful in taking a multi-stakeholder stance as will be made clear later on in this section. Therefore, the aforementioned areas need to be re-classified to better fit the RCEAF's goals.

We undertake this classification task in two steps: first, some of the areas are identified to be purely impact-based. Hence, these areas are taken, by the RCEAF, to be constituents of their corresponding RCEAF impact dimension. Second, some areas can be condensed together since they are of a similar focus. More specifically, (1) "economically prosperous economy" goes on to be a part of the "economic" dimension. Similarly, (5) "low carbon economy" is included in the "environmental" impact dimension, and the (2) "zero-waste economy" is broken down into an impact part (looking at waste produced) and an operational part, the "(zero-waste) regenerative economy" (looking at CE-loops and the performance economy). Its operational part, therefore, is

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also considered to include the (8) “bioeconomy” area, since this is concerned with organic CE-loops. Additionally, this operational side is also considered to include (9) “service/performance economy” since, while not operating in a loop, it contributes primarily to similar waste-reduction-centred goals. (4) “Energy-efficient and renewable-energy-based economy” and (11) “Resource and material efficient economy” are condensed into an all-encompassing area of “MRE-efficient and renewable-energy-based economy” (where MRE=Material/Resource/Energy). The (10) “collaborative/sharing economy” is considered to be a part of the (12) “socially oriented economy” by the RCEAF. The resulting classification (presented in Figure 8), together with the explicit consideration of the RDCP framework’s objectives (Figure 7), aims to contribute to the utility of the indicators by enhancing their suitability to aid decision-making, on top of maintaining their communicative and educational benefits.

Finally, we require that the RCEAF takes a multi-stakeholder perspective, reflecting the CE-centric QNH model. In order to achieve this, we recognise two modes of interaction between stakeholders and the areas of assessment (Figure 8) that have been identified – active and passive. More precisely, interactions where a stakeholder *acts* to affect operational (intrinsic) aspects of the CE are considered active (see Table 9). Similarly, passive interactions are the ones where stakeholders *are affected* by social, environmental or economic impacts of their regional context (see Table 10). This further illustrates the importance of explicitly considering intrinsic (operational) and impact-based (goals) areas of assessment separately for the RCEAF. The former allows for the consideration of all active stakeholder interactions while the latter collects all the passive ones. In Tables 9 and 10 we identify and summarise active and passive stakeholder interactions with all the areas of assessment of the RCEAF.

In sum, the RCEAF seeks to (1) capture measures capable of indicating progress towards the objectives of the new RDCP framework, (2) to properly and proportionally reflect the concept of the CE at the regional level and (3) to capture stakeholders’ engagement and how they are impacted by the different impact categories (environmental, social and economic). In doing so, it offers the basis on which a novel indicator system can be built, that is capable of properly assessing the CE at the regional EU level. The main strengths and novel contributions of the RCEAF arise from:

1) **The explicit consideration of the RDCP framework’s objectives**: This is a new framework whose objectives are concerned with driving the investment of the EU in the 2021-2027 period.
2) **The categorisation into intrinsic (operational-oriented) and impact indicators**: This ensures that the indicator system provides a balanced view of both mechanisms and goals that characterise the CE. Moreover, this classification also allows for the active engagement of stakeholders and the impacts they are affected by to be addressed and captured. Although stakeholder involvement is widely recognised to be essential for CE-policymaking, there are currently no CE-indicator systems that consider stakeholders’ interactions (active and passive) with the regional CE like the RCEAF does.

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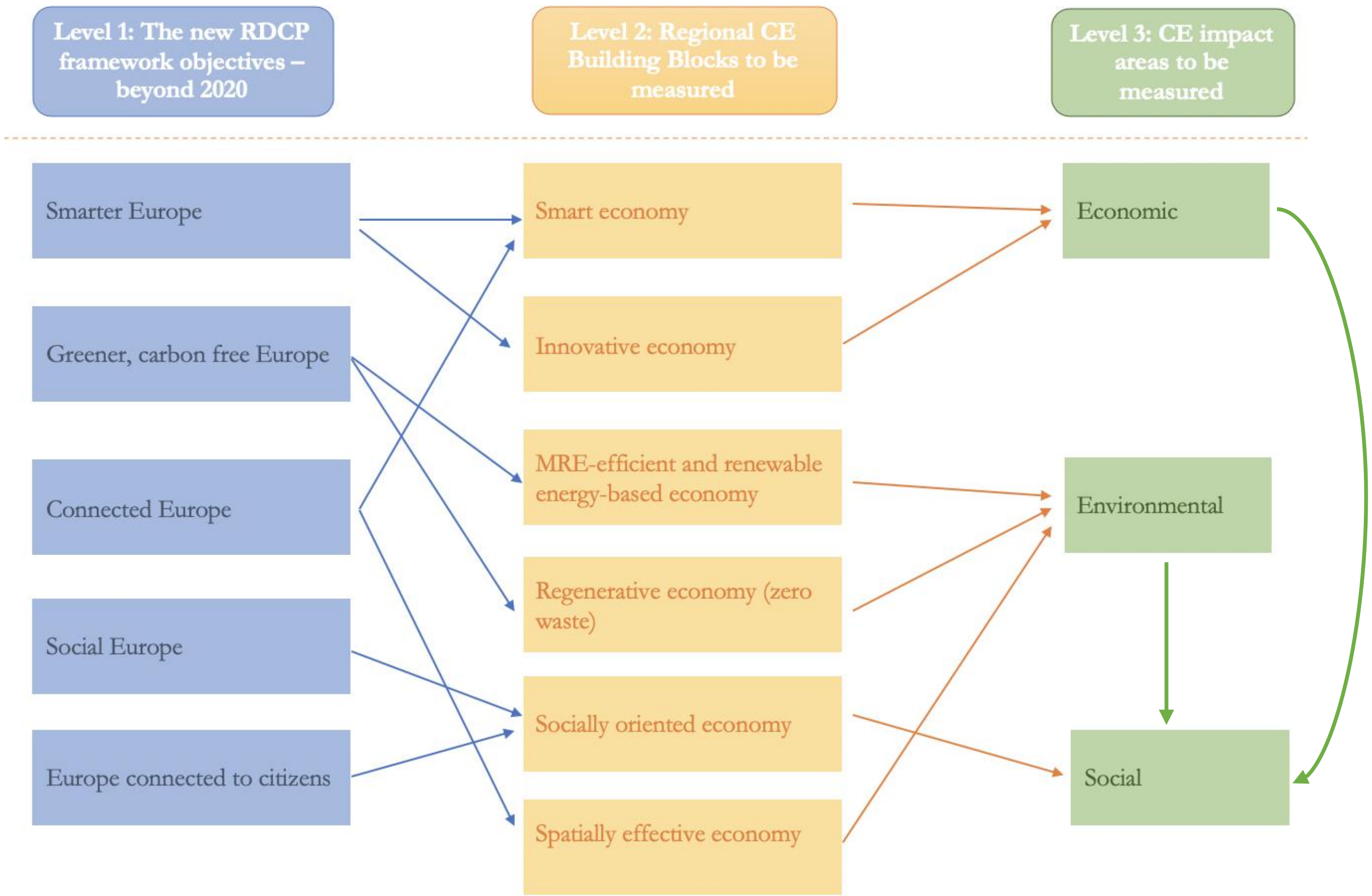

Figure 7: Regional CE-centric Assessment Framework - RCEAF (Source: adapted from Avdiushchenko and Zajaç, 2019; Avdiushchenko, 2018)

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Table 9: Active interactions between stakeholders and intrinsic areas of assessment of the RCEAF.
Green = strong interaction and yellow = weaker interaction.

	Regional CE building blocks (intrinsic) to be measured					
	Smart economy	Innovative economy	MRE-efficient & renewable energy-based economy	Regenerative economy (zero waste)	Socially oriented economy	Spatially effective economy
Academia	Education on ICT skills open to the general public. Availability and encouragement of online services use.	Education on eco-entrepreneurship with a focus on innovation and design.	Education/research on STEM subjects with a focus on materials and energy. Education/research on environmental sciences.	Research and knowledge building Zero waste capacity building i.e. training, skills and technology development	Social entrepreneurship programs Student-hub enabling social enterprise initiatives	Related scientific publications Involvement in related programmes and Projects
Industry	Enterprises providing ICT training to their employees. Industry making their interaction with their demand side ICT based.	Innovative enterprise share (per sector). Eco-innovations. Patents related to recycling.	Per sector MRE-efficiency. MRE-efficiency of green enterprises (per sector)	Recycling Maintaining, Remanufacturing. Products as service sector market shares.	Social enterprises Collaborative economy-based enterprises Social crowdfunding	Industrial symbiosis areas Sharing economy Urbanisation rate
Government	Availability of comprehensive government services online.	Investment on research and development in relation to GDP. Encouragement of eco-innovations through subsidies/tax-reduction.	Investment on MRE-efficiency and related R&D. Transition to renewable energies. Electricity saving initiatives.	Investment on R&D in relation to biotechnology.	Public funding for social enterprises	Accessibility by different means of transportation Green buildings and sustainable infrastructure Eco Industrial Parks
Civil Society	Engagement in ICT based services such as internet access (and therefore their purchase) etc.	Entrepreneurship related to eco-innovations.	Absolute and relative consumption of energy, materials and resources in households.	Recycling, Maintaining Preference for durable products/services Preference for PSS	Social innovations Collaborative economy Community-driven initiatives	Urban population Use of public or non-motorised means of transport

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Table 10: Passive interactions between stakeholders and impact dimensions of assessment of the RCEAF

	CE impact dimensions to be measured		
	Social	Economic	Environmental
	Increased CE knowledge base, including more curriculums and programs offering the CE-specific knowledge and training	Decreased at-poverty risk and similar measures of economic wellbeing are relevant to academia since people living in better economic conditions are more able to engage in education.	A better resource/energy efficiency and the mitigation of negative environmental damage is at the core of abundant research globally. All environmental impacts are relevant to academia.
	Industry's contribution to new job creation and an increase of employment in circular businesses. Awareness and cultural aspects of social impacts will increase market power of CE-oriented businesses and industries.	The CE transition will lead to emergence of new circular start-ups or social enterprises and growth of businesses in the product-service sectors and waste management.	Industry-wide or sector-wide reduction of GHG emissions and share of carbon neutral or climate positive organisations in a region Resource-efficiency in the production cycle
	At the core of all governance is the goal of achieving positive social, economic and environmental outcomes. As a result, all these impacts are important to policymaking.		
	The social dimension is usually measured at the scale of civil society. These impacts will capture the civil society's wellbeing and their adaptation to the CE.	Household income and the state of the economy determine society's ability to engage in economic activity. Thus, sustaining it and all its positive social impacts.	Health issues as a result of environmental degradation.

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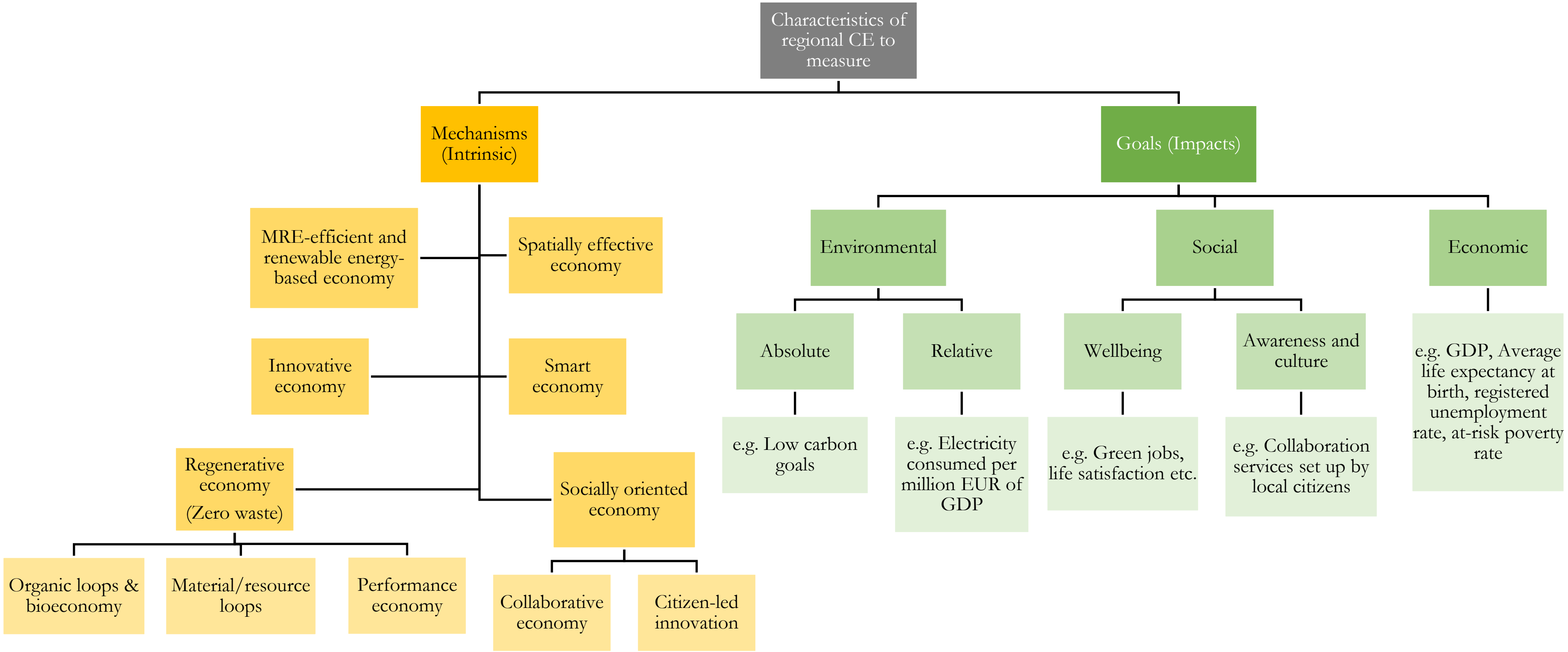

Figure 8. Tree-diagram of the areas of assessment of the RCEAF.

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5. CONCLUSIONS

The EU policy implementation at a regional level stresses importance of a regional monitoring framework in the transition to a CE. However, despite the importance of measuring CE advancement in a regional context, there are lack of measurement systems and indicators that can provide a critical assessment of CE adoption in cities and regions. Therefore, this report provided a comprehensive review of the available indicators and measurement systems for evaluating CE transition at a regional level and introduced a conceptual framework for assessing CE at a regional level.

The first section provided an overview of the two prior reports that have emerged from WP4; these covered regional policies and the introduction of the CE-centric QNH model that can be used to be to map stakeholders when implementing CE in a regional context. The second section provided the rationale for regional CE measurement systems and promoted NUTS 2 regions as catalysts for circular change. The third section analysed current attempts to measure and assess circularity. This analysis encompassed academic papers that propose a measurement framework for CE assessment at the regional level, as well as relevant papers in the grey literature providing indicators and measurements. Due to the lack of measurement systems at the regional level, the review also included a survey of measurement systems that can either be scaled down or scaled up to be incorporated into a regional monitoring framework. Considering the different approaches being adopted in Europe and China, and the more long-standing engagement of the Chinese government with the CE transition, both perspectives have been analysed separately. Based on the limitations identified in existing measurement systems, the last chapter introduced a conceptual framework – Regional CE-centric Assessment Framework (RCEAF) – to assess the level of implementation of the circular economy and its impacts at the regional subnational level in Europe. The proposed framework is fully aligned with the new Regional Development and Cohesion Policy Framework and considers multi-dimensional and multi-stakeholder aspects of the CE, providing an unbiased assessment of the CE transition in Europe at a NUTS 2 regional level. The proposed framework can be used to further develop measurement system specific to the regional context and monitor the advancement of circular economy for an evidence-based regional policy.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Innovative Training Networks (H2020-MSCA-ITN-2018) scheme, grant agreement number 814247 (ReTraCE).

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